### BD Vacutainer® Venous Blood Collection

**Tube Guide**

<table>
<thead>
<tr>
<th>Tube with BD Hemogard™ Closure</th>
<th>Tubes with Conventional Stopper</th>
<th>Additive Details</th>
<th>Inversions at Blood Collection*</th>
<th>Laboratory Use</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gold</strong></td>
<td>Red/Black</td>
<td>• Clot activator and gel for serum separation</td>
<td>5</td>
<td>For serum determinations in chemistry. May be used for routine blood donor screening and diagnostic testing of serum for infectious disease.** Tube inversions ensure mixing of clot activator with blood. Blood clotting time: 30 minutes.</td>
</tr>
<tr>
<td><strong>Light Green</strong></td>
<td>Green/Gray</td>
<td>• Lithium heparin and gel for plasma separation</td>
<td>8</td>
<td>BD Vacutainer® PST™ Tube for plasma determinations in chemistry. Tube inversions prevent clotting.</td>
</tr>
<tr>
<td><strong>Red</strong></td>
<td></td>
<td>• None (glass)</td>
<td>0</td>
<td>For serum determinations in chemistry. May be used for routine blood donor screening and diagnostic testing of serum for infectious disease.** Tube inversions ensure mixing of clot activator with blood. Blood clotting time: 60 minutes.</td>
</tr>
<tr>
<td><strong>Orange</strong></td>
<td>Gray/Yellow</td>
<td>• Thrombin</td>
<td>8</td>
<td>For stat serum determinations in chemistry. Tube inversions ensure complete clotting, which usually occurs in less than 5 minutes.</td>
</tr>
<tr>
<td><strong>Royal Blue</strong></td>
<td></td>
<td>• Clot activator (plastic serum)</td>
<td>8</td>
<td>For trace-element, toxicology, and nutritional chemistry determinations. Special stopper formulation provides low levels of trace elements (see package insert).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• K₂EDTA (plastic)</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td><strong>Green</strong></td>
<td></td>
<td>• Sodium heparin</td>
<td>8</td>
<td>For plasma determinations in chemistry. Tube inversions prevent clotting.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Lithium heparin</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td><strong>Gray</strong></td>
<td></td>
<td>• Potassium oxalate/ sodium fluoride</td>
<td>8</td>
<td>For glucose determinations. Oxalate and EDTA anticoagulants will give plasma samples. Sodium fluoride is the antiglycolytic agent. Tube inversions ensure proper mixing of additive and blood.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Sodium fluoride/ Na₂EDTA</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Sodium fluoride (serum tube)</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td><strong>Tan</strong></td>
<td></td>
<td>• K₂EDTA (plastic)</td>
<td>8</td>
<td>For lead determinations. This tube is certified to contain less than .01 µg/mL (ppm) lead. Tube inversions prevent clotting.</td>
</tr>
<tr>
<td><strong>Yellow</strong></td>
<td></td>
<td>• Sodium polyanethol sulfonate (SPS)</td>
<td>8</td>
<td>SPS for blood culture specimen collections in microbiology. Tube inversions prevent clotting.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Acid citrate dextrose additives (ACD): Solution A - 22.0 g/L trisodium citrate, 8.0 g/L citric acid, 24.5 g/L dextrose</td>
<td>8</td>
<td>ACD for use in blood bank studies, HLA phenoyping, and DNA and paternity testing.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Solution B - 13.2 g/L trisodium citrate, 4.8 g/L citric acid, 14.7 g/L dextrose</td>
<td>8</td>
<td></td>
</tr>
</tbody>
</table>

*Inversions at Blood Collection indicate the number of inversions required for proper mixing of additive and blood.*

**BD Tube Guide. Courtesy and © 2008 Becton, Dickinson and Company.**
Lavender
- Liquid K$_2$EDTA (glass)
- Spray-coated K$_2$EDTA (plastic)
- K$_2$EDTA and K$_3$EDTA for whole blood hematology determinations. K$_2$EDTA may be used for routine immunohematology testing and blood donor screening. Tube inversions prevent clotting.

White
- K$_3$EDTA with gel
- For use in molecular diagnostic test methods (such as but not limited to polymerase chain reaction [PCR] and/or branched DNA [bDNA] amplification techniques).

Pink
- Spray-coated K$_2$EDTA
- For whole blood hematology determinations. May be used for routine immunohematology testing and blood donor screening. Designed with special cross-match label for patient information required by the AABB. Tube inversions prevent clotting.

Light Blue
- Buffered sodium citrate 0.105 M (+3.2%) glass
- 0.109 M (+3.2%) plastic
- Citrate, theophylline, adenosine, dipyridamole (CTAD)
- For coagulation determinations. CTAD for platelet function assays and routine coagulation determination. Tube inversions prevent clotting.

Clear
- None (plastic)
- For use as a discard tube or secondary specimen collection tube.

Red/Gray
- None (plastic)
- For serum determinations in chemistry. May be used for routine blood donor screening, immunohematology testing,*** and diagnostic testing of serum for infectious disease.*** Tube inversions ensure mixing of clot activator with blood. Blood clotting time: 60 minutes.

Green
- Sodium heparin
- Lithium heparin
- For plasma determinations in chemistry. Tube inversions prevent clotting.

Lavender
- Spray-coated K$_3$EDTA (plastic)
- For whole blood hematology determinations. May be used for routine immunohematology testing and blood donor screening.*** Tube inversions prevent clotting.

Light Blue
- 0.105 M sodium citrate (+3.2%)
- For coagulation determinations. Tube inversions prevent clotting.

* Invert gently, do not shake
** The performance characteristics of these tubes have not been established for infectious disease testing in general; therefore, users must validate the use of these tubes for their specific assay-instrument/reagent system combinations and specimen storage conditions.
*** The performance characteristics of these tubes have not been established for immunohematology testing in general; therefore, users must validate the use of these tubes for their specific assay-instrument/reagent system combinations and specimen storage conditions.

PHILLIPS

Manual of I.V. Therapeutics
Evidence-Based Infusion Therapy
SEVENTH EDITION

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To Lynn Phillips:
As an expert infusion therapy nurse and dedicated nursing instructor, Lynn wrote and published the first edition of this textbook in 1983. I am honored to take over Lynn’s role as the author of this important work. Lynn asked and entrusted me to carry on with her “baby” starting with the sixth edition, for which I served as the co-author. Now in its seventh edition, it is named the Phillips Manual of IV Therapeutics in recognition of the work that Lynn began so many years ago. Thank you, Lynn, for all you have done to promote best practices for infusion therapy and for giving me the opportunity to continue with your mission!

To all nursing students—you are our future!

And to my wonderful, dedicated colleagues who support and promote the Infusion Therapy Standards of Practice, making sure that our patients receive the best possible care.
Preface

The Phillips Manual of I.V. Therapeutics: Evidence-Based Practice for Infusion Therapy, seventh edition, provides comprehensive information on infusion therapy for the nursing student and practicing nurse. Continuing with this edition is the focus on evidence-based practice. Knowledge and application of evidence-based practices are essential for every nurse who cares for vascular access devices and administers infusion therapy. The dimensions of the nurse’s role continue to expand relative to insertion of a variety of vascular access devices and the use of technology. New infusion devices and techniques continue to be introduced, and research continues to evolve supporting the importance of nursing interventions in improving patient safety and reducing the risk of infusion-related complications. The seventh edition continues to address pediatric and older adult patients in a separate section in each chapter. With many patients requiring infusion therapy beyond the acute care setting, home care implications are also addressed. This textbook incorporates the 2016 Infusion Therapy Standards of Practice published by the Infusion Nurses Society as well as other important evidence-based clinical practice guidelines from a variety of professional organizations.

This self-paced, comprehensive text presents information in a format ranging from simple to complex, incorporating theory into clinical application. The skills of recall, nursing process, critical thinking, and patient education are covered, along with detailed summaries, providing the foundation one needs to become a knowledgeable practitioner. At the end of many of the chapters, the psychomotor skills associated with infusion therapy are presented in step-by-step procedures with rationale based on standards of practice.

Each chapter includes accompanying objectives, defined glossary terms that are bolded within the text, a summary of chapter highlights, and a critical thinking case study. Chapter post-tests, available in the text in previous edition, are now available on the DavisPlus Website. Icons and special boxes are used throughout each chapter to key the reader to Websites, patient education, home care issues, cultural considerations, and standards of practice. Skill Checks, 100 test questions, PowerPoint presentations, and math calculation tests are included on the DavisPlus faculty ancillaries, which can be used in the educational setting as well as in agencies for validating nursing competencies in infusion skills. The icons used in this seventh edition are as follows:

- ![Icon](image1.png) Identifies key points of theory content
- ![Icon](image2.png) Identifies Nursing Fast Facts that are in italic and shaded within the chapter for important nursing practice information.
- ![Icon](image3.png) Identifies relevant studies in Evidence-Based Practice (EBP)
Preface

Identifies Nursing Points of Care

Identifies Home Care Issues

Identifies Patient Education information

Identifies a media link, which refers to DavisPlus, and is located in the critical thinking case study section at the end of each chapter.

INS Identifies Infusion Nurses Society (INS) Standards of Practice

The seventh edition of this textbook is organized from foundations of practice followed by basic practices for all nurses and concludes with specialty infusion practices. The first three foundation chapters are designed to give in-depth information to the reader on nursing practice related to infusion therapy (nursing process applied to infusion therapy, legal and ethical responsibilities, evidence-based practice background, and performance improvement), infection prevention and risk management practices, and fundamentals of fluid and electrolyte balance.

The subsequent seven chapters provide the essential solid foundation in infusion therapy practices, including parenteral solutions, infusion equipment, peripheral and central vascular access device insertion and management, complications, medication infusion modalities, and infusion calculations. Alternative infusion routes, including subcutaneous, intraosseous, and intraspinal, are also addressed. This edition has incorporated recurring displays for cultural and ethnic-related issues. Key concepts for nursing practice are identified as “Nursing Fast Facts,” and “Note” identifies an important theory concept.

The last two chapters encompass the additional topics of transfusion therapy and parenteral nutrition. The DavisPlus Website contains questions based on standards of practice and follows the guidelines of the INS Core Curriculum for certification. The chapter post-test questions are also now located on the Website. DavisPlus also includes guidelines for discussion and answers to the case studies as well as additional math calculation problems and answers. The DavisPlus Website provides the learner with Web-based ancillaries, an additional 50 interactive flashcards for learning terminology, interactive case studies, and Web links for further research.

I hope this new edition provides you, whether you are a practicing healthcare professional or student, with valuable information to ensure safe practice of infusion therapy and a sound reference for this constantly advancing field.

LISA GORSKI
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The nurses in the specialty practice of infusion therapy

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Chapter 1
An Overview of Professional Practice Issues and Infusion Therapy

LEARNING OBJECTIVES
On completion of this chapter, the reader will be able to:
1. Define infusion-related professional practice terminology.
2. Identify methods used to assess competency.
3. Discuss the value of nursing certification.
4. Define evidence-based practice.
5. Apply the nursing process to infusion practice.
6. Apply quality improvement strategies to infusion practice.
7. Differentiate between structure, process, and outcome standards.
8. Describe the impact of value-based purchasing on hospital reimbursement.
9. Discuss risk management strategies.
10. Identify the sources of laws.
11. Identify four elements that must be met in a malpractice claim.
12. Describe the role of the nurse as an expert witness.
13. Identify principles used in ethical decision making.

Glossary

Assessment The systematic and continuous collection, organization, validation, and documentation of data; the first step of the nursing process
Barcoding system Encodes data electronically into a series of bars and spaces, which are scanned by lasers into a computer to identify the object being labeled
Benchmarking Process of measuring and comparing the results of processes with those of the best performers
Civil law Laws that affect the legal rights of private persons or corporations
Competency Includes aspects of performance such as skills, knowledge, ability, and judgment
Criminal law Offense against the general public; affects welfare of society as a whole
Data collection Gathering information through interviewing, observing, and inspecting
Documentation  A recording, in written or electronic form, containing original, official, or legal information

Evaluation  Measuring the degree to which goals/outcomes have been achieved and identifying factors that positively or negatively influence goal achievement

Evidence-based practice (EBP)  Conscientious use of current best evidence (e.g., research) in making decisions about patient care; it de-emphasizes practice based on tradition and ritual

Expert testimony  Witness from the same professional specialty who examines evidence, reviews pertinent literature, gives depositions, and potentially testifies in court. An expert nurse gives advice and consultation throughout the litigation process.

Goal  Broad statement of a desired outcome

Implementation  Carrying out planned nursing interventions; the fifth step of the nursing process

Liable  Legally responsible for damages, answerable

Malpractice  Negligent conduct of a professional person

Negligence  Not acting in a reasonable or prudent manner

Nursing diagnosis  A clinical judgment about actual or potential individual, family, or community experiences/responses to health problems; identification of nursing diagnoses is the second step of the nursing process

Nursing standard  Specific statement about the quality of a facet of nursing care

Outcome  Result of the performance (or nonperformance) of a function or process(es)

Performance improvement (PI)  Continuous study and adaptation of functions and processes of a health-care organization to increase the probability of achieving desired outcomes and to better meet the needs of patients and other users of services

Planning  Determining how to prevent, reduce, or resolve identified patient problems; how to support client strengths; and how to implement nursing interventions in an organized, individualized, and goal-directed manner; the fourth step of the nursing process

Process  A goal-directed, interrelated series of actions, events, mechanisms, or steps

Quality assessment (QA)  Process including data collection and data analysis in evaluating a problem

Quality improvement (QI)  Builds on the data identified in quality assessment to identify action steps, including monitoring, evaluating, and problem solving

Risk management  Process that centers on identification, analysis, treatment, and evaluation of real and potential hazards

Standard of care  Focuses on the recipient of care consistent with minimum safe professional conduct and describes outcomes of care that patients can expect to receive

Standards of nursing practice  Focuses on the provider and defines competent care along with the activities and behavior needed to achieve positive patient outcomes
Introduction

As a recognized nursing specialty, infusion nursing includes the placement, care, and management of a vascular access device (VAD), administration of a wide variety of infusion solutions and medications, and related assessment and monitoring. The intravenous (I.V.) route is the most commonly used infusion route; however, other infusion routes include intraosseous, subcutaneous, and intraspinal. Non-I.V. infusions may be appropriate for administration in certain situations and with selected fluids and medications. Infusion therapy is administered in all health-care settings, including hospitals, long-term care facilities, outpatient settings, physician offices, and patients’ homes. In fact, the majority of hospitalized patients will receive infusion therapy, and most nurses at some point of, or throughout, their career will be involved in infusion care. The patient populations served by this specialty practice range from neonates to elderly patients. Because VAD care and infusion administration have become such common areas of nursing practice, nurses may consider these practices very routine. However, there are risks, some complications are serious and even life-threatening, and many complications are preventable with sound nursing care. Regardless of the setting, the nurse must have a thorough understanding and knowledge of the type of access device being utilized, the appropriateness of the selected device for the prescribed therapy, the care and maintenance of the device, the potential complications related to the device and infusion solutions, and techniques for safe infusion administration. As stated in the Infusion Nurses Society (INS) Standards, infusion therapy is provided with attention to safety and quality with individualized care that is collaborative, culturally sensitive, and age appropriate (Gorski, Hadaway, Hagle, McGoldrick, Orr, & Doellman, 2016, p. S11).

This chapter provides an overview of professional practice issues relevant to infusion nursing practice. The practice of infusion nursing encompasses nursing management and coordination of care to the patient in accordance with:

1. State Nurse Practice Acts
2. Standards of practice, including those established by the INS
3. Organizational policies, procedures, and/or practice guidelines
4. Accreditation requirements
Delivery of Quality Care

Clinical Competency

Competency Standards

The American Nurses Association (ANA, 2015a) asserts that the public has a right to expect the registered nurse to demonstrate professional competence. In its recommendations about the future of nursing, the Institute of Medicine (now called the National Academy of Medicine) (2011) states that nurses must be engaged in lifelong learning to gain the competencies needed to provide care for diverse populations across their patients’ life spans. The ANA Standards of Professional Nursing Practice (2015a, p. 76) include the Standard of Education, which states that the registered nurse seeks knowledge and competence reflective of current nursing practice and promotes futuristic thinking.

Competence and competency are two frequently used terms that sound similar and may be used interchangeably; however, they do have different meanings. The ANA (2015a) states that competence can be defined, measured, and defined; it is an outcome and an ongoing process. A competency is an “expected level of performance that integrates knowledge, skills, abilities, and judgment” (ANA, 2015a, p. 44). Competency integrates the following aspects of performance related to patient care:

1. Skills: Psychomotor, communication, interpersonal, diagnostic
2. Knowledge: Examples include thinking, understanding, professional standards of practice, insights from personal experience
3. Ability: Capacity to act effectively
4. Judgment: Critical thinking, problem solving, ethical reasoning, decision making (ANA, 2015a, p. 44)

Competence is assessed using different methods, yet there is no single tool or method that “guarantees” competence (ANA, 2015a). A variety of methods are used, including written tests and direct observation of a skill, whether in the work setting, in a skills laboratory, or through use of simulation (Table 1-1). Observing performance of a skill in the work environment is the preferred method for evaluating invasive infusion therapy skills (Gorski et al., 2016, p. S19). Competency assessment requires a checklist that includes objective, measurable assessment of the actual performance, such as specific criteria or critical behaviors, and the criteria for achieving success in the performance. To ensure a careful and rigorous assessment of a nurse’s competency, it is critically important that the “competency assessor,” often referred to as the nurse preceptor, is competent with the skill being assessed (Gorski et al., 2016, p. S19).
Competency validation should occur before providing patient care (e.g., upon orientation to the organization) and on an ongoing basis based upon the associated risk and known problems, concerns, and/or outcomes within the organization (Gorski et al., 2016, p. S19). Risks and concerns that may drive additional competency validation include clinical outcome data (e.g., increase in infection rates), occurrence or sentinel event reports, implementation of new equipment or technology, evaluation of patient satisfaction (e.g., problems with peripheral I.V. placement), or changes in patient populations. When the health-care organization chooses to measure or validate specific competencies, it should do so in a thorough and ongoing fashion, including looking at new, significant, and/or high-risk practices, interventions, or activities that are unfamiliar to staff members.

Documentation of Competency

Competency is documented on forms or checklists that focus on objective and measurable performance of the competency. The health-care organization establishes what constitutes competency (e.g., percentage of performance) and when additional education and/or competency assessment is required. Components of a competency form include:

1. Competency statement that reflects a measurable goal
2. Performance criteria or critical behaviors based upon domains of learning criteria:
   - Cognitive criteria (knowledge)
   - Psychomotor (skills such as placement of a peripheral I.V. catheter)
3. Methods used for demonstrating performance: written tests, simulation, return demonstrations, and clinical demonstration of skill to nurse preceptor

All professional nurses are accountable and responsible for all parts of the tasks associated with infusion therapy and for tasks that are delegated to the licensed practical/vocational nurse or technician for care rendered to the patient.

INS Standard  The clinician is responsible and accountable for attaining and maintaining competence with infusion therapy administration and VAD
insertion/management within her or his scope of practice (Gorski et al., 2016, p. S18).

Value of Certification

Professional nursing certification programs have long established their value and importance to health-care organizations and to patients and their families. The American Board of Nursing Specialties (ABNS) was formed in 1991 with a mission to promote the value of specialty nursing certification to all stakeholders. Certification, as defined by the ABNS (n.d.), is the formal recognition of specialized knowledge, skills, and experience demonstrated by achievement of standards identified by a nursing specialty to promote optimal health outcomes. Nursing certification has become a high priority, especially in hospitals that pursue and attain designation through the Magnet Recognition® or Pathways to Excellence® programs of the American Nurses Credentialing Center (ANCC, n.d.; Solomon, Lahl, Soat, Bena, & McClelland, 2016).

Whereas basic nursing licensure indicates a minimal professional practice standard, certification is a mark of excellence, validates nursing knowledge and skills, and protects the public. In a study examining the value of certification in Magnet® and non-Magnet hospitals, the top three values of certification reported by nurses were personal accomplishment, validates knowledge, and personal satisfaction (McLaughlin & Fetzer, 2015).

Health-care organizations place a high value on nursing certification. Based on initiatives for certification from across the country, the American Association of Critical-Care Nurses identified five themes of best practices in creating a culture for nursing certification: commitment to excellence, a supportive and encouraging environment, goal-directed evaluations, availability of educational resources, and celebrations for rewarding excellence (Fleischman, Meyer, & Watson, 2011).

The INS provides certification specific to infusion therapy with the designation of CRNI® (certified registered nurse, infusion). Other certifications that include components of infusion therapy are as follows:

1. Oncology Nursing Certification Corporation (OCN®): www.oncc.org
2. Pediatric Nursing Certification Board (CPN®): www.pncb.org

Evidence-Based Practice

Evidence-based practice (EBP) is an essential characteristic of an effective health-care system. Both the ANA and the INS expect that nurses integrate evidence and research findings into practice (ANA, 2015a; Gorski et al., 2016). Although a comprehensive discussion of evidence-based practice is beyond the scope of this textbook, EBP is defined and addressed. Evidence-based practice
is defined as a problem-solving approach to clinical practice and administrative issues that integrates:

- A systematic search for and critical appraisal of the most relevant evidence to answer a burning clinical question
- One’s own clinical expertise
- Patient preferences and values (Melnyk & Fineout-Overholt, 2014)

The ANA (2015a, p. 87) defines EBP as a lifelong problem-solving approach that integrates the best evidence from well-designed research studies and evidence-based theories; clinical expertise and evidence from assessment of the health consumer’s history and condition, as well as health-care resources; and patient, family, group, community, and population preferences and values. It de-emphasizes practice based on tradition and ritual.

Consider the following simple example of EBP implementation: You are a nurse working in the outpatient department and for many years have cared for a patient who receives a monthly infusion through an implanted vascular access port. You have used povidone iodine for skin antisepsis prior to port access. This patient has never had a catheter-related bloodstream infection. The evidence supports chlorhexidine/alcohol solution as a superior agent and is preferred for skin antisepsis; you also know that povidone iodine is still considered an acceptable agent. This patient does not want to switch antiseptic agents because he has never had a problem and is afraid to make any changes to his usual protocol. You understand the research supporting the use of chlorhexidine, but you also use your clinical judgment based on the patient’s history and take into account your patient’s preferences, and you do not change his protocol.

EBP is important to the infusion nurse because of the rapidly expanding dimensions of the nurse’s role, the ongoing introduction of new infusion products and technology, and the growing base of research addressing VAD care and management and complication prevention. Each time a new device or technique is introduced, new practices must be considered. Questions must be asked when new technology is introduced, such as:

- What are the studies supporting the benefits of the technology?
- In what health-care settings has the technology been evaluated?

As ongoing safety initiatives are introduced into health-care settings and with the increasing presence of practice guidelines, it is imperative that the infusion nurse use evidence to support infusion practice. The 2016 INSs Infusion Therapy Standards of Practice (Gorski et al., 2016) is an evidence-based document. A major change in the 2016 Standards was made in relation to the name. Previously they were called Infusion Nursing Standards, but in 2016, the title was changed to Infusion Therapy Standards. Recognizing that infusion therapy is the responsibility of all clinicians involved in the practice, such as physicians and pharmacists, and because it may also include technicians and unlicensed assistive personnel, the 2016 Standards are aimed at all clinicians involved in infusion practice. As a leader in promoting standards of practice since 1980, the
INS recognizes that provision of infusion therapy is an interprofessional practice and does not solely belong to or is not solely owned by nurses. In another look at the ANA Standards, competencies under the ANA Standard on Collaboration also include the need to identify the areas of expertise and contribution of other professionals and key stakeholders and to articulate the role and responsibilities of the nurse within the team (ANA, 2015a, p. 73).

The INS's 2016 Standards include 64 Standards and associated Practice Criteria. The Standards are broad statements that describe expectations of practice applicable to infusion therapy in all settings. A standard is defined by the ANA as an authoritative statement enunciated and promulgated by the profession by which the quality of practice, service, or education can be judged (ANA, 2015a, p. 89). An INS example is Standard 33, Vascular Access Device Site Preparation and Device Placement: “Skin antisepsis is performed prior to VAD placement” (Gorski et al., 2016, p. S64). Regardless of the situation or health-care setting, skin antisepsis is always performed before placing a VAD; it is a standard (Table 1-2).

The Practice Criteria provide specific guidance in the implementation of the corresponding Standard, answering the question: So how is skin antisepsis best performed? Each Practice Criterion is supported by evidence and is rated as reflecting the strength of the body of evidence; all references to support the criteria are cited. Practice criteria in Standard 33 related to skin antisepsis include evidence-based recommendations for specific site preparation, including the use of >0.5% chlorhexidine in alcohol solution as the preferred skin antisepctic agent (Gorski et al., 2016, p. S65). This Practice Criterion is rated as Level I evidence. According to the INS table of the Strength of the Body of Evidence, this is the highest level of evidence, based on meta-analysis, systematic literature review, and a guideline based on randomized controlled trials (RCTs), or at least three well-designed RCTs. Should chlorhexidine solution be unavailable or contraindicated, the Practice Criteria provide additional recommendations for alternative antiseptic solutions, such as an iodophor or 70% alcohol.

Using the 2016 INS Standards to advance appropriate changes in policies or procedures is one way to apply EBP to infusion practice. Relevant INS Standards

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**Table 1-2 Sources of Evidence**

- Published research
- Published research utilization report
- Published quality improvement report
- Published meta-analysis
- Published systematic or integrative literature review
- Published review of the literature
- Policies, procedures, protocols
- Published guidelines
- Practice exemplars, stories, opinions
- General or background information/texts/reports
- Unpublished research, reviews, poster presentations, similar materials
- Conference proceedings, abstracts, presentations
will be highlighted throughout this text. With infusion therapy, as with many areas of clinical practice, there are unanswered questions, there may be limited research, and there is a constant influx of newly published studies to read and review. Although nurses may apply EBP through evidence-based guidelines, policies, or protocols, nurses also are actively involved in EBP when the answers are not so easily found. Numerous evidence-based models are available; however, all share certain steps as follows:

1. Select a topic or ask the question.
2. Search and critique the evidence.
3. Adapt the evidence for use in a specific practice environment.
4. Implement the EBP.
5. Evaluate the effect on patient care processes and outcomes (Titler, 2007).

There are a variety of scales used to rate the evidence. Table 1-3 lists the rating scale used by the Centers for Disease Control and Prevention (O’Grady et al., 2011) in their guidelines addressing infection prevention related to intravascular devices; it also lists excerpts from the INS (Gorski et al., 2016) rating scale. Of note, INS does not rate the strength of the recommendation; rather, it rates only the strength of the evidence used to support each Practice Criterion.

Table 1-3 Two Examples of Evidence Rating Scales

<table>
<thead>
<tr>
<th>Category IA: Strongly recommended for implementation and strongly supported by well-designed experimental, clinical, or epidemiological studies.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Category IB: Strongly recommended for implementation and supported by some experimental, clinical, or epidemiological studies and a strong theoretical rationale; or an accepted practice (e.g., aseptic technique) supported by limited evidence.</td>
</tr>
<tr>
<td>Category IC: Required by state or federal regulations, rules, or standards.</td>
</tr>
<tr>
<td>Category II: Suggested for implementation and supported by suggestive clinical or epidemiological studies or a theoretical rationale.</td>
</tr>
<tr>
<td>Unresolved issue: Represents an unresolved issue for which evidence is insufficient or no consensus regarding efficacy exists.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Excerpts From the Strength of the Body of Evidence Rating in the INS Standards of Infusion Nursing (Gorski et al., 2016)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level I: Evidence description: Meta-analysis, systematic literature review, guideline based on randomized controlled trials (RCTs), or at least three well-designed RCTs</td>
</tr>
<tr>
<td>Level I A/P: Includes evidence from anatomy, physiology, and pathophysiology as understood at the time of the writing</td>
</tr>
<tr>
<td>Level III: One well-designed RCT, several well-designed clinical trials without randomization, or several studies from quasi-experimental designs focused on the same question; includes two or more well-designed laboratory studies</td>
</tr>
<tr>
<td>Level V: Clinical article, clinical/professional book, consensus report, case report, guideline based on consensus, descriptive study, well-designed QI project, theoretical basis, recommendations by accrediting bodies and professional organizations, or manufacturer recommendations for products or services</td>
</tr>
</tbody>
</table>

Sources: O’Grady et al., 2011; Gorski et al., 2016. Reprinted with permission.
Selected Websites
Joanna Briggs Institute: http://joannabriggs.org
An international not-for-profit research and development Centre within the Faculty of Health and Medical Sciences at the University of Adelaide, South Australia. Collaborates internationally with over 70 entities across the world, promoting and supporting the synthesis, transfer, and utilization of evidence through identifying feasible, appropriate, meaningful, and effective health-care practices to assist in the improvement of health-care outcomes globally.

Agency for Healthcare Research and Quality: www.ahrq.org
The mission of the AHRQ is to produce evidence to make health care safer, higher quality, more accessible, equitable, and affordable, and to work within the U.S. Department of Health and Human Services and with other partners to make sure that the evidence is understood and used.

Additional websites on web-based Ancillary—Student/General

NOTE: Throughout this textbook, examples of evidence are noted in EBP Boxes threaded within the chapters in italic type.

Nursing Process Related to Infusion Therapy
The six steps of the nursing process are identified as the Standards of Practice by the ANA (2015a). These Standards provide each nurse with a framework to utilize when working with a patient. For the patient who receives infusion therapy, the process begins with assessment skills and continues until the patient no longer requires a VAD or infusions to meet health-care maintenance.

Assessment
According to ANA Standards of Practice (2015a), assessment consists of the collection of pertinent data, including and addressing physiological, functional, emotional, cognitive, sexual, cultural, age-related, environmental, spiritual, and economic issues. Assessment includes both subjective and objective information. The following are examples of areas to assess in relation to infusion therapy:

Subjective
- Patient’s related fears of infusion therapy
- Patient’s experiences with prior infusion therapy
- Patient’s needs and stated preferences for venipuncture site, if applicable
- Patient’s best learning method, health literacy, language barriers, and readiness to learn

Objective
- Review of patient’s past and present medical history
- Physical assessment
- Review of laboratory data and radiographic studies
- Assessment of level of growth and development for neonate and pediatric clients
- Potential factors affecting readiness to learn, such as weakness, fatigue, anxiety, and/or functional limitations
Factors that guide decision making in placing the most appropriate VAD for the patient: characteristics of the prescribed infusate, anticipated duration of therapy, physical assessment, health history, support systems and resources, patient preference

Peripheral vein assessment and selection based on age, vein condition, activity level, and needs

**Diagnosis**

The nursing diagnosis is used to describe and label patient problems based on an analysis of assessment data. Defined by NANDA International (2017), a nursing diagnosis is a clinical judgment about actual or potential individual, family, or community experiences/responses to health problems/life processes. The nursing diagnosis provides the basis for selecting nursing interventions to achieve outcomes for which the nurse has accountability. Nursing diagnoses are validated with the patient, family, and other health-care providers. The ANA (2015a) states that registered nurses use nursing and medical diagnoses depending upon educational and clinical preparation and legal authority.

The ANA (2015b) recognizes and supports the use of terminology sets that support nursing practice. Use of a standard terminology or language in the electronic health record (EHR) allows for clear communication among members of the health-care team and for data collection that can be used in quality improvement. Standardized terminology is also critical in increasing visibility of nursing interventions and in strengthening adherence to the standards of practice. Below are some examples of ANA-recognized terminology sets that include nursing diagnoses, interventions, and/or outcomes:

- NANDA Nursing diagnoses, definitions, and classification: www.nandanursingdiagnosislist.org
- Nursing Interventions Classification (NIC): https://nursing.uiowa.edu/cncc/nursing-interventions-classification-overview
- Nursing Outcomes Classification (NOC): https://nursing.uiowa.edu/cncc/nursing-outcomes-classification-overview
- Omaha System: www.omahasystem.org
- International Classification for Nursing Practice (ICNP): www.icn.ch/what-we-do/international-classification-for-nursing-practice-icnpr
- Clinical Care Classification System (CCC): www.sabacare.com
- Perioperative Nursing Data Set: www.aorn.org/aorn-org/education/individuals/continuing-education/online-courses/introduction-to-pnds

In this textbook, nursing diagnoses developed by NANDA are used. Nursing diagnoses related to infusion therapy are included in each chapter of this textbook. Some examples include:

1. Fluid volume deficit related to failure of regulatory mechanisms
2. Risk for infection related to compromised host defenses
3. Ineffective protection related to inadequate nutrition
Collaborative problems are physiological complications that nurses monitor to detect onset or changes in status. Nurses manage collaborative problems using physician-prescribed as well as nursing-prescribed interventions (Ackley, Ladwig, & Makic, 2017).

**Outcomes Identification**

The third step in the nursing process is the identification of expected outcomes for a plan of care that is individualized to the patient (ANA, 2015a). It is important that time frames for attaining the outcomes be identified. The nurse collaborates with the patient, family, and other health-care providers (including the physician and clinicians from other health-care disciplines) in developing expected outcomes. Patient values and ethical and cultural considerations should be incorporated into the process of identifying expected outcomes. Outcomes can be developed in one of two ways: by using the standardized terminology of the NOC list or by developing an appropriate outcome statement. General suggested outcome statements are provided in this textbook.

**NOTE:** In each of the subsequent chapters of this textbook, NOC is presented in a table with nursing diagnoses appropriate for the topic and along with NIC. A comprehensive list of NOC is found in the book by Moorhead, Johnson, Maas, and Swanson (2013). Care plans are always individualized; the tables in the chapters are suggested for use with the patient who receives infusion therapy.

**Planning**

Planning involves the prescription of strategies and alternative strategies to attain the identified expected outcomes (ANA, 2015a). Planning sets the stage for writing nursing actions by establishing the plan of care. Planning also includes development of strategies to attain the outcomes, validation of physician’s or authorized prescriber’s order(s), coordination and communication with the appropriate ancillary departments, and use of techniques to prevent complications.

**Implementation of Interventions/Nursing Actions**

Implementation is the “action plan” and the fifth step of the nursing process. The interventions are the concepts that link specific nursing activities and actions to expected outcomes. The nurse is expected to implement the plan in a safe and timely manner, utilize evidence-based interventions and treatments, partner with all members of the health-care team, and use all appropriate resources (ANA, 2015a).

Nursing actions include both independent and collaborative activities. Independent activities are actions performed by the nurse using his/her own discretionary judgment. Collaborative activities are actions that involve mutual decision making between two or more health-care practitioners. Implementation of infusion therapy includes administration of medications and solutions, care and maintenance of the VAD, and patient and family education. The care must
be coordinated within and across all types of health-care settings for patients who transition to another setting (e.g., home care or long-term care). Specific examples of implementation of infusion therapy–related nursing actions include:

1. Adherence to established infection prevention practices and maintenance of aseptic technique
2. Preparation of infusate solutions with medication additives
3. Initiation of appropriate actions in the event of adverse reactions or complications
4. Provision of infusion therapy–related patient education that is culture and age appropriate
5. Documentation of all care delivered

NIC is a comprehensive, standardized classification of treatments that nurses perform. A comprehensive list of NIC interventions is provided in an NIC text by Bulecheck, Butcher, Dochtermann, and Wagner (2013).

NOTE: In each of the subsequent chapters of this textbook, NIC is presented in a table with nursing diagnoses appropriate for the topic, along with NOC. All care plans must be individualized; therefore, the tables in the chapters present suggestions for direction of nursing actions related to the nursing diagnosis.

Evaluation

The evaluation phase of the nursing process is often the most ignored phase of the nursing process. Outcomes must be evaluated in relation to the structures and processes of the plan of care and the timelines for attainment (ANA, 2015a). The evaluation phase is the feedback and control part of the nursing process. Evaluation loops back to assessment, which was begun in the initial phase. As new data are collected, a nursing judgment must be made as to whether diagnoses, outcomes, the plan, and/or implementation need to be revised. Three judgments are possible:

1. The evaluation data indicate that the health-care problem has been resolved.
2. The plan of care should be revised.
3. The plan of care should be continued based on the conclusion that the outcome has not been met at this time.

Quality Improvement

Quality improvement (QI) programs include a variety of activities that advance safety and excellence in practice. Quality improvement is not a single activity, and it does not occur only in the nursing department. In relation to infusion therapy, QI programs include surveillance aggregation, analysis and reporting of infections, morbidity and mortality rates associated with infections, infusion-related quality indicators, and adverse events such as infiltration and phlebitis (Gorski et al., 2016, p. S21).
Effective quality improvement programs take place at all organizational levels. There are a variety of quality models and approaches used in health care. “Quality assurance” is an old, outdated term that may still be used. Quality assurance focused mainly on documentation of certain aspects of care. For example, medical records could be reviewed to determine whether there was documentation that the peripheral I.V. catheter site was assessed every 4 hours. Documentation is being checked rather than an assessment of patient care. The reality is that quality cannot be ensured, but it is measured, managed, and improved upon (Fletcher, 2014).

**Quality Models**

**Quality assessment** (QA) and QI are components of a two-step process. QA includes data collection and data analysis. It may include a retrospective and/or a concurrent review of care and may include review of medical records as well as other data or observation of care. Outcomes of care and patient satisfaction are monitored. Consider the following example:

On a hospital medical unit, the nurses identified what they believed were too many cases of phlebitis for their patients with peripheral I.V. catheters. Working with the QI director, the nurses decided to collect data on the prevalence of phlebitis, to use a standardized tool in identifying phlebitis, and to define a time frame for data collection. Two certified infusion nurses on the unit both would evaluate the I.V. sites.

QI is the second step of the process. It builds on the data obtained in the QA process and identifies the action steps needed to improve the care (Fletcher, 2014). In the previous example, based on the literature, the prevalence of phlebitis on the medical unit was determined to be high. Potential causes of the high rate are discussed among the nursing team and the QI department, and plans to improve the rate are identified and implemented. To evaluate the effects of the changes, the QA process would be implemented again, using the same data-collection strategy to assess whether changes in care lowered the phlebitis rate.

Using audits and providing specific feedback as part of a QI program are increasingly addressed in the literature as an approach in improving care quality. Examples include unit-based reports of outcomes such as central line–associated bloodstream infection (CLABSI) and completion of VAD insertion checklists (Marschall et al., 2014). In one example, nurses and managers were provided with individual “report cards” relative to their patients, including visual observations of the central line (e.g., was the dressing intact and dated, was a chlorhexidine-impregnated dressing in place?), the infusion system (e.g., tubing labeled, a disinfectant cap on any unused lumens), and documentation (e.g., site assessment, patency, condition of dressing) (Morrison, Raffaele, & Brennaman, 2017). In their report cards, nurses were informed of CLABSI contributing factors (e.g., nonintact dressings, no disinfectant cap). There was a total of 487 bedside nurse reports and 113 unit case reports. Through this process, improved compliance with established central line procedures, as defined by reduction in CLABSI risk factors, was demonstrated.
Performance Improvement

The term performance improvement (PI) was originally introduced by The Joint Commission (TJC) at the beginning of the millennium. It represents another shift in quality management philosophy. Although it has been acknowledged that quality is difficult to define, “performance” is more easily defined, described, and measured. Performance is described by what is done and how well it is done in providing health care.

Total Quality Management

Total quality management (TQM) is an outgrowth of several health-care organizations that adopted a management system fostering continuous improvement at all levels and for all functions by focusing on maximizing customer satisfaction. This proactive approach emphasizes “doing the right thing” for customers. Examples of TQM models are Six Sigma and lean manufacturing (Fletcher, 2014). Six Sigma focuses on eliminating variations so that there are no defects. For example, a written standard for an insertion tray for peripherally inserted central catheter (PICC) placement is developed to reduce the risk for breaks in aseptic technique during the procedure. Lean manufacturing focuses on reduction of waste of supplies, for example, ensuring that all items on the PICC tray are used and not wasted.

INS Standard The clinician participates in quality improvement activities advancing safety and excellence in infusion therapy (Gorski et al., 2016, p. S21).

Standards

Structure Standards

Structure standards consist of the conditions and mechanisms that provide support for the actual provision of care. Examples of organizational structure standards include mission, philosophy, and organizational goals. Another example is policies, which are not considered negotiable. An example of an infusion policy that is an organizational structure standard is that only nurses who have completed and demonstrated competence through attendance at a formal chemotherapy course and who meet additional competency standards are allowed to administer antineoplastic drugs.

Process Standards

Process standards focus on the functions of what is actually done in giving and receiving care. Process is a goal-directed, interrelated series of actions, events, mechanisms, or steps. It includes a patient's activities in seeking care, data collection, and a practitioner's activities in making a nursing diagnosis, along with evaluation of actual performance of procedures. This link sets the standards by which evaluation can take place. Process standards include job descriptions, clinical procedures, practice guidelines, protocols, and clinical pathways.
Outcome Standards

Outcome standards are statements of the result of the performance (or nonperformance) of a function or process. Outcomes may be stated in negative terms, such as infection or mortality rates, but are more often stated in positive terms, such as pain control or prevented hospitalizations. Certain outcomes in health care are publicly reported, as discussed below in a subsequent section.

Standards as Domains of Organizational Structure

Quality of health care is also viewed in domains of structure. Sierchio (2010) identifies three domains: the organizational leadership, the health-care professional, and the patient/consumer of health care.

Standards of Care

The recipient of care, the patient, is the focus of standards of care. Standards of care can be voluntary, such as those promulgated by professional groups, or they may be mandated legislatively. TJC expects that an individual organization will develop standards of care that reflect the missions, values, and philosophy of that agency. Standards of care describe the results or outcomes of care and focus on the patient. An example of a nursing standard of care is: “The patient is free of infection related to infusion therapy” (Sierchio, 2010, p. 33).

Standards of Practice

Standards of practice focus on the provider of care and represent acceptable levels of practice in patient care delivery. Like the standards of care, practice standards address the clinical aspects of patient care services and imply patient outcomes. Standards of nursing practice define nursing accountability and provide a framework for evaluating professional competency. Standards of practice are consistent with research findings, national norms, and legal guidelines, and they complement the expectations of regulatory agencies. These standards reflect commitment to quality patient care and include generic and specialty standards of practice (Sierchio, 2010). A standard of practice correlating to the standard of care stated above is: “The peripheral insertion site is aseptically cleansed with antimicrobial solution before catheter insertion” (Sierchio, 2010, p. 33).

There are two types of nursing practice standards: internal and external. Internal standards are those developed within the profession of nursing for the purpose of establishing the minimum level of nursing care. These documents guide nursing care and can be used as a yardstick to measure the practice of individual nurses. An example of internal standards is the ANA (2015a) Standards of Practice, which are universal to nursing practice in all settings. Specialty standards are applicable to specific areas of practice, such as the INS's Infusion Therapy Standards of Practice (Gorski et al., 2016).

External standards are guides for nursing developed by non-nurses, the government, or institutions. These standards describe the specific expectations of agencies or groups that utilize the services of nurses. Examples of external standards include state nurse practice acts and those established by accreditation organizations as discussed below.
Additional Components of Quality Improvement

Benchmarking

Benchmarking is the process of measuring and comparing the results of processes with those of the best performers. The goal of benchmarking is to identify the best practices so that an organization can improve its performance.

Managers can benchmark to help decide a variety of factors, such as where to allocate resources more efficiently, when to seek outside assistance, how to quickly improve current operations, and whether customer requirements are being adequately met.

Benchmarking can be used in infusion therapy to validate infusion therapy teams. For example, the rate of I.V. infiltrations could be compared between hospitals that use an infusion therapy team and hospitals that do not.

Accreditation and National Patient Safety Goals

Many health-care organizations are accredited by outside organizations. Accreditation is a voluntary process that demonstrates an organization’s desire to adhere to the highest standards. There are several accrediting organizations. Specific to home care, accreditation organizations include the Accreditation Commission for Health Care (ACHC) and the Community Health Accreditation Program (CHAP).

Hospitals very often seek accreditation by TJC; however, TJC also offers accreditation programs for home care and ambulatory care. Each year, TJC identifies National Patient Safety Goals. The 2017 National Patient Safety Goals for hospitals (TJC, 2017a) include:

- Identify patients correctly.
- Improve staff communication.
- Use medicines safely.
- Use alarms safely.
- Prevent infection (includes focus on preventing CLABSI).
- Identify patient safety risks.
- Prevent mistakes in surgery.

The 2017 National Patient Safety Goals for home care (TJC, 2017b) include:

- Identify patients correctly.
- Use medicines safely.
- Prevent infection.
- Prevent patients from falling.
- Identify patient safety risks.

Value-Based Purchasing and Publicly Reported Outcomes

Health-care reform mandated by the Affordable Care Act (ACA) resulted in financial incentives for improvement in the quality of health care under the Centers for Medicare & Medicaid Services (CMS). Beginning in October 2012, hospitals were rewarded financially for both achievement and improvement in care, affecting 1% of payments beginning in 2012 for all admissions and increasing to 2% in
October 2017. Over time, value-based purchasing (VBP) will affect other sectors of the health-care system beyond hospitals. For example, the home health value-based purchasing (HHVBP) model was implemented on January 1, 2016 (CMS, 2016). It is a complex model that includes a randomized state selection methodology, reporting frameworks, payment methodology, and measures for performance. CMS recognizes the uniqueness of home care as compared with other types of services (i.e., care provided in a home versus a brick and mortar institution) and has designed the HHVBP model for results to be generalizable to the population.

There are three pay-for-performance programs mandated by the ACA:

- VBP
- Hospital-Acquired Condition (HAC)
- Hospital Readmissions Reduction Program (HRRP)

Under VBP, hospital performance is evaluated on a number of health-care quality measures. Based upon these evaluations, there are financial awards for those hospitals that perform well and penalties for those that do not. This is a budget-neutral program in that a percentage of Medicare revenue is withheld and then distributed back to organizations based upon the results of various measures or a total hospital performance score (Raso, 2015). Quality measures are grouped into several domains, which currently include clinical care process, clinical care outcomes, safety, patient experience of care, and efficiency (Brooks, 2016). Relevant to infusion therapy, CLABSI is an outcome that counts several times. Under the domain of safety, CLABSI is counted twice: as part of a composite of eight safety measures and on its own. In addition to its reporting under VBP, it is also counted as an HAC. CLABSI is measured using a standardized infection ratio that compares the actual CLABSI number with the predicted number based on a risk adjustment of a standard population. This is a publicly reported outcome.

**NURSING FAST FACT!**

Nurses greatly influence VBP, HAC, and HRRP quality measures. In relation to CLABSI, nurses ensure safe and evidence-based catheter insertion procedures and postinsertion care aimed at reducing the risk for infection and other complications. The patient experience, for example, is improved when highly competent and skilled nurses place a peripheral I.V. properly on the first attempt.

A variety of health-care outcomes are publicly reported and may be used by health-care customers in choosing an organization. Organizations certified by CMS must provide data on outcomes. A “star” rating is given to each health-care organization (1 to 5 stars; the average star rating is approximately 3). In the case of hospitals, the overall rating summarizes up to 57 measures that are reflective of common conditions that hospitals treat, such as heart attacks or
pneumonia. Examples of publicly reported outcomes for home care include hospitalization rates for home care patients, improvement in the symptom of dyspnea, improvement in pain, and patient satisfaction. Examples of publicly reported outcomes for long-term care facilities include health inspection results and deficiencies, and quality of care measures such as percentage of patients with pressure ulcers.

**Websites**

Hospital Compare: www.medicare.gov/hospitalcompare
Home Health Care Compare: www.medicare.gov/homehealthcompare
Nursing Home Compare: www.medicare.gov/NursingHomeCompare

**Patient Experience Data**

Patient experience is based upon a survey (Hospital Consumer Assessment of Healthcare Providers and Systems [HCAHPS]), is part of VBP, is also publicly reported for health-care organizations, and impacts reimbursement, either positively or negatively. Organizations may also choose to perform other methods of patient data collection beyond standardized surveys, such as making follow-up phone calls after patient discharge or obtaining patient satisfaction information via a focus group or postcare interview.

**Risk Management**

The INS’s *Infusion Therapy Standards of Practice* define risk management as “a process that centers on identification, analysis, treatment, and evaluation of real and potential hazards” (Gorski et al., 2016, p. S154). Risk management strategies include a variety of approaches, such as ensuring the competence of clinicians and the presence of quality improvement programs aimed at achieving positive patient outcomes, as previously addressed in this chapter. Some examples of risk management strategies that may decrease the risk of potential liability to the organization or to the clinician include:

- Informed consent
- Analysis of unusual occurrence reports
- Systemic (root cause) analysis of serious adverse (sentinel) events
- Comprehensive and thorough documentation
- Safe infusion medication administration

One specific example of a risk assessment and management program from the U.S. Food and Drug Administration (FDA) is the Risk Evaluation and Mitigation Strategy (REMS) program. REMS is a strategy for managing the risks associated with certain high-risk drugs. The FDA can require a REMS:

- Before approval of the drug if the FDA determines a REMS is necessary to ensure that the benefits of the drug outweigh the risks
- Postapproval if the FDA becomes aware of new safety information and determines that a REMS is necessary to ensure that the benefits of the drug outweigh the risks
Nurses may be involved in REMS programs in the following ways:

- Possibly enrolling patients in specific REMS programs required for some high-risk drugs
- Assessing patients’ understanding of the information they have been given, and providing and reinforcing patient education
- Explaining to patients why it is important to promptly report symptoms such as adverse reactions
- Assessing and monitoring patients for adverse events; in many cases, nurses have most of the primary contact with outpatients who are reporting symptoms
- Administering the drug in some cases

A listing of drugs that have a REMS in place can be found on the following website: www.accessdata.fda.gov/scripts/cder/rems/index.cfm. There are a number of infusion drugs on the REMS list, including some monoclonal antibodies used in cancer care.

### Informed Consent

One of the most effective proactive strategies taken in risk management is informed consent (Alexander & Webster, 2010). Health-care professionals have a legal duty to provide a patient with ample information regarding the health treatment or procedure that will be performed and to obtain an informed consent before proceeding. The purpose of informed consent is to provide patients with the information they need to make a rational and knowledgeable decision regarding whether to undergo treatment. The focus is on the patient’s understanding of the procedure and not just on procurement of the patient's signed consent to undergo the procedure.

The right of self-determination provides the basis for informed consent and is grounded in the bioethical principles of autonomy. A competent adult (competence to consent) is aware of the consequences of a decision and has the ability to make reasonable choices about health care, including the right to refuse health care.

There are categories of necessary elements for informed consent and informed refusal. The first category comprises the information elements. This involves the disclosure of appropriate information. Generally, this disclosure must include benefits and risks of the procedure, alternative procedures, benefits and risks of the alternatives, and qualifications of the provider. It is important to consider health literacy when conveying information: Providing information may require documents for a fourth- to sixth-grade reading level; non-English-speaking/reading patients may need qualified medical interpreters. Resources may be needed for patients who have visual or hearing limitations. There should always be adequate opportunity for patients to ask questions and convey any concerns.
The second category consists of the consent elements. The consent must be voluntary, not coerced. Consent can be manifested by conduct. For example, the nurse states, “I am going to restart your I.V. now,” and the patient holds out his/her arm.

There may be limits to consent, such as waiver of consent. The patient must know that options and risks exist, even if he/she does not want to know what they are. Other limits to consent include verbal limits; for example, the patient may tell the infusion nurse, “Okay, I will let you try to restart my I.V., but only once.”

Of note, although a minor child cannot grant consent, the concept of “assent,” or agreement, to treatment is recommended for children ages 7 years and older. Information regarding the treatment should be given to the child in a manner that considers the child’s readiness for knowledge and developmental level (Gorski et al., 2016, p. S28).

The duty to obtain informed consent belongs to the person who will perform the procedure, but it also may belong to the licensed person who is aware that the patient has not been informed, does not understand, or did not consent (Table 1-4).

**INS Standard** Obtain informed consent for all invasive procedures and treatments in accordance with local or state law and organizational policy. The clinician performing the invasive procedure facilitates the process and obtains informed consent. The patient or surrogate (e.g., legally authorized representative such as a person who holds power of attorney for the patient) has the right to accept or refuse treatment (Gorski et al., 2016, p. S26).

**NURSING FAST FACT!**

Health-care providers tend to use complicated medical terminology and many acronyms! When communicating with patients, it is important to use plain and simple language, avoiding jargon, complex medical terms, and most acronyms. Plain language makes it easier for everyone to understand and use health information. Some examples are as follows:

- Instead of “associated with,” say “goes along with” or “happens with”
- Instead of “bacteria,” say “germs”
- Instead of “contaminated,” say “not clean” or “dirty”
- Instead of “disease,” say “sickness” (Centers for Disease Control and Prevention [CDC], 2016)

Informed consents can become invalid if a change in the patient’s medical status alters the risks and benefits of the treatment.
Unusual Occurrence Reports

Unusual occurrence reports, also called incident or adverse event reports, are documented when there is a deviation in care. In fact, hospitals must track and analyze instances of patient harm as a condition of participation in the Medicare program; unusual occurrence reports are a common means for satisfying this requirement. In a government report, 13.5% of hospitalized Medicare beneficiaries experienced an adverse event during their hospitalization that resulted in extra hospital days, life-sustaining intervention, or permanent disability, or resulted in death (U.S. Department of Health and Human Services [USDHHS], 2012). An additional 13.5% experienced temporary events that required treatment. In this report, failure to report events as incidents or occurrences was common. For example, symptomatic I.V. infiltration was reported only 20% of the time, and I.V. fluid overload was not reported at all.

Less is known about adverse events in other health-care settings. In a small pilot study involving two skilled nursing facilities (SNF), major complications (bloodstream infection and catheter-associated venous thrombosis) occurred in 11 patients with PICCs (20%), and minor complications (e.g., occlusion, dressing disruption) occurred in 18 (32%) (Chopra et al., 2015). The researchers recommend quality improvement efforts to benchmark practice, identify gaps, and institute improvements in PICC care in SNFs. For home care patients, the risk of infection for VADs or other access devices is accepted to be low because the risk of transmission associated with multiple patients and multiple providers in an institution is eliminated (Gorski, 2017). However, there remains a great

Table 1-4  Elements of Informed Consent

<table>
<thead>
<tr>
<th>Criteria</th>
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<tbody>
<tr>
<td>Patient must be mentally competent and capable of granting consent.</td>
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<tr>
<td>Patient must be of legal age, or the parent of a minor.</td>
</tr>
<tr>
<td>A legally designated health-care surrogate may act for the patient.</td>
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<tr>
<td>Patient must be able to understand the language.</td>
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<table>
<thead>
<tr>
<th>Information Elements</th>
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</thead>
<tbody>
<tr>
<td>Clear and sufficient information about the procedure</td>
</tr>
<tr>
<td>Information must include:</td>
</tr>
<tr>
<td>Benefits and risks of the procedure</td>
</tr>
<tr>
<td>Alternative procedures</td>
</tr>
<tr>
<td>Benefits and risks of the alternatives</td>
</tr>
<tr>
<td>Potential complications</td>
</tr>
<tr>
<td>Risks of refusing the procedure</td>
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<tr>
<td>Qualifications of the provider</td>
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<table>
<thead>
<tr>
<th>Consent Elements</th>
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<tbody>
<tr>
<td>Consent form on chart or waiver of consent</td>
</tr>
<tr>
<td>Signature on an informed consent is a formality and not always required; typically used with special procedures such as central line placement</td>
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</tbody>
</table>

Adapted from: Alexander & Webster, 2010; Gorski et al., 2016.
need for more research in identifying home care–related infections and other adverse events, and in identifying the best interventions to reduce such risks.

Unusual occurrence reports are records of an event and are considered an internal and confidential reporting mechanism as part of a QI program. They should be reported to the superior staff member, and the episode must be objectively documented, but reference to any occurrence report should not appear in the legal patient record.

The occurrence report contains the following points:

1. Patient’s admitting diagnosis/age
2. Date when the incident occurred/location of the incident
3. Patient’s room number (hospitalized patient)
4. Type of incident
5. Nature of incident (e.g., medication error, mislabeling, misreading, policy and procedure not followed, overlooked order on chart, patient identification not checked). It should be noted (on the unusual occurrence report) if a physician's order was needed after the occurrence.
6. Factual description of the incident, including other people involved (witnesses)
7. Patient’s condition before the incident
8. Results of the incident or injury
9. Actions taken (e.g., physician notification, interventions)

Patterns of unusual occurrences are monitored and analyzed for trends. Nursing staff members must feel free to file reports; a report is not an admission of negligence. These reports have the potential to save lives by identifying unsafe practices.

**INS Standard** The clinician reports and documents adverse or serious adverse events associated with infusion therapy (Gorski et al., 2016, p. S31).

**Serious Adverse (Sentinel) Events**
Defined by the U.S. Food and Drug Administration (2016), an adverse event is any undesirable experience associated with the use of a medical product/medications in a patient, and the event is considered “serious” and reportable to the FDA when the patient outcome is death, disability, a life-threatening condition, when it requires initial or prolonged hospitalization, or requires intervention to prevent permanent damage. TJC (2017) uses the term “sentinel event” when it involves death, permanent harm, or severe temporary harm and intervention is required to sustain life. Other outcomes of sentinel events might
include unexpected, additional care. Serious adverse/sentinel events require immediate investigation and response. A root cause analysis (RCA) or other systemic investigation or analysis is required for serious adverse events, recurrent problems, and for “near-misses” (Gorski et al., 2016, S31). Such an approach focuses on system issues, procedures, human resources, products/equipment, processes, and training gaps, allowing for identification of causes, event analysis, and strategies for prevention. It is important to recognize that not all sentinel events occur because of an error, and not all errors result in sentinel events. Information regarding sentinel event reporting to TJC is voluntary. The vast majority of events are reported from hospital settings; however, other accredited organizations also report sentinel events, including long-term care, home care, and ambulatory care facilities. The most commonly reported sentinel event categories from 2005 through the second quarter of 2016 are listed in Table 1-5.

**Documentation**

Documentation is an essential requirement for nurses across all health-care settings. Although documentation is often viewed as a burdensome process that detracts from patient care, it is a professional responsibility. Nursing documentation is used for a variety of purposes:

1. Communication within the health-care team: It includes assessments, medication records, orders and implementation, patient responses and outcomes, and plans of care to ensure that health-care team members make informed patient care decisions and provide quality care.
2. Communication with other professionals not directly involved in patient care:
   - Credentialing of health-care practitioners within the organization
   - Legal matters: When a lawsuit is filed, the patient record becomes the major source of information about the care the patient received.
   - Regulation and legislation: Clinical documentation is used in evaluating and quantifying quality, such as the information seen in public reports of clinical outcomes.
   - Reimbursement: Documentation provides evidence of illness severity, service intensity, and outcomes of care on which reimbursement is based.

<table>
<thead>
<tr>
<th>Table 1-5</th>
<th>Most Frequently Reviewed Sentinel Event Categories (Based Upon Those Reported to TJC) 2005–2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wrong patient, site, or procedure</td>
<td></td>
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<tr>
<td>Unintended retention of a foreign body</td>
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<tr>
<td>Delay in treatment</td>
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<tr>
<td>Suicide</td>
<td></td>
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<tr>
<td>Operative/postoperative complications</td>
<td></td>
</tr>
<tr>
<td>Patient fall</td>
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</table>

Source: The Joint Commission, 2017c.
Research: Documentation may be used in research studies evaluating patient characteristics and outcomes of care.

Quality and PI: Documentation is the primary source of evidence for measuring performance outcomes, including nursing-sensitive measures such as data from the National Database of Nursing Quality Indicators (NDNQI) (ANA, 2010).

**Documentation** should be an accurate, timely, and complete account of the care rendered to the patient. The health-care record documents the patient's history, health status, and goal achievement. The record should be objective and completed promptly. Documentation should include only standard abbreviations according to the organization's policy and procedures. Nurses and other health-care providers should keep charts free of criticisms or complaints. In an office or home care environment, dates of return visit, canceled or failed appointments, all telephone conversations, and all follow-up instructions should be recorded on the chart.

The many formats for charting include the problem-oriented medical record, pie charting, focus charting, narrative charting, and charting by exception. Regardless of the format developed for documenting infusion therapy, basic requirements of the plan of care exist, including goals, nursing diagnoses, and nursing interventions and outcomes. As discussed earlier in the chapter, use of standard nursing terminologies in the EHR allows for clear communication among the health-care team members and data collection that can be used in QI. Standardized terminology is also critical for increased visibility of nursing interventions and greater adherence to the standards of practice.

The INS Standards of Practice (Gorski et al., 2016, p. S29) provides some specific recommendations for infusion-related documentation. Documentation should include:

- Patient/caregiver/family education
- Site preparation, infection prevention, safety precautions taken during insertion (e.g., standardized checklist to ensure all steps were followed)
- Type, length, and gauge of VAD
- Date and time of insertion, number and location of attempts, identification of site, type of dressing, identification of person inserting the device, use of visualization technology (e.g., ultrasound)
- For midline (ML) catheters and PICCs: External catheter length, mid-arm circumference, length of catheter inserted, radiographic confirmation of catheter tip location
- Confirmation of anatomic tip location (central VADs [CVADs])
- Condition of site, dressing, site care/dressing changes
- Infusion drug/solution: Dose, rate, time, route, method of administration, VAD patency
- When multiple catheter devices or catheter lumens are being used, documentation should clearly indicate what fluids and medications are being infused through each pathway.
Assessment of ongoing need for VAD
- Patient’s symptoms, response to therapy, and/or laboratory test results

**Infusion Medication Safety**

There is a great potential for patient harm and death from errors related to I.V. medications. The effects of medications given via the I.V. route are immediate and systemic, and it is difficult to reverse the pharmacological effects after administration. Furthermore, many I.V. medications are considered high-alert medications as identified by the Institute for Safe Medication Practices (ISMP, 2014). High-risk medications are drugs that bear a heightened risk of causing significant patient harm when they are used in error. Some examples include chemotherapy medications, opioid analgesics, insulin, and parenteral nutrition. Medication errors may not occur more often with high-alert medications; however, the consequences of an error may be severe.

Some measures that may be taken to reduce risk include making drug information easily available, limiting access to high-alert medications, using automated alerts, and standardizing the ordering, storage, preparation, and administration of these products (ISMP, 2014). A double-check of the high-risk medication prescription by two independent nurses prior to administration is a common strategy utilized by many organizations. This strategy involves two clinicians separately checking each component of the medication use process, apart from each other, and then comparing results. When done correctly, this is an effective process; however, the ISMP (2013) does not recommend that this be used for all high-risk medications but rather for selected medications that pose the greatest risk of harm. A standard process should be developed by the organization, and clinicians should be well educated. Fewer checks done correctly for tasks that pose the greatest risk are more effective than an abundance of independent double-checks done incorrectly (ISMP, 2013).

Technology is important to safe infusion medication administration. The use of “smart pumps” in administration of I.V. medications is becoming the standard of care across all settings. In fact, the ISMP (2017) has identified administration of high-alert medication infusions via programmable infusion pumps that use dose error-reduction software (i.e., smart pumps) as a “best practice.” The dose error-reduction software includes a drug library. Features include clinical alerts (e.g., prompts the nurse to use a filter), dosing limit, and stop alert, which notifies the nurse that a drug dosage is outside of the expected range. As with any technology, errors can still occur, and it is imperative that the alerts are evaluated regularly to determine whether clinicians are appropriately responding to them. In a published QI study, an assessment of practice found that nurses were using the drug library only 37% of the time (Harding, 2012). Through involvement of a QI team, interventions resulted in a doubling of drug library use by the end of the study period. The use of smart pumps is just a single, albeit important, component in infusion medication administration safety.

Barcodes were implemented in 2004 as a response to the alarming number of patient deaths resulting from medication errors uncovered by the Institute
of Medicine. A barcoding system encodes data electronically into a series of bars and spaces, which is scanned by lasers into a computer to identify the object being labeled. Barcode medication administration (BCMA) technology generates standard reports from recorded errors made, errors prevented, and reasons why nurses overrode warning messages. Use of BCMA is an additional important strategy in medication safety, but it is not fail-safe. Computerized prescriber order entry (CPOE) is another medication safety strategy used in automating and standardizing medication orders. Safe practices related to infusion medication administration are addressed further in Chapter 10.

EBP In a systematic review of the literature related to BCMA and whether use of BCMA reduced medication administration errors, only six studies met the study criteria (Young, Slebodnik, & Sands, 2010). Although the researchers found limited evidence to evaluate BCMA effectiveness, they found additional medication error categories beyond the classic five rights of medication administration (right patient, right medication, right time, right dose, right route). These included omitted doses, wrong rate, doses administered without an order, extra doses given, expired dose, incorrect dilution, patient wristband not scanned or missing, allergies not documented, and incorrect dosage form.

Legal and Ethical Issues

Sources of Law

In the United States, there are four primary sources of law: (1) constitutional law, (2) statutory law, (3) administrative law, and (4) common law. In addition, law can be divided into two main branches: private law and public law. Constitutional law is a formal set of rules and principles that describe the powers of a government and the rights of the people. Rights guaranteed in the Bill of Rights are consistent with the ethical principles of autonomy, confidentiality, respect for persons, and veracity. As participants in the healthcare system, nurses cannot be forced to forfeit any constitutionally guaranteed rights.

Formal laws written and enacted by federal, state, or local legislatures are known as statutory or legislative laws. Only a minimal number of statutes dealing with malpractice existed before the mid-1970s. Changes in Medicare and Medicaid laws, statutory recognition of nurses in advanced practice, and healthcare reform legislation all are examples of statutory or legislative law.

Administrative law is a form of law set by administrative agencies, such as the FDA or CMS. State boards of nursing are another example of this type of legislative body. These boards are empowered to revoke or annul a nurse’s license where there is evidence of incompetence, negligence, or fraud. The final source of law is common law, which is court-made law. The courts are responsible for interpreting the statutes. Most malpractice law is not addressed by statute but is established by the courts.
Legal Terms

Legal terms that nurses should become familiar with are criminal law, civil law, tort, malpractice, and the rule of personal liability. Criminal law relates to an offense against the general public caused by the potential harmful effect to society as a whole. A government authority prosecutes criminal actions, and punishment includes imprisonment, fine, or both. Violation of the Nurse Practice Act or the Medical Practice Act by an unlicensed person is considered a criminal offense.

Civil law or private law affects the legal rights of private persons and corporations. The branches of private law that are most applicable to nursing practice are contract law and tort law. Noncompliance with private law generally leads to a granting of monetary compensation to the injured party.

A private wrong, by act or omission, is referred to as a tort. Most tort law is founded in common law. Torts may be classified as intentional, quasi-intentional, or unintentional (Alexander & Webster, 2010). Intentional torts involve the purposeful invasion of a person's legal rights. Examples include assault, battery, false imprisonment, and restraints as a form of false imprisonment. The terms assault and battery, although usually used together, have different legal meanings. Both are intentional torts. Assault is defined as the unjustifiable attempt or threat to touch a person without consent that results in fear of immediately harmful or threatening contact. Touching need not actually occur. Battery is the unlawful, harmful, or unwarranted touching of another or the carrying out of threatened physical harm. Regardless of intent or outcome, touching without consent is considered battery. Even when the intention is beneficent and the outcome is positive, if the act is committed without permission, the nurse can be charged with battery. When dealing with a rational patient who refuses treatment, it is best to explain the treatment, verbally reassure the patient, and then notify the physician of refusal.

Quasi-intentional torts are civil wrongs that involve a person's reputation or peace of mind. They include slander (written statements that are false and malicious) and libel (spoken statements) (Alexander & Webster, 2010). Another example is breach of confidentiality, which may affect a person's peace of mind. Nurses have a legal duty and professional responsibility to ensure the right to privacy and confidentiality.

Negligence is an example of an unintentional tort, defined as “an inadvertent act or failure to act that results in injury or harm” (Alexander & Webster, 2010, p. 53).

Malpractice is a type or subset of negligence, committed by a person in a professional capacity. Above simple negligence, malpractice is the form of negligence in which any professional misconduct, unreasonable lack of professional skill, or nonadherence to the accepted standard of care causes injury to a patient.

There are four elements of a malpractice claim, all of which must be met to substantiate a claim:

1. It must be established that the nurse had a duty to the patient.
   * Simply put, the nurse is responsible in some way to the patient. For example, when a nurse is assigned to care for a specific patient, there is duty.
2. A breach of care or failure to carry out that duty must be proven.
   - Breach of duty may include an omission of care (e.g., failure to assess or provide an intervention) or a commission of care (e.g., administering an I.V. medication through a catheter despite patient complaints of pain). The nurse violates the duty of care by not adhering to an appropriate standard of care. Sources for the standard of care may include the state nurse practice act, organizational policies and procedures, published standards, and/or testimony of a nurse expert.

3. The patient must suffer actual harm or injury.

4. There must be a causal relationship between the breach of duty and the injury suffered.
   - The injury is a result of negligence on the part of the nurse. It must be proved that if the nurse had not been negligent, it is more likely than not that the patient would not have suffered harm (Reising, 2012).

**NURSING FAST FACT!**

Without injury, there is not malpractice even if there was a breach of duty. And not all injuries are a result of malpractice.

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**Legal Causes of Action Related to Nursing Practice**

Malpractice suits against nurses have risen significantly over the past 10 years (Reising, 2012). In a review of the literature, Painter, Dudjak, Kidwell, Simmons, and Kidwell (2011) assert that most malpractice cases involving nurses occur in hospital settings and involve nonspecialized nurses. Professional liability claims between January 2010 and December 2014 were analyzed by a large professional liability insurance provider (CNA/NSO, 2015). There were 549 professional liability claims involving registered or licensed practical/vocational nurses that resulted in a payment of greater than $10,000. These were closed claims as defined by financial compensation sought and the matter resolved through judgment, settlement, or verdict, with or without payment. While the highest percentage of claims was in the area of adult medical-surgical nursing, the frequency of claims was increased in non-hospital-based sites such as home care/hospice as compared to earlier data. Allegations of malpractice were divided into the categories of treatment and care (highest percentage at 45.9%), scope of practice, assessment, monitoring, medication administration, documentation (lowest percentage at 0.5%), and patient rights. Nurses must be aware at all times that failure to observe, failure to intervene, and verbal rather than written orders are potential risks for all nursing areas. Nurses must assess each patient and formulate a plan of care to meet the specific patient’s needs.

Because of its invasive nature and the risk for complications, infusion therapy is one area that carries a high risk for malpractice. For example, permanent nerve damage may occur when a peripheral I.V. catheter is placed in an inappropriate
location or when an infiltration goes undetected, and the patient may die from a
catheter-related bloodstream infection.

It is important to recognize that nurses are liable for their own wrongdoings
in carrying out physicians’ orders. A physician cannot protect a nurse from an
act of negligence by bypassing this rule with verbal assurance. This rule is
relevant to nurses in the areas of medication errors and administration of
I.V. fluids. Nurses have a legal and professional responsibility to be knowledge-
able about administration of the I.V. fluids and medications, techniques for
initiating and maintaining infusion devices, and identification of and interventions
in the event of a complication.

When a nurse is named as a defendant in a malpractice suit, it is reported to
the National Practitioner Data Bank (NPDB). This information clearinghouse,
created in 1990 under Title V of Public Law 99-660, collects and releases all
licensure actions taken against all health-care practitioners and health-care
entities. The intent is to provide health-care quality, protect the public, and reduce
health-care fraud and abuse (USDHHS, 2015). Information is submitted to the
NPDB by medical malpractice players, state boards of nursing, and hospitals. The
NPDB reports are reviewed regularly by state boards of nursing and credentialing
committees, allowing licensing bodies and employers to make informed decisions
(Brooke, 2012). The NPDB identifies five distinct categories for registered nurses.

1. Nonspecialized RNs
2. Nurse anesthetists
3. Nurse midwives
4. Nurse practitioners
5. Clinical nurse specialists/advance practice nurses

The Infusion Nurse’s Role as Expert Witness

The role of expert witness is relatively new to the nursing profession. The nurse
acting as an expert witness strengthens the argument that nursing is an
autonomous profession in that no other profession can appropriately judge the
practice of nurses.

Expert testimony is required when the case is dependent on scientific and
technical information that is more than common knowledge. Serving as an
expert witness involves a complex and extensive process of examining evidence,
reviewing pertinent nursing literature, giving depositions, and potentially test-
ifying in court. An expert nurse gives advice and consultation throughout the
litigation process. The nurse acting as an expert witness may testify either on
behalf of the plaintiff, providing an opinion as to whether there was a deviation
in the standard of care, or on behalf of the defendant, testifying that the actions
represented reasonable nursing care. The role of the expert is NOT to establish
standards of care; rather, the expert’s role is to educate the judge and jury
regarding the standards already established by the profession (Alexander &
Webster, 2010). Extensive experience and certification, such as national
I.V. certification, are important characteristics possessed by the nurse acting
as an expert witness.
Reducing the Risk for Malpractice

*Maintain Clinical Competency*

The nurse should understand the state’s scope of practice and comply with organizational policies and procedures. It is important that the nurse not accept patient care assignments where competence has not been established, for example, accessing an implanted port without prior education. It is a nursing and professional responsibility to stay current in practice, to attend relevant educational classes and in-service programs, and to ensure that necessary competencies have been completed.

*Assess and Monitor*

Ongoing assessment of the patient receiving infusion therapy is critical. This includes assessment of the catheter site and the surrounding area for any signs of complications, such as infection, flow rate of medications/solutions, and patient’s response to the infusion, and for evidence of potential side effects or adverse reactions. When laboratory work is ordered, the results should be reviewed for abnormalities. Changes in the patient’s condition and abnormal laboratory test results should be communicated promptly to the physician. Examples of failure to monitor include not assessing the I.V. site with appropriate frequency and not addressing patient complaints about the I.V. site.

*Prevent Infections*

An infection is the result of an invasion of a pathogen in a host by various modes of transmission. The presence of an infusion device puts a patient at risk for infection. Considerable attention is placed on infusion-related infections because they are considered preventable events in all settings. Factors contributing to infection risk include inadequate or ill-timed site care, failure to adhere to aseptic technique during catheter insertion and during infusion administration, failure to remove an unnecessary catheter, and failure to recognize and report early signs of infection.

*Use Equipment Properly*

Failure to use equipment properly—specifically, the improper use of add-on devices, arm boards, and restraint devices—may lead to an adverse patient event. Incorrect use of filters or electronic infusion devices (EIDs) also has the potential to result in rapid or inadequate rates of infusion. Lack of immediate response to an audible alarm of an EID can compromise patient safety and place the patient at risk.
Protect the Patient From Harm

Protecting the patient from avoidable injury is an important practice issue. TJC’s National Patient Safety Goals emphasize protection of the patient with adherence to the following 2017 standards:

- Identify the patient correctly.
- Improve staff communication.
- Use medicines safely.
- Prevent infection.
- Prevent errors in surgery.

Malpractice Case Example

A 72-year-old man is admitted in critical condition and requires I.V. fluids and emergency medications, including several drugs classified as vesicants; among them are 50% dextrose, sodium bicarbonate, and calcium chloride. For immediate treatment, the physician orders peripheral I.V. access and the nurse places two peripheral I.V. catheters for administration of the I.V. fluids and medications. The nurse decides to place 18-gauge catheters, one in each hand, and has some difficulty, resulting in two attempts at each placement. As the hours go on, the nurse continues to administer the prescribed medications and to monitor the patient. There is an extravasation in the hand, and the tissue injury spreads and worsens over time (Fig. 1-1). Ultimately, there is a malpractice suit. In hindsight, how could this injury have been prevented?

As you will learn more about peripheral I.V. catheters, proper guidelines for placement and monitoring, and prevention of complications in Chapters 6 and 9, you will learn that

Figure 1-1 Extravasation injury. Photograph courtesy of Lisa Gorski.
An Overview of Professional Practice Issues and Infusion Therapy

this is a preventable injury. Some important aspects of care related to administration of vesicant drugs and prevention of extravasation include:

- Recognition and knowledge of vesicant drugs and risk for extravasation
- Awareness of risk factors for extravasation (e.g., small, fragile veins, multiple venipunctures, altered mental status in that patient is unable to report symptoms)
- Placement issues such as avoiding areas of flexion; avoiding sites on dorsal aspect of the hand or the wrist; use of the smallest gauge catheter appropriate to the infusion therapy.
- Infusion administration issues such as ensuring the patency of the catheter by ensuring the presence of a blood return before each infusion, stopping the infusion immediately in the presence of any signs/symptoms (e.g., pain, burning, swelling, leakage, no blood return)
- Patient advocacy: Collaborate with the licensed prescriber and advocate for early central line placement, anticipating that this critically ill patient will continue to require vascular access for fluids and multiple medications.

Ethical Issues Related to Infusion Therapy

Code of Ethics

It is expected that all nurses practice in an ethical manner. An ethical nurse acts as a patient advocate; maintains patient confidentiality, safety, and security; and respects, promotes, and preserves human autonomy, dignity, rights, and diversity (Gorski et al., 2016, p. S11). A code of ethics acknowledges the acceptance by a profession of the responsibilities and the trust that society has conferred and recognizes the duties and obligations inherent in that trust.

The Infusion Nursing Code of Ethics is based on the premises that infusion nurses both individually and collectively practice with awareness, and that there are principles that guide the infusion nurse’s actions. It is the purpose of the code to offer the infusion nurse a model for ethical decision making (INS, 2001). The principles used in ethical and moral decision making are based on the following:

- Autonomy (right to self-determination, independence)
- Beneficence (doing good for patients)
- Nonmaleficence (doing no harm to patients)
- Veracity (truthfulness)
- Fidelity (obligation to be faithful)
- Justice (obligation to be fair to all people)

The ANA Code of Ethics for Nurses With Interpretive Statements, originally published in 2001, was revised and updated in 2015 and should be part of every nurse’s library. It consists of nine broad provisions:

- Provisions 1-9: Assert the fundamental values and commitments of nurses (e.g., compassion, respect, advocacy)
- Provisions 4-6: Identify duties and responsibilities (e.g., decision making, competence, personal and professional growth)
Provisions 7-9: Describe duties of the nurse beyond individual patient encounters (e.g., advance profession through research and scholarly inquiry, protection of human rights, maintain integrity of the profession, social justice) (ANA, 2015c)

Home Care Issues

The home infusion nurse must deliver safe, effective quality care in the home. In accordance with the Gorski Model for Safe Home Infusion Therapy, it is predicted that positive outcomes, which include the absence of infusion therapy–related complications, patient satisfaction, and healthcare provider satisfaction, are maximized when four aspects of care are addressed during the home care planning process and during the process of providing care. These include:

1. Appropriate patient selection: Not all patients are good candidates for home infusion therapy. Willingness to be involved in the plan of care and clinical condition and stability must be evaluated.
2. Effective patient education: Patients must learn various aspects of infusion therapy and care and monitoring of the VAD.
3. Meticulous patient care and comprehensive assessment and monitoring: Nurses must provide evidence-based care and assess and monitor carefully for any signs of complications related to the infusion or VAD.
4. Interprofessional communication and collaboration: Nurses must communicate with physicians or other prescribers, pharmacists, and others regarding patient assessment, progress toward goals, and any problems (Gorski, 2017).

The home care nurse must have a variety of well-developed skills, which include the following:

- Excellent assessment skills
- Ability to effectively teach patients and caregivers
- Ability to effectively communicate with patients, caregivers, and other health-care–related professionals, including physicians, pharmacists, insurance case managers, and other members of the agency health-care team
- In-depth knowledge of infusion access devices and infusion equipment, including
  - Knowledge of community resources and reimbursement
  - Good organizational skills with the ability to function independently

A successful home infusion program ensures patient safety when the following processes and structures are in place:

- Written agency policies and procedures for home infusion therapy
Home Care Issues—cont’d

- Discharge planning and/or agency intake processes, which include evaluation of the patient’s status and of the appropriateness and safety of administering the prescribed infusion drug or fluid in the home.
- Nurses are educated in agency protocols, with validated competency in administration of home infusion therapies provided by the agency.
- Tools and educational resources are available to support home infusion nurses, patients, and caregivers.

Health-care providers deliver a variety of services in the home care setting. The following interventions may be provided:

1. Administration of I.V. medications (e.g., antimicrobials, chemotherapy, opioid analgesics), solutions, and parenteral nutrition
2. Peripheral I.V. catheter placement, care, and maintenance
3. ML catheter placement, care, and maintenance
4. CVAD care and management
   a. Routine site care and dressing changes
   b. Implant ed port access
   c. Declotting
   d. Blood withdrawal from CVADs
5. Administration of other fluids and medications via other routes such as the subcutaneous route.

NOTE: Each subsequent chapter addresses home care issues related to the chapter topic.

Patient Education

Teaching is a major component of clinical infusion practice and is an independent nursing function. According to the ANA’s Code of Ethics for Nurses (2015c), nurses are responsible for promoting and protecting the rights, health, and safety of patients. The INS Standards (Gorski et al., 2016) address the development of teaching methods, assessment of health literacy, and evaluation of learning. When planning patient teaching, factors such as age, developmental and cognitive level, culture, and language preferences must be taken into account. Depending on the circumstances, patient family members and/or caregivers should also be involved in the education process.

Health literacy is a critical component of patient education. When providing patient education, nurses often use many written materials without...
Patient Education—cont’d

consistently assessing the patient’s or family member’s ability, or even desire, to read multiple handouts. The assessment should address how the patient best learns. Many patients will prefer to learn skills through observation and supervised practice. Whether the nurse uses written materials or verbal presentation of concepts, simplicity is best. Medical jargon should be avoided, which often is difficult because health-care providers tend to speak using acronyms (e.g., CVAD) and terminology not always familiar to the layperson (e.g., “hand hygiene” instead of “wash your hands”). For patients who have limited literacy skills or for those who speak English as a second language, the use of pictures, diagrams, and audiovisual aids should be used.

It is critical that learning be evaluated and reevaluated. Patients or their family members who are learning to self-administer their infusions or to care for their VAD must adhere to the same level of aseptic technique for infusion administration as practiced by the nurse.

NOTE: Each subsequent chapter will present key patient education points related to the content of that chapter.

Chapter Highlights

- Infusion nursing includes the placement, care, and management of a VAD, administration of a wide variety of infusion solutions and medications, and related assessment and monitoring.
- Competency integrates skills, knowledge, ability, and judgment. The nurse is responsible for attaining and maintaining competence.
- Components of EBP include evidence from research/evidence-based theories and opinions of leaders; evidence from assessment of the patient’s history, physical examination, and availability of health resources; clinical expertise; information about patient preferences and values.
- The nursing process includes the six steps of assessment, diagnosis, outcomes identification, planning, implementation, and evaluation.
- Quality improvement includes a variety of activities aimed at advancing safe and quality care.
- Under VBP, health-care organizations are evaluated on a variety of health-care measures, with financial rewards for those organizations that perform well and penalties for those that do not.
- Examples of risk management strategies include informed consent, documentation, analysis of unusual occurrence reports and systemic analysis of serious adverse events, and safe infusion medication administration.
Legal issues for the infusion nurse require that the nurse understand four primary sources of law and legal terms. Malpractice is defined by meeting four elements: duty of care, breach of duty, injury, and causation.

Codes of ethics dictate the responsibilities, trust, and obligations inherent in that trust. The Infusion Nursing Code of Ethics and the ANA Code of Ethics guide the ethical practice of infusion therapy.

**Thinking Critically: Case Study**

You are a supervisor of a hospital medical-surgical unit. Nurses on the unit have expressed concern about the number of I.V. infiltrations, frustrated that they are needing to replace the peripheral I.V. catheters, and they are also concerned about patient complaints and dissatisfaction with care. Upon discussion with the Performance Improvement Coordinator, it is decided to do a QA study to quantify the problem. They have chosen to develop a tool for a retrospective medical record audit that would be appropriate to quantify the prevalence of infiltration. The goal of this audit is to substantiate the problem and, based upon the results and problems identified, to develop steps needed to decrease the number of infiltrations.

**Case Study Questions**

1. Who should be included on this committee?
2. Identify some criteria to be included in the audit tool.

**References**


An Overview of Professional Practice Issues and Infusion Therapy


ISMP. (2013). Independent double checks: undervalued and misused: Selective use of this strategy can play an important role in medication safety www.ismp.org/newsletters/acuteCare/showarticle.aspx?id=51


LEARNING OBJECTIVES

After completing this chapter, the reader will be able to:

1. Define terminology related to the immune system, infections and infection prevention, and occupational hazards.
2. Describe the function of the immune system.
3. Identify the organs involved in the immune system.
4. Identify five mechanisms of transmission of microorganisms.
5. Identify the four potential routes for microorganisms to gain access to the bloodstream.
6. Describe potential intrinsic and extrinsic causes of bloodstream infection.
7. Describe standard and transmission-based precautions.
8. Identify the importance of aseptic technique in reducing infection risk.
9. State key interventions of the central line bundle.
10. Describe postinsertion vascular access device care and maintenance interventions important to infection prevention.
11. Discuss the importance of safe practices in relation to needlestick injury.
12. Discuss the occupational risks of hazardous drugs and latex allergy for the infusion nurse.

Glossary

Airborne precautions   Methods used to prevent transmission of infectious agents (e.g., tuberculosis, rubeola) that remain infectious over long distances when suspended in the air

Antibody    A protective substance produced by B lymphocytes in response to an antigen. Antibodies identify and neutralize or destroy antigens.

Antigen    A foreign substance that induces an immune system response. Examples of antigens include disease-causing organisms and toxic substances (e.g., insect venom)

Aseptic technique    A set of specific practices and procedures performed in a manner that minimizes the risk of transmission of pathogenic microorganisms to patients
Blood-borne pathogens  Microorganisms carried in blood and body fluids that are capable of infecting other persons

**Bloodstream infection (BSI)**  The presence of bacteria in the blood

**Chain of infection**  The process by which infections spread

**Colonization**  Growth of microorganisms in a host without the production of overt clinical symptoms or detected immune reaction

**Contact precautions**  Methods used to prevent transmission of infectious agents by direct contact (person-to-person) or indirect contact (no direct person-to-contact; contact occurs from a reservoir on contaminated surfaces or objects or from vectors)

**Dissemination**  Shedding of microorganisms from an individual into the immediate environment or movement of microorganisms from a confined site (skin to bloodstream to other parts of the body)

**Droplet precautions**  Methods used to prevent transmission of infectious agents from the respiratory tract that do not remain suspended in the air over a long distance

**Endogenous**  Caused by factors within the body

**Epidemiology**  Branch of science concerned with the study of factors determining the occurrence of diseases in a defined human population; used in establishing programs to prevent and control development of disease and its spread

**Exogenous**  Originating outside of the organism

**Extrinsic contamination**  Contamination with microorganisms during preparation or administration

**Hand hygiene**  A general term that applies to hand washing, antiseptic hand wash, antiseptic hand rub, or surgical hand antisepsis

**Health-care–associated infections (HAIs)**  Infections that patients acquire during the course of receiving treatment for other conditions or that health-care workers (HCWs) acquire while performing their duties within a health-care setting

**Hematogenous**  Produced by or derived from the blood; disseminated through the bloodstream or by the circulation

**Host**  The organism from which a microorganism obtains its nourishment

**Immunosuppression**  Interference with the development of immunological responses; may be artificially induced by chemical, biological, or physical agents or may be caused by disease

**Intrinsic contamination**  Contamination that originates prior to use (e.g., during manufacturing)

**Leukopenia**  Any condition in which the number of leukocytes in the circulating blood is lower than normal

**Pathogenicity**  The state of producing or being able to produce pathological changes and disease

**Reservoir**  Living or nonliving material in or on which an infectious agent multiplies and develops and is dependent on for its survival in nature
Resident flora  Microorganisms that are indigenous to each individual and are present mainly on the skin and in the respiratory, gastrointestinal, and reproductive systems

Sepsis  A complication caused by the body’s overwhelming and life-threatening response to an infection, which can lead to tissue damage, organ failure, and death

Standard precautions  Strategies to reduce the risk of exposure to blood and body fluids and to reduce the spread of infection; requires consistent use for all patients regardless of their infection status

Susceptible host  Person with inadequate defenses against an invading pathogen. Host is the organism from which a parasite obtains its nourishment.

Transient flora  Microorganisms that may be present in or on the body under certain conditions and for certain lengths of time; they are easier to remove by mechanical friction than are resident flora.

Transmission  Movement of an organism from the source to the host

Virulence  Relative power and degree of pathogenicity possessed by organisms to produce disease

Introduction

The presence of a vascular access device (VAD) allows microorganisms direct access to the circulatory system, thus providing risk for the development of a bloodstream infection (BSI). In fact, the presence of a central vascular access device (CVAD) is the most common cause of BSIs. However, today such infections are considered preventable. An understanding of infection concepts and terminology, the immune system, common causative organisms, and evidence-based practices shown to decrease infection risk is essential for the nurse providing infusion therapy.

There are also occupational hazards for the nurse who provides infusion therapy, such as exposure to blood-borne pathogens and needlestick injury, chemical exposure to hazardous drugs, and latex allergy. In addition to protecting the patient from infection, nurses must be aware of such risks and protect themselves by adhering to important safety practices addressed in this chapter. In the United States, the following organizations set standards or guidelines for infection prevention and health-care worker (HCW) safety:

- Association for Professionals in Infection Control and Epidemiology, Inc. (APIC), which emphasizes prevention and promotion of zero tolerance for health-care–associated infections (HAIs) and adverse events. APIC: www.apic.org
- Centers for Disease Control and Prevention (CDC), which is a division of the U.S. Department of Health and Human Services and establishes guidelines for infection control practices. CDC: www.cdc.gov
**Immune System Function**

The goal of the immune system is to prevent or limit invasion of the body by **antigens**. Antigens are defined as any foreign substances that induce an immune system response. They include pathogenic microorganisms such as bacteria, viruses, fungi, parasites, and cancer cells. The immune system consists of organs, the innate (or nonspecific) immune system, and the adaptive immune system, which recognizes and remembers antigens. The organs and cells involved in the immune system form a complex system in which antigens and immune system cells are constantly moving through the lymphatic and circulatory system and associated immune organs. Immune system organs include the thymus, bone marrow, lymph nodes, spleen, liver, Peyer’s patches, appendix, tonsils and adenoids, and lungs. The location and functions of these organs are listed in Table 2-1. The appropriate immune response occurs when the immune system recognizes and destroys invading antigens.

**Mechanisms of Defense**

There are two types of immunity: innate (also called nonspecific) and adaptive. Innate immunity is the first line of defense against antigens. Innate immunity...
## Table 2-1 Organs of the Immune System

<table>
<thead>
<tr>
<th>Organs</th>
<th>Location</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Primary</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thymus (part of lymphatic system)</td>
<td>Superior and anterior mediastinum</td>
<td>Largest and most active from neonate to puberty, then atrophies</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Involved in T-cell development</td>
</tr>
<tr>
<td>Bone marrow</td>
<td>Hollow interior of long bones</td>
<td>Major hematopoietic organ, producing red and white blood cells (WBCs) and platelets</td>
</tr>
<tr>
<td><strong>Secondary</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lymphatic vessels and nodes</td>
<td>Interconnected system of vessels throughout body</td>
<td>Lymph fluid is filtered at the lymph nodes, removing foreign material such as bacteria and cancer cells. Involved in WBC production when bacteria are recognized, causing lymph node swelling</td>
</tr>
<tr>
<td>Spleen (part of lymphatic system)</td>
<td>Left upper abdominal quadrant beneath diaphragm</td>
<td>Filters antigens</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Removes old red blood cells and stores red cells, leukocytes, platelets, lymphocytes; serves as hematopoietic organ</td>
</tr>
<tr>
<td>Liver</td>
<td>Right upper abdominal quadrant, small intestine</td>
<td>Kupffer cells filter out antigens</td>
</tr>
<tr>
<td>Peyer’s patches, appendix</td>
<td>Right lower abdominal quadrant</td>
<td>Areas of lymphoid tissue that contain B cells and T cells</td>
</tr>
<tr>
<td>Tonsils and adenoids</td>
<td>Pharynx</td>
<td>Tonsils and adenoids are part of lymphatic system</td>
</tr>
<tr>
<td>Lungs</td>
<td>Thoracic cavity</td>
<td>Filter antigenic material and cellular debris</td>
</tr>
</tbody>
</table>

is present before exposure to an antigen and is not enhanced by successive exposures (Levinson, 2016).

**First Line of Defense/Nonspecific or Innate Defenses**

The first line of defense of the innate system is the presence of physical and chemical barriers that limit entry of microorganisms into the body. These include:

- Intact skin and epithelial surfaces that act as mechanical barriers
- Presence of normal microflora on the skin that compete with pathogens for nutrients and inhibit pathogen growth through lactic acid production
- Normal flora of the throat, colon, and vagina occupy receptors that prevent colonization by pathogens
- Secretions, all of which (e.g., gastrointestinal [GI], respiratory, urogenital tracts, tear glands, breast milk) contain antibodies
Hydrochloric acid production in the stomach and low pH in the vagina maintain an acidic pH that rapidly destroys microorganisms. Lysosomes in tears and other secretions involved in degradation of bacterial cell walls (Levinson, 2016; Storey & Jordan, 2008).

Additional physiological mechanisms include the nares, trachea, and bronchi, which are covered with mucous membranes that trap and then expel pathogens. The nose contains hairs that filter the upper airway, and the nasal passages, sinuses, trachea, and larger bronchi are lined with cilia that elevate mucus-containing trapped organisms and sweep microorganisms upward from the lower airways. Coughing and sneezing forcefully expel organisms from the respiratory tract. Through mechanical action, peristalsis in the GI tract and urinary tract expels organisms from the internal environment of the host.

**NURSING FAST FACT!**

Recognize that when a venipuncture is performed, the body’s first line of defense—intact skin—is broken, thus presenting a potential portal of entry for microorganisms.

**Second Line of Defense/Nonspecific or Innate Defenses**

When the first line of defense fails, the innate immune system performs two functions: killing invading microbes and activating adaptive immune responses (Levinson, 2016). Components of innate immunity include:

- Natural killer (NK) cells, which kill cells infected by viruses
- Neutrophils, which ingest and destroy microbes
- Macrophages and dendritic cells, which ingest and destroy microbes and present antigens to helper T cells (these cells are involved not only in the innate immune system defense but also in activating the adaptive immune response)
- Interferons, which inhibit replication of viruses
- The complement cascade, which is activated by contact with bacterial cell walls, viruses, fungi, cancer cells, endotoxins, and antigen/antibody complexes.
  - This is a system of plasma proteins (complement) that trigger a cascade of reactions resulting in the coating of pathogens and attacking of cell membranes, causing the pathogens to rupture. Complement also signals basophils to release the chemical histamine, which prompts inflammation.
- Inflammation, which limits the spread of microorganisms
- Fever, which slows down bacterial growth
- Transferrin and lactoferrin sequester iron, which is required for bacterial proliferation (Levinson, 2016).

Although innate immunity eliminates microbes and prevents infectious diseases, it is not enough. For example, children who have intact innate immunity
but no adaptive immunity suffer from repeated and life-threatening infections (Levinson, 2016).

**Tertiary Defenses/Adaptive or Specific Immunity**

Adaptive immunity develops after exposure to an antigen, improves on repeated exposures, and is specific (Levinson, 2016). Memory is formed so that the next time the same infection is encountered, there is immunity and no inflammatory response. Adaptive immunity is mediated by antibodies that are produced by B lymphocytes and two types of T lymphocytes: helper T cells and cytotoxic T cells. Cells accountable for adaptive immunity have a long memory for specific antigens and exhibit diversity in that they can respond to millions of different antigens (Levinson, 2016).

Adaptive immunity can be active or passive. Active immunity is resistance after contact with a foreign antigen such as a microorganism. Passive immunity is resistance based on antibodies that were “preformed” in another host. Examples include the immunoglobulins passed from mother to fetus during pregnancy and the preformed antibodies given to treat a disease during the incubation period (e.g., rabies). Risks and disadvantages include possible hypersensitivity reactions to the antibodies and short life span of such antibodies. “Passive active” immunity involves giving preformed antibodies (e.g., immunoglobulins) for immediate protection and vaccinations for long-term protection against certain diseases (Levinson, 2016).

**Leukocytes and the Immune System**

Leukocytes, or white blood cells (WBCs), orchestrate both nonspecific immunity through the inflammatory response and adaptive immunity. A differential WBC count provides specific information related to infections and disease. Normal WBC counts range from 5000 to 10,000/mL. **Leukopenia** is defined as a reduction of the number of leukocytes in the blood to a count of less than 5000/mm³. The types and functions of the different types of leukocytes are listed in Table 2-2.

**Lymphocytes and Adaptive Immunity**

As mentioned earlier, the B and T lymphocytes are involved in adaptive immunity. There are two major branches of the adaptive immune response: humoral (antibody-mediated) immunity and cell-mediated immunity. Humoral immunity includes the production of antibody molecules in response to an antigen. This is mediated by the B lymphocytes (also called B cells). Mature B cells are found in bone marrow, lymph nodes, spleen, some areas of the intestine, and to a smaller extent in the bloodstream (Czaplewski & Vizcarra, 2014). When stimulated by an antigen, they mature into plasma cells, which produce antibodies. Antibodies are also called immunoglobulins.

Immunoglobulins circulate throughout the body, interacting with and aiding in the destruction of potentially harmful microorganisms and toxins. The
main functions of these antibodies are to neutralize toxins and viruses and to make bacteria easier to phagocytize (Levinson, 2016). There are five classes of immunoglobulins:

**IgG:** The major immunoglobulin in the bloodstream; can enter the tissue spaces and coat microorganisms to expedite their destruction by other immune cells; the only immunoglobulin that crosses the placenta and passes on immunity to the infant (i.e., passive immunity)

**IgA:** Found in tears, saliva, and secretions of the respiratory and GI tracts

**IgD:** Remains attached to B cells and plays an important role in early B-cell response

**IgE:** Present in trace amounts; responsible for allergy symptoms

**IgM:** Present and remains in bloodstream, where it effectively kills bacteria (Czaplewski & Vizcarra, 2014)
In contrast to humoral immunity, cell-mediated immunity does not involve antibody production. The response is mediated by the T lymphocytes, which do not produce antibodies but attack antigens directly. Cytotoxic T lymphocytes (also called T cells), activated macrophages, activated NK cells, and cytokines are produced in response to antigens. The cytotoxic T cells directly destroy antigens; they also respond to foreign tissues in the body, such as a transplanted organ. The NK cells come from the bone marrow and are involved in killing virus-infected cells; they may play a role in cancer prevention. Macrophages are large WBCs found in many organs. They remove debris and worn-out cells, and they secrete monokines, which are an important chemical signal to the immune response. Cytokines include interferons, interleukins, and growth factors, which boost the immune system, repair damage, and defend against infection (Czaplewski & Vizcarra, 2014).

**Impaired Host Resistance**

Many factors can result in impaired host defense. Persons who acquire an infection because of a deficiency in any of their multifaceted host defenses are referred to as **compromised** hosts. Persons with major defects related to specific immune responses are referred to as **immunosuppressed** hosts. These two terms often are used interchangeably. Patients with immune dysfunction generally will exhibit the following characteristics:

1. Infections occur frequently.
2. Infections are more severe than usual.
3. Unusual infecting agents or infections with opportunistic organisms occur.
4. Patients have incomplete response to treatment without complete elimination of the infecting agent.

**Immune System Disorders**

Disorders in the immune system consist either of an excessive immune response or a deficient immune response. Examples of an excessive immune response can be found with autoimmune diseases such as rheumatoid arthritis, Crohn’s disease, and inflammatory skin diseases, and as a result of transplant-related rejection. In such cases, biological agents such as monoclonal antibodies may be administered to suppress the immune system.

There are two types of immune deficiencies. Primary immune deficiencies result from an inborn defect in the cells of the immune system. Deficiencies in the immune response may be due to a congenital, acquired, or inherited immune
dysfunction. There are many primary immune disorders, ranging from common to rare. Examples include agammaglobulinemia and hypogammaglobulinemia.

Secondary immunodeficiencies arise from disease processes or therapies that decrease immune system organ or cell function. These deficiencies are acquired. Examples include chronic lymphocytic leukemia and human immunodeficiency virus/acquired immunodeficiency syndrome (HIV/AIDS).

Website
Immune Deficiency Foundation: http://primaryimmune.org

Basic Principles of Epidemiology

Epidemiology is the study of factors determining the occurrence of diseases in human populations (Archibald, 2012). Factors and determinants leading to infection are discussed in this section.

Infection is defined as the successful transmission of microorganisms into a host after the microorganisms evade or overcome the host’s defense mechanisms. Proliferation and invasion of organisms result in clinical signs and symptoms such as inflammation, drainage, or fever. Colonization is the presence of a microorganism on or within body sites without a detectable host immune response, cellular damage, or clinical symptoms. A carrier (or colonized person) is an individual colonized with a specific microorganism and from whom the organism can be recovered but who shows no signs or symptoms of the presence of the microorganism. A carrier may have a history of previous disease. The carrier state may be transient (short term), intermediate (on occasion), or chronic (long term, permanent, or persistent).

Dissemination is the shedding of microorganisms into the immediate environment from a person carrying the microorganisms. Cultures of air samples, surfaces, and objects reveal dissemination or shedding of microorganisms. Some facilities routinely culture all or selected asymptomatic staff in an attempt to identify carriers of certain organisms; however, such surveys lack practical relevance unless they are related to a specific outbreak of disease.

Chain of Infection

Infections result from interaction between infectious agents and susceptible hosts. This interaction is called transmission. The chain of infection refers to six links that make up the chain: the causative agent or microorganism; the place where the organism naturally resides (reservoir); a portal of exit from the reservoir; a method (mode) of transmission; a portal of entry into a host; and the susceptibility of the host. To control infection, the chain of infection must be attacked at its weakest link (Fig. 2-1).

First Link: Causative Agent

The first link in the chain of infection is the microbial agent or source, which may be a bacterium, fungus, virus, or parasite. The majority of HAIs are caused by bacteria and viruses. The ability of an organism to induce disease is called its
virulence or invasiveness. The ability of microorganisms to induce disease is referred to as pathogenicity, and it may be assessed via disease/colonization ratios.

**Second Link: Reservoir**

All organisms have a reservoir, or source of microorganisms. The source of a microorganism may be animate (e.g., humans, the patient’s own microorganisms) or inanimate (e.g., bedside tables, artificial fingernails, toys). The reservoir is where the organism maintains its presence, metabolizes, and replicates. Viruses survive better in human reservoirs, whereas the gram-negative bacteria may have human, animal, or inanimate reservoirs.

**Third Link: Portal of Exit From Reservoir**

The exit site is important in transmission of infection. Organisms from humans usually have a single portal of exit, but multiple portals of exit are possible. The major portals of exit are the respiratory tract, GI tract, and skin (e.g., in wounds). In addition, blood may be a portal of exit and is a concern for nurses and other health care providers.

**Fourth Link: Method (Mode) of Transmission**

After a microorganism leaves its source or reservoir, it requires a means of transmission to reach another person or host through a receptive portal of entry. There are five mechanisms of transmission:

1. **Contact transmission:** Contact transmission can be divided into two subgroups. The first, direct transfer of organisms, involves body-surface-to-body-surface contact and physical transfer of microorganisms between
a susceptible host and an infected or colonized person (e.g., occurs when turning a patient or performing other patient-care activities), or through touching, biting, kissing, or sexual intercourse. The second subgroup, indirect-contact transmission, involves contact of a susceptible host with a contaminated intermediate object, usually inanimate (e.g., contaminated instruments, needles, dressing, or hands). Examples of organisms that can be transmitted via contact are *Staphylococcus* and *Enterococcus* (Siegel, Rhinehart, Jackson, & Chiarello, 2007).

2. Droplet transmission: Droplet transmission is a form of contact transmission. The mechanism of transfer of the pathogen to the host is different from that of contact transmission. Droplet transmission is considered a separate route of transmission. Transmission via large-particle droplets (>5 mm in size) requires close contact between the source and recipient, usually 3 to 6 ft. Examples of pathogens transmitted by the droplet route are *Bordetella pertussis* and *Neisseria meningitides* (Siegel et al., 2007).

3. Airborne transmission: Airborne transmission occurs by dissemination of airborne droplet nuclei of evaporated droplets containing microorganisms that remain suspended in the air for long periods of time. Examples of airborne transmission are *Mycobacterium tuberculosis*, rubeola, and varicella viruses (Siegel et al., 2007).

4. Vehicle-borne transmission: A vehicle is an inanimate substance that serves as an intermediate means to transport and that introduces an infectious agent into a susceptible host. Examples are toys, handkerchiefs, soiled linen, and clothes.

5. Vector-borne transmission: A vector is a living creature (e.g., animal, insect) that serves as an intermediate means for transporting an infectious agent. An example is the mosquito carrying the West Nile virus (Siegel et al., 2007).

**Fifth Link: Portal of Entry to the Susceptible Host**

A person can become infected once the organism enters the body. The skin is a barrier to infectious agents; however, any break in the skin can readily serve as a portal of entry. The mucous membranes and the respiratory, GI, and urinary tracts are other portals of entry. An organism may colonize one site and cause no disease, but the same organism at another site may result in clinical disease. For example, *Escherichia coli* routinely colonizes the GI tract and under normal circumstances does not cause disease; however, *E. coli* in the urinary tract can cause infection.

**Sixth Link: Host Response**

A host can respond to a microorganism in one of three ways: with a subclinical infection, a clinically apparent illness, or the extreme response of death. The same organism infecting different hosts can result in a clinical spectrum of disease that is the same, similar, or different in various individuals. A susceptible host is a person with inadequate defenses against the invading organism. Susceptibility is influenced by factors such as age (e.g., very young or very old), family associations, occupation, travel, access to preventive health care, vaccination status,
and hospitalization (Archibald, 2012). Patients who are receiving immune suppression treatment for cancer or an autoimmune disease, have a chronic illness, or have undergone a successful organ transplant are susceptible hosts.

**Classification of Infections**

**Location**

When infections can cause harm in a limited region of the body (e.g., upper respiratory tract or bladder), these infections are considered local. Systemic infections occur when the pathogens invade the bloodstream and spread through the body. A bacteremia or BSI is defined by the clinical presence of bacteria in the blood, whereas sepsis is a systemic response resulting in an overwhelming and life-threatening response to an infection, which can lead to tissue damage, organ failure, and death (CDC, 2016a). The source of the pathogen must be identified.

Endogenous infections are caused by a person’s own flora. Sources of endogenous infections include body sites inhabited by microorganisms such as the skin and the GI tract. For example, resident microorganisms on a patient’s skin may lead to a BSI after venipuncture if the skin preparation and antisepsis were inadequate. Exogenous infections result from sources outside a person’s body. It may not always be possible to determine whether a particular organism isolated from a patient with HAIs is exogenous or endogenous.

**Stages**

Many infections follow a fairly predictable course of events. The duration and intensity of symptoms may vary from one individual to the next.

- Incubation: The time between exposure to an infectious agent and the first appearance of symptoms.
- Prodromal stage: Characterized by the first appearance of vague symptoms. Not all infections have a prodromal stage.
- Illness: The stage marked by appearance of signs and symptoms characteristic of the disease.
- Decline: The stage during which the patient’s immune defenses, along with any medical therapies, successfully reduce the number of pathogens. Symptoms begin to fade.
- Convalescence: Characterized by tissue repair and return to health.

**NOTE:** If the patient’s immune defenses and medical treatment are ineffective, death in the patient may result.

**Health-Care–Associated Infections**

HAIs are infections that patients develop while they are receiving care in a health-care setting. In the United States, device-associated infections (includes central line–associated bloodstream infections [CLABSI], catheter-associated
urinary tract infections [CAUTI], and ventilator-associated pneumonia) accounted for 25.6% of infections based upon a prevalence survey of acute care hospitals (Magill et al., 2014). In the case of CLABSI, the length of hospital stay and cost of care are increased, with an average cost of $70,696 and a range between $40,412 and $100,980 (Magill et al., 2014).

VAD-related infections are among the hospital-acquired conditions considered to be preventable adverse events; thus, their treatment is not reimbursed under CMS. Aligning payment with patient outcomes represents a significant change in government policy, and prevention of infections is a major healthcare goal. As discussed in Chapter 1, TJC (2017) includes CLABSI prevention as one of the 2017 National Patient Safety Goals.

**Vascular Access Device–Related Infections: Scope and Terminology**

In recent years, most of the focus related to VAD-related infections has been on central lines, particularly in the ICU setting. However, the importance and significance of BSI in hospital units beyond intensive care and those associated with peripheral I.V. catheters are now recognized and increasingly addressed (Austin, Sullivan, Whittier, Lowy, & Uhlemann, 2016; Davis, 2014; Mermel, 2017). Although the evidence indicates a 2- to 64-fold greater risk of BSI with CVADs compared to peripheral catheters, the large number of catheters used translates into potentially thousands of infections each year (Mermel, 2017). The evidence will continue to evolve and inform clinicians of risks and evidence-based practices to address this issue. Notably, in an observational study of 1000 patients with peripheral catheters, researchers reported no peripheral catheter–related BSIs (Marsh, Webster, Larsen, Cooke, Mihala & Rickard, 2017).

There are limited current data regarding the rate of these infections in alternate sites such as nursing homes and home care settings. Indwelling devices, including VADs, were associated with higher rates of infection in the nursing home population (Montoya & Mody, 2011). In a point prevalence study of 10,939 veterans, peripherally inserted central catheters (PICCs) were associated with increased risk for infection (Tsang et al., 2010). Quality improvement efforts are recommended to benchmark practice, identify gaps, and institute improvements in skilled nursing facilities (Chopra et al., 2015). In general, the risk of infection for patients living at home with VADs or other access devices is accepted to be low. A major advantage to home infusion therapy is that the risk of transmission associated with multiple patients and multiple providers in an institution is eliminated in the home setting (Gorski, 2017). Some patients, however, may face increased risk for infection due to such factors as being immunocompromised (e.g., pediatric oncology patients), having a multilumen VAD, or receiving a higher-risk infusion such as parenteral nutrition (PN) (e.g., Buchman, Opilla, Kwasny, Diamantidis, & Okamoto, 2014; Keller et al., 2016; Rinke et al., 2013; Shang, Ma, Poghosyan, Dowding, & Stone, 2014).
It is important to understand the terminology used to describe VAD-related infections. The terms catheter-related bloodstream infection (CRBSI) and central line–associated bloodstream infection (CLABSI) are often used interchangeably, but they have different meanings. CRBSI is a more rigorous definition that requires specific laboratory testing that identifies the catheter as the source of the BSI. CLABSI is a primary BSI (i.e., no apparent infection at another site) that develops in a patient with a central line in place within the 48-hr period before onset of the BSI that is not related to another site. The microorganisms most frequently implicated in CLABSIs are coagulase-negative staphylococci, Staphylococcus aureus, and Candida (Association for Professionals in Infection Control and Epidemiology [APIC], 2015).

Central Line–Associated Bloodstream Infection Surveillance and Public Reporting

Historically, HAIs were perceived as being inevitable consequences of health care. That is no longer the case. Today, HAIs are considered preventable and unacceptable. This has led to public reporting of their occurrence in the United States as well as in other countries. Many states require mandatory public reporting of HAIs, although there is variation in reporting requirements. Medicare-eligible hospitals are required to track and report CLABSIs. The data are reported on the Hospital Compare website (www.hospitalcompare.hhs.gov). The National Healthcare Safety Network (NHSN) is the oldest and most well-developed HAI surveillance system. It is a voluntary and secure Internet-based system. Starting in 2008, all types of health-care facilities in the United States could enroll in the NHSN for data collection, reporting, and analysis (CDC, 2015).

Pathogenesis of Vascular Access Device–Related Infections

There are four potential routes for introducing microorganisms into a patient's bloodstream (APIC, 2015; Safdar, Maki, & Mermel, 2014a):

- Extraluminal: Migration of skin organisms at the insertion site into the catheter tract and along the catheter surface, thus gaining access to the external catheter surface.
- Microorganisms attach to the catheter at the tip and to the external surface as the catheter enters through the epidermis. The source of the microorganisms is the patient's skin or the health-care provider's hands.
- Microorganisms from the patient's skin can enter the catheter tract during the dwell time of the catheter.
- The extraluminal source for infection is the predominant cause in the short term (e.g., within the first 2 weeks after VAD insertion; Mermel, 2011).

- Intraluminal: Direct contamination of the catheter or catheter hub by contact with contaminated hands or fluids or devices. Microorganisms gain access through the internal catheter lumen of the catheter.
- Risk is present every time the catheter is accessed. During medication or fluid administration, catheter flushing, or changing of the needleless
connector or I.V. tubing, microorganisms can enter the catheter lumen. The source of the microorganisms may be the hands of the health-care provider, patient, or caregiver.

- Risk is present if I.V. solutions are not properly handled (i.e., improper refrigeration of infusates, failure to adhere to aseptic technique during solution preparation, or use of multidose vials for more than one patient).
- The intraluminal route is associated with prolonged CVAD dwell time as the number of catheter manipulations and accesses increase (Mermel, 2011).
- **Hematogenous** seeding of bacteria from another type of infection present in the patient, such as a urinary tract infection. This is a less common cause.
- Infusate contamination (Fig. 2-2).

Risk factors for CLABSI include both nonmodifiable and potentially modifiable factors (Table 2-3).

**Intrinsic Versus Extrinsic Causes of Bloodstream Infection**

Potential contamination of the infusion system can occur by extrinsic contamination, which occurs during preparation or administration, or by intrinsic contamination, which occurs during manufacturing.

Extrinsic contamination of parenteral fluids can occur during administration of solutions and medications via many possible sources. Microorganisms gain access from air entering the bottles, from entry points into the administration

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**Figure 2-2** Sources of I.V. cannula-related infections. (From Safdar, N., Maki, D. G., & Mermel, L. A. [2014] In J.R. Jarvis [ed.], *Bennett & Brachman’s hospital infections* [6th ed.]. Philadelphia, PA: Lippincott Williams & Wilkins. Used with permission.)
set, from the I.V. device through the line, or at the junction between the administration set and the catheter hub. Extrinsic contamination is preventable in all settings. Examples of extrinsic contamination include:

- During admixture procedure in the pharmacy when laminar flow hoods are not used
- Incorrect use of admixing equipment
- Improper refrigeration
- Improper technique, such as failure to maintain a closed, sterile I.V. system, touch contamination of the catheter and syringe, and failure to disinfect the needleless connector

Intrinsic contamination of the infusate is considered rare but can occur during the manufacturing and sterilization processes before the containers reach the health-care organization. Damage can occur during storage and delivery. Glass containers can become cracked or damaged and plastic bags punctured. Bacteria and fungi may invade a hairline crack in an I.V. container. When intrinsic contamination occurs, it can cause epidemic device-related infections because of the large numbers of patients in multiple hospitals who may be affected.

**NOTE:** Unopened samples of the suspect lot or lots should be quarantined and saved for analysis.

Before use, any glass container lacking a vacuum when opened should be considered contaminated. To prevent potential infection due to intrinsic causes, follow these steps prior to initiating infusions:

- Examine containers of fluid against light and dark backgrounds for cracks, defects, turbidity, and particulate matter.
Squeeze plastic bags gently to check for loss of integrity.
Observe for droplet formation on the I.V. bag surface.
Inspect all protective coverings and seals.
Inspect the solution for clarity and check expiration dates.

Any concerns about the infusate should result in nonuse of the infusate and reporting to the U.S. Food and Drug Administration.

**Nursing Fast Fact!**
The most important measure to prevent BSIs from contaminated in-use (extrinsic) infusate is stringent asepsis during the preparation and compounding of admixtures in the hospital central pharmacy or in individual patient-care units. Aseptic technique should be followed at all times during infusion therapy, and the administration set should be changed at periodic intervals.

Poor technique while using and handling I.V. equipment can lead to contamination. Pay attention to the following:

1. **Needleless connectors:** Needleless connectors are potential sites for intraluminal contamination. Failure to disinfect the needleless connectors prior to flushing or medication administration is a significant problem, increasing the risk for BSI (Moureau & Flynn, 2015). The INS recommends a vigorous mechanical scrub using an acceptable disinfecting agent (e.g., 70% alcohol, alcoholic chlorhexidine solution) and allowing it to dry prior to each VAD access (Gorski et al., 2016a, p. S68). While there is no clear, evidence-based direction for length of scrubbing time, 15 seconds is a common protocol. TJC (2017) states the following in the National Patient Safety Goals: “Use a standardized protocol to disinfect catheter hubs and injection ports prior to accessing the port.” New products are available, including needleless connectors with built-in antimicrobial protection and disposable alcohol disinfection caps with an alcohol sponge, which are attached to the needleless connector in between intermittent infusions (Fig. 2-3).

2. **Three-way stopcocks:** These adjunct devices are potential sources of transmission of bacteria because their ports, which are unprotected by sterile covering, are open to moisture and contaminants. These devices may be connected to CVADs and arterial lines and are frequently used for drawing blood. The INS (Gorski et al., 2016a, p. S72) states that use of stopcocks is not recommended. However, if they are used, stopcocks with integrated needleless connection are preferred rather than placement of a solid cap over the stopcock. As with all infusion-related procedures, aseptic technique is vital when accessing the ports.

3. **Administration sets:** Intravenous administration sets must be changed based on several factors. The administration set is changed immediately...
when contamination is suspected or when the integrity of the system has been compromised (Gorski et al., 2016a). Another important aspect relates to the situation of intermittent infusions. It is also critical that a sterile, compatible covering device be aseptically attached to the end of the administration set when it is disconnected from the needleless connector on the end of the VAD. Failure to do so is another important factor contributing to increased infection risk. Administration sets used for intermittent infusions are changed at least every 24 hours. There is a high risk of contamination at the spike end and the male luer end of the administration set when it is repeatedly disconnected and reconnected (Gorski et al., 2016a, p. S84).

**NURSING FAST FACT!**

What do you do if you accidentally drop the end of administration set tubing on the patient’s bed or on the floor? Is it acceptable to scrub the end of the tubing with an alcohol wipe rather than throw it away, wasting the administration set? The answer is no. If you know, or suspect, that the integrity of the product has been compromised, do not use it.

**INS Standard** Primary and secondary continuous administration sets used to administer fluids other than lipid, blood, or blood products should be changed no more frequently than every 96 hours. They shall be changed immediately when contamination is suspected or when the integrity of the product or system has been compromised. The administration set shall be...
changed whenever the peripheral catheter is rotated or when a new CVAD is changed (Gorski et al., 2016a, p. S84).

**INS Standard** To prevent the entry of microorganisms into the vascular system, the needleless connector should be consistently and thoroughly disinfected using 70% alcohol, tincture of iodine, or chlorhexidine gluconate/alcohol combination prior to each access (Gorski et al., 2016a, p. S68).

Microorganisms most frequently encountered in catheter-related BSIs are listed in Table 2-4.

### Diagnosing Infection: Culturing Techniques

When an infusion-related infection is suspected, cultures may be obtained to ascertain the source of infection. Culture specimens may include one or all of the following:

- Purulent exudate from the catheter exit site
- Catheter tip/segment
- Administration set
- Infusate
- Patient’s blood

The recommended method for culturing a catheter is the semiquantitative culture technique (Procedures Display 2-1). This technique involves the laboratory technician rolling the catheter segment across an agar plate. Colony-forming units (CFUs) are counted after overnight incubation. Disadvantages of the semiquantitative method are as follows: (1) this method may fail to detect bacteremia of the internal lumens of the catheter tip; and (2) the catheter must be removed for culturing and may not actually be the source of infection.

When culturing drainage at the catheter–skin site, do not cleanse the area to be cultured. On the other hand, when preparing to remove and culture a catheter, the skin around the insertion site must be cleansed with an antiseptic solution prior to catheter removal and allowed to air-dry. If a blood culture is

<table>
<thead>
<tr>
<th>Source</th>
<th>Pathogens</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peripheral I.V. catheter related</td>
<td>Most common causative organism in bloodstream infection (BSI) is <em>Staphylococcus aureus</em>, including methicillin resistant</td>
</tr>
<tr>
<td>Central venous access device related</td>
<td>Gram-positive organisms are most commonly reported causative organisms, including coagulase-negative staphylococci, <em>S. aureus</em>, including methicillin resistant, <em>Enterobacteriaceae</em>, <em>Candida</em> species, <em>Corynebacterium</em> spp, Other gram-negative rods</td>
</tr>
</tbody>
</table>

Sources: APIC, 2015; Austin et al., 2016.
required, it is recommended that a phlebotomy team obtain the samples (Mermel et al., 2009).

**NURSING FAST FACT!**

When obtaining blood through a catheter for culture, the first sample of blood obtained through the catheter is used to inoculate the culture bottles. This is different than the procedure followed when obtaining blood samples for laboratory studies via a catheter, where the initial blood sample is discarded.

**NURSING FAST FACT!**

Growth of 15 or more CFUs from a catheter tip segment represents catheter colonization (Mermel et al., 2009).

Any purulent drainage at the exit site should be collected for culture and gram staining to determine whether gram-positive or gram-negative bacteria are present (Gorski et al., 2016a, p. S107). If the I.V. solution is the suspected source of infection, send the fluid container and the tubing to a laboratory for analysis.

Blood culture samples may be obtained via a peripheral vein and through the VAD. Important procedural considerations include the following: use of phlebotomy teams for blood cultures is recommended; obtain the sample before any antibiotic therapy; use an antiseptic skin preparation prior to venipuncture to avoid contamination of blood specimen; and change the needleless connector prior to drawing blood specimens through a catheter to reduce risk of obtaining a contaminated specimen (Gorski et al., 2016a, p. S87).

**Strategies for Preventing Infection**

Nurses involved in maintaining VADs must have the knowledge base and competency to implement evidence-based interventions to reduce infection risk. The principles of infection prevention provide the foundation for the delivery of infusion therapy. Prevention begins with knowledge regarding the techniques used to prevent infection.

1. **Standard and Transmission-Based Precautions**

   **Standard precautions** are intended to be applied to the care of all patients in all health-care settings, regardless of the suspected or confirmed presence of infectious agents, whereas transmission-based precautions are applied in the presence of known or suspected certain communicable infections. Of note, although these guidelines apply to all settings, the CDC recognizes the shift in health settings to community-based and ambulatory settings and, in 2011, released a summary guide of recommendations specifically aimed at outpatient settings (CDC, 2016b). The specific elements of standard and transmission-based precautions are as follows (Siegel et al., 2007).
Tier One: Standard Precautions

Standard precautions incorporate the fundamentals of universal precautions (designed to reduce exposure risks to blood-borne pathogens) and body substance isolation (designed to reduce the risk of exposures to pathogens residing in moist body fluids) and require consistent use for all patients regardless of their infection status. Standard precautions are intended to protect the healthcare provider as well as the patient from health-care–associated transmission of infectious agents (Siegel et al., 2007).

Standard precautions are based on the principle that all blood, body fluids, secretions, and excretions (except sweat), nonintact skin, and mucous membranes may contain transmissible infectious agents. Standard precautions include the following infection prevention practices: hand hygiene; personal protective equipment (PPE) such as gloves, gowns, masks, eye protection, or face shields; and safe injection practices. The application of standard precautions is determined based on the type of interaction with the patient. For example, with peripheral venipuncture, only gloves would normally be worn. In summary, standard precautions are imposed when:

1. there is risk of exposure to blood,
2. there is risk of exposure to other body fluids, including secretions and excretions (not including sweat), whether or not evidence of blood is present,
3. nonintact skin is present, and
4. there will be contact with any mucous membranes.

Three additional elements of standard precautions are specifically aimed at protecting the patient. They are:

1. Respiratory hygiene/cough etiquette
2. Safe injection practices
3. Use of masks for insertion of catheters or injection of material into spinal or epidural spaces via lumbar puncture procedures (Siegel et al., 2007)

Respiratory Hygiene/Cough Etiquette

The need for vigilance and prompt implementation of infection control measures at the first point of encounter within a health-care setting (e.g., reception and triage areas, outpatient clinics, and physician offices) led to this strategy targeted at patients and accompanying family members with undiagnosed transmissible respiratory infections. The term cough etiquette is derived from recommended source control measures for M. tuberculosis. Respiratory hygiene/cough etiquette includes:

- Education of health-care facility staff, patients, and visitors
- Posted signs in language(s) appropriate to the population served with instructions to patients and accompanying family members or friends
- Source control measures, such as the patient covering the mouth/nose with a tissue when coughing and promptly disposing of used tissues, and the coughing patient using a face mask when tolerated and appropriate
Hand hygiene after contact with respiratory secretions
Spatial separation, ideally greater than 3 ft, of persons with respiratory infections in common waiting areas, when possible

**NURSING FAST FACT!**
Health-care personnel are advised to observe droplet precautions (e.g., wear a mask) and hand hygiene when examining and caring for patients with signs and symptoms of respiratory infection (Siegel et al., 2007).

**SAFE INJECTION PRACTICES**
Poor infection prevention practices and lack of or poor aseptic technique with injections have led to a campaign aimed at safe practices (CDC, 2011). Areas of concern include (1) reinsertion of used needles into a multidose vial or solution container and (2) use of a single needle/syringe to administer I.V. medication to multiple patients. Whenever possible, use of single-dose vials is preferred over multidose vials, and multidose vials are used only with a single patient. Outbreaks related to unsafe injection practices indicate that some health-care personnel are unaware of, do not understand, or do not adhere to basic principles of infection control and aseptic technique. Use the CDC Injection Safety Checklist (Fig. 2-4) to ensure that the health-care organization is adhering to safe injection practices.

**NURSING FAST FACT!**
The use of saline extracted from I.V. bags for the purpose of catheter flushing has resulted in outbreaks of infection and is an unacceptable practice.

**INS Standard** Single-use systems include single-dose vials and prefilled syringes and are the preferred choices for flushing and locking. If multidose containers must be used, each container should be dedicated to a single patient (Gorski et al., 2016a, p. S77).

**INFECTION CONTROL PRACTICES FOR SPECIAL LUMBAR PUNCTURE PROCEDURES**
In October 2005, a Healthcare Infection Control Practices Advisory Committee (HICPAC) reviewed evidence related to eight cases of bacterial meningitis infection by *Streptococcus* species from oropharyngeal flora of HCWs after myelography. The conclusion warranted the additional protection of a face mask for the individual placing a catheter or injecting material into the spinal or epidural spaces (Siegel et al., 2007).
Tier Two: Transmission-Based Precautions

Transmission-based precautions are the second tier of isolation precautions. These additional precautions are based on the known or suspected infectious state of the patient and the possible routes of transmission. It is important to recognize that there are exceptions to application of transmission-based precautions, most notably the home setting, where the risk of transmission is not
well defined, an isolation room is not possible, and family members already exposed to diseases generally do not wear masks. Nurses and HCWs who care for patients with infectious diseases need to use some protection. Standard precautions should always be followed. There are three categories of transmission-based precautions:

1. **Airborne precautions**, which require special air handling and ventilation to prevent the spread of organisms. When suspended in air, infectious agents remain infectious over long distances; examples include the organisms that cause tuberculosis, varicella, and measles. The preferred patient placement is in an airborne infection isolation room (AIIR). The AIIR is a single-patient room that is equipped with special air handling and ventilation capacity that meet the American Institute of Architects/Facility Guidelines Institute standards for AIIRs (e.g., monitored negative pressure relative to the surrounding area; 12 air exchanges per hour for new construction and renovation and six air exchanges per hour for existing facilities; air exhausted directly to the outside or recirculated through high-efficiency particulate air [HEPA] filtration before return). Health-care personnel caring for the patient on airborne precautions wear a respirator (HEPA or N95 respirators for patients with tuberculosis), depending on the disease-specific recommendations. The respirator is donned before entering the room or, in the case of a patient at home, before entering the home setting (Siegel et al., 2007).

2. **Droplet precautions**, which require the use of mucous membrane protection (eye protection and masks) to prevent infectious organisms from contacting the conjunctivae or mucous membranes of the nose or mouth. Examples of infections are mumps, rubella, influenza, adenovirus, rhinovirus, and pertussis. The pathogens do not remain infectious over long distances; special air handling and ventilation are not required to prevent droplet transmission. A single-patient room is preferred. Patients on droplet precautions who must be transported outside of the room should wear a mask if tolerated and follow respiratory hygiene/cough etiquette (Siegel et al., 2007).

3. **Contact precautions**, which require the PPE use of gloves and gowns when direct skin-to-skin contact or contact with a contaminated environment is anticipated. Don PPE when entering the room and discard it before exiting the room to contain pathogens, especially those that have been implicated in transmission through environmental contamination, such as vancomycin-resistant *Enterococcus* (VRE), *Clostridium difficile*, noroviruses and other intestinal tract pathogens, and respiratory syncytial virus (RSV) (Siegel et al., 2007).

2. **Hand Hygiene**

Hand hygiene has been shown to significantly decrease the risk of contamination and cross-contamination. Touch contamination is a common cause of transfer of pathogens. Although the CDC guidelines on hand hygiene published in 2002
remain current, more recent evidence-based practice guidelines were published in 2009 by the World Health Organization (WHO).

**Skin Function/Barrier Protection**

The stratum corneum is the most superficial layer of the top layer of the skin (the epidermis). Its function is to reduce water loss, provide protection against abrasive action and microorganisms, and act as a barrier to the environment. The barrier function results from the dying, degeneration, and compaction of underlying epidermis and from the process of synthesis of the stratum corneum occurring at the same rate as loss.

When using specific products for hand hygiene, it is important to maintain normal barrier function. The normal barrier function is biphasic: 50% to 60% of barrier recovery typically occurs within 6 hours, but complete normalization of barrier function requires 5 to 6 days (CDC, 2002).

**Transmission of Pathogens on Hands**

Bacteria present on hands fall into two categories: resident and transient. **Resident flora** reside under the superficial cells of the stratum corneum and on the skin surface. *Staphylococcus epidermidis* is the most dominant resident. **Transient flora** are microorganisms acquired through patient contact and by contact with environmental surfaces; they tend to be more amenable to removal by routine hand hygiene (WHO, 2009). Transmission of health-care–associated pathogens from one patient to another via the hands of HCWs requires the following sequence of events:

1. Organisms that are present on the patient’s skin (both normal intact skin as well as wounds) or that have been shed onto inanimate objects must be transferred to the hands of HCWs. Areas of skin that tend to be highly colonized include the perineum and inguinal area as well as the axillae, trunk, and upper extremities.
2. These organisms must be capable of surviving for at least several minutes on the hands of personnel.
3. Hand hygiene by the worker is inadequate or omitted entirely, or the agent used for hand hygiene is inappropriate.
4. The contaminated hands of the HCW must come in direct contact with another patient (WHO, 2009).

**Preparations Used for Hand Hygiene**

Alcohol-based products are more effective for standard hand washing or hand antiseptis by HCWs than are soaps or antimicrobial soaps. Applying friction removes most microbes and should be practiced when placing invasive devices, when persistent antimicrobial activity is desired, and when it is important to reduce the numbers of **resident flora** in addition to transient microorganisms (CDC, 2002). Alcohols are not appropriate for use when hands are visibly dirty or contaminated or when known spore-forming pathogens are suspected, as discussed below.
Recommendations for Hand Hygiene in Health-Care Settings

Recommendations are summarized as follows:

- Wash hands with either a nonantimicrobial or an antimicrobial soap and water when hands are visibly dirty or contaminated with proteinaceous material, when hands are visibly soiled with blood or body fluids, and after using the toilet. Rub hands together vigorously for at least 15 seconds (CDC, 2002).
- An alcohol-based hand rub is preferred for hand hygiene (WHO, 2009), as listed in the bullet points below, except when exposure to spore-forming pathogens is suspected or proven (e.g., presence of *C. difficile*); then soap and water should be used to wash hands.
  - Alcohol kills microbes quickly when applied on the skin. Although there is no residual activity, regrowth of bacteria occurs more slowly after use.
  - Alcohol-based hand rubs that contain humectants cause less drying and irritation than soaps.
  - When using an alcohol-based hand rub, apply a palmful and cover all surfaces of hands, rubbing until hands are completely dry (CDC, 2002); this should take 20 to 30 seconds (WHO, 2009).
- Perform hand hygiene:
  - Before and after touching a patient
  - After contact with body fluids, excretions, mucous membranes, non-intact skin, or wound dressings
  - If moving from a contaminated body site to another body site while providing care on the same patient
  - After removing gloves (sterile and nonsterile)
  - Before handling an invasive device, whether or not gloves are worn
  - After contact with inanimate object(s) in immediate vicinity of patient; this includes medical equipment such as infusion pumps

“My Five Moments for Hand Hygiene” is a model for hand hygiene that is used worldwide. It can be correlated to the indications for hand hygiene (WHO, 2009). The five moments are:

1. Before touching a patient
2. Before a clean/aseptic procedure
3. After body fluid exposure
4. After touching a patient
5. After touching a patient’s surroundings

EBP Based upon a review of the evidence, hospital surfaces (e.g., bed rails, tray tables) are frequently contaminated with important health-care–associated pathogens including methicillin-resistant *Staphylococcus aureus* (MRSA), vancomycin-resistant *Enterococcus* (VRE), norovirus, *Clostridium difficile*, and *Acinetobacter* species and thus are an important source of infection transmission. Critically important to reducing transmission of these pathogens are
ADDITIONAL HAND HYGIENE RECOMMENDATIONS

Several studies have demonstrated that skin underneath rings is more heavily colonized than comparable areas of skin on fingers without rings. According to WHO (2009), wearing of rings or other jewelry should be discouraged during health care for several reasons: sharp-surfaced rings can puncture gloves, hanging jewelry can pose a potential physical danger (e.g., get caught in equipment), and poorly maintained jewelry may harbor microorganisms. Additional recommendations include:

1. Do not wear artificial fingernails or extenders when having direct contact with patients at high risk.
2. Keep natural nail tips less than ¼ in. long.
3. Wear gloves, as part of standard precautions, when in contact with blood or body fluids, mucous membranes, and nonintact skin, and never wear the same pair of gloves for the care of more than one patient.

3. Aseptic Technique

Aseptic technique must be followed for all clinical procedures associated with risk for infections. This includes virtually all infusion procedures. Yet, there is often confusion and misunderstanding about terminology. Once a package is opened and sterile supplies are exposed to the air, the term aseptic technique is used, in preference to sterile technique. As defined earlier in this chapter, aseptic technique is defined as a set of specific practices and procedures performed in a manner that minimizes risk of transmission of pathogenic microorganisms to patients. Aseptic non-touch technique (ANTT) is a unique standardized approach to aseptic technique in widespread use in over 30 countries (ANTT, 2017; Rowley, Clare, Macqueen, & Molyneux, 2010). Based on a theoretical and practice framework, hand hygiene and presence of an aseptic field promote aseptic technique, but effective “non-touch” technique ensures hand hygiene and attention to surface cleaning and disinfection. Newer technologies that include no-touch methods of room disinfection (e.g., ultraviolet light) and “self-disinfecting” surfaces (e.g., copper) show promise (Weber, Anderson, & Rutala, 2013).
Critical to ANTT, key sites (e.g., catheter insertion site) and key parts of the supplies used for an infusion must not be touched, whether with or without gloves, to ensure asepsis. Examples of key parts:

- The peripheral I.V. catheter, once taken out of the package and its protective covering removed, cannot be touched before insertion.
- The tip of the flush syringe is protected by a cap that is not to be removed until it is ready for use. The syringe tip must not be touched prior to insertion into the needleless connector.
- The male luer-end of the administration set must be protected by a cap and not touched prior to insertion into the needleless connector or the VAD.
- Needleless connectors must be appropriately disinfected prior to access.

Website
http://annt.org/ANTT_Site/about.html

**NURSING FAST FACT!**
It is critical to infection prevention that any I.V.-related product not be used when it is known to no longer be sterile, and any breaks in asepsis should result in prompt disposal and replacement of the product.

### 4. Skin Antisepsis

Skin antisepsis prior to VAD placement and as part of site care during catheter dwell time is a critical step in reducing the risk of infection. Skin antisepsis is important because bacteria on the skin at the insertion site can travel along the external surface of the catheter during VAD catheter insertion and during catheter dwell. Acceptable antiseptics for skin antisepsis include chlorhexidine/alcohol solution, 70% alcohol, tincture of iodine, or an iodophor. Chlorhexidine/alcohol solution is the standard of practice and is the preferred antiseptic agent recommended by the INS (Gorski et al., 2016a); unlike the other antiseptic agents, it has a residual effect on the skin that lasts for up to 48 hours. When using chlorhexidine in infants younger than 2 months, caution is recommended due to risks of skin irritation and burns. However, chlorhexidine was reported as the primary skin antiseptic agent used in neonatal intensive care units (Sharp, 2014).

Of note, TJC (2017) provides guidance for prevention of catheter-associated BSIs with its National Patient Safety Goals. One of the goals addresses the requirement for use of an antiseptic cited in the scientific literature or endorsed by a professional organization for skin preparation during CVAD insertion.

For patients who are sensitive or allergic to chlorhexidine or alcohol, povidone-iodine is considered an acceptable disinfectant. To be most effective, povidone-iodine requires at least 1.5 to 2 min of contact time on the skin (Gorski et al., 2016a, 2016b; Pedivan, 2015). For patients with compromised skin integrity or for infants younger than 2 months, the povidone-iodine is
removed with sterile normal saline or sterile water to prevent absorption of the product through the skin (Gorski et al., 2016a). This is because iodine absorption through the skin may impact thyroid function in infants.

Additional important aspects of skin preparation include the following:

- Antimicrobial solutions in a single-unit use configuration should be used.
- Alcohol should not be applied after the application of povidone-iodine preparation because alcohol negates the effect of povidone-iodine.
- The antimicrobial preparation solution should be allowed to air-dry completely before proceeding with the VAD insertion procedure or as part of routine site care, prior to dressing placement.

NURSING FAST FACT!

- It is never acceptable to speed up the drying process of skin antisepsis by “blowing” on or fanning the area!

5. Catheter Dressings

Maintaining a clean, dry, and occlusive dressing is important in protecting the catheter insertion site and reducing the risk for infection. A dressing is placed at the time of catheter insertion and is regularly changed as part of the overall site care procedure with CVADs.

Dressing choices include transparent dressings, gauze dressings, and antimicrobial dressings. Use of a transparent versus a gauze dressing is based on the patient’s preference and needs because there is no current evidence supporting one choice over the other. Most often, the transparent dressing is preferred based on the following advantages:

- Less frequent need for replacement (and associated site care)
- Recommendations for transparent dressing changes are every 5 to 7 days (Gorski et al., 2016a, p. S82)
- Ability to easily and continually visualize the insertion site for any signs of local infection without disturbing the dressing
- Less cost in supplies and in nursing time as a result of less frequent dressing changes

Gauze dressings are changed at least every 2 days (Gorski et al., 2016a, p. S82). Indications for use of a gauze dressing include:

- Site drainage; for example, gauze dressings are often used on newly placed CVADs because bleeding may occur in the first 24 hours
- Patients who perspire excessively
- Patients who have a sensitivity or allergic reaction to transparent dressings

Dressings should always be changed earlier than the scheduled 2- or 7-day interval if they become loosened, dislodged, or wet, or if blood or drainage is
The presence of a damp dressing or drainage around the site provides a culture medium for bacterial growth, which increases the risk of infection.

EBP A study of CVAD dressings in ICU patients found that more than two dressing changes for disruption (e.g., undressed site or soiled dressing) were associated with a higher than threefold increase in the risk for infection (Timsit et al., 2012). The researchers assert that assessing the CVAD dressing and ensuring dressing integrity are important elements of postinsertion care.

Antimicrobial dressings, such as chlorhexidine-impregnated dressings, are recommended for use in hospitalized patients (Safdar et al., 2014b). Even when health-care organizations have a low baseline CLABSI rate, further reduction has been demonstrated. One product is a small, round sponge disc that incrementally releases chlorhexidine. It is placed around the catheter at the exit site, covered with a transparent dressing, and changed every 7 days. Note that it is not a stand-alone dressing in that it is always covered with another dressing, usually a transparent one (Fig. 2-5). Another product consists of a transparent dressing with an integrated chlorhexidine gel pad of (Fig. 2-6).

Another aspect of dressing care is the importance of protecting the catheter dressing from water. The catheter and connecting device (e.g., needleless connector) should be protected with an impermeable cover during showering. There are products specifically designed for this purpose (Fig. 2-7).

NURSING FAST FACT!

Some nurses like to place a transparent dressing over the gauze dressing to secure the gauze in place. It is important to recognize that if gauze is used under the transparent dressing, it is considered a gauze dressing and must be changed at least every 48 hours. A gauze dressing is often placed under the wings to stabilize the noncoring needle with implanted ports, followed by application of a transparent dressing. If the gauze does not obstruct the needle insertion site, the transparent dressing may be changed every 5 to 7 days (Gorski et al., 2016a, p. S82).

Figure 2-5 Biopatch®. (Courtesy of J&J Wound Management, Division of Ethicon, Inc., Somerville, NJ.)
Figure 2-6  Chlorhexidine (CHG) transparent semipermeable dressing. (Courtesy of 3M Medical Division, St. Paul, MN.)

Figure 2-7  Aquaguard. (Courtesy of Cenorin, LLC, Kent, WA.)
6. Catheter Stabilization

Catheter stabilization is considered an important step in the care of peripheral I.V. catheters, nontunneled CVADs, and PICCs. Catheter movement in and out of the insertion site allows pathogens on the skin to migrate into the catheter tract. The concept of catheter stabilization often is confusing. Many nurses believe that the dressing itself stabilizes or secures the catheter in place or that use of surgical strips (Steri-Strips) or sterile tape will stabilize the catheter. However, there is no evidence supporting the benefits of a dressing or tape alone in catheter hub stabilization.

Stabilization is achieved through use of an engineered stabilization device. Because the presence of sutures may increase the risk for infection, their use is not recommended (Gorski et al., 2016a, p. S73). A common type of engineered stabilization device consists of an adhesive pad and a mechanism to hold the catheter to the pad. The purpose is to control catheter movement at the catheter insertion site (Fig. 2-8). A novel stabilization product specific for PICC stabilization is a small metal anchor that is placed beneath the skin in the subcutaneous tissue. Advantages to this product are no need for replacement, ease of site antisepsis, and no adhesives, which can be an issue for some patients. This product was found to be efficacious in a small study of 68 inpatients and outpatients in three different institutions (Egan, Siskin, Weinmann, & Galloway, 2013) (see Chapter 5, Fig. 5-21). As researchers look to the future and explore

Figure 2-8  Transparent dressing over a peripherally inserted central catheter with stabilization device—StatLock®. (Courtesy of Mark R. Hunter, CRNI, VA-BC, RN.)
new ideas in clinical practice, new strategies such as tissue adhesives (i.e., “glue” at the insertion site) are being studied for their role in catheter stabilization (Bugden et al., 2016).

**INS Standard** Stabilize and secure VADs to prevent VAD complications and unintentional loss of access (Gorski et al., 2016a, p. S72).

7. Antimicrobial-/Antiseptic-Impregnated Catheters

Catheters that are coated or impregnated with antimicrobial or antiseptic agents can decrease the risk for catheter-related BSIs. Several different types of materials are used to coat catheters. They include:

- Chlorhexidine/silver sulfadiazine: Newest generation available with coating over both internal and external luminal surfaces; more expensive than standard catheters.
- Minocycline/rifampin: Available impregnated on both external and internal surfaces. Although there is concern about development of antimicrobial resistance, this risk is low.
- Platinum/silver: Ionic metals have a broad antimicrobial activity and are being used in catheters and cuffs.

There are also new catheters with chlorhexidine chemically bound to both the internal and external catheter surfaces (see Chapter 5, Central Vascular Access Devices, for more information). Based on current guidelines, use of antiseptic- or antimicrobial-impregnated CVADs is recommended as a special approach if the CLABSI rate has not decreased with implementation of basic CLABSI prevention strategies, or if patients have limited venous access and a history of recurrent CLABSI, or if patients are at heightened risk for complications from a CLABSI (e.g., patient with a prosthetic heart valve) (Marschall et al., 2014).

8. Central Line Bundle

Although today many specialty nurses, in addition to physicians, are placing CVADs, nonspecialty nurses may also play an important role in assisting and ensuring that CVADs are placed according to the central line bundle. Implementation of the “central line bundle” in acute care hospitals has resulted in a markedly decreased rate of CVAD-related infections. The concept of a “bundle” originally was identified by Resar, Griffin, Haraden, and Nolan (2012). A bundle is a group of evidence-based interventions that, when implemented consistently together as a “package,” result in better outcomes than any component implemented individually.

The basic components of the central line bundle adopted by the IHI in its 5 Million Lives Campaign include:

- Hand hygiene prior to catheter insertion
- Maximal sterile barrier precautions with insertion (catheter inserter wears a cap, mask, sterile gloves and gown, and a large sterile drape is placed over patient during insertion)
• Chlorhexidine skin antisepsis
• Avoidance of the femoral site
• Daily review of line necessity with prompt removal of unnecessary lines (Resar et al., 2012)

The origin of the bundle came from a now classic study. With implementation of the above interventions, a 66% reduction in the CLABSI rate was demonstrated across 103 ICUs in the state of Michigan (Pronovost et al., 2006). In addition to the bundle, interventions included comprehensive education, use of CVAD carts that contain all needed supplies, a checklist to ensure that all procedures are followed, and the power to stop the procedure for any breaches.

9. Other Aspects of Postinsertion Care

Optimal care at the time of catheter placement can prevent infections, but the risk of infection is present the entire time the catheter is in place. Research and attention continue to be aimed at postinsertion care and maintenance. Unlike a bundle used with catheter insertion, which is a single point in time, post-insertion care involves many clinicians and potentially several areas of care, from the hospital to outpatient, long-term care setting, or home care. Every time the catheter is accessed or cared for such as during flushing, medication administration, and site care, there is risk for microbial contamination.

Ongoing attention to the catheter site through regular skin antisepsis, use of antimicrobial dressing products, and dressing replacement, as discussed above, is important in preventing growth of skin microorganisms. As discussed earlier, contamination of the catheter and catheter hub gives microbes access via the internal catheter lumen. To summarize interventions to reduce risk, attention must be paid to the following:

• Hand hygiene
• Aseptic technique used with all access procedures
• Administration set changes as discussed earlier
• Changing needleless connectors according to manufacturer’s recommendations
• Disinfection of needleless connectors prior to access and use of alcohol disinfection caps placed on needleless connectors between intermittent access for infusions

**EBP Use of a disinfection cap impregnated with alcohol and placed on the needleless connector** significantly reduced line contamination, density of organisms, and CLABSI. This study was done in an acute care facility and involved three phases: phase 1 baseline—standard scrub of needleless connector, phase 2—disinfection cap placed on all CVADs, and phase 3—back to standard scrub. Infection rates were reduced in phase 2 and increased back to phase 1 levels when the organization reverted back to a standard scrub of the needleless connector (Wright, Tropp, & Schora, 2013).

The use of antimicrobial locking solutions, such as dilute vancomycin/heparin solution or other antimicrobial solutions (e.g., ethanol, citrate), may be considered for therapeutic use or for prophylactic use in the treatment or prevention of CLABSI. Current guidelines recommend their use in patients with long-term CVADs who have a history of multiple CLABSI, in high-risk populations, and in organizations with unacceptably high rates of CLABSI despite adherence to basic CLABSI prevention strategies (Gorski et al., 2016a, p. S79; Marschall et al., 2014). Although studies have demonstrated reduced risk for infection, concerns about antimicrobial resistance remain and limit their use as a routine practice. There also is concern about the effect of the solution on the catheter; for example, the use of ethanol is not recommended with certain types of CVADs (e.g., polyurethane material) because it can break down the catheter material. Manufacturer’s recommendations should always be reviewed and considered.

**NURSING POINTS OF CARE**

**PREVENTION OF INFUSION-RELATED INFECTIONS**

**Nursing Assessment**

**History**

- History of any exposure to pathogens in the environment, including work, recent travel, contact with people who are ill
- Past and present disease histories
- Immunization history
- Risk factors for infection (Table 2-3)

*Continued*
Physical Assessment
- Baseline laboratory studies: WBC count, differential (Table 2-5)
- Vital signs, especially elevated temperature and pulse rate
- Assess for signs of local infection: Erythema, inflammation, purulent drainage, tenderness, warmth at catheter site
- Assess skin turgor and mucous membranes

Key Nursing Interventions
1. Reduce exposure to pathogens through the use of aseptic technique.
2. Follow standard precautions at all times and transmission-based precautions as appropriate.
3. Maintain skin integrity and natural defenses against infection.
4. Use aseptic technique with all infusion-related procedures.
5. Pay attention to skin antisepsis at time of VAD placement and with routine site care.
6. Remove the peripheral I.V. catheter at first sign of complications or if no longer necessary.
7. Change the VAD dressing regularly (e.g., every 5 to 7 days with transparent dressing) and earlier if the dressing becomes wet, soiled, or nonocclusive.
9. Monitor for:
   a. Signs and symptoms of infection (fever, hypotension, positive blood cultures)
   b. Oxygen saturation with oximetry
10. Inspect all infusates before administering.

Occupational Hazards
Occupational hazards specifically associated with infusion therapy include risk for exposure to blood-borne pathogens, exposure to hazardous drugs, and latex allergy. Inserting VADs, administering infusions, handling and discarding sharps, and assisting with sterile procedures and many other high-risk procedures are ordinary parts of the daily practice regimen for nurses who administer infusion therapy.

Blood-Borne Pathogens
Injuries from needlesticks and other sharps are a serious concern for all HCWs. Pathogens such as hepatitis B virus (HBV), hepatitis C virus (HCV), and HIV pose grave and potentially deadly risks to HCWs. A survey sponsored by the American Nurses Association (ANA, 2008) identified three main causes of needlestick injury accounting for two-thirds of the problem: while giving an injection, before activating the safety feature, and during disposal of a nonsafety
### Table 2-5 Common Tests for Evaluating the Presence or Risk of Infusion-Related Infections

<table>
<thead>
<tr>
<th>Test</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>White blood cell (WBC) count with differential</td>
<td>A breakdown of the types of WBCs; normal WBC count is 5000 to 10,000/mm³. Constitute the body’s primary defense system against foreign organisms, tissues, and other substances. Life span of a normal WBC is 13 to 20 days. Produced in bone marrow. Leukocytosis (WBC) and leukopenia (WBC): Acute leukocytosis is initially accompanied by changes in WBC count, followed by changes in individual WBCs.</td>
</tr>
<tr>
<td>Blood culture</td>
<td>A sample of blood is placed on culture media and evaluated for growth of pathogens. Collected whenever bacteremia or septicemia is suspected.</td>
</tr>
<tr>
<td>Panels to evaluate specific disease exposure</td>
<td>Blood tests to evaluate exposure to specific diseases (e.g., human immunodeficiency virus [HIV], hepatitis). Identifies immunocompromised status.</td>
</tr>
<tr>
<td>Immunoglobulin (IgA, IgG, IgM) levels</td>
<td>Blood tests to evaluate humoral immunity status. Immunoglobulins neutralize toxic substances, support phagocytosis, and destroy invading microorganisms. Evaluates humoral immunity status. IgA: Evaluates anaphylaxis associated with transfusion of blood and blood products. IgG: Chronic or recurrent infections. IgM: Viral infections.</td>
</tr>
<tr>
<td>C-reactive protein (CRP)</td>
<td>CRP is a glycoprotein produced by the liver in response to acute inflammation. CRP assay is a nonspecific test that determines the presence (not the cause) of inflammation; it is often ordered in conjunction with ESR.</td>
</tr>
<tr>
<td>Cold agglutinin titer</td>
<td>Used to diagnose atypical infections by detecting antigens in the blood. Cold agglutinins are antibodies that cause clumping or agglutination of red blood cells (RBCs) at cold temperatures in individuals who are infected by a particular organism.</td>
</tr>
<tr>
<td>Erythrocyte (RBC) sedimentation rate ([ESR], or sedimentation rate)</td>
<td>Measures rate of sedimentation of RBCs in an anticoagulated whole blood sample over a specified period of time. The basis of the ESR test is the alteration of blood proteins by inflammatory and necrotic processes. Nonspecific indicator of widespread inflammatory reaction as a result of infection or autoimmune disorders.</td>
</tr>
</tbody>
</table>


device. Other less common causes include after a coworker left a sharp on a surface, in response to an action by a coworker, and while activating a safety feature.

In 2000 Congress passed the Needlestick Safety and Prevention Act (NSPA) (www.gpo.gov/fdsys/pkg/PLAW-106publ430/html/PLAW-106publ430.htm), and the following year OSHA (2001) published an amended version of the blood-borne pathogens standard. Although these efforts have resulted in increased use of safety-engineered devices in health care, there is still work to do.
The International Sharps Injury Prevention Society (ISIPS) is an organization that promotes safety-engineered products, providing education, information, and product knowledge aimed at reducing sharps injury. This helpful website provides numerous resources. A very helpful resource is a listing of safety products by category (e.g., safety I.V. catheters, safety lancets).

There are several categories of safety devices. Active devices require the HCW to activate a safety mechanism. Failure to do so leaves the worker unprotected; thus, education in proper use by HCWs is critical. Passive safety devices remain in effect before, during, and after device use and do not require activation. The INS (Gorski et al., 2016a, p. S40) recommends consideration of passive safety-engineered devices for needlestick injury prevention. An integrated safety design means that the safety feature is built in as an integral part of the device and cannot be removed; this is the preferred design feature. An accessory safety device is external to the device and must be carried to or temporarily or permanently fixed to the point of use; because this is dependent on employee compliance, it is less desirable. Types of safety devices relevant to infusion therapy are listed in Table 2-6.

Requirements of the OSHA blood-borne pathogens standard include the following:

- A written exposure control plan aimed at eliminating/minimizing exposure to blood-borne pathogens. This plan must be reviewed every year.
- Attention to adherence to standard precautions, previously addressed in this chapter.
- Engineering controls and work practices to eliminate or minimize worker exposure. These are aimed at isolating or removing pathogens from the workplace and include sharps disposal containers and safety needle products.
- Input from nonmanagerial HCWs responsible for patient care in selection of engineering controls
- Prohibition from bending, recapping, or removing contaminated needles from a syringe
- Proper disposal: Use of sharps containers, not overfilling containers, no shearing or breaking of needles

NURSING FAST FACT!

It is estimated that there are 385,000 sharps injuries in hospital-based HCWs each year. This does not take into account injuries that occur in nonhospital settings. It is estimated that as many as 40% of U.S. registered nurses work in those settings (CDC, 2013; Daley, 2017).

Sharps injury factors in home care include use of non-safety devices, especially those obtained by patients (e.g., lancets/insulin syringes), and work environment issues such as cluttered homes and distractions (Markkanen, Galligan & Quinn, 2017).
Use of PPE
Free HBV vaccinations
Postexposure evaluation and follow-up, including access to prophylaxis treatment and procedures for evaluating the circumstances surrounding exposure incidents
Record-keeping, including an employer sharps injury log (OSHA, 2001)

**Mucocutaneous Exposure to Blood-Borne Pathogens**

Although most attention is paid to needlestick or sharps, mucocutaneous transmission is another route of exposure to blood-borne pathogens. This refers to blood or body fluid exposure through a break in intact skin or from mucous membrane exposure of the eyes, nose, or mouth of the HCW. Although the chance of becoming infected with HIV after mucocutaneous exposure to infected blood is 0.1% (one-third the chance after a needlestick injury) and the risks of HBV and HCV infection also are lower, the risks should not be underestimated (Delisio, 2012). Exposure may occur from accidental splashing of blood into the eyes or a skin cut, when starting or removing VAD, during disposal of body fluids, or during dressing of an open wound. A 2003 study found that nurses had a higher mucocutaneous exposure rate than physicians and medical technologists. More than one-third (39%) of registered nurses and one-fourth (27%) of licensed practical nurses said they had experienced one or more mucocutaneous blood exposures in the previous 3 months, yet few reported their exposures (Delisio, 2012).

**Prevention of Exposure to Blood-Borne Pathogens**

- Consider all blood, body fluids, secretions, and excretions (except sweat), nonintact skin, and mucous membranes as potentially infectious.
- Use hand hygiene.
- Follow standard precautions.
- Use appropriate PPE (gloves, gown, mask, eye protection, face shield) during care.
- Use safety products.

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**Table 2-6 Sharps Safety Devices and Recommendations**

<table>
<thead>
<tr>
<th>Practice</th>
<th>Safety Recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blood drawing</td>
<td>Shielded or self-blunting needles for vacuum tube phlebotomy</td>
</tr>
<tr>
<td></td>
<td>Shielded, retracting, or self-blunting butterfly-type needles</td>
</tr>
<tr>
<td></td>
<td>Automatically retracting finger/heelstick lancets</td>
</tr>
<tr>
<td></td>
<td>Plastic (not glass) blood collection vacuum tubes</td>
</tr>
<tr>
<td></td>
<td>Ensure that blood is never injected through the rubber stopper of a vacuum tube using an exposed needle</td>
</tr>
<tr>
<td>Infusion</td>
<td>Needleless infusion systems</td>
</tr>
<tr>
<td></td>
<td>Vascular access devices with safety feature; passive safety products preferred</td>
</tr>
<tr>
<td></td>
<td>Safety noncoring needle for implanted port access</td>
</tr>
</tbody>
</table>

Sources: Gorski et al., 2016a; International Health Care Worker Safety Center (n.d.).
• Become involved in product evaluation and decision making. Nurses must realize that the right to be involved is part of the NSPA (Foley, 2012). The INS (Gorski et al., 2016a, p. S32) states that clinicians should be involved in the evaluation of infusion-related technologies, including aspects related to infection prevention and safety.

**NOTE:** Safety features for needleless and needle protection systems are discussed in Chapter 5.

**Websites**


CDC: Bloodborne infectious diseases: HIV/AIDS, Hepatitis B, Hepatitis C: [www.cdc.gov/niosh/topics/bbp](http://www.cdc.gov/niosh/topics/bbp)


International Sharps Injury Prevention Society: [http://isips.org](http://isips.org)

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**NURSING FAST FACT!**

The primary barriers to protect HCWs from blood and/or body fluid exposures are gloves in conjunction with appropriate hand hygiene practices and appropriate PPE.

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**Hazardous Drugs**

Hazardous drugs include cancer chemotherapy, antivirals, hormones, some biologic drugs, and others. HCWs who work with or near hazardous drugs may be exposed to these agents in the air or on work surfaces, clothing, medical equipment, or patient urine or feces. Nurses are exposed to hazardous drugs during infusion administration, such as when priming and disconnecting I.V. administration sets, changing infusion containers, and during disposal. Pathways of exposure include skin contact with drugs and inhalation. Hazardous drugs have demonstrated the ability to cause chromosome breakage in circulating lymphocytes, mutagenic activity in urine, and skin necrosis after surface contact with abraded skin or damage to normal skin. OSHA published guidelines for the management of cytotoxic (antineoplastic) drugs in the workplace in 1986 and updated those guidelines in 2004 (NIOSH, 2004). NIOSH publishes periodic updated lists of hazardous drugs (NIOSH, 2016). Drugs are considered hazardous when they exhibit one or more of the following characteristics in humans or animals:

1. Carcinogenicity (e.g., leukemia, lymphoma, skin cancer)
2. Teratogenicity or other developmental toxicity (e.g., learning disabilities in offspring)
3. Reproductive toxicity (e.g., menstrual cycle changes, spontaneous abortion, infertility)
4. Organ toxicity at low doses
5. Genotoxicity (e.g., chromosomal damage)
6. Structure and toxicity of new drugs that mimic existing drugs determined hazardous by the above criteria (NIOSH, 2016)

Nurses who administer hazardous drugs require special education aimed at personal protection. Some of the guidelines from NIOSH (2004) aimed at reducing risk of exposure are accomplished by:

- Hazardous drug preparation in an area that is devoted to that purpose alone and is restricted to authorized personnel only.
- Preparation of hazardous drugs inside a ventilated cabinet designed to protect workers and others from exposure and to protect all drugs that require sterile handling.
- Using chemotherapy sharps disposal containers for drug-contaminated syringes and other supplies.
- Cleaning and decontaminating work areas before and after each activity involving hazardous drugs and at the end of each shift.
- Cleaning up small spills of hazardous drugs immediately and using proper safety precautions and PPE. For nurses who provide chemotherapy in the home setting, a “spill kit” should be available in the homes of patients receiving such infusions.
- Wearing chemotherapy gloves and disposable closed-front, long-sleeved gowns during drug preparation and administration.
- Using a face shield when splashes to the eyes, nose, or mouth occur and when adequate engineering controls (e.g., sash or window on a ventilated cabinet) are not available.
- Washing hands with soap and water immediately after using personal protective clothing such as disposable gloves and gowns.

Although most organizations pay attention to the NIOSH guidelines, they are voluntary guidelines and have not been enforced (Eisenberg, 2012). In a survey, a researcher found that nurses do not consistently implement safety precautions such as wearing chemotherapy gloves and gowns (Polovich & Clark, 2012). Of note, the state of Washington passed bills in 2011 requiring facilities to follow NIOSH guidelines (Eisenberg, 2012). Moving forward, the United States Pharmacopeia in a new chapter (USP <800>) published new, enforceable stringent standards for handling hazardous drugs with an implementation date of December 1, 2019 (USP, 2017).

**Latex Allergy**

Natural rubber latex (NRL) allergy is a serious medical issue for HCWs. Latex allergy develops with exposure to NRL, a plant cytosol that was used extensively
to manufacture medical gloves and other medical devices. The prevalence of latex allergy has been the highest in HCWs, rubber industry workers, patients with multiple injuries, and children with bladder issues (Gawchik, 2011). Allergic reactions to latex range from asthma to anaphylaxis, which can result in chronic illness, disability, career loss, and death. There is no treatment for latex allergy except complete avoidance of latex. Patients and health-care providers must be assured of safety from sensitization and allergic reaction to latex.

Three types of reactions occur with latex exposure:

1. Latex allergy (immediate hypersensitivity): Occurs within minutes to hours after exposure. Mild reactions include skin redness, hives, and/or itching. More severe reactions include runny nose, sneezing, itchy eyes, scratchy throat, wheezing, coughing, or difficulty breathing. Although anaphylactic shock can occur, it usually is not associated with the first exposure.

2. Irritant contact dermatitis: The most common reaction, which includes symptoms of dry, itchy, irritated skin

3. Allergic contact dermatitis (delayed hypersensitivity): Similar to a poison ivy reaction that shows up 24 to 96 hours after contact (NIOSH, 2010)

In recent years, the incidence of latex allergy in the United States has significantly decreased as a result of prevention efforts, although it remains a worldwide problem because of continued use of powdered latex gloves (Gawchik, 2011). Many other medical products may contain latex. Examples include tapes, catheters, goggles, masks, electrode pads, injection ports on I.V. administration sets, blood pressure cuffs, and stethoscopes (NIOSH, 2010). In the home setting, many objects also may contain latex, such as baby bottle nipples, balloons, erasers, carpeting, and dishwashing gloves (NIOSH, 2010). HCWs with an allergy to NRL who are providing care in the home setting should be aware of these additional objects that may place them at increased risk for an allergic response.

Nurses working in infusion therapy are at risk because of the common routes of exposure. The routes of exposure for latex reaction for infusion specialists include aerosols and glove contact. Employer recommendations to prevent latex exposure include the following:

- Use of gloves that are latex free and resistant to blood-borne pathogens (e.g., nitrile, vinyl)
- If latex gloves are used, the gloves should be made of reduced protein and powder free.
- Education and training for employees
- Medical evaluation for any employees with early symptoms
- Frequent cleaning of areas potentially contaminated with latex dust

**INS Standards** Exposure to latex in the environment is minimized. Low-allergen, powder-free gloves, nitrile gloves, glove liners, or other similar alternatives are used. Labels on medical devices, equipment, and supplies should be reviewed for the presence of latex (Gorski et al., 2016a, p. S35).
Those persons sensitive to latex should take the following precautions:

- Avoid all contact with latex.
- Avoid areas where latex is likely to be inhaled.
- Inform the employer.
- Before receiving any injections or undergoing any medical procedures, consult about any modifications in supplies used.
- Wear a medical identification bracelet (NIOSH, 2010).

To reduce the risk of an allergic response, avoid using hand lotions or lubricants that contain mineral oil, petroleum salves, and other hydrocarbon-based gels or lotions to prevent the breakdown of the glove material and to maintain barrier protection. Do not reuse disposable examination gloves because disinfecting agents can damage the barrier properties of gloves. Following hand hygiene guidelines is recommended after gloves are removed and before a new pair is applied. Gloves should not be stored where they will be subjected to excessive heat, direct ultraviolet or fluorescent light, or ozone (NIOSH, 2010).

**NOTE:** Manufacturers of nonlatex- and nonchlorine- (nonvinyl and non-neoprene) containing gloves are listed on DavisPlus, along with additional website resources of on latex allergy.

**NURSING POINTS OF CARE:**

**ALLERGIC RESPONSE TO LATEX**

**Assessment**

- Obtain a history of risk factors (persons with neural tube defects, atopic individuals including those with allergies to food products); those who possess a known or suspected NRL allergy; persons with ongoing occupational exposure to NRL (e.g., HCWs, rubber industry workers, laboratory personnel).
- Question the patient about associated symptoms of itching, swelling, and redness after contact with rubber products such as rubber gloves, balloons, and barrier contraceptives.

**Key Nursing Interventions**

- Treat latex-sensitive patients as if they have NRL allergy.
- Supply materials and items that are latex free.
- Collaborate with the pharmacy to have a list of latex-containing drugs available.
- Encourage wearing of MedicAlert bracelet.
- Encourage carrying an emergency kit.

*Continued*
The Pediatric Patient
The pediatric population is diverse, and the risk of infection varies with age, birth weight, underlying disease, host factors, medications, type of device, and nature of the infusion therapy. Immunity and risk for infection are of particular concern in the newborn infant. Antibodies are provided primarily through passive immunity by immunoglobulin G (IgG) transfer across the placenta during pregnancy. This maternal antibody wanes over time, with little remaining by 3 to 6 months of age (Levinson, 2016). Newborns also have less effective T-cell function.

The Older Adult
Immunity generally declines with age. There is a reduced IgG response to certain antigens, fewer T cells, and a reduced and delayed hypersensitivity response (Levinson, 2016). These conditions result in increased susceptibility to infections; also, the severity of infections is worse in older than in younger adults (Levinson, 2016; Smith & Cotter, 2012).

Home Care Issues
As discussed earlier, standard precautions apply in the home setting, but transmission-based precautions must be adapted and applied as appropriate in the home setting. For example, the patient with active tuberculosis may be quarantined in the home, and home care staff providing care could be fitted for and provided N95 respirators to wear when making a home visit. In the case of multidrug-resistant organisms (MDROs), such as methicillin-resistant *Staphylococcus aureus* (MRSA), standard precautions apply unless a higher level of precautions is required. In that case, limit the use of patient-care equipment utilized repeatedly (e.g., blood pressure cuff, stethoscope), leave it in the home, and transport it to an appropriate site for cleaning and disinfection (Siegel et al., 2007). Each nurse or aide providing care in the home needs appropriate equipment and supplies related to infection control. The home health clinician typically carries a “nursing bag” from home to home. It should contain needed supplies such as blood pressure cuffs, stethoscope, blood glucose meter (glucometer), pulse oximeter, hand hygiene, and other medical supplies (e.g., dressings); disinfectants to clean equipment (e.g., stethoscope diaphragm) after use; and a spill kit in case a large amount of blood or body fluid spills on the floor or any other surface. Because it is recognized that microorganisms may be transferred to the nursing bag, many organizations employ “bag technique” strategies such as using a barrier under the bag, hand hygiene prior to accessing equipment, and routine bag cleaning. It is recommended that the bag not be brought into the home for patients with MDROS, for patients on contact precautions, in the presence of infestations, and in grossly contaminated homes (McGoldrick, 2017).
Home Care Issues—cont’d

EBP An often-cited study that has not been replicated involved culturing the nursing bags from four different home care agencies. It was found that approximately 84% of the outside of the bags cultured positive for human pathogens (15.9% multidrug-resistant organisms [MDROs]); 48.4% of the inside of the bags had positive cultures (6.3% MDROs), and 43.7% of patient-care equipment was contaminated with human pathogens (5.6% MDROs). Although this study described the existence of pathogens only on the nursing bag, it is recognized that there is potential risk for transmission of infection from one patient to another via contaminated nursing bags (Bakunas-Kenneley & Madigan, 2009).

The home care provider should establish policies and procedures for handling waste.

- Sharps containers must be used for all contaminated sharps generated by the nurse.
- Infusion pharmacies may deliver sharps containers to the patient’s home and pick them up when therapy is completed or the containers are full. Alternatively, the use of “mail back” sharps container programs are increasingly common; the patient is provided with packaging and labeling to return the containers when they are full.
- Prepackaged kits available from a number of manufacturers include sharps disposal systems and chemotherapy spill kits.

Patient Education

In all health-care environments, patient education is an important component in preventing infusion-related complications. Education regarding vascular access management is crucial. Information regarding catheter management should be individualized to meet the patient’s needs but remain consistent with established policies and procedures for infection control.

Education should include:

- Instructions on hand hygiene; aseptic technique; and the concept of dirty, clean, and sterile
- Proper methods for handling equipment
- Judicious use of antibiotics, which is a major nursing role to slow an epidemic of drug-resistant infections
- Importance of adhering to directions for prescribed antibiotics
- Dressing changes

Continued
Patient Education—cont’d

- Assessment of the site and the key signs and symptoms to report to the home care agency, hospital health-care worker, or physician
- Information regarding emergency procedures should the catheter break or rupture

**Allergy**

- Provide information about natural rubber latex allergy and sensitivity

### Nursing Process

The nursing process is a six-step process for problem solving that guides nursing action. See Chapter 1 for details on the steps of the nursing process related to vascular access. The following table focuses on nursing diagnoses, nursing outcomes classification (NOC), and nursing interventions classification (NIC) for infection control and risk management. Nursing diagnoses should be patient specific and outcomes and interventions individualized. The NOC and NIC presented here are suggested directions for development of outcomes and interventions.

<table>
<thead>
<tr>
<th>Nursing Diagnoses Related to Infection Control and Safety</th>
<th>Nursing Outcomes Classification (NOC)</th>
<th>Nursing Interventions Classification (NIC)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Risk for allergy response: Latex, related to:</strong> Exposure to environmental allergen (natural latex rubber protein)</td>
<td>Allergic response: Localized or systemic, immune hypersensitivity response Tissue integrity: Skin and mucous membranes</td>
<td>Allergy management, environmental risk protection (latex precautions)</td>
</tr>
<tr>
<td><strong>Skin integrity, impaired, related to:</strong> External: Chemical substances, mechanical factors (e.g., shearing forces, pressure, vascular access device [VAD]), pharmaceutical agent Internal: Alteration in skin turgor, immunodeficiency, impaired circulation</td>
<td>Tissue integrity: Primary intention healing of VAD insertion site</td>
<td>Incision site care, skin surveillance</td>
</tr>
<tr>
<td><strong>Infection, risk for, related to:</strong> Invasive procedure, chronic illness, alteration in skin integrity, leukopenia, immunosuppression</td>
<td>Risk control: Infectious process management</td>
<td>Infection control; infection protection</td>
</tr>
<tr>
<td><strong>Protection, ineffective, related to:</strong> Abnormal blood profile (leukopenia), extremes of age, pharmacological agent (antineoplastic), immune disorders, inadequate nutrition</td>
<td>Health-promoting behavior; immune status</td>
<td>Infection prevention, infection protection</td>
</tr>
</tbody>
</table>

Sources: Ackley, Ladwig, & Makic, 2017.
Chapter Highlights

- The purpose of the immune system is to recognize and destroy invading antigens. Organs of the immune system include the thymus, bone marrow, lymph nodes, spleen, liver, Peyer’s patches, appendix, tonsils and adenoids, and lungs.
- There are two types of immunity:
  - Innate or nonspecific immunity: Present before exposure to antigens
  - Adaptive or specific immunity: Develops after exposure to antigens
- The chain of infection includes six links:
  - Causative agent
  - Reservoir
  - Portal of exit
  - Method of transmission
  - Portal of entry
  - Host response
- An HAI is an infection that a patient develops while receiving care in a healthcare setting.
- Infusion-related infections:
  - VAD-related infection
  - Infusate-related infections: Intrinsic contamination (by manufacturer) (rare) and extrinsic contamination (during preparation and maintenance)
  - Culturing techniques: Semiquantitative method
  - Culture one or all of the following, depending on symptoms and observation of catheter site.
    - Catheter–skin junction: Do not use alcohol to cleanse before culturing.
    - Catheter
    - Infusate with administration set
    - Patient’s blood
- Strategies to prevent/treat infection include:
  - Following standard precautions
  - Adhering to aseptic technique
  - Performing hand hygiene
  - Using appropriate skin antisepsis
  - Regular site care including skin antisepsis and dressing replacement
  - Using catheter stabilization devices
  - Implementation of the central line bundle
  - Postinsertion care strategies
- Occupational risks associated with infusion therapy include:
  - Biological exposure to blood-borne pathogens
  - Needlestick injuries
  - Chemical exposure
  - Latex allergy
References


ANTT. (2017). What is aseptic non touch technique (ANTT®)? Retrieved from http://antt.org/ANTT_Site/what_is_ANTT.html


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Delegation
This procedure should not be delegated. It is a registered nurse's responsibility to assess and apply critical thinking skills to obtain the necessary cultures.

Procedure | Rationale
--- | ---
1. Verify orders. | 1. A written order is a legal requirement.
2. Introduce yourself to the patient. | 2. Establishes nurse–patient relationship
3. Verify the patient's identity. | 3. Patient safety goal
4. Perform hand hygiene. | 4. Important means of preventing the spread of infection
5. Explain procedure to patient. | 5. Prepares patient for procedure

Culture: Drainage present at catheter–skin junction
Follow steps 1–5 above
6. Gather supplies: Clean gloves, culture tube, site care supplies.

Continued
PROCEDURES DISPLAY 2-1  
Steps in Culturing Catheter-Skin Junction, Catheter, Infusate, and Blood—cont’d

**Procedure**

7. Don clean gloves.
8. Remove dressing over I.V. site and discard appropriately according to organizational procedures.
9. Remove gloves and perform hand hygiene.
10. Don another pair of clean gloves.
11. Swab purulent drainage with a sterile swab and place swab into culture tube using aseptic technique.
12. Recap the culture tube.
13. Perform site care per organizational procedure if catheter is to be left in place.
14. Remove gloves, perform hand hygiene, label culture tube with patient name, date and time, and source of culture.

**Culture: Catheter tip**
Follow steps 1–5 above.

**Rationale**

7. Standard precautions
8. Soiled dressings are potentially infectious and must be discarded properly.
9. Standard precautions; always perform hand hygiene between glove changes.
11. To obtain culture
14. Ensures obtaining results from the correct patient

6. Reduces the risk for air embolism during catheter removal.
7. Preparation

6. Position patient in supine flat or Trendelenburg for CVAD catheter removal.
Infection Prevention and Occupational Risks

CHAPTER 2

PROCEDURES DISPLAY 2-1

Steps in Culturing Catheter-Skin Junction, Catheter, Infusate, and Blood—cont’d

Procedure

8. Put on sterile gloves.

9. Cleanse skin at catheter exit site with antiseptic solution and allow to dry.

10. Place sterile drape in proximity to catheter–skin junction.

11. Remove catheter. For patients with CVADs, ask patient to employ Valsalva’s maneuver or exhale during procedure. Place catheter on sterile drape, avoiding contact with surrounding skin, and place occlusive dressing using petroleum-based ointment and gauze or a transparent semipermeable membrane (TSM) dressing to exit site. Pay special attention to reducing risk of air embolism with CVADs (see Chapter 9).

12. Remove gloves and perform hand hygiene.

13. Put on second pair of sterile gloves.

14. Cut a 2-in. segment of CVAD catheter tip using sterile scissors; for short peripheral catheter, cut entire length of catheter from catheter hub.

Rationale

8. Prevents transfer of skin pathogens onto catheter

9. To reduce the risk of microorganisms on the skin contaminating catheter during removal process

10. For placement of catheter on removal; to reduce risk of contaminating catheter, thus reducing risk for false-positive results

11. To reduce risk of contaminating catheter; to reduce risk for air embolism; safe catheter removal

12. Standard precautions; always perform hand hygiene between glove changes

13. Standard precautions; maintain aseptic technique with catheter tip culture to reduce false-positive results

Continued
### PROCEDURES DISPLAY 2-1

#### Steps in Culturing Catheter-Skin Junction, Catheter, Infusate, and Blood—cont’d

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>15. Uncap culture tube.</td>
<td></td>
</tr>
<tr>
<td>16. Drop catheter segment into culture tube, maintaining aseptic technique.</td>
<td></td>
</tr>
<tr>
<td>17. Recap the culture tube and label with patient’s name, date and time, and specimen type.</td>
<td>17. Ensures obtaining results from the correct patient</td>
</tr>
</tbody>
</table>

**Culture: Infusate**

Follow steps 1–5.

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>6. Gather supplies: Gloves, syringe.</td>
<td>6. Preparation</td>
</tr>
<tr>
<td>7. Put on gloves.</td>
<td>7. Standard precautions</td>
</tr>
<tr>
<td>8. Disinfect injection port of infusate container with disinfectant (e.g., 70% alcohol, chlorhexidine/alcohol) for at least 15 seconds using a twisting motion and allow to dry.</td>
<td>8. Prevent cross-contamination from port site</td>
</tr>
<tr>
<td>9. Insert sterile needleless syringe into injection port of infusate bag.</td>
<td>9. To obtain sterile sample of infusate</td>
</tr>
<tr>
<td>10. Withdraw approximately 5 mL of infusate into syringe.</td>
<td>10. Amount needed for culture</td>
</tr>
<tr>
<td>11. Remove the syringe from the infusate container.</td>
<td></td>
</tr>
<tr>
<td>12. Inject syringe contents into appropriate culture bottles.</td>
<td></td>
</tr>
<tr>
<td>13. Label culture bottles with patient’s name, date and time, and specimen type.</td>
<td>13. Ensures obtaining results from the correct patient</td>
</tr>
</tbody>
</table>

Source: INS (Gorski et al., 2016b).
Chapter 3
Fundamentals of Fluid and Electrolyte Balance
Lynn D. Phillips

LEARNING OBJECTIVES
After completing this chapter, the reader will be able to:
1. Define terminology related to fluids and electrolytes.
2. Identify the three fluid compartments within the body.
3. State the functions of body fluids.
4. Differentiate between active and passive transport.
5. Describe the homeostatic mechanisms.
6. Compare and contrast the movement of water in hypotonic, hypertonic, and isotonic solutions.
7. Compare and contrast fluid volume deficit and fluid volume excess.
8. List the six major body systems assessed for fluid balance disturbances.
9. State the seven major electrolytes within the body fluids.
10. Contrast each of the seven electrolytes and their major roles in body fluids.
11. Identify signs and symptoms of both deficits and excesses of sodium, potassium, calcium, magnesium, chloride, and phosphate.
12. Identify patients at risk for electrolyte imbalances.
13. State the normal pH range of body fluids.
15. Compare clinical manifestations of acidosis and alkalosis.

Glossary

**Acidosis**  An actual or relative increase in the acidity of blood due to an accumulation of acids or an excessive loss of bicarbonate; blood pH below normal (<7.35)

**Active transport**  The process by which a cell membrane moves molecules against a concentration or electrochemical gradient. Metabolic work is required.
**Alkalosis** An actual or relative increase in blood alkalinity due to an accumulation of alkalis or a reduction of acids in the blood; blood pH above normal (>7.45)

**Anion** Negatively charged electrolyte

**Antidiuretic hormone (ADH)** A hormone secreted from the pituitary mechanism that causes the kidney to conserve water; sometimes referred to as the “water-conserving hormone”

**Atrial natriuretic peptide (ANP)** ANP is a cardiac hormone that is released when atria are stretched by high blood volume

**Body fluid** Body water in which electrolytes are dissolved

**Brain natriuretic peptide (BNP)** BNP is a cardiac hormone that is released when the ventricles are stretched by high blood volume. BNP levels are used in the evaluation of heart failure.

**Cation** Positively charged electrolyte

**Chvostek’s sign** A sign elicited by tapping the facial nerve about 2 cm anterior to the ear lobe, just below the zygomatic process; the response is a spasm of the muscles supplied by the facial nerve

**Diffusion** The movement of a substance from a region of high concentration to one of lower concentration

**Extracellular fluid (ECF)** Body fluid located outside the cells

**Filtration** The process of passing fluid through a filter using pressure

**Fingerprinting edema** A condition in which imprints are made on the hands, sternum, or forehead when the area is pressed firmly by the fingers

**Fluid volume deficit (FVD)** A fluid deficiency; hypovolemia; an equal proportion of loss of water and electrolytes from the body

**Fluid volume excess (FVE)** The state of exceeding normal fluid levels; hypervolemia; retention of both water and sodium in similar proportions to normal ECF

**Homeostasis** The state of dynamic equilibrium of the internal environment of the body that is maintained by the ever-changing processes of feedback and regulation in response to external or internal changes

**Hypertonic** Having a concentration greater than the normal tonicity of plasma; solution of higher osmotic concentration than that of an isotonic solution; greater than 375 mOsm/L

**Hypotonic** Having a concentration less than the normal tonicity of plasma; solution of lower osmotic concentration than that of an isotonic solution

**Insensible loss** Fluid loss that is not perceptible to the individual; nonvisible form of water loss that is difficult to measure (e.g., perspiration)

**Interstitial fluid** Body fluid between the cells

**Intracellular fluid (ICF)** Body fluid inside the cells

**Intravascular fluid** The fluid portion of blood plasma

**Isotonic** Having an osmotic pressure equal to that of blood; equivalent osmotic pressure; between 250 and 375 mOsm/L

**Licensed independent practitioner (LIP)** An individual permitted by law to provide care and services without direction or supervision within the scope of the individual’s granted clinical privileges, license, and organizational policies
Oncotic pressure  The osmotic pressure exerted by colloids (proteins), as when albumin exerts oncotic pressure within the blood vessels and helps to hold the water content of the blood in the intravascular compartment

Osmolality  The number of milliosmoles per kilogram of solvent

Osmolarity  The number of milliosmoles per liter of solution

Osmosis  The movement of water from a lower concentration to a higher concentration across a semipermeable membrane

pH  A measure of hydrogen ion (H+) concentration; the degree of acidity or alkalinity of a substance

Sensible loss  Output that is measurable (e.g., urine)

Solute  The substance that is dissolved in a liquid to form a solution

Syndrome of inappropriate antidiuretic hormone secretion (SIADH)  A condition in which excessive ADH is secreted, resulting in hyponatremia

Tetany  Continuous tonic spasm of a muscle

Trousseau’s sign  A spasm of the hand elicited when the blood supply to the hand is decreased or the nerves of the hand are stimulated by pressure; elicited within several minutes by applying a blood pressure (BP) cuff inflated above systolic pressure

**Introduction**

Fluid and electrolyte balance in our bodies is critical to life. Every nurse must possess a fundamental understanding of the composition and distribution of body fluids and the maintenance of homeostasis. Any imbalance of fluids, such as dehydration or fluid excess, or electrolyte imbalance can be life-threatening. Nurses in all settings will monitor laboratory values as well as signs and symptoms of fluid and electrolyte indicators for evidence of imbalances.

**Body Fluid Composition**

Body fluid is body water in which electrolytes are dissolved. Water is the largest single constituent of the body. Body water, the medium in which cellular reactions take place, constitutes approximately 60% of total body weight (TBW) in young men and 50% to 55% in women. Table 3-1 lists percentages of total body fluids in relation to age and gender. Fat tissue contains little water, and the percentage of total body water varies considerably based on the amount of body fat present. In addition, total body water progressively decreases with age, making up about 50% of body weight in older adults (Kamel & Halperin, 2016).

**Cultural and Ethnic Considerations**

A person’s age, gender, ethnic origin, and weight can influence the amount and distribution of body fluid. For example, African Americans often have larger numbers of fat cells compared with other groups and therefore have less body water (Giger, 2016).
**Fluid Distribution**

**Homeostasis** is dependent on fluid and electrolyte intake, physiological factors (e.g., organ function, hormones, age, gender), disease state factors (e.g., respiratory, renal, metabolic disorders), external environmental factors (e.g., temperature, humidity), and pharmacological interventions.

Water is a neutral polar molecule in which one part is negative and one part is positive. Body water is distributed within cells and outside cells. The body water within the cells is referred to as **intracellular fluid (ICF)**. Fluid outside the cells is referred to as **extracellular fluid (ECF)** and consists of two compartments: interstitial and intravascular fluid. Approximately 40% of the TBW is composed of the fluid inside the cell (ICF). Another 20% is fluid outside the cell (ECF) and is divided between interstitial and intravascular spaces, with 15% in the tissue (interstitial) space and only 5% in the plasma (intravascular) space. The **interstitial fluid** lies outside of the blood vessels in the interstitial spaces between the body cells. Lymph and cerebrospinal fluids, although highly specialized, usually are regarded as interstitial fluid. Figure 3-1 shows a representation of body water distribution.

An exchange of fluid occurs continuously among the intracellular, plasma, and interstitial compartments. Of these three spaces, the intake of fluid or elimination from the body directly influences only the plasma. Changes in the intracellular and interstitial fluid compartments occur in response to changes in the volume or concentration of the plasma.

The internal environment needs to remain in homeostasis; therefore, the intake and output (I&O) of fluid must be relatively equal, as occurs in healthy individuals. In persons who are ill, this balance is frequently upset, and intake of fluid may become diminished or even cease. Output may vary with the influences of increased temperature, increased respiration, draining wounds, or gastric suction.

Normal sources of water on a daily basis include liquids, water-containing foods, and metabolic activity. In healthy adults, the intake of fluids varies from 1000 to 3000 mL/day, and oxidation produces 200 to 300 mL.

**Table 3-1  Percentages of Total Body Fluid in Relation to Age and Gender**

<table>
<thead>
<tr>
<th>Age</th>
<th>Total Body Fluid (% of Body Weight)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full-term newborn</td>
<td>70–80</td>
</tr>
<tr>
<td>1-year-old</td>
<td>64</td>
</tr>
</tbody>
</table>
| Puberty to 39 years | Men: 60  
|                   | Women: 55                           |
| 40–60 years       | Men: 55  
|                   | Women: 47                           |
| >60 years         | Men: 52  
|                   | Women: 46                           |

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The elimination of fluid is considered either sensible (measurable) loss or insensible (not measurable) loss. Water is eliminated from the body by the skin, kidneys, bowels, and lungs. Approximately 300 to 500 mL of water is eliminated through the lungs every 24 hours, and the skin eliminates about 500 mL/day of water in the form of perspiration. The amount of insensible loss in an adult is approximately 1000 mL/day. Losses through the gastrointestinal (GI) tract are only about 100 to 200 mL/day because of reabsorption of most of the fluid in the small intestines. Increased losses of GI fluids can occur from diarrhea or intestinal fistulas (Hinkle & Cheever, 2013).

The metabolic rate increases with fever; it rises approximately 12% for every 1°C (7% for every 1°F increase in body temperature). Significant sweat losses occur if a patient's body temperature exceeds 101°F (38.3°C) or if the room temperature exceeds 90°F. Fever also increases the respiratory rate, resulting in additional loss of water vapor through the lungs (Porth, 2015). Insensible loss is also increased if respirations are increased to more than 20 per minute.

**Fluid Function**

Fluids within the body have several important functions. The ECF transports nutrients to the cells and carries waste products away from the cells via the capillary beds. Body fluids are in constant motion, maintaining living
conditions for body cells. The fluid within the body also has the following functions:

2. Regulates body temperature.
3. Transports material to and from cells.
4. Serves as an aqueous medium for cellular metabolism.
5. Assists digestion of food through hydrolysis.
6. Acts as a solvent in which solutes are available for cell function.
7. Serves as a medium for excretion of waste.

Fluid Transport

Body fluids are in constant motion, maintaining healthy living conditions for body cells. The ECF interfaces with the outside world and is modified by it, but the ICF remains stable. Nutrients are transported by the ECF to the cells, and wastes are carried away from the cells via the capillary beds (Kee, Paulanka, & Polek, 2010).

Movement of particles through the cell membrane occurs through four transport mechanisms: passive transport, which consists of diffusion, filtration, and osmosis; and active transport. Materials are transported between the ICF and the extracellular compartment by these four mechanisms.

Passive Transport

Passive transport is also referred to as non-carrier-mediated transport. It is the movement of solutes through membranes without the expenditure of energy. It includes passive diffusion, osmosis, and filtration.

Diffusion

Diffusion is the passive movement of water, ions, and lipid-soluble molecules randomly in all directions from a region of high concentration to an area of low concentration. Diffusion occurs through semipermeable membranes by the substance’s either passing through pores, if small enough, or dissolving in the lipid matrix of the membrane wall. If there is no force opposing diffusion, particles distribute themselves evenly. Many substances can diffuse in both directions through the cell membrane. Influencing factors in the diffusion process are concentration differences, electrical potential, and pressure differences across the pores. The greater the concentration, the greater the rate of diffusion. An increase in the pressure on one side of the membrane increases the molecular forces striking the pores, thus creating a pressure gradient. Other factors that increase diffusion include:

- Increased temperature
- Increased concentration of particles
- Decreased size or molecular weight of particles
- Increased surface area available for diffusion
- Decreased distance across which the particle mass must diffuse
**Filtration**

Filtration is the transfer of water and a dissolved substance from a region of high pressure to a region of low pressure; the force behind it is hydrostatic pressure (i.e., the pressure of water at rest). The pumping heart provides hydrostatic pressure in the movement of water and electrolytes from the arterial capillary bed to the interstitial fluid. Diffusion moves in either direction across a membrane; filtration moves in one direction only because of the hydrostatic, osmotic, and interstitial fluid pressures. Filtration is likened to pouring a solution through a sieve: The size of the opening in the sieve determines the size of the particle to be filtered.

The plasma compartment contains more protein than the other compartments. Plasma protein, composed of albumin, globulin, and fibrinogen, creates an oncotic pressure at the capillary membrane, which prevents fluid from the plasma from leaking into the interstitial spaces. Oncotic pressure created within the plasma by the presence of protein (mainly albumin) keeps the water in the vascular system.

Starling’s law of the capillaries maintains that, under normal circumstances, fluid filtered out of the arterial end of a capillary bed and reabsorbed at the venous end is exactly the same, creating a state of near-equilibrium (Starling, 1896). However, it is not exactly the same because of the difference in hydrostatic pressure between the arterial and venous capillary beds. The pressure that moves fluid out of the arterial end of the network totals 28.3 mm Hg. The pressure that moves fluid back into circulation at the venous capillary bed is 28 mm Hg. The small amount of excess remaining in the interstitial compartment is returned to the circulation by way of the lymphatic system (Kee et al., 2010).

**Osmosis**

Osmosis is the passage of water from an area of lower particle concentration toward one with a higher particle concentration across a semipermeable membrane. For a membrane to be semipermeable, it has to be more permeable to water than to solutes. This process tends to equalize the concentration of two solutions.

Osmosis governs the movement of body fluids between the intracellular and ECF compartments, therefore influencing the volumes of fluid within each. Through the process of osmosis, water flows through semipermeable membranes toward the side with the higher concentration of particles (thus from lower to higher) (Hankins, 2010).

**Osmotic Pressure Gradients**

Osmotic pressure develops as solute particles collide against each other. Osmotic pressure is the amount of hydrostatic pressure needed to draw a solvent (water) across a membrane, and it develops as a result of a high concentration of particles colliding with one another. As the number of solutes increases, there is less space for them to move; therefore, they come in contact with one another more frequently. This results in increased osmotic pressure, which causes the movement
of fluid. The osmotic pressure differs at the cell membrane and the capillary membrane. The process of osmosis depends on how much of the membrane is involved and on certain characteristics of the solution (Hankins, 2010). The colloid osmotic pressure is influenced by proteins because proteins are the only substances dissolved in the plasma and interstitial fluid that do not diffuse readily through capillary membranes. The concentration of protein in plasma is two to three times greater than that of the proteins found in the interstitial fluid. Only the substances that do not pass through the semipermeable membrane exert osmotic pressure. Therefore, proteins in the ECF spaces are responsible for the osmotic pressure at the capillary membrane. Osmotic pressure is measured in milliosmoles (mOsm).

**Osmolarity Versus Osmolality**

The osmotic activity of a solution may be expressed in terms of either its osmolarity or its osmolality. Osmolarity refers to the solute concentration in fluid by the number of milliosmols (mOsm) in 1 L of solution. Osmolality refers to the solute concentration in the fluid by weight and is expressed as the number of milliosmols (mOsm) in 1 kg of solution. Osmolarity usually refers to fluids outside the body, and osmolality refers to fluids inside the body. Because 1 L of water weighs 1 kg, the terms osmolarity and osmolality are often used interchangeably (Porth, 2015).

**Active Transport**

Active transport is similar to diffusion except that it acts against a concentration gradient. Active transport occurs when it is necessary for ions (electrolytes) to move from an area of low concentration to an area of high concentration. By definition, active transport implies that energy expenditure must take place for the movement to occur against a concentration gradient. Adenosine triphosphate (ATP) is released from the cell to enable certain substances to acquire the energy needed to pass through the cell membrane. For example, sodium concentration is greater in ECF; therefore, sodium tends to enter by diffusion into the intracellular compartment. This tendency is offset by the sodium–potassium pump, which is located on the cell membrane. In the presence of ATP, the sodium–potassium pump actively moves sodium from the cell into the ECF. Active transport is vital for maintaining the unique composition of both the extracellular and intracellular compartments (Wilkinson, Treas, Barnett, & Smith, 2015).

**Tonicity of Solutions**

A change in water content causes cells either to swell or shrink. The term tonicity refers to the tension or effect that the effective osmotic pressure of a solution with impermeable solutes exerts on cell size because of water movement across a cell membrane. Tonicity is determined solely by effective solutes such as glucose, which cannot penetrate the cell membrane, thereby producing an osmotic force that pulls water into or out of the cell and causing it to change size. Solutions to which body cells are exposed can be classified as isotonic, hypotonic, or hypertonic, depending on whether they cause cells to swell or shrink. Cells placed in an isotonic solution, which has the same effective osmolality as ICFs, neither shrink nor swell (Porth, 2015).
When cells are placed in a hypotonic solution, which has a lower effective osmolality than ICFs, they swell as water moves into the cells. When they are placed in a hypertonic solution, which has a greater effective osmolality than ICFs, they shrink as water is pushed out of the cells.

Figure 3-2 shows the movement of water by osmosis in hypotonic, isotonic, and hypertonic solutions.

Isotonic solutions, such as 0.9% sodium chloride (NaCl) and 5% dextrose in water, have the same osmolarity as normal body fluids. Solutions that have an osmolarity of 250 to 375 mOsm/L are considered isotonic solutions. They

---

**Hypotonic**

Cells will swell as water moves into them when placed in a hypotonic solution (less than 250 mOsm/L).

**Isotonic**

There is no effect on fluid movement between the ECF and ICF when placed in an isotonic solution (between 250 and 375 mOsm/L).

**Hypertonic**

Water within the cells moves to the ECF compartment when placed in a hypertonic solution (greater than 375 mOsm/L).

---

Figure 3-2 Effects of fluid shifts in (A) hypotonic, (B) isotonic, and (C) hypertonic states. (Adapted from Kuhn, M. [1998]. Pharmacotherapeutics: A nursing process approach [4th ed., p. 128]. Philadelphia, PA: F.A. Davis, with permission.)
have no effect on the volume of fluid within the cell; the solution remains within the ECF space. Isotonic solutions are used to expand the ECF compartment.

**Hypotonic** solutions contain less salt than the intracellular space. When infused, they have an osmolarity below 250 mOsm/L and move water into the cell, causing the cell to swell and possibly burst. By lowering the serum osmolarity, hypotonic solutions shift body fluids out of the blood vessels and into the interstitial tissue and cells. Hypotonic solutions hydrate cells and can deplete the circulatory system. An example of a hypotonic solution is 2.5% dextrose in water.

**Hypertonic** solutions, conversely, cause the water from within a cell to move to the ECF compartment, where the concentration of salt is greater, causing the cell to shrink. Hypertonic solutions have an osmolarity of 375 mOsm/L and above. These solutions are used to replace electrolytes. When hypertonic dextrose solutions are used alone, they also are used to shift ECF from interstitial tissue to plasma. Examples of hypertonic solutions are 5% dextrose and 0.9% NaCl, or 5% dextrose and lactated Ringer's solution. Figure 3-3 illustrates tonicity (osmolarity) ranges.

### Fluid and Electrolyte Homeostatic Mechanisms

Regulation of body water is maintained through exogenous sources, such as the intake of food and fluids, and endogenous sources, which are produced within the body through a chemical oxidation process. Several homeostatic mechanisms are responsible for the balance of fluid and electrolytes within the body. When homeostasis is compromised and imbalance occurs, the nurse is responsible for managing the exogenous source of fluid replacement via the IV route. The endogenous sources of balancing fluid and electrolytes are various body systems such as the cardiovascular, lymphatic, renal, respiratory, nervous, and endocrine systems.

### Cardiovascular System and Atrial Natriuretic Factor

The pumping action of the heart provides circulation of blood through the kidneys under pressure, which allows urine to form. Renal perfusion makes renal function possible. Blood vessels provide plasma to reach the kidneys in sufficient volume (20% of circulating blood volume) to permit regulation of water and electrolytes. Baroreceptors located in the carotid sinus and aortic arch respond

<table>
<thead>
<tr>
<th>Hypertonic solutions</th>
<th>375</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isotonic = Blood plasma</td>
<td>290</td>
</tr>
<tr>
<td>Hypotonic solutions</td>
<td>250</td>
</tr>
</tbody>
</table>

*Figure 3-3* Tonicity osmolarity ranges of solutions.
to the degree of stretch of the vessel wall, which has been generated by the body's reaction to hypovolemia. The response is to stimulate fluid retention.

Atrial natriuretic peptide (ANP) is produced in response to atrial stretching. Brain natriuretic peptide (BNP) is produced in the ventricles. High ventricular filling pressures stimulate the release of both ANP and BNP, resulting in diuretic and antihypertensive effects. While ANP was discovered first, concentrations of BNP in the cardiac tissue are higher and the BNP is considered more clinically useful. An elevated BNP level is a marker of increased left ventricular filling pressures (caused by excess fluid volume) and LV dysfunction and is commonly used as a marker for heart failure (Schrieber, 2016).

**Lymphatic System**

The lymphatic system serves as an adjunct to the cardiovascular system by removing excess interstitial fluid (in the form of lymph) and returning it to the circulatory system. Fluid overload in the interstitial compartment would result if it were not for the lymphatic system. The lymphatic system carries the excess fluid, proteins, and large particulate matter that cannot be reabsorbed by the venous capillary bed out of the interstitial compartment. This minute excess (0.3 mm Hg) accounts for 1.7 mm/min of fluid. If the lymphatic system were not continually removing this small amount of fluid, there would be a buildup of 2448 mL in the interstitial compartment over a 24-hour period of time (Porth, 2015).

**Kidneys**

The kidneys are vital to the regulation of fluid and electrolyte balance. The kidney is the main regulator of sodium. The kidney monitors arterial pressure and retains sodium when arterial pressure is decreased and eliminates it when arterial pressure is increased (Porth, 2015). The kidneys normally filter 170 L of plasma per day in the adult and excrete only 1.5 L of urine (Porth, 2015). They act in response to blood-borne messengers such as aldosterone and antidiuretic hormone (ADH). Renal failure can result in multiple fluid and electrolyte imbalances.

Functions of the kidneys in fluid balance are:

- Regulation of fluid volume and osmolarity by selective retention and excretion of body fluids
- Regulation of electrolyte levels by selective retention of needed substances and excretion of unneeded substances
- Regulation of pH of ECF by excretion or retention of hydrogen ions (H+)
- Excretion of metabolic wastes (primarily acids) and toxic substances (Kee et al., 2010)

**Renin–Angiotensin–Aldosterone Mechanism**

The renin–angiotensin–aldosterone system exerts its action through angiotensin II and aldosterone. Renin is a small enzyme protein that is released by the kidney in response to changes in arterial pressure, the glomerular filtration rate, and the amount of sodium in the tubular fluid. Aldosterone acts at the level of the cortical collecting tubules of the kidneys to increase sodium reabsorption while increasing potassium elimination (Porth, 2015).
Respiratory System

The lungs are vital for maintaining homeostasis and constitute one of the main regulatory organs of fluid and acid–base balance. The lungs regulate acid–base balance by regulating the hydrogen ion (H+) concentration. Alveolar ventilation is responsible for the daily elimination of approximately 13,000 mEq of H+ ions. The kidneys excrete only 40 to 80 mEq of hydrogen daily. Under influence from the medulla, the lungs act promptly to correct metabolic acid–base disturbances by regulating the level of carbon dioxide (CO2) (a potential acid) in the ECF. Functions of the lungs in body fluid balance are:

- Regulation of metabolic alkalosis by causing compensatory hypoventilation, resulting in CO2 retention and increased acidity of the ECF
- Regulation of metabolic acidosis by causing compensatory hyperventilation, resulting in CO2 excretion and thus decreased acidity of the ECF
- Removal of 300 to 500 mL of water daily through exhalation (i.e., insensible water loss)

Endocrine System

The glands responsible for aiding in homeostasis are the adrenal, pituitary, and parathyroid glands. The endocrine system responds selectively to the regulation and maintenance of fluid and electrolyte balance through hormonal production.

Water

Holliday and Segar (1957) established that, regardless of age, all healthy persons require approximately 100 mL of water per 100 calories metabolized for dissolving and eliminating metabolic wastes. That means that a person who expends 1800 calories of energy requires approximately 1800 mL of water for metabolic purposes. Two main physiological mechanisms assist in regulating body water: thirst and ADH. Both mechanisms respond to changes in extracellular osmolality and volume.

Thirst

Thirst is controlled by the thirst center in the hypothalamus. There are two stimuli for true thirst based on water need: cellular dehydration caused by an increase in extracellular osmolality, and a decrease in blood volume, which may or may not be associated with a decrease in serum osmolality. Thirst develops when there is as little as 1% to 2% change in serum osmolality (Ayus, Achinger, & Arieff, 2008).

NURSING FAST FACT!

Thirst is one of the earliest symptoms of hemorrhage and often is present before other signs of blood loss appear.
Antidiuretic Hormone

ADH, the pituitary hormone that influences water balance, is also called vasopressin. This hormone, which affects renal reabsorption of water, is also referred to as the “water-conserving” hormone. Functions of ADH are to maintain osmotic pressure of the cells by controlling renal water retention or excretion and controlling blood volume. Excessive secretion of ADH results in the syndrome of inappropriate antidiuretic hormone secretion (SIADH).

As with thirst, ADH levels are controlled by extracellular volume and osmolality. A small increase in serum osmolality is sufficient to cause ADH release. A blood volume decrease of 5% to 10% produces a maximal increase in ADH levels. As with many other homeostatic mechanisms, acute conditions produce changes in ADH levels.

Numerous drugs (e.g., alcohol, narcotic antagonists) can block ADH activity or reduce tubular responsiveness to ADH (e.g., lithium, demeclocycline), which results in increased water loss, causing dehydration and hypernatremia. Increased ADH secretion may be the result of disease (hormone-secreting tumor, head injury) or may be related to administration of drugs such as chlorpropamide, vinca alkaloids, carbamazepine, cyclophosphamide, tricyclic antidepressants, and narcotics (Porth, 2015).

Factors that affect ADH production include pathological changes such as head trauma and tumors of the brain or lung, anesthesia and surgery in general, and certain drugs (e.g., barbiturates, antineoplastics, and nonsteroidal anti-inflammatory drugs).

Parathyroid Hormone

The parathyroid gland is embedded in the corners of the thyroid gland and regulates calcium and phosphate balance. The parathyroid gland influences fluid and electrolytes, increases serum calcium levels, and lowers serum phosphate levels. A reciprocal relationship exists between extracellular calcium and phosphate levels. When the serum calcium level is low, the parathyroid gland secretes more parathyroid hormone (PTH). PTH can increase the serum calcium level by promoting calcium release from the bone as needed. Calcitonin from the thyroid gland increases calcium return to the bone, thus decreasing the serum calcium level.

Aldosterone

The adrenal cortex is important in fluid and electrolyte homeostasis. The primary adrenocortical hormone influencing the balance of fluid is aldosterone. Aldosterone is responsible for renal reabsorption of sodium, which results in the retention of chloride and water and the excretion of potassium. Aldosterone also regulates blood volume by regulating sodium retention.

Epinephrine

Epinephrine, another adrenal hormone, increases BP, enhances pulmonary ventilation, dilates blood vessels needed for emergencies, and constricts unnecessary vessels.
**Cortisol**

When produced in large quantities, the adrenocortical hormone cortisol can produce sodium and fluid retention and potassium deficit. Table 3-2 summarizes the regulators of fluid and electrolyte balance.

**Physical Assessment of Fluid and Electrolyte Needs**

A body systems approach is the best method for assessing fluid and electrolyte imbalances related to infusion therapy. The nurse should begin by obtaining a history, assessing vital signs, performing a focused physical assessment, monitoring pertinent laboratory test results, and evaluating I&O. The purpose of this data gathering is to identify clients at risk for or already experiencing alterations in fluid and electrolyte balance.

<table>
<thead>
<tr>
<th>Table 3-2</th>
<th>Regulators of Fluid Balance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Homeostatic Mechanism</strong></td>
<td><strong>Action</strong></td>
</tr>
<tr>
<td>Cardiovascular</td>
<td>Baroreceptor in carotid sinus and aortic arch responds to hypovolemia. Release of ANP and BNP result in diuresis and lowering of blood pressure.</td>
</tr>
<tr>
<td>Lungs</td>
<td>Lungs excrete 400–500 mL of water daily through normal breathing.</td>
</tr>
<tr>
<td>Kidneys</td>
<td>Kidneys excrete 1000–1500 mL of body water daily. Water excretion may vary according to the balance between fluid intake and fluid loss.</td>
</tr>
<tr>
<td>Lymphatics</td>
<td>Plasma protein that shifts to the tissue spaces cannot be reabsorbed into the blood vessels. Lymphatic system promotes the return of water and protein from the interstitial spaces to the vascular spaces.</td>
</tr>
<tr>
<td>Skin</td>
<td>Skin excretes 300–500 mL of water daily through normal perspiration.</td>
</tr>
<tr>
<td>Electroyte</td>
<td>Sodium promotes water retention. With a water deficit, less sodium is excreted via kidneys; thus, more water is retained.</td>
</tr>
<tr>
<td>Nonelectrolytes</td>
<td>Protein and albumin promote body fluid retention. These nondiffusible substances increase the colloid osmotic (oncotic) pressure in favor of fluid retention.</td>
</tr>
<tr>
<td><strong>Hormones</strong></td>
<td></td>
</tr>
<tr>
<td>Antidiuretic hormone (ADH)</td>
<td>ADH is produced by the hypothalamus and stored in the posterior pituitary gland. ADH is secreted when there is an extracellular fluid volume deficit or an increased osmolality. ADH promotes water reabsorption from the distal tubules of the kidneys.</td>
</tr>
<tr>
<td>Aldosterone</td>
<td>Aldosterone is secreted from the adrenal cortex. It promotes sodium, chloride, and water reabsorption from the renal tubules.</td>
</tr>
<tr>
<td>Renin</td>
<td>Decreased renal blood flow increases the release of renin, an enzyme, from the juxtaglomerular cells of the kidneys. Renin promotes peripheral vasoconstriction and the release of aldosterone (sodium and water retention).</td>
</tr>
</tbody>
</table>
Nursing history related to fluid and electrolyte balance includes questions about past medical history, current health concerns, food and fluid intake, fluid elimination, medications, and lifestyle. The physical assessment correlates data with the nursing history, validating subjective information. Focused assessment includes, but is not limited to, neurological evaluation of level of consciousness (LOC), cardiovascular system, respiratory system, skin, special senses, and weight. Laboratory data should be assessed in a comprehensive review of patient fluid and electrolyte needs.

**Neurological System/Focus on Level of Consciousness**

Changes in LOC occur with changes in serum osmolality or changes in serum sodium. They also can occur with acute acid–base imbalances. Fluid volume changes, along with serum sodium levels, affect the central nervous system (CNS) cells, resulting in irritability, lethargy, confusion, seizures, or coma. CNS cells shrink in sodium excess and expand when serum sodium levels decrease. Sensation of thirst depends on excitation of the cortical centers of consciousness. The use of antianxiety agents, sedatives, or hypnotic agents can lead to confusion and disorientation, causing the patient to forget to drink fluid (Heitz & Horne, 2012).

Assessment of neuromuscular irritability is particularly important when imbalances in calcium, magnesium, sodium, and potassium are suspected. Electrolyte imbalances can cause neurological system signs and symptoms. Abnormal reflexes occur with calcium and magnesium imbalances, including Trousseau’s and Chvostek’s signs. Hyperkalemia (increase in potassium level) can cause flaccid paralysis. Paresthesia may occur in patients with acid–base imbalances (Heitz & Horne, 2012).

There is a progressive loss of CNS cells with advancing age, along with decreases in the senses of smell and touch. The thirst mechanism in older adults may be diminished and is a poor guide for fluid needs in older patients. An ill patient may not be able to verbalize thirst or to reach for a glass of water.

**Cardiovascular System**

The quality and rate of the pulse are indicators of how the patient is tolerating the ECF volume. The peripheral veins in the extremities provide a way of evaluating plasma volume. By examining the hand veins, one can evaluate the plasma volume. Peripheral veins empty in 3 to 5 seconds when the hand is elevated and fill in the same amount of time when the hand is lowered to a dependent position. Peripheral vein filling takes longer than 3 to 5 seconds in patients with sodium depletion and extracellular dehydration (Kee et al., 2010). Slow emptying of the peripheral veins indicates overhydration and excessive blood volume (Fig. 3-4).

A fall of 20 mm Hg in systolic BP when shifting the patient from the lying to the standing position (postural hypotension) may indicate fluid volume deficit (FVD). However, it is important to recognize that assessment of orthostatic vital signs alone lack the sensitivity to reliably detect volume losses less than 1,000 ml (Emergency Nurses Association, 2015).
Diagnostic accuracy when checking orthostatic vital signs is improved when checking from a supine to a standing position. In an evidence-based practice guideline, the Emergency Nurses Association (2015) recommends the following procedures when assessing orthostatic vital signs:

- Have the patient lie in a flat supine position for 5-10 minutes, then check BP and pulse.
- Have the patient stand up and check the BP and pulse at both one and three minutes after standing.
- Pay attention to symptoms such as dizziness or syncope as they are more sensitive indicators of fluid volume loss than changes in vital signs alone.
- A drop of 20 mm Hg or more in systolic BP, 10 mm Hg or more in diastolic BP, and/or an increase in heart rate of 20 or more may be indicative of fluid volume loss in adults.

The jugular vein provides a built-in manometer for evaluation of central venous pressure (CVP). Changes in fluid volume are reflected by changes in neck vein filling. When a patient is supine, the external jugular veins fill to the anterior border of the sternocleidomastoid muscle. Flat neck veins in the supine position indicate a decreased plasma volume. When the patient is in a 45-degree position, the external jugular vein distends no higher than 2 cm above the sternal angle. Neck veins that distend from the top portion of the sternum to the angle of the jaw indicate elevated venous pressure (Fig. 3-5).
Edema indicates expansion of interstitial volume. Edema can be localized (usually caused by inflammation) or generalized (usually related to capillary hemodynamics). It is important to note that the presence of periorbital edema suggests significant fluid retention. Pitting edema should be assessed by pressing the skin over bony surfaces of the tibia or sacrum and rated according to severity from 1+ to 4+. While there are varying scales for assessing pitting edema based upon depth of the pitting, duration of pitting, or the time to rebound, there is more objectivity in assessing time as compared to depth. An example of a scale (Med-Health.net, 2017) is as follows:

1+ = barely detectable (2 mm) and immediate rebound upon release of pressure.
2+ = 4mm deep pit. A few seconds to rebound.
3+ = 6mm deep pit. 10-12 seconds to rebound.
4+ = 8mm deep pit (very deep). >20 seconds to rebound.

Respiratory System
A key to the assessment of circulatory overload is an assessment of the lung fields. Changes in respiratory rate and depth may be a compensatory mechanism for acid–base imbalance. Tachypnea (>20 respirations/min) and dyspnea may indicate fluid volume excess (FVE). Moist crackles in the absence of cardiopulmonary disease indicate FVE. Shallow, slow breathing may indicate metabolic alkalosis or respiratory acidosis. Deep, rapid breathing may indicate respiratory alkalosis or metabolic acidosis.
Skin Appearance and Temperature

Assessments of temperature and skin surface are key in determining fluid volume changes. Pinching the area over the hand, inner thigh, sternum, or forehead can enable assessment of skin turgor. In a well-hydrated person, the pinched skin immediately falls back to its normal position when released. This elastic property, referred to as turgor, is dependent partially on interstitial fluid volume. In a person with FVD, the skin may remain slightly elevated for many seconds. In persons older than 55 years, skin turgor is generally reduced because of loss of elasticity, particularly in areas that have been exposed to the sun. A more accurate assessment can be made on the skin over the sternum. A condition in which placement of fingers firmly on the patient’s skin leaves finger imprints is called fingerprinting and is associated with FVE. Fingerprinting edema is demonstrated by pressing a finger firmly over the sternum or other body surface for a period of 15 to 30 seconds. On removal of the finger, a positive sign is a visible fingerprint similar to that seen when a fingerprint is made on paper with ink.

Special Senses

The eyes, mouth, lips, and tongue are other key indicators of fluid volume imbalances. The absence of tearing and salivation in a child is a sign of FVD. In a healthy person, the tongue has one longitudinal furrow. In a person with FVD, the tongue has additional longitudinal furrows and is smaller because of fluid loss (Porth, 2015).

Mucous membranes often show the first sign of dehydration. As fluid volume decreases, the mouth becomes dry and sticky and the lips dry and cracked. In FVD, the patient’s eyes tend to appear sunken; in significant FVE, periorbital edema is present.

**NURSING FAST FACT!**

Good oral hygiene is imperative with mouth-breathing patients. If the patient is receiving good oral care and the crusted, dry, furrowed tongue does not improve, FVD must be restored to aid in solving this problem.

Body Weight

Taking daily weights of patients with potential fluid imbalances is an important clinical tool. Accurate body weight measurement is a better indicator of gains or losses than I&O records. A loss or gain of 1 kg (2.2 lb) reflects a loss or gain of 1 L of body fluid. Generally, FVD or excess is considered severe when body weight fluctuates 15% higher or lower than the person’s normal body weight.

Table 3-2 summarizes the regulators of fluid balance.
Laboratory Values
The review and interpretation of a patient's laboratory findings provide important objective data for analysis of alterations in fluid balance and of major electrolyte imbalances. The blood gas analysis is a key indicator, along with physical assessment, of acid–base imbalances. Tests that reflect the proper function of the heart and kidneys are of particular importance and require close scrutiny for early detection of fluid imbalances. Table 3-3 summarizes laboratory findings for monitoring fluid and electrolyte imbalances.

Disorders of Fluid Balance
Fluid volume imbalances may reflect an increase or a decrease in total body fluid or an altered distribution of body fluids. There are two major alterations in ECF balance: FVD and FVE.

Fluid Volume Deficit (Hypovolemia)
Extracellular FVD (hypovolemia) reflects a contracted vascular compartment caused by either a significant ECF loss or an accumulation of fluid in the interstitial space. ECF deficit is also referred to as dehydration. It may be caused by an actual decrease in body water, excessive fluid loss or inadequate fluid intake, or a relative decrease in which fluid (plasma) shifts from the intravascular compartment to the interstitial space, a process called “third spacing” (Porth, 2015). Depending on the type of fluid lost, hypovolemia may be accompanied by acid–base, osmolar, or electrolyte imbalances. Prolonged hypovolemia may lead to the development of acute renal failure (Heitz & Horne, 2012).

Etiology
FVD occurs when there is either an excessive loss of body water or an inadequate compensatory intake. The ECF consists predominantly of the electrolytes sodium and chloride, both of which tend to attract water; loss of these electrolytes also leads to loss of water. GI dysfunction is the most common cause of ECF deficit. Other common causes include diaphoresis and overzealous use of diuretics.

FVD also occurs in third spacing, which is caused by peritonitis, intestinal obstruction, postoperative conditions, thrombophlebitis, acute pancreatitis, ascites, fistula drainage, and burns. Third spaces are extracellular body spaces in which fluid is not normally present in large amounts but in which fluid can accumulate. Fluid that accumulates in third spaces is physiologically useless because it is not available for use. Common sites for collection of third space fluid include tissue spaces, abdomen, pleural spaces, and pericardial space (Porth, 2015).

COMMON CAUSES OF ISOTONIC DEHYDRATION
- Hemorrhage resulting in loss of fluid, electrolytes, proteins, and blood cells in proportional amounts, resulting in inadequate vascular volume
- GI losses: Vomiting, diarrhea, nasogastric (NG) suction, drainage from fistulas and tubes; tend to be lost in proportional amounts
### Table 3-3 Summary of Laboratory Evaluation for Fluid and Electrolyte Imbalances

<table>
<thead>
<tr>
<th>Test</th>
<th>Clinical Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Kidneys</strong></td>
<td></td>
</tr>
<tr>
<td>Blood urea nitrogen (BUN)</td>
<td>Assess nutritional support; evaluate hydration and renal function.</td>
</tr>
<tr>
<td>Creatinine</td>
<td>Evaluate for renal impairment. Assess known or suspected disorder involving muscles in the absence of renal disease.</td>
</tr>
<tr>
<td>Specific gravity</td>
<td>Urine concentration reflects fluid volume concentrations and hydration status.</td>
</tr>
<tr>
<td>Urine osmolarity</td>
<td>Monitor for fluid imbalances.</td>
</tr>
<tr>
<td><strong>Blood Chemistry</strong></td>
<td></td>
</tr>
<tr>
<td>Calcium, ionized</td>
<td>Identify individuals with hypocalcemia; monitor patients with renal failure in whom secondary hyperparathyroidism may occur. Monitor patient with sepsis or magnesium deficiency.</td>
</tr>
<tr>
<td>Chloride, blood</td>
<td>Assist in confirming diagnosis of disorder associated with abnormal chloride values in acid–base and fluid volume imbalances. Differentiate between types of acidosis.</td>
</tr>
<tr>
<td>Magnesium, blood</td>
<td>Determine electrolyte balance in renal failure and chronic alcoholism. Evaluate cardiac dysrhythmias.</td>
</tr>
<tr>
<td>Potassium, blood</td>
<td>Assess known or suspected disorder associated with renal disease, glucose metabolism, trauma, or burns. Evaluate electrolyte imbalances (especially in the older adult). Evaluate cardiac dysrhythmias, especially during digitalis therapy. Monitor acidosis (potassium moves from red blood cells [RBCs] into extracellular fluid in acidotic states).</td>
</tr>
<tr>
<td>Sodium, blood</td>
<td>Determine whole-body stores of sodium. Monitor effectiveness of drug therapy, especially of diuretics on serum sodium levels. Determine hydration status.</td>
</tr>
<tr>
<td>Complete blood count (CBC)</td>
<td>CBC screening for hemoglobin, hematocrit, RBC, white blood cell, and platelets prior to replacement of these components or when expanding extracellular fluid.</td>
</tr>
<tr>
<td><strong>Blood Gases</strong></td>
<td></td>
</tr>
<tr>
<td>pH, hydrogen ion</td>
<td>The pH, negative logarithm of the hydrogen ion concentration, determines the acidity or alkalinity of body fluids.</td>
</tr>
<tr>
<td>Bicarbonate (HCO₃⁻)</td>
<td>Alkaline substance that is over half of the total buffer base in the blood. Role in maintaining pH of 7.35 to 7.45.</td>
</tr>
<tr>
<td>Partial pressure of oxygen (Paco₂)</td>
<td>Determines amount of oxygen available to bind with hemoglobin. Paco₂ is decreased in respiratory diseases.</td>
</tr>
<tr>
<td>Partial pressure of CO₂ (Paco₂)</td>
<td>Partial pressure of CO₂ reflects adequacy of alveolar ventilation. The pH affects the combining power of oxygen and hemoglobin.</td>
</tr>
<tr>
<td><strong>Miscellaneous</strong></td>
<td></td>
</tr>
<tr>
<td>Serum glucose</td>
<td>Monitor osmotic diuresis.</td>
</tr>
</tbody>
</table>

Fever, environmental heat, and diaphoresis result in profuse sweating, causing water and sodium loss.

Burns initially damage skin and capillary membranes, allowing fluid, electrolytes, and proteins to escape into the burned tissue, resulting in inadequate vascular volume.

Diuretics cause excessive loss of fluid and electrolytes in proportional amounts.

Third space fluid shifts occur when fluid moves from the vascular space into physiologically useless extracellular spaces (Kee et al., 2010).

**Common Causes of Hypertonic Fluid Dehydration**

- Inadequate fluid intake: Patients who are unable to respond to thirst independently (bedridden, infants, older adults who have nausea, those with anorexia, those who are nothing by mouth [NPO] without adequate fluid replacement)
- Decreased water intake results in ECF solute concentration and leads to cellular dehydration (Kee et al., 2010).

**Clinical Manifestations**

Clinically, ECF deficit is characterized by acute weight loss, by altered cardiovascular function that reflects the underlying ECF volume deficit, and by complaints of nausea and vomiting. The cardiovascular assessment is the most important part of the process to determine plasma volume changes. In a patient who is hypovolemic, the heart rate increases, the BP decreases, and the peripheral pulses are weak. Symptoms reflecting a dehydrated state include sunken eyeballs and poor skin turgor, and oliguria commonly is seen.

**Laboratory Findings**

- Hemoconcentration with the serum hemoglobin, hematocrit, and proteins increased.
- BUN is elevated above 20 mg/100 mL.
- Urine specific gravity reflects high solute concentration greater than 1.030.

**Nursing Points of Care**

**Hypovolemia (FVD)**

**Nursing Assessment**

1. Complete a client history identifying factors that may cause FVD, such as vomiting, diarrhea, limited fluid intake, large draining wound, or diuretic therapy.

*Continued*
Treatment for patients with an ECF volume deficit entails fluid replacement (orally or intravenously) until the oliguria is relieved and the cardiovascular and neurological systems stabilize. Isotonic electrolyte solutions, such as 0.9% NaCl or lactated Ringer's solution, are used to treat hypotensive patients with FVD. A hypotonic electrolyte solution (0.45% NaCl) is often used to provide electrolyte and free water for renal excretion of metabolic wastes.

If the patient with severe FVD is not excreting enough urine, the LIP needs to determine whether the depressed renal function is caused by reduced renal blood flow secondary to FVD or acute tubular necrosis. A fluid challenge test is used in this situation. A typical example involves administering 100 to 200 mL of sodium chloride solution (0.9% NaCl) over 15 minutes. The goal is to provide fluids rapidly enough to attain adequate tissue perfusion without compromising the cardiovascular system (Hinkle & Cheever, 2013).

NURSING FAST FACT!

Extreme caution must be exercised in fluid replacement therapy to avoid fluid overload.
Fluid Volume Excess (Hypervolemia)

ECF volume excess causes an expansion of the ECF compartment. The primary cause of ECF excess is cardiovascular dysfunction. FVE is always secondary to an increase in total body sodium content, which causes total body water increase. Normally, the posterior pituitary decreases secretion of the ADH when excess water moves into the cells. This causes the kidney to eliminate excess fluid. However, if a patient has excessive secretion of ADH, the water will be retained, which places the patient at risk for FVE. Excessive secretion of ADH can be caused by fear, pain, and postoperative reaction 12 to 24 hours after surgery, along with acute infections.

Etiology

Conditions that cause overhydration include excessive administration of oral or IV fluids containing sodium, excessive irrigation of body cavities or organs, and use of hypotonic fluids to replace isotonic fluid loss. When sodium and water are retained in the same proportion, iso-osmolar FVE occurs. Edema is commonly associated with excess extracellular body fluid or excess fluid due to IV overhydration. Physiological factors leading to edema may be caused by various clinical conditions, such as heart failure (HF), kidney failure, cirrhosis of the liver, steroid excess, and retention of sodium (Kee et al., 2010).

**NOTE:** Azotemia (increased nitrogen levels in the blood) can occur with FVE when urea and creatinine are not excreted because of decreased perfusion by the kidneys and excretion of wastes (Hinkle & Cheever, 2013).

**COMMON CAUSES OF ISOTONIC OVERHYDRATION**

- Renal failure leading to decreased excretion of water and sodium
- HF leading to stasis of blood in the circulation and venous congestion
- Excess fluid intake of isotonic IV solutions
- High corticosteroid levels as a result of therapy, stress response, or disease causing sodium and water retention
- High aldosterone levels (stress response to adrenal dysfunction, liver damage, or metabolic problems)

**COMMON CAUSES OF HYPOTONIC OVERHYDRATION (WATER INTOXICATION)**

- More fluid gained than solute
- Serum osmolality falls, causing cells to swell (cerebral cells most sensitive)
- Repeated plain water enemas
- Overuse of hypotonic IV fluids
- In young children or infants, ingestion of inappropriately prepared formula and/or excess water (use of water bottle as pacifier)
- SIADH causes kidneys to retain large amounts of water without sodium.
Clinical Manifestations

Clinically, ECF volume excess has distinct signs and symptoms, the most prominent being weight gain. A constant irritating nonproductive cough is frequently the first clinical symptom of hypervolemia. It is caused by excess fluid “backed up” into the lungs.

Edema usually is not apparent until 2 to 4 kg of fluid has been retained. Alterations in respiratory and cardiovascular function are present and include hypertension and tachycardia. Moist crackles in the lung usually indicate that the lungs are congested with fluid. Cyanosis is a late symptom of pulmonary edema resulting from hypervolemia. In addition to having the common assessment findings, some patients experience confusion, altered LOC, skeletal muscle weakness, and increased bowel sounds.

Peripheral edema present in the morning may result from inadequate cardiac, hepatic, or renal function. Peripheral edema in the evening may result from fluid stasis or dependent edema. An increase in vascular volume may be evidenced by distended neck veins, slow-emptying peripheral veins, a full and bounding pulse, and an increase in CVP.

Laboratory Findings

Laboratory findings are variable and usually nonspecific.

- BUN, serum protein, albumin, hemoglobin, and hematocrit may be decreased as a result of hemodilution.
- Serum osmolality will be decreased below 280 mOsm/kg.
- B-type natriuretic peptide (BNP) is increased to greater than 100 pg/mL in congestive HF.
- Serum sodium is decreased if hypervolemia occurs as a result of excessive water retention.
- Urine specific gravity is decreased if kidney is attempting to excrete excess volume.

NURSING FAST FACT!
Peripheral edema should be assessed in the morning before the patient gets out of bed. A weight gain of 2.2 lb is equivalent to the retention of 1 L of body water.

NURSING FAST FACT!
Severe or prolonged isotonic FVE in a person with a healthy heart and kidneys usually is compensated by increased urinary output.
Treatment

Medical management is directed toward sodium and fluid restriction, administration of diuretics, and treatment of the underlying cause (Porth, 2015). The treatment of FVE focuses on providing a balance between sodium and water I&O. Diuretic therapy is commonly used to increase sodium elimination. If renal function is so severely impaired that pharmacological agents cannot act efficiently, hemodialysis or peritoneal dialysis may be considered to remove nitrogenous wastes, control potassium and acid–base balance, and remove sodium and fluid (Hinkle & Cheever, 2013). Table 3-4 summarizes the fluid imbalances of hypovolemia and hypervolemia.

Basic Principles of Electrolyte Balance

Chemical compounds in solution behave in one of two ways: They separate and combine with other compounds, or they remain intact. One group of compounds remains intact; these are called nonelectrolytes (e.g., urea, dextrose, creatinine). These compounds do not separate from their complex form when
**Fundamentals of Fluid and Electrolyte Balance**

**Table 3-4 Quick Assessment Guide for Fluid Imbalances**

<table>
<thead>
<tr>
<th>Area of Clinical Assessment</th>
<th>Signs and Symptoms of Fluid Volume Deficit (Hypovolemia)</th>
<th>Signs and Symptoms of Fluid Volume Excess (Hypervolemia)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Neurological</strong></td>
<td>Irritability, restlessness, lethargy, confusion (seizures and coma) Thirst</td>
<td>Confusion</td>
</tr>
<tr>
<td><strong>Cardiovascular</strong></td>
<td>Frank or postural hypotension Tachycardia Weak, thready pulses Decreased pulse volume Cool extremities with delayed capillary refill Flat neck veins Poor peripheral vein filling Central venous pressure (CVP) &lt;4 cm</td>
<td>Galloping heart rhythm (heart S3 sound) in adults Distended neck veins Slow-emptying hand veins CVP &gt;11 cm Bounding full pulse Peripheral edema</td>
</tr>
<tr>
<td><strong>Respiratory</strong></td>
<td>Lungs clear Respirations may be rapid and shallow</td>
<td>Tachypnea (&gt;20) and dyspnea Irritated cough Hacking cough, becoming moist and productive Labored breathing Wet lung sounds (moist crackles) Decreased O2 saturation Cyanosis</td>
</tr>
<tr>
<td><strong>Skin Appearance and Temperature</strong></td>
<td>Low-grade fever Dry skin &quot;tenting&quot; Sunken or depressed fontanels in infants</td>
<td>Bulging fontanels in children &lt;18 months Edematous skin (1+ to 4+)</td>
</tr>
<tr>
<td><strong>Eyes</strong></td>
<td>Decreased tearing and dry conjunctiva Sunken eyelids</td>
<td>Periorbital edema</td>
</tr>
<tr>
<td><strong>Lips</strong></td>
<td>Dry lips, cracked</td>
<td>No change</td>
</tr>
<tr>
<td><strong>Oral Cavity</strong></td>
<td>Dry Increased tongue furrows, tongue coated Sticky mucous membranes</td>
<td>No change</td>
</tr>
<tr>
<td><strong>Urine Volume and Concentration</strong></td>
<td>Concentrated urine and low volume &lt;30 mL/hr Specific gravity high: &gt;1.035</td>
<td>Polyuria Specific gravity &lt;1.005</td>
</tr>
<tr>
<td><strong>Body Weight</strong></td>
<td>Weight loss 5%: Mild deficit 5%–10%: Moderate deficit &gt;15%: Severe deficit (especially important in children)</td>
<td>Weight gain (acute and rapid) 5%: Mild excess 5%–10%: Moderate excess &gt;15%: Severe excess</td>
</tr>
<tr>
<td><strong>Diagnostic Laboratory Findings</strong></td>
<td>Normal or high hematocrit and blood urea nitrogen (BUN) Serum osmolarity elevated: &gt;300 Serum sodium &gt;150 mEq Serum glucose elevated: &gt;120 mg/dL</td>
<td>Hematocrit and BUN decreased Serum osmolality low: &lt;275 Serum sodium low: &lt;125 mEq</td>
</tr>
</tbody>
</table>

Sources: Kee et al., 2010; Porth, 2015.
added to a solution. The second group of compounds, electrolytes, dissociates or separates in solution. These compounds break up into separate particles known as ions in a process called ionization. The major electrolytes in body fluids are sodium, potassium, calcium, magnesium, chloride, phosphorus, and bicarbonate.

Each ion, which is the dissociated particle of an electrolyte, carries an electrical charge, either positive or negative. Negative ions are called anions, and positive ions are called cations.

Electrolytes are active chemicals that unite. The ions are expressed in terms of milliequivalents (mEq) per liter rather than milligrams. A milliequivalent measures chemical activity or combining power rather than weight. For example, when a hostess creates a guest list for a party, she does not invite 1000 lb of boys per 1000 lb of girls; rather, she invites the same number of boys and girls. In total, the milliequivalents of cations in a given compartment is equal to the milliequivalents of anions. There are 154 mEq of anions and 154 mEq of cations in the plasma. Each water compartment of the body contains electrolytes. The concentration and composition of electrolytes vary from compartment to compartment. Table 3-5 gives a diagrammatic comparison of electrolyte composition in the fluid compartments.

Most of the electrolytes have more than one physiological role; often several electrolytes work together to mediate chemical events. The physiological roles of electrolytes include:

- Maintaining electroneutrality in fluid compartments
- Mediating enzyme reactions
- Altering cell membrane permeability
- Regulating muscle contraction and relaxation
- Regulating nerve impulse transmission
- Influencing blood clotting time

The electrolyte content of ICF differs from that of ECF. Usually only ECF plasma electrolytes are measured because of the special techniques required to measure the concentration of electrolytes in ICF. The serum plasma levels of electrolytes are important in the assessment and management of patients with electrolyte imbalances.

**Nursing Diagnosis and Electrolyte Imbalances**

Certain physiological complications that nurses monitor to detect onset or changes in status are considered collaborative problems. Nurses manage collaborative problems using physician- and nursing-prescribed interventions to minimize the complications of the events. Electrolyte imbalances are collaborative problems, and for collaborative problems nursing focuses on monitoring for onset of change in status of physiological complications.
**General Diagnostic Statement**

Risk for electrolyte imbalance: A person with an electrolyte imbalance is experiencing or is at risk for experiencing a deficit or excess of one or more electrolytes.

*Nursing interventions:* The nurse will monitor laboratory values and signs and symptoms of specific electrolyte imbalances and administer I.V fluids as ordered and monitor their effects.

**NOTE:** For each of the following electrolytes, the Nursing Points of Care focuses on assessments and nursing interventions that support collection of data for monitoring for changes in status.

**Sodium (Na⁺)**

Normal Reference Value: 135 to 145 mEq/L

---

**Table 3-5** Comparison of Electrolyte Composition in Fluid Compartments

<table>
<thead>
<tr>
<th>Intracellular Water (approx. mEq/L)</th>
<th>Extracellular Water (approx. mEq/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Intracellular</strong></td>
<td><strong>Plasma</strong></td>
</tr>
<tr>
<td>Cations</td>
<td>Anions</td>
</tr>
<tr>
<td>205 mEq</td>
<td>205 mEq</td>
</tr>
</tbody>
</table>

![Diagram of electrolyte composition in fluid compartments]

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For each of the following electrolytes, the Nursing Points of Care focuses on assessments and nursing interventions that support collection of data for monitoring for changes in status.
Physiological Role

The physiological role of sodium includes:

- Neuromuscular: Transmission and conduction of nerve impulses (sodium pump)
- Body Fluids: Responsible for the osmolality of vascular fluids
- Cellular: Maintain water balance. Sodium shifts into cells as potassium shifts out of cells—depolarization (cell activity). When sodium shifts out of cells, potassium shifts back into cells—repolarization (enzyme activity).
- Acid–base: Sodium combines with chloride or bicarbonate to regulate acid–base balance (Kee et al., 2010).

**NURSING FAST FACT!**

Doubling the serum sodium level gives the approximate serum osmolality.

The major function of sodium is to maintain ECF volume. Extracellular sodium level has an effect on the cellular fluid volume based on the principle of osmosis. Sodium represents about 90% of all the extracellular cations. Sodium does not easily cross the cell wall membrane and therefore is the most abundant cation of ECF.

A low serum sodium level results in dilute ECF, therefore allowing water to be drawn into the cells (lower to higher concentration). Conversely, if the serum sodium is high, water is drawn out of the cells, leading to cellular dehydration. Figure 3-6 shows the relationship between sodium and cellular fluid. The normal daily requirement for sodium in adults is approximately 100 mEq.

The kidneys are extremely important in the regulation of sodium, which is primarily accomplished through the action of the hormone aldosterone. Hyponatremia is a common complication of adrenal insufficiency because of aldosterone and cortisol deficiencies. Older adult persons have a slower rate of aldosterone secretion, which places them at risk for sodium imbalances.

Figure 3-6  Sodium and cellular fluid relationship. (A) Hyponatremia. The cell swells as water is pulled in from ECF. (B) Hypernatremia. The cell shrinks as water is pulled out into ECF.
Three factors can create a sodium imbalance:

1. Change in the sodium content of the ECF, such as a deficit caused by excessive vomiting
2. Change in the chloride content, which can affect both the sodium concentration and the amount of water in the ECF; when the ratio of chloride to sodium deviates from normal, it is reflected as an acid–base imbalance
3. Change in the quantity of water in the ECF

**Serum Sodium Deficit: Hyponatremia**

Hyponatremia is a common electrolyte disorder in which the sodium level is below normal (<135 mEq/L). It is often a complication of other medical illnesses such as heart failure, liver failure, or renal failure. A low sodium level can be the result of an excessive loss of sodium or an excessive gain of water; in either event, hyponatremia is caused by a relatively greater concentration of water than of sodium. Sodium deficit usually is associated with hypervolemic states.

**ETIOLOGY**

The pathophysiology that contributes to sodium deficit (hyponatremia) is often a sign of a serious underlying disease; there are also many causes of hyponatremia.

All GI secretions contain sodium; therefore, any abnormal loss of GI secretions can cause a sodium deficit. GI disorders such as vomiting, diarrhea, drainage from suction or fistulas, and excessive tap water enemas may also cause hyponatremia.

Another cause of hyponatremia is loss from skin as a result of excessive sweating, combined with excessive water consumption and the use of thiazide diuretics, which are especially dangerous with low-salt diets. In addition, excessive parenteral hypo-osmolar fluids such as dextrose in water solutions can cause hyponatremia.

Hormonal factors such as labor induction with oxytocin and SIADH reduce the amount of sodium per volume, which in turn leads to dilutional hyponatremia. Oxytocin has been shown to have an intrinsic ADH effect by increasing water reabsorption from the glomerular filtrate. Cerebral ICF excess (hyponatremic encephalopathy) is associated with the risk of seizures, coma, and death, which can occur when water shifts into the brain cells (Kee et al., 2010). Researchers believe that physiological responses in premenopausal women place them at higher risk than men for hyponatremic encephalopathy because estrogen stimulates ADH release and antagonizes the brain's ability to adapt to swelling (Ayus et al., 2008). In men, androgens suppress ADH release and enhance the brain's ability to adapt to swelling. Young women account for most of the reported...
cases of fatalities secondary to hyponatremia. Marathon runners have been shown to develop hyponatremic encephalopathy related to dilutional hyponatremia (Rosner & Kirven, 2007).

**Clinical Manifestations**

Hyponatremia affects cells of the CNS. Patients with chronic hyponatremia may experience impaired sensation of taste, anorexia, muscle cramps, feelings of exhaustion, apprehension, feelings of impending doom (at Na⁺ <115), and focal weaknesses (e.g., hemiparesis, ataxia). Patients with acute hyponatremia caused by water overload experience the same symptoms as well as fingerprinting edema (sign of intracellular water excess). Patients undergoing operative procedures involving irrigations (e.g., transurethral resection of prostate [TURP], endometrial ablation) may develop hyponatremia.

**Laboratory Findings**

- Serum sodium: Less than 135 mEq/L
- Serum osmolarity: Less than 280 mOsm/L
- Urine specific gravity: Less than 1.010 (except in SIADH)
- Urine sodium: Decreased (usually less than 20 mEq/L)
- Hematocrit: Above normal when FVD exists
- Decreased BUN

**Treatment/Collaborative Management**

Treatment of patients with hyponatremia aims to provide sodium by the dietary, enteral, or parenteral route. Patients able to eat and drink can easily replace sodium by ingesting a normal diet. Those unable to take sodium orally must take the electrolyte by the parenteral route. An isotonic saline or Ringer's solution (e.g., 0.9% sodium chloride [NaCl], or lactated Ringer's solution may be ordered. The immediate goal of therapy is the correction of acute symptoms, gradual return of sodium to a normal level, and, if necessary, restoration of normal ECF volume.

Acute symptomatic hyponatremia requires more aggressive treatment. Treatment must be individualized. Too rapid correction of chronic hyponatremia (lasting >24–48 hours) may cause irreversible neurological damage and death as a result of osmotic demyelination (Kamel & Halperin, 2016).

General treatment guidelines for patients with hyponatremia are:

1. Replace sodium and fluid losses through diet or parenteral fluids.
2. Restore normal ECF volume.
3. Restrict water intake.
4. Increase the excretion of water without electrolytes.
5. Correct any other electrolyte losses such as potassium or bicarbonate.

Treatment of hyponatremia with fluid volume overload includes:

1. Remove or treat underlying cause such as SIADH.
2. Administer loop diuretic (thiazide diuretics should be avoided).
3. Water restriction to 1000 mL/day establishes negative water balance and increases plasma sodium levels in most adults.
When the primary problem is water retention, it is safer to restrict water than to administer sodium. An IV solution that can contribute to hyponatremia is excessive administration of 5% dextrose in water.

Permanent neurological damage may occur in patients with acute symptomatic hyponatremia as a result of failure to adequately treat hyponatremic encephalopathy. The replacement of sodium chloride solution by infusion pump should be at a rate calculated to elevate the plasma sodium level about 1 mEq/L/hr. Too rapid elevation of sodium (>25 mEq/L in the first 48 hr) can cause brain damage (Kamel & Halperin, 2016).

**NURSING POINTS OF CARE**

**HYPONATREMIA**

**Nursing Assessment**
- Obtain a patient history of high-risk factors for hyponatremia (vomiting, diarrhea, eating disorders, low-sodium diet).
- Obtain a history of medications, with emphasis on those predisposing patients to hyponatremia (e.g., diuretics).
- Assess for signs and symptoms of hyponatremia (weight gain without peripheral edema, fingerprinting, edema, poor skin turgor, dry mucosa, headache, decreased saliva production, orthostatic fall in BP, nausea, and vomiting).
- Obtain baseline laboratory tests (e.g., serum sodium, serum osmolarity, serum potassium, serum chloride, urine specific gravity).

**Key Nursing Interventions**
1. Monitor laboratory test results, with emphasis on serum sodium.
2. Monitor GI losses.
3. Monitor for signs and symptoms of hyponatremia: CNS changes (coma, headache), weakness, nausea, muscle cramps, vomiting, diarrhea, and apprehension. In severe cases status epilepticus, coma, and obtundation occur and are related to cellular swelling and cerebral edema (Hinkle & Cheever, 2013).
5. Restrict water when hyponatremia is caused by hypervolemia.
6. Follow LIP orders as to rate and type of IV fluid to administer.
Serum Sodium Excess: Hypernatremia
The serum level of sodium is elevated to above 145 mEq/L in hypernatremia. This elevation can be caused by a gain of sodium without water or a loss of water without loss of sodium. There are two primary defenses against hypernatremia: (1) thirst response and (2) excretion of maximally concentrated urine through increased production of ADH. Sodium is the major determinant of ECF osmolality; therefore, hypernatremia causes hypertonicity. Hypertonicity causes a shift of water of the cells, which leads to cellular dehydration. Dehydration of the cerebral cells results in the development of CNS symptoms (Heitz & Horne, 2012).

Etiology
Increased levels of serum sodium can occur with water loss or deprivation of water, when a person cannot respond to thirst, and during hypertonic tube feeding with inadequate water supplements. Sodium gain can occur with excessive parenteral administration of sodium-containing solutions and with near-drowning in salt water. Sodium is lost in cases of watery diarrhea (a particular problem in infants), increased insensible loss, ingestion of sodium in unusual amounts, profuse sweating, heatstroke, and diabetes insipidus when water intake is inadequate (Hinkle & Cheever, 2013).

Clinical Manifestations
Patients with hypernatremia may experience marked thirst; elevated body temperature; swollen tongue; red, dry, sticky mucous membranes; and tachycardia. In severe hypernatremia, disorientation and irritability or hyperactivity can occur when the patient is physically stimulated.

Laboratory Findings
- Serum sodium: Greater than 145 mEq/L
- Chloride may be elevated.
- Serum osmolarity: Greater than 295 mOsm/kg
- Urine specific gravity: Greater than 1.015 (except for those with diabetes insipidus)
- Dehydration test: Water is withheld for 16 to 18 hours; serum and urine osmolarity are checked 1 hour after administration of ADH; this test is used to identify the cause of polyuric syndromes (central vs. nephrogenic diabetes insipidus).

EBP Ferry (2005) found that because the aging process causes a decrease in thirst, once a geriatric client experiences thirst, he or she may have a severe water deficit and sodium excess.

Treatment/Collaborative Management
The goal of treatment of patients with hypernatremia is gradual lowering of the serum sodium level (usually over 48 hours) by infusing a hypotonic electrolyte solution such as 0.45% normal saline or 5% dextrose in water. Many clinicians
consider a hypotonic sodium solution to be safer than D5W because it allows a gradual reduction in the serum sodium level, thereby decreasing the risk of cerebral edema (Porth, 2015). The sodium level should not be lowered by more than 15 mEq/L in an 8-hour period for adults (Hinkle & Cheever, 2013).

Generally, treatment guidelines for hypernatremia are:

1. Infusion of hypotonic electrolyte solution (0.45% NaCl or 5% dextrose in water). If the sodium level is more than 160 mEq/L, 5% dextrose in water is indicated.
2. Decreasing sodium levels by use of diuretics, which induce excretion of water and sodium.
3. Administration of desmopressin acetate (DDAVP) to treat central diabetes insipidus. Treating the underlying cause (e.g., fever, diarrhea) minimizes abnormal fluid loss.
4. Removal of the cause of hypernatremia; for example, discontinuing medications that cause increase in sodium levels (lithium), or correcting electrolyte imbalances such as hypokalemia and hypercalcemia (Hinkle & Cheever, 2013).

NURSING POINTS OF CARE

HYPERNATREMIA

Nursing Assessment

- Obtain a patient history of high-risk factors for hypernatremia (e.g., increased sodium intake, water deprivation, increased adrenocortical hormone production, use of sodium-retaining drugs).
- Assess for signs and symptoms of hypernatremia (restlessness and weakness, disorientation, delusions, thirst), which result from dehydration of cells (Hinkle & Cheever, 2013).
- Obtain baseline values of laboratory tests, especially serum sodium.

Key Nursing Interventions

1. Monitor laboratory test results, with emphasis on serum sodium and serum osmolarity.
2. Monitor fluid I&O and daily weight.
3. Monitor for signs and symptoms of hypernatremia related to abnormal loss of water or large gains of sodium, which include thirst, CNS effects (agitation to convulsions), weight gain and edema, elevated BP, elevated temperature, and tachycardia.
4. Monitor for signs of pulmonary edema when the patient is receiving large amounts of parenteral sodium chloride.
5. Promote increased mobility if appropriate.
7. Administer orders from LIP of hypotonic sodium monitoring rate.
Potassium (K+)

Normal Reference Value: 3.5 to 5.0 mEq/L.

Physiological Role

The physiological role of potassium includes:

- Regulation of fluid volume within the cell
- Promotion of nerve impulse transmission
- Contraction of skeletal, smooth, and cardiac muscle
- Control of hydrogen ion (H+) concentration, acid–base balance; when potassium moves out of the cell, hydrogen ions move in, and vice versa.
- Role in enzyme action for cellular energy production

Potassium is an intracellular electrolyte present as 98% in the ICF and 2% in the ECF. Potassium is a dynamic electrolyte. Cellular potassium replaces ECF potassium if it becomes depleted. Potassium is acquired through diet and must be ingested daily because the body has no effective method of potassium storage. The daily requirement is 40 mEq. Potassium influences both skeletal and cardiac muscle activity. Alterations in the concentration of plasma potassium change myocardial irritability and rhythm. Potassium moves easily into the intracellular space when the body is metabolizing glucose. It moves out of the cells during strenuous exercise, when cellular metabolism is impaired, or when the cell dies. Potassium, along with sodium, is responsible for transmission of nerve impulses. During nerve cell innervation, these ions exchange places, creating an electrical current (Kee et al., 2010).

There is a relationship between acid–base imbalances and potassium balance. Hypokalemia can cause alkalosis, which in turn can further decrease serum potassium. Hyperkalemia can cause acidosis, which in turn can further increase serum potassium.

The regulation of potassium is related to several other processes, including:

- Sodium level: Enough sodium must be available for exchange with potassium.
- Hydrogen ion excretion: When there is an increase in hydrogen ion excretion, there is a decrease in potassium excretion.
- Aldosterone level: An increased level of aldosterone stimulates and increases excretion of potassium.
- Potassium imbalances are commonly seen in clinical practice because of their association with underlying disease, injury, or ingestion of certain medications.

Serum Potassium Deficit: Hypokalemia

Hypokalemia is a serum potassium level below 3.5 mEq/L. It usually reflects a real deficit in total potassium stores; however, it may occur in patients with normal potassium stores when alkalosis is present. Hypokalemia is a common disturbance; many factors are associated with this deficit, and many clinical conditions contribute to it.


**ETIOLOGY**

Many conditions can lead to potassium deficit, including GI and renal loss, increased use of diuretic, increased perspiration, shifting of extracellular potassium into the cells, and poor dietary intake. GI loss can result from diarrhea or laxative overuse, prolonged gastric suction, and protracted vomiting. Renal loss can result from potassium-wasting diuretic therapy; excessive use of glucocorticoids; ingestion of drugs such as sodium penicillin, carbenicillin, or amphotericin B; excessive ingestion of European licorice (which mimics the action of aldosterone); and excessive steroid administration.

Sweat loss can result from heavy perspiration in persons acclimated to the heat. Shifting into the cells can occur with parenteral nutrition (PN) therapy without adequate potassium supplementation, or with alkalosis or excessive administration of insulin. Poor dietary intake can occur with anorexia nervosa, bulimia, and alcoholism.

**CLINICAL MANIFESTATIONS**

Clinical symptoms rarely develop before the serum potassium level has decreased to less than 3 mEq/L unless the rate of decline has been rapid (Hinkle & Cheever, 2013). Patients with hypokalemia may experience neuromuscular changes such as fatigue, muscle weakness, diminished deep tendon reflexes, and flaccid paralysis (late). Other symptoms include anorexia, nausea, vomiting, irritability (early), increased sensitivity to digitalis, electrocardiographic (ECG) changes, and death (in those with severe hypokalemia) caused by cardiac arrest.

**LABORATORY AND ECG FINDINGS**

- Serum potassium: Less than 3.5 mEq/L.
- Arterial blood gas (ABG): May show metabolic alkalosis (increased pH and bicarbonate ion)
- Elevated serum glucose levels (increased insulin secretion and increased osmotic pressure)
- ECG: ST-segment depression, flattened T wave, presence of U wave, and ventricular dysrhythmias. The ECG tracing in Figure 3-7 reflects changes when potassium is below normal.

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**NURSING FAST FACT!**

Clinical signs and symptoms rarely occur before the serum potassium level has fallen below 3 mEq/L.

Potassium replacement must take place slowly to prevent hyperkalemia. Extreme caution should be used when potassium chloride replacement exceeds 120 mEq in 24 hours. The patient must be monitored for dysrhythmias.
Replacement of potassium is the key concept in treating patients with potassium deficit. Replace potassium either by mouth or intravenously. The usual oral dose is 40 to 80 mEq/day in divided doses. IV potassium is necessary if hypokalemia is severe or if the patient is unable to tolerate oral potassium. IV potassium is irritating to the vessels, so the rate must be adjusted to prevent phlebitis. Potassium usually is replaced in combination with chloride or phosphate. Hypokalemia is frequently associated with ECF volume deficit and chloride loss; potassium chloride is usually ordered. Hypokalemia associated with metabolic acidosis may be treated with potassium bicarbonate or citrate (Heitz & Horne, 2012).

General treatment guidelines include:

1. Mild hypokalemia usually is treated with dietary increases of potassium or oral supplements.
2. Salt substitutes (e.g., Morton Salt Substitute, Co-Salt, Adolph’s Salt Substitute) contain potassium and can be used to supplement potassium intake.
3. If the serum potassium is below 2 mEq/L, monitor the patient’s ECG and administer potassium by a secondary piggyback set in a volume of 100 mL (Hinkle & Cheever, 2013). Table 3-6 lists guidelines for IV potassium, and Table 3-7 gives critical guidelines for nursing in IV administration of potassium.

**NOTE:** Never give potassium IV push/bolus.
Serum Potassium Excess: Hyperkalemia

Hyperkalemia occurs less frequently than hypokalemia, but it can be more dangerous. It seldom occurs in patients who have normal renal function. Hyperkalemia is defined as a serum plasma level of potassium above 5.0 mEq/L. The main causes of hyperkalemia are (1) increased intake of potassium (oral or parenteral), (2) decreased urinary excretion of potassium, and (3) movement of potassium out of the cells and into the extracellular space.

**Etiology**

High levels of serum potassium can be caused by either a gain in potassium intake or a shift of potassium from the ICF to the ECF. Hyperkalemia can be caused by excessive administration of potassium parenterally or orally; severe renal failure resulting in reduced potassium excretion; release of potassium...
from altered cellular function (as occurs with burns or crush injuries); and acidosis.

Drugs that can cause a predisposition to hyperkalemmas include potassium penicillin, indomethacin, amphetamines, nonsteroidal anti-inflammatory drugs, alpha agonists, beta blockers, succinylcholine, cyclophosphamide, and potassium-sparing diuretics. Pseudohyperkalemia can occur with prolonged tourniquet application during blood withdrawal (Kee et al., 2010).

**Clinical Manifestations**

The cardiac effects of elevated serum potassium usually are not significant when the level is less than 7 mEq/L but will be present when the level is 8 mEq/L or greater (Hinkle & Cheever, 2013). Patients with hyperkalemia may experience changes that will be seen on the ECG, irregular pulse, vague muscle weakness, flaccid paralysis, anxiety, nausea, abdominal cramping, and diarrhea.

**Laboratory and ECG Findings**

- Serum potassium: Greater than 5.0 mEq/L with clinical symptoms present after 7 mEq/L.
- ABG values: Metabolic acidosis (decreased pH and bicarbonate ion).
- ECG: Widened QRS, prolonged PR, and ventricular dysrhythmias (Fig. 3-8).
- If dehydration is causing hyperkalemia, then hematocrit, hemoglobin, and sodium and chloride levels should be drawn.
- If associated with renal failure, creatinine and BUN levels should be drawn.
TREATMENT/COLLABORATIVE MANAGEMENT

The goal is to treat the underlying cause and return the serum potassium to a safe level. In acute hyperkalemia, administration of IV calcium gluconate, glucose and insulin, beta₂ agonists, or sodium bicarbonate is temporary. It is usually necessary to follow these medications with a therapy that removes potassium from the body (Heitz & Horne, 2012).

The following are guidelines for the treatment of patients with hyperkalemia:

1. The goal is to treat the underlying cause and return the serum potassium level to normal.
2. Restrict dietary potassium in mild cases.
3. Discontinue potassium supplements.
4. Cation exchange resins (Kayexalate) may be given PO, NG, or via retention enema to exchange sodium for potassium in the bowel.
5. Administer IV calcium gluconate if necessary for cardiac symptoms. Administer IV sodium bicarbonate, which alkalinizes the plasma and causes a temporary shift of potassium into the cells.
6. Administer regular insulin (10–25 units) and hypertonic dextrose (10%), which causes a shift of potassium into the cells.
7. Peritoneal dialysis or hemodialysis may be ordered.
8. A beta₂ agonist (albuterol or salbutamol) may be ordered by nasal inhalation or IV to shift potassium into the cells.

Table 3-7 provides critical guidelines for nursing in the treatment of patients with potassium excess.

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**Figure 3-8** Sample ECG tracing showing hyperkalemia. The ECG tracing for hyperkalemia shows progressive changes: tall, thin T waves; prolonged PR intervals; ST-segment depression; widened QRS; and loss of P wave.
NURSING POINTS OF CARE

HYPERKALEMIA

Nursing Assessment

- Obtain client history relative to high-risk factors for hyperkalemia (renal disease, potassium-sparing diuretics, excessive salt substitute use).
- Assess for signs of hyperkalemia (disturbances in cardiac conduction, skeletal muscle weakness, paralysis of respiratory and speech muscles).
- Obtain baseline ECG; assess for altered T waves.
- Obtain baseline serum potassium.

Key Nursing Interventions

1. Monitor laboratory test results, especially serum potassium.
2. Keep accurate I&O records.
3. Monitor for changes in cardiac response.
4. Monitor vital signs, with special attention to tachycardia and bradycardia.
5. Administer IV potassium at rate ordered by LIP following guidelines.

Table 3-7 Critical Guidelines for Removal of Potassium

<table>
<thead>
<tr>
<th>Treatment Guidelines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium polystyrene sulfonate is a cation exchange resin that removes potassium from the body by exchanging sodium for potassium in the intestinal tract. This method should not be the sole treatment of severe hyperkalemia because of its slow onset. Oral sodium polystyrene sulfonate (15–30 g); may repeat every 4–6 hours as needed. Removes potassium in 1–2 hours. Rectal sodium polystyrene sulfonate (50 g) as retention enema. When administering, use an inflated rectal catheter to ensure retention of the dissolved resin for 30–60 minutes. Removes potassium in 30–60 minutes. Each enema can lower the plasma potassium concentration by 0.5–1.0 mEq/L.</td>
</tr>
<tr>
<td>Dialysis is used when more aggressive methods are needed. Peritoneal dialysis is not as effective as hemodialysis. Whereas peritoneal dialysis can remove approximately 10–15 mEq/hr, hemodialysis can remove 25–35 mEq/hr.</td>
</tr>
<tr>
<td>Glucose and insulin</td>
</tr>
<tr>
<td>Emergency measures</td>
</tr>
</tbody>
</table>

Sources: Gahart et al., 2016; Heitz & Horne, 2012.
Calcium (Ca$^{2+}$)

**Normal Reference Value:** 4.5 to 5.5 mEq/L or 9 to 11 mg/dL

**Physiological Role**
The physiological role of calcium includes:

- Maintaining skeletal elements; calcium is needed for strong, durable bones and teeth
- Regulating neuromuscular activity
- Influencing enzyme activity
- Converting prothrombin to thrombin, a necessary part of the material that holds cells together

Calcium ions are most abundant in the skeletal system, with 99% residing in the bones and teeth. Only 1% is available for rapid exchange in the circulating blood bound to protein. PTH is responsible for the transfer of calcium from bone to plasma. PTH also augments the intestinal absorption of calcium and enhances net renal calcium reabsorption. Calcium is acquired through dietary intake. Adults require approximately 1 g of calcium daily, along with vitamin D and protein, which are required for absorption and utilization of this electrolyte.

Calcium is instrumental in activating enzymes and stimulating essential chemical reactions. It plays an important role in maintaining the normal transmission of nerve impulses and has a sedative effect on nerve cells. Calcium plays its most important role in the conversion of prothrombin to thrombin, a necessary sequence in the formation of a clot.

Calcium and phosphate have a reciprocal relationship; that is, an increase in calcium level causes a drop in the serum phosphorus concentration, and a drop in calcium causes an increase in phosphorus level.

Calcium is present in three different forms in the plasma: (1) ionized (50% of total calcium); (2) bound (<50% of total calcium); and (3) complexed (small percentage that combines with phosphate). Only ionized calcium (iCa; i.e., calcium affected by plasma pH, phosphorus, and albumin levels) is physiologically important. A relationship between iCa and plasma pH is reciprocal; an increase in pH decreases the percentage of calcium that is ionized. The relationship between plasma phosphorus and iCa also is reciprocal. Albumin does not affect iCa, but it does affect the amount of calcium bound to proteins (Porth, 2015).

**Serum Calcium Deficit: Hypocalcemia**
A reduction of total body calcium levels or a reduction of the percentage of iCa causes hypocalcemia. Total calcium levels may be decreased as a result of increased calcium loss or altered regulation (hypoparathyroidism). The most common cause of low total calcium level is hypoalbuminemia.

**Etiology**
Total calcium levels may be decreased because of increased calcium loss, reduced intake secondary to altered intestinal absorption, and altered regulation, as occurs in patients with hypoparathyroidism.
The most common cause of hypocalcemia is inadequate PTH secretion caused by primary hypoparathyroidism or surgically induced hypoparathyroidism. It also can result from calcium loss through diarrhea and wound exudate, acute pancreatitis, hyperphosphatemia usually associated with renal failure, inadequate intake of vitamin D or minimal sun exposure, prolonged NG tube suctioning resulting in metabolic alkalosis, and infusion of citrated blood (citrate–phosphate–dextrose). Patients who receive massive transfusions are at risk for hypocalcemia due to a reaction to toxic proportions of citrate, which is used as a preservative in blood. The citrate ion can combine with the recipient’s serum calcium, causing a calcium deficiency. Many drugs can lead to the development of hypocalcemia, including potent loop diuretics, Dilantin and phenobarbital, antineoplastic drugs, some radiographic contrast media, large doses of corticosteroids, heparin, and antacids (Hinkle & Cheever, 2013).

**Clinical Manifestations**

Patients with hypocalcemia may experience neuromuscular symptoms (e.g., numbness of the fingers), cramps in the muscles (especially the extremities), hyperactive deep tendon reflexes, and a positive Trousseau’s sign (Fig. 3-9) and Chvostek’s sign (Fig. 3-10).

Other symptoms include irritability, memory impairment, delusions, seizures (late), prolonged QT interval, and altered cardiovascular hemodynamics that may

*Figure 3-9* Positive Trousseau’s sign. Carpopedal attitude of the hand when blood pressure cuff is placed on the arm and inflated above systolic pressure for 3 minutes. A positive reaction is the development of carpal spasm.
precipitate congestive HF. In patients with hypocalcemia caused by citrated blood transfusion, the cardiac index, stroke volume, and left ventricular stroke work values have been found to be lower.

The most dangerous symptom associated with hypocalcemia is the development of laryngospasm and tetany-like contractions. A low magnesium level and a high potassium level potentiate the cardiac and neuromuscular irritability produced by a low calcium level. However, a low potassium level can protect patients from hypocalcemic tetany.

**NURSING FAST FACT!**

Today's blood analyzers allow measurement of the iCA level. The normal serum iCA level is 2.2 to 2.5 mEq/L or 4.25 to 5.25 mg/dL (Kee et al., 2010).

**Laboratory and Radiographic Findings**

- iCA level less than 4.0 mg/dL
- Radiographic films that detect bone fractures and thinning
- Bone mass density tests for signs of osteoporosis
- Potential for hypomagnesemia (1 mg/dL)
- Potential for hypokalemia (<3.5 mEq/mL)
- Hyperphosphatemia (>2.6 mEq/mL)
- Potential for elevated creatinine from renal insufficiency
TREATMENT/COLLABORATIVE MANAGEMENT

The goal of treatment is to alleviate the underlying cause. Treatment of patients with hypocalcemia consists of:

1. Administration of calcium gluconate, orally (preferred) with calcium supplements, 1000 mg/day, to raise the total serum calcium level by 1 mg/dL.
2. Patients with symptomatic hypocalcemia less than 7.5 mg/dL usually require parenteral calcium. Hypocalcemia in adults is treated with 5 to 20 mL (2.3–9.3 mEq) of a 10% solution by IV injection slowly or diluted in 1000 mL of 0.9% sodium chloride over 12 to 24 hours. Do not exceed 200 mg/min (Gahart, Nazareno, & Ortega, 2016).

NOTE: Follow current rate administration guidelines for safe IV administration of medications. It is important to recognize that I.V. calcium preparations (calcium gluconate and calcium chloride) are vesicants, capable of causing severe tissue damage upon extravasation (see Chapter 9).

NURSING POINTS OF CARE

HYPOCALCEMIA

Nursing Assessment

- Obtain history relative to potential causes of hypocalcemia (low-calcium diet, lack of vitamin D, low-protein diet, chronic diarrhea, hormonal disorders).
- Postoperative hypoparathyroidectomy first 24 to 48 hours
- Obtain history of drugs that could predispose the patient to hypocalcemia (furosemide [Lasix], cortisone).
- Assess for signs of hypocalcemia (tetany, which is the most characteristic symptom; seizures, tingling in tips of fingers and around mouth).
- Obtain baseline values for serum calcium, iCA serum albumin, and acid–base status.

Key Nursing Interventions

1. Observe safety precautions and prepare to adopt seizure precautions if hypocalcemia is severe.
2. Monitor laboratory test results, with emphasis on serum and ionized calcium.
3. Monitor ECGs for changes in pattern.
4. Monitor for signs of cardiac arrhythmias in patients receiving digitalis and calcium supplements.
5. Monitor for hypocalcemia in patients receiving massive transfusion of citrated blood.

Continued
Serum Calcium Excess: Hypercalcemia

Hypercalcemia is caused by excessive release of calcium from bone, almost always from malignancy, hyperparathyroidism, thiazide diuretic use, or excessive calcium intake.

**Etiology**

Most symptoms of hypercalcemia are present only when the serum calcium level is greater than 12 mg/dL and tend to be more severe if hypercalcemia develops quickly. Causes of hypercalcemia include hyperparathyroidism, Paget’s disease, multiple fractures, and overuse of calcium-containing antacids. Patients with solid tumors that have metastasized (e.g., breast, prostate, malignant melanomas) or with hematological tumors (e.g., lymphomas, acute leukemia, and myelomas) are also at risk for developing hypercalcemia.

Drugs that predispose an individual to hypercalcemia include calcium salts, megadoses of vitamin A or D, thiazide diuretics (potentiate action of PTH), androgens or estrogen for breast cancer therapy, IV lipids, lithium, and tamoxifen.

**Clinical Manifestations**

Patients with hypercalcemia may experience neuromuscular symptoms such as muscle weakness, incoordination, lethargy, deep bone pain, flank pain, and pathological fractures (caused by bone weakening). Other symptoms include constipation, anorexia, nausea, vomiting, polyuria or polydipsia leading to uremia if not treated, and renal colic caused by stone formation. Patients taking digitalis must take calcium with extreme care because it can precipitate severe dysrhythmias.

**Laboratory and Radiographic Findings**

- Serum iCA: Greater than 5.5 mg/dL
- Serum PTH: Increased levels in primary or secondary hyperparathyroidism
- Radiography: May reveal osteoporosis, bone cavitations, or urinary calculi
TREATMENT/COLLABORATIVE MANAGEMENT

Hypercacemia should be treated according to the following guidelines:

1. Treat the patient’s underlying disease.
2. Administer saline diuresis. Fluids should be forced to help eliminate the source of the hypercalcemia. A solution of 0.45% NaCl or 0.9% NaCl IV dilutes the serum calcium level. Rehydration is important to dilute Ca\(^{2+}\) ions and promote renal excretion.
3. Give inorganic phosphate salts orally (Neutra-Phos) or rectally (Fleet enema).
4. Provide hemodialysis or peritoneal dialysis to reduce serum calcium levels in life-threatening situations.
5. Use furosemide, 20 to 40 mg every 2 hours, to prevent volume overloading during saline administration.
6. Administer calcitonin, 4 to 8 units/kg intramuscularly or subcutaneously every 6 to 12 hours. This will temporarily lower the serum calcium level by 1 to 3 mg/100 mL.
7. Give bisphosphonates to inhibit bone reabsorption. Pamidronate 60 to 90 mg in 1 L of 0.9% NaCl or 5% dextrose in water infused over 24 hours is effective (Hinkle & Cheever, 2013).

NURSING POINTS OF CARE

HYPERCALCEMIA

Nursing Assessment

- Obtain a patient history of probable cause of hypercalcemia (e.g., cancer); excessive use of calcium supplements, antacids, or thiazide diuretics; or steroid therapy.
- Assess for signs of hypercalcemia (muscle weakness, incoordination, anorexia, nausea and vomiting, constipation; abdominal and bone pain).
- Obtain baseline values for serum calcium and serum phosphate.
- Obtain baseline ECG.
- Assess client’s fluid volume status and mental alertness.

Key Nursing Interventions

1. Monitor changes in vital signs and laboratory test results.
2. Encourage the patient to drink 3 to 4 L of fluid per day.
3. Encourage the patient to consume fluids (e.g., cranberry or prune juice) that promote urine acidity to help prevent formation of renal calculi.
4. Keep accurate fluid I&O records.
5. Monitor for digitalis toxicity (toxic level >2 mg/mL).
6. Handle the patient gently to prevent fractures.
7. Encourage the patient to avoid high-calcium foods.
Magnesium (Mg$^{2+}$)

Normal Reference Value: 1.5 to 2.5 mEq/L or 1.8 to 3.0 mg/dL

Physiological Role

The physiological role of magnesium includes:

- Enzyme action
- Regulation of neuromuscular activity (similar to calcium)
- Regulation of electrolyte balance, including facilitating transport of sodium and potassium across cell membranes, influencing the utilization of calcium, potassium, and protein

Magnesium is a major intracellular electrolyte. The normal diet supplies approximately 25 mEq of magnesium. Approximately one-third of serum magnesium is bound to protein; the remaining two-thirds exist as free cations. The same factors that regulate calcium balance influence magnesium balance. Magnesium balance is also affected by many of the same agents that decrease or influence potassium balance.

Magnesium acts directly on the myoneural junction and affects neuromuscular irritability and contractility, possibly exerting a sedative effect. Magnesium acts as an activator for many enzymes and plays a role in both carbohydrate and protein metabolism. Magnesium affects the cardiovascular system, acting peripherally to produce vasodilation. Imbalances in magnesium predispose the heart to ventricular dysrhythmias (Hinkle & Cheever, 2013).

Serum Magnesium Deficit: Hypomagnesemia

Hypomagnesemia is often overlooked in critically ill patients. This imbalance is considered to be one of the most underdiagnosed electrolyte deficiencies. Symptoms of hypomagnesemia tend to occur when the serum level drops below 1.0 mEq/L.

Etiology

Hypomagnesemia can result from chronic alcoholism; malabsorption syndrome, especially if the small bowel is affected; prolonged malnutrition or starvation; prolonged diarrhea; acute pancreatitis; administration of magnesium-free solutions for more than 1 week; and prolonged NG tube suctioning.

Drugs that predispose an individual to hypomagnesemia include aminoglycosides, diuretics, cortisone, amphotericin, digitalis, cisplatin, and cyclosporine. Infusion of collected blood preserved with citrate also can cause hypomagnesemia (Heitz & Horne, 2012).

Clinical Manifestations

Patients with hypomagnesemia often experience neuromuscular symptoms, such as hyperactive reflexes, coarse tremors, muscle cramps, positive Chvostek’s and Trousseau’s signs (see Figs. 3-9 and 3-10), seizures, paresthesia of the feet and legs, and painfully cold hands and feet. Other symptoms include disorientation, dysrhythmias, tachycardia, and increased potential for digitalis toxicity.
LABORATORY AND ECG FINDINGS

- Serum magnesium: Less than 1.5 mEq/L
- Urine magnesium: Helps to identify renal causes of magnesium depletion
- Serum albumin: A decrease may cause a decreased magnesium level resulting from the reduction in protein-bound magnesium.
- Serum potassium: Decreased because of failure of the cellular sodium–potassium pump to move potassium into the cell and because of the accompanying loss of potassium in the urine
- Serum calcium: May be reduced because of a reduction in the release and action of PTH
- ECG: Findings of tachydysrhythmia, prolonged PR and QT intervals, widening of the QRS, ST-segment depression, and flattened T waves. A form of ventricular tachycardia (i.e., torsades de pointes) associated with all three electrolyte imbalances (magnesium, calcium, potassium) may develop.

TREATMENT/COLLABORATIVE MANAGEMENT

Treatment of patients with hypomagnesemia includes identification and removal of the cause. Magnesium sulfate is the parenteral replacement and can be administered intramuscularly or intravenously. The drug is available in strengths of 10%, 12.5%, and 50%. A suggested order for adults is 10 mL of a 50% solution.

1. Administering oral magnesium salts: Magnesium oxide (Mag-Ox) or magnesium chloride (Slow-Mag). Magnesium-containing antacids may also be used.
2. Administering IM injection, the dosage is divided.
3. Administering IV infusion, the dosage is diluted into 1 L of solution (Kee et al., 2010).

NOTE: Follow current rate administration guidelines for safe IV administration of medications.

Table 3-8 provides critical guidelines for nurses who are administering magnesium.

Table 3-8 Critical Guidelines for Administration of Magnesium

- Double-check the order for magnesium administration to ensure that it stipulates the concentration of the solution to be used. Do not accept orders for “amps” or “vials” without further clarification.
- Use caution in patients with impaired renal function; watch urine output.
- Reduce other central nervous system depressants when given concurrently with magnesium preparations.
- Therapeutic doses of magnesium can produce flushing and sweating, which occur most often if the administration rate is too fast.
- Closely assess patients receiving magnesium.
Serum Magnesium Excess: Hypermagnesemia

Hypermagnesemia occurs when a person’s serum level is greater than 2.5 mEq/L. The most common cause of hypermagnesemia is renal failure in patients who have an increased intake of magnesium.

NURSING FAST FACT!

Be aware that other CNS depressants can cause further depressed sensorium when magnesium sulfate is being administered. Therefore, be prepared to deal with respiratory arrest if hypermagnesemia inadvertently occurs during administration of magnesium sulfate.

NURSING POINTS OF CARE

HYPOMAGNESEMIA

Nursing Assessment

- Obtain a patient history, being alert to factors that predispose to hypomagnesemia such as alcoholism, laxative abuse, parenteral nutrition (PN), and potassium-wasting diuretic use.
- Assess for signs and symptoms of hypomagnesemia (not all related to magnesium but resulting from secondary changes in potassium and calcium metabolism, tonic–clonic or focal seizures, laryngeal stridor, dysphagia, positive Chvostek’s and Trousseau’s signs, ECG changes, marked alterations in mood).
- Obtain baseline values for laboratory tests, serum magnesium, serum calcium, and serum potassium.
- Obtain baseline ECG.

Key Nursing Interventions

1. Monitor vital signs.
2. Monitor for dysphagia, nausea, and anorexia.
3. Monitor for muscle weakness and athetoid movements (slow, involuntary twisting movements).
4. Monitor closely for digitalis toxicity (toxic level >2 mg/mL).
5. Keep accurate I&O records. Monitoring urine output is essential before, during, and after magnesium administration.
6. Notify LIP if urine output drops below 100 mL over 4 hours.
7. Have calcium gluconate available to treat hypocalcemic tetany.
8. Initiate seizure precautions if necessary to protect from injury (Martin, Gonzalez, & Slatopolsky, 2009).

Serum Magnesium Excess: Hypermagnesemia

Hypermagnesemia occurs when a person’s serum level is greater than 2.5 mEq/L. The most common cause of hypermagnesemia is renal failure in patients who have an increased intake of magnesium.
ETIOLOGY
Renal factors that lead to hypermagnesemia include renal failure, Addison’s disease, and inadequate excretion of magnesium by kidneys.

Other causes include hyperparathyroidism; hyperthyroidism; and iatrogenic causes such as excessive magnesium administration during treatment of patients with eclampsia, hemodialysis with excessively hard water using a dialysate inadvertently high in magnesium, or ingestion of medications high in magnesium, such as antacids and laxatives.

CLINICAL MANIFESTATIONS
The major symptoms of hypermagnesemia result from depressed peripheral and central neuromuscular transmissions. Patients with hypermagnesemia may experience neuromuscular symptoms such as flushing and sense of skin warmth, lethargy, sedation, hypoactive deep tendon reflexes, and depressed respirations, and weak or absent cry in newborns. Other symptoms include hypotension, sinus bradycardia, heart block, and cardiac arrest (serum level >15 mEq/L) and increased susceptibility to digitalis toxicity, nausea, vomiting, and seizures. The most common occurrence of hypermagnesemia is in individuals who have renal failure with an increased intake of magnesium (Heitz & Horne, 2012).

LABORATORY AND ECG FINDINGS
- Serum magnesium: Greater than 2.5 mEq/L
- ECG: Possible findings of widened QRS complex, and prolonged QT interval (at levels >2.5 mEq/L)

TREATMENT/COLLABORATIVE MANAGEMENT
The goal of treatment is to remove the cause of the hypermagnesemia, for example, by discontinuing or avoiding use of magnesium-containing medications, especially in patients with decreased renal function. Guidelines for treatment of patients with hypermagnesemia are:

1. Decrease oral magnesium intake.
2. Administer diuretics and 0.45% sodium chloride solution to enhance magnesium excretion in patients with adequate renal function.
3. Administer IV calcium gluconate (10 mL of 10% solution) to antagonize the neuromuscular effects of magnesium in patients with lethal hypermagnesemia.
4. Support respiratory function.
5. Administer peritoneal dialysis or hemodialysis in severe cases of hypermagnesemia.
Phosphorus (HPO$_4^{2-}$)

Normal Reference Value: 2.5 to 4.5 mg/dL.

**Physiological Role**

The physiological role of phosphorus:

- is essential to all cells.
- plays a role in metabolism of proteins, carbohydrates, and fats.
- is essential to energy, is necessary for the formation of high-energy compounds ATP and adenosine diphosphate (ADP).
- as a cellular building block, is the backbone of nucleic acids and is essential to cell membrane formation.
- enables delivery of oxygen; functions in formation of red blood cell enzyme.

Approximately 80% of phosphorus in the body is contained in the bones and teeth, and 20% is abundant in the ICF. PTH plays a major role in homeostasis of phosphate because of its ability to vary phosphate reabsorption in the proximal tubule of the kidney. PTH also allows for the shift of phosphate from bone to plasma.

Phosphorus plays an important role in the delivery of oxygen to tissues by regulating the level of 2,3-diphosphoglycerate (2,3-DPG), a substance in red blood cells that decreases the affinity of hemoglobin for oxygen.
Serum Phosphate Deficit: Hypophosphatemia

Phosphorus is a critical constituent of all the body’s tissues. Hypophosphatemia occurs when the serum level is below the lower limit of normal (<2.5 mg/dL). This imbalance may occur in the presence of total body phosphate deficit or may merely reflect a temporary shift of phosphorus into the cells.

ETIOLOGY

Hypophosphatemia can result from overzealous refeeding, PN administered without adequate phosphorus, malabsorption syndromes, or alcohol withdrawal. GI causes of loss include vomiting and chronic diarrhea.

Hormonal influences such as hyperparathyroidism enhance renal phosphate excretion. Drugs that predispose an individual to hypophosphatemia include aluminum-containing antacids (which bind phosphorus, thereby lowering serum levels), diuretics, androgens, corticosteroids, glucagon, epinephrine, gastrin, and mannitol. Hypophosphatemia can also be caused by certain treatments for diabetic ketoacidosis (dextrose with insulin causes a shift of phosphorus into the cells). In hypophosphatemia, the oxygen-carrying capacity of the blood decreases due to decreased 2,3-DPG and gas exchange. With decreased 2,3-DPG levels, the oxyhemoglobin dissociation curve shifts to the right; that is, at a given oxygen tension of arterial blood (PaO₂) level, more oxygen is bound to hemoglobin, and less is available to the tissues (Heitz & Horne, 2012).

CLINICAL MANIFESTATIONS

Hypophosphatemia can affect the CNS, neuromuscular and cardiac status, and the blood. An affected patient may experience disorientation, confusion, seizures, paresthesia (early), profound muscle weakness, tremor, ataxia, incoordination, dysarthria, dysphagia, and congestive cardiomyopathy. Hypophosphatemia affects all blood cells, especially red cells. It causes a decline in 2,3-DPG levels in erythrocytes. 2,3-DPG in red cells normally interacts with hemoglobin to promote the release of oxygen. It is thought that hypophosphatemia predisposes a person to infection (Hinkle & Cheever, 2013).

LABORATORY AND RADIOGRAPHIC FINDINGS

- Serum phosphorus: Less than 2.5 mg/dL (1.7 mEq/L)
- Serum PTH: Elevated
- Serum magnesium: Decreased because of increased urinary excretion of magnesium
- Serum alkaline phosphatase: Increased with increased osteoblastic activity
- Radiography: Skeletal changes of osteomalacia or rickets
TREATMENT/COLLABORATIVE MANAGEMENT

Treatment should focus on identification and elimination of the cause, for example, by avoiding use of phosphorus-binding antacids. Treatment can also include:

1. For mild to moderate deficiency, oral phosphate supplements (e.g., Neutra-Phos, Phospho-Soda) can be administered.
2. For severe hypophosphatemia, administer IV sodium phosphorus or potassium phosphorus solutions.

NURSING POINTS OF CARE

HYPOPHOSPHATEMIA

Nursing Assessment

- Obtain a patient history with focus on factors that put patients at high risk for hypophosphatemia, such as alcoholism, use of TPN, and diabetic ketoacidosis.
- Assess for signs of hypophosphatemia (irritability, fatigue, apprehension, weakness, paresthesias, dysarthria, dysphagia, seizures). Obtain baseline laboratory values of serum phosphate and serum calcium.

Key Nursing Interventions

1. Monitor for cardiac, GI, and neurological abnormalities.
2. Monitor for changes in laboratory test results.
4. Use safety precautions when a patient is confused.
5. Monitor for refeeding syndrome once oral feeding is restarted after prolonged starvation.
6. Monitor for other electrolyte complications of phosphorus administration (hypocalcemia, hyperphosphatemia).
7. Administer IV sodium or potassium phosphate at prescribed rate not to exceed 10 mEq/hr.
8. Monitor for infiltration due to the potential for tissue sloughing and necrosis.

Serum Phosphate Excess: Hyperphosphatemia

Etiology

Hyperphosphatemia can result from renal insufficiency, hypoparathyroidism, or increased catabolism. It is also seen in patients with cancer states, such as myelogenous leukemia and lymphoma.

Drugs that can predispose an individual to hyperphosphatemia include oral phosphates, IV phosphates; phosphate laxatives; and excessive vitamin D, tetracyclines, and methicillin.
CLINICAL MANIFESTATIONS
Patients with hyperphosphatemia may experience many symptoms, including hypocalcemia; tetany (short term); soft-tissue calcification (long term); mental changes, such as apprehension, confusion, and coma; and increased 2,3-DPG levels in red blood cells.

LABORATORY AND RADIOGRAPHIC FINDINGS
- Serum phosphorus: Greater than 4.5 mg/dL (2.6 mEq/L)
- Serum calcium: Useful in assessing potential consequences of treatment
- Serum PTH: Decreased in those with hypoparathyroidism
- BUN: To assess renal function
- Radiography: Skeletal changes of osteodystrophy

TREATMENT/COLLABORATIVE MANAGEMENT
Treatment should include the following regimen:
1. Identify the underlying cause of hyperphosphatemia.
2. Restrict dietary intake.
3. Administer the intake of phosphate-binding gels (e.g., Amphojel, Basaljel, Dialume).
4. Administer vitamin D preparations such as calcitriol, which is available in oral (Rocaltrol) and parenteral (Calcijex) forms.

NURSING POINTS OF CARE
HYPERPHOSPHATEMIA

Nursing Assessment
- Obtain a patient history for factors that place patients at high risk for hyperphosphatemia (e.g., renal insufficiency, laxative use).
- Assess for signs and symptoms of hyperphosphatemia (tetany with tingling sensation in the fingertips and around the mouth; anorexia, nausea, vomiting, bone and joint pain, muscle weakness, tachycardia).
- Obtain baseline laboratory values for serum phosphate.
- Assess 24-hour urinary output; less than 600 mL/day increases serum phosphate levels.

Key Nursing Interventions
1. Monitor for cardiac, GI, and neuromuscular abnormalities.
2. Monitor changes in laboratory test results.
4. Observe the patient for signs and symptoms of hypocalcemia; when phosphate levels increase, calcium levels decrease.
Table 3-9 summarizes clinical problems associated with electrolyte imbalances.

**Chloride (Cl⁻)**

**Normal Reference Value:** 95 to 108 mEq/L

**Physiological Role**

The physiological role of chloride is:

- Regulation of serum osmolarity
- Regulation of fluid balance; when sodium is retained, chloride is also retained, causing water retention and increased fluid volume.
- Control of acidity of gastric juice
- Regulation of acid–base balance
- Role in oxygen–CO₂ exchange (chloride shift)

Chloride is the major anion in the ECF. Changes in serum chloride concentration usually are secondary to changes in one or more of the other electrolytes.

<table>
<thead>
<tr>
<th>Clinical Problem</th>
<th>Sodium (Na⁺)</th>
<th>Potassium (K⁺)</th>
<th>Calcium (Ca²⁺)</th>
<th>Magnesium (Mg²⁺)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cardiovascular</strong></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Myocardial infarction</td>
<td>Na⁺↓</td>
<td>K⁺↓</td>
<td>—</td>
<td>Mg²⁺↓</td>
</tr>
<tr>
<td>(hypovolemia)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heart failure (HF)</td>
<td>Na⁺↑</td>
<td>K⁺ Normal</td>
<td>—</td>
<td>Mg²⁺↓ Normal</td>
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<tr>
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<tr>
<td>Vomiting and diarrhea</td>
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<td>K⁺</td>
<td>Ca²⁺↓</td>
<td>Mg²⁺↓</td>
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<td>K⁺↓</td>
<td>Ca²⁺↓</td>
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<td>K⁺↓</td>
<td>Ca²⁺↓</td>
<td>Mg²⁺↓</td>
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<tr>
<td>Intestinal fistula</td>
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<td>K⁺↓</td>
<td>—</td>
<td>Mg²⁺↓</td>
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<td>GI surgery</td>
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<td>K⁺↓</td>
<td>—</td>
<td>Mg²⁺↓</td>
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<td>K⁺↓</td>
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<td>Mg²⁺↓</td>
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<tr>
<td>Hyperphosphatemia</td>
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<td>—</td>
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</tr>
<tr>
<td>Transfused citrated blood</td>
<td>—</td>
<td>—</td>
<td>Ca²⁺↓</td>
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<td>K⁺↓</td>
<td>—</td>
<td>Mg²⁺↓</td>
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<td>Addison’s disease</td>
<td>Na⁺↓</td>
<td>K⁺↑</td>
<td>—</td>
<td>Mg²⁺↓</td>
</tr>
<tr>
<td>Diabetic ketoacidosis</td>
<td>Na⁺↑</td>
<td>K⁺↑ Diuresis</td>
<td>Ca²⁺↓ Ionized</td>
<td>Mg²⁺↓</td>
</tr>
</tbody>
</table>
Chloride has a reciprocal relationship with bicarbonate (HCO$_3^-$). For example, a decrease in HCO$_3^-$ concentrations results in a reciprocal rise in chloride level; when chloride level decreases, HCO$_3^-$ level increases in compensation. Chloride exists primarily combined as sodium chloride or hydrochloric acid. Serum chloride is most frequently measured for its inferential value.

Reabsorption of chloride by the renal tubules is one of the major regulatory functions of the kidneys. As sodium chloride is reabsorbed, water follows through osmosis. It is through this function that vascular blood volume is maintained.

Chloride plays its most important role in acid–base balance. Its role in the pH balance of the ECF is referred to as the “chloride shift.” The chloride shift is an ionic exchange that occurs within red blood cells. This shift preserves the electrical neutrality of the red blood cells and maintains the 1:20 ratio of carbonic acid and HCO$_3^-$ that is essential for pH balance of the plasma.

**Table 3-9 Clinical Problems Associated With Electrolyte Imbalances—cont’d**

<table>
<thead>
<tr>
<th>Clinical Problem</th>
<th>Sodium (Na$^+$)</th>
<th>Potassium (K$^+$)</th>
<th>Calcium (Ca$^{2+}$)</th>
<th>Magnesium (Mg$^{2+}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypoparathyroidism</td>
<td></td>
<td></td>
<td>Ca$^{2+}\downarrow$</td>
<td></td>
</tr>
<tr>
<td>Hyperparathyroidism</td>
<td></td>
<td></td>
<td>Ca$^{2+}\downarrow$</td>
<td>Mg$^{2+}\uparrow$</td>
</tr>
<tr>
<td><strong>Renal</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acute renal failure</td>
<td>Na$^+\uparrow$</td>
<td>Oliguria K$^+\downarrow$</td>
<td></td>
<td>Mg$^{2+}\uparrow$</td>
</tr>
<tr>
<td>Chronic renal failure</td>
<td>Na$^+\uparrow$</td>
<td></td>
<td>Ca$^{2+}\downarrow$/↑</td>
<td>Mg$^{2+}\uparrow$</td>
</tr>
<tr>
<td><strong>Miscellaneous</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cancer</td>
<td>Na$^+\downarrow$</td>
<td>K$^+\downarrow$/↑</td>
<td>Ca$^{2+}\uparrow$</td>
<td>Mg$^{2+}\downarrow$</td>
</tr>
<tr>
<td>Burns</td>
<td>Na$^+\downarrow$</td>
<td>K$^+\downarrow$/↑</td>
<td>Ca$^{2+}\downarrow$</td>
<td>Mg$^{2+}\downarrow$</td>
</tr>
<tr>
<td>Acute pancreatitis</td>
<td></td>
<td></td>
<td>Ca$^{2+}\downarrow$</td>
<td></td>
</tr>
<tr>
<td>Syndrome of inappropriate antidiuretic hormone secretion (SIADH)</td>
<td>Na$^+\downarrow$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metabolic acidosis</td>
<td>K$^+\downarrow$</td>
<td></td>
<td>Ca$^{2+}\downarrow$</td>
<td></td>
</tr>
<tr>
<td>Metabolic alkalosis</td>
<td>K$^+\downarrow$</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Chloride has a reciprocal relationship with bicarbonate (HCO$_3^-$). For example, a decrease in HCO$_3^-$ concentrations results in a reciprocal rise in chloride level; when chloride level decreases, HCO$_3^-$ level increases in compensation. Chloride exists primarily combined as sodium chloride or hydrochloric acid. Serum chloride is most frequently measured for its inferential value.

Reabsorption of chloride by the renal tubules is one of the major regulatory functions of the kidneys. As sodium chloride is reabsorbed, water follows through osmosis. It is through this function that vascular blood volume is maintained.

Chloride plays its most important role in acid–base balance. Its role in the pH balance of the ECF is referred to as the “chloride shift.” The chloride shift is an ionic exchange that occurs within red blood cells. This shift preserves the electrical neutrality of the red blood cells and maintains the 1:20 ratio of carbonic acid and HCO$_3^-$ that is essential for pH balance of the plasma.

**NOTE:** Chloride is discussed further under acid–base balance. Imbalances in chloride are reflected in metabolic alkalosis and metabolic acidosis.
Acid–Base Balance

Regulation of the hydrogen ion concentration of body fluids is actually the key component of acid–base balance. The pH of a fluid reflects the hydrogen ion concentration of that fluid. The normal pH of arterial blood ranges from 7.35 to 7.45. A solution is either basic or acidic depending on the concentration of hydrogen ions in the solution, and the pH scale is used to describe the hydrogen ion concentration. The pH scale is a logarithmic scale with values from 0.00 to 14.00. A neutral solution (i.e., neither acidic nor basic) has a pH of 7.00 (Porth, 2015).

The inverse proportion of the pH to the concentration of hydrogen ions is reflected in the concept that the higher the pH value, the lower the hydrogen ion concentration. Conversely, the lower the pH value, the higher the hydrogen ion concentration. Therefore, a pH below 7.35 reflects an acidic state, whereas a pH greater than 7.45 indicates alkalosis and a lower hydrogen ion concentration. A variation from 7.35 to 7.45 of 0.4 in either direction can be fatal. Figure 3-11 shows the pH scale.

Three mechanisms operate to maintain the appropriate pH of the blood:

1. Chemical buffer systems in the ECF and within the cells
2. Removal of CO₂ by the lungs
3. Renal regulation of the hydrogen ion concentration

Chemical Buffer Systems

The buffer systems are fast-acting defenses that provide immediate protection against changes in the hydrogen ion concentration of the ECF. The buffers also serve as transport mechanisms that carry excess hydrogen ions to the lungs.

A buffer is a substance that reacts to minimize pH changes when either acid or base is released into the system. There are three primary buffer systems in
the ECF: the hemoglobin system, the plasma protein system, and the bicarbonate system. The capacity of a buffer is limited; therefore, after the components of a buffer system have reacted, they must be replenished before the body can respond to further stress.

The hemoglobin and deoxyhemoglobin found in red blood cells, together with their potassium salts, act as buffer pairs. The electrolyte chloride shifts in and out of the red blood cells according to the level of oxygen in the blood plasma. For each chloride ion that leaves a red blood cell, a bicarbonate ion enters the cell; for each chloride ion that enters a red blood cell, a bicarbonate ion is released.

Plasma proteins are large molecules that contain the acid (or base) and salt form of a buffer. Proteins then have the ability to bind or release hydrogen ions.

The bicarbonate buffer system maintains the blood's pH in the range from 7.35 to 7.45, with a ratio of 20 parts bicarbonate to 1 part carbonic acid by a process called hydration of CO₂, which is a means of buffering the excess acid in the blood. If a strong acid is added to the body, the ratio is upset. In this acid imbalance, the largest amount of CO₂ diffuses in the plasma to the red blood cells; CO₂ then combines with plasma protein. CO₂ that is dissolved in the blood combines with water to form carbonic acid (Hinkle & Cheever, 2013).

Respiratory Regulation
In healthy individuals, the lungs form a second line of defense in maintaining the acid–base balance. When CO₂ combines with water, H₂CO₃ is formed. Therefore, an increase in the acid CO₂ lowers the pH of blood, creating an acidic state; a decrease in the CO₂ level increases the pH, causing the blood to become more alkaline. After H₂CO₃ is formed, it dissociates into CO₂ and water. The CO₂ is transferred to the lungs, where it diffuses into the alveoli and is eliminated through exhalation. Therefore, the rate of respiration affects the hydrogen ion concentration. An increase in respiratory rate causes CO₂ to be blown off by the lungs, resulting in an increase in pH. Conversely, a decrease in respiratory rate causes retention of CO₂ and thus a decrease in pH. This means that the lungs can either hold the hydrogen ions until the deficit is corrected or inactivate the hydrogen ions into water molecules to be exhaled with the CO₂ as vapor, thereby correcting the excess. It takes from 10 to 30 minutes for the lungs to inactivate the hydrogen molecules by converting them to water molecules (Hinkle & Cheever, 2013).

Renal Regulation
The kidneys regulate the hydrogen ion concentration by increasing or decreasing the HCO₃⁻ ion concentration in the body fluid by a series of complex chemical reactions that occur in the renal tubules. The regulation of acid–base balance by the kidneys occurs chiefly by increasing or decreasing the HCO₃⁻ ion concentration in body fluids. Hydrogen is secreted into the tubules of the kidney, where it is eliminated in the urine. At the same time, sodium is reabsorbed from the tubular fluid into the ECF in exchange for hydrogen and combines with HCO₃⁻ ions to form the buffer NaHCO₃.
The kidneys help to regulate the extracellular concentration of $\text{HCO}_3^-$ ions. Two buffer systems help the kidney to eliminate excess hydrogen in the urine: the phosphate buffer system and the ammonia buffer system. With each of these systems, an excess of hydrogen is secreted and $\text{HCO}_3^-$ ions are formed; sodium is reabsorbed, thus forming NaHCO$_3$. The time it takes for a change to occur in the acid–base balance can range from a fraction of a second to more than 24 hours. Although the kidneys are the most powerful regulating mechanism, they are slow to make major changes in the acid–base balance (Hinkle & Cheever, 2013; Kamel & Halperin, 2016).

**Major Acid–Base Imbalances**

There are two types of acid–base imbalances: (1) metabolic (base bicarbonate deficit and excess) acidosis and alkalosis, and (2) respiratory (carbonic acid deficit and excess) acidosis and alkalosis. The balanced pH of the arterial blood is 7.4, and only small variations of up to 0.05 can exist without causing ill effects. Deviations of more than five times the normal concentration of $\text{H}^+$ in the ECF are potentially fatal (Porth, 2015).

**Metabolic Acid–Base Imbalances**

**Bicarbonate: Normal Reference Value:** 22 to 26 mEq/L

**Metabolic Acidosis: Base Bicarbonate Deficit**

Metabolic acidosis ($\text{HCO}_3^-$ deficit) is a clinical disturbance characterized by a low pH and a low plasma $\text{HCO}_3^-$ level. This condition can occur by a gain of hydrogen ion ($\text{H}^+$) or a loss of $\text{HCO}_3^-$. Metabolic acidosis can be divided clinically into two forms, according to the values of the serum anion gap: high anion gap acidosis and normal anion gap acidosis. The anion gap reflects normally unmeasured anions (phosphates, sulfates, and proteins) in the plasma (Hinkle & Cheever, 2013).

**Etiology**

Metabolic acidosis occurs with loss of $\text{HCO}_3^-$ from diarrhea, draining fistulas, and administration of TPN. Diabetes mellitus, alcoholism, and starvation cause ketoacidosis. Respiratory or circulatory failure, ingestion of certain drugs or toxins (e.g., salicylates, ethylene glycol, methyl alcohol), some hereditary disorders, and septic shock cause lactic acidosis. It also can result when renal failure leads to excessive retention of hydrogen ions.

**NURSING FAST FACT!**

Hyperkalemia usually is present in clinical cases of acidosis due to shift of potassium out of the cells. Later as the acidosis is corrected, potassium moves back into the cells (Hinkle & Cheever, 2013).
CLINICAL MANIFESTATIONS
Patients with metabolic acidosis may experience CNS-related symptoms such as headache, confusion, drowsiness, increased respiratory rate, and Kussmaul respirations. Other symptoms include nausea, vomiting, decreased cardiac output, and bradycardia (when serum pH is <7.0).

LABORATORY AND ECG FINDINGS
- ABG values: pH less than 7.35, HCO₃⁻ less than 22 mEq/L
- PaCO₂: Less than 38 mm Hg
- Serum HCO₃⁻: Less than 22 mEq/L
- Serum electrolytes: Elevated potassium possible because of exchange of intracellular potassium for hydrogen ions in the body’s attempt to normalize the acid–base environment
- ECG: Dysrhythmias caused by hyperkalemia

COMMON CAUSES OF METABOLIC ACIDOSIS
- GI abnormalities: Starvation, severe malnutrition, chronic diarrhea
- Renal abnormalities: Kidney failure
- Hormonal influences: Diabetic ketoacidosis, hyperthyroidism, thyrotoxicosis
- Other: Trauma, shock, excess exercise, severe infection, fever

TREATMENT/COLLABORATIVE MANAGEMENT
Patients with metabolic acidosis are treated by
1. Reversing the underlying cause (e.g., diabetic ketoacidosis, alcoholism related to ketoacidosis, diarrhea, acute renal failure, renal tubular acidosis, poisoning, lactic acidosis)
2. Eliminating the source (if the cause is excessive administration of sodium chloride)
3. Administering NaHCO₃ (7.5% 44.4 mEq/50 mL or 8.4% 50 mEq/50 mL IV when pH is ≤7.2). Concentration depends on severity of acidosis and presence of any serum sodium disorders.
4. Potassium replacement: Hyperkalemia usually is present, but potassium deficit can occur. If a deficit of less than 3.5 mEq/L is present, the potassium deficit must be corrected before NaHCO₃ is administered because the potassium shifts back into the ICF when the acidosis is correct.

NURSING FAST FACT!
Give NaHCO₃ cautiously to avoid having patients develop metabolic alkalosis and pulmonary edema secondary to sodium overload.
Metabolic Alkalosis: Base Bicarbonate Excess

Metabolic alkalosis (i.e., HCO$_3^-$ excess) is a clinical disturbance characterized by a high pH and a high plasma HCO$_3^-$ concentration. It can be produced by a gain of HCO$_3^-$ or a loss of hydrogen ion.

ETIOLOGY

Metabolic alkalosis occurs with GI loss of hydrogen ions from gastric suctioning and vomiting. Renal loss of hydrogen ions occurs from potassium-losing diuretics, excess of mineralocorticoid, hypercalcemia, and hypoparathyroidism. In patients with hypokalemia and carbohydrate refeeding after starvation, hydrogen ions shift from ECF into the cells, depleting serum levels. This also occurs when excessive ingestion of alkalis (e.g., antacids such as Alka-Seltzer), parenteral administration of NaHCO$_3$ during cardiopulmonary resuscitation, and massive blood transfusions increase serum levels of HCO$_3^-$ (Porth, 2015).

CLINICAL MANIFESTATIONS

Patients with metabolic alkalosis may experience dizziness and depressed respirations in addition to impaired mentation, tingling of fingers and toes, circumoral
paresthesia, and hypertonic reflexes. Other symptoms include hypotension, cardiac dysrhythmias, hyperventilation, hypokalemia, and decreased iCA (i.e., carpopedal spasm).

LABORATORY AND ECG FINDINGS

- ABG values: pH greater than 7.45; HCO₃⁻ greater than 26 mEq/L
- PaCO₂: Greater than 42 mm Hg
- Serum HCO₃⁻: Greater than 26 mEq/L
- Serum electrolytes: Low serum potassium (<4 mEq/L) and low serum chloride
- ECG: Assess for dysrhythmias (Hinkle & Cheever, 2013)

COMMON CAUSES OF METABOLIC ALKALOSIS

- Chloride depletion: Loss of gastric secretions, vomiting, NG tube drainage, diarrhea
- Potassium depletion: Primary aldosteronism, mineral corticoid excess, laxative abuse
- Hypercalcemic states: Hypercalcemia of malignancy, acute milk alkali syndrome
- Miscellaneous: Medication (bicarbonate ingestion, carbenicillin, ampicillin), refeeding syndrome, hypoproteinemia

TREATMENT/COLLABORATIVE MANAGEMENT

Patients with metabolic alkalosis are treated by

1. Reversing the underlying cause
2. Administering sufficient chloride for the kidney to excrete the excess HCO₃⁻. Usually isotonic sodium chloride infusion corrects the deficit.
3. Replacing potassium if K⁺ is low. Usually potassium chloride is preferred because chloride losses can be replaced simultaneously. Carbonic anhydrase inhibitors such as acetazolamide (Diamox) are useful for correcting metabolic alkalosis in patients who cannot tolerate rapid volume expansion. Acetazolamide causes a large increase in renal secretion of HCO₃⁻ and K⁺, so it may be necessary to supplement potassium prior to administration of medication.
4. Administering acidifying agents such as diluted HCl and ammonium chloride (NH₄Cl). There are serious side effects, so this solution is not commonly used (Hinkle & Cheever, 2013).
Respiratory Acid–Base Imbalances

Normal Reference Value: Partial pressure of CO₂ (PaCO₂): 38 to 42 mm Hg

Respiratory Acidosis: Carbonic Acid Excess

Respiratory acidosis is caused by inadequate excretion of CO₂ and inadequate ventilation resulting in increased serum levels of CO₂ and H₂CO₃. Acute respiratory acidosis usually is associated with emergency situations.

Etiology

Acute respiratory acidosis can result from pulmonary, neurological, and cardiac causes, such as pulmonary edema; aspiration of a foreign body; pneumothorax; severe pneumonia; severe, prolonged exacerbation of acute asthma; overdose of sedatives; cardiac arrest; and massive pulmonary embolism.

Chronic respiratory acidosis results from emphysema, bronchial asthma, bronchiectasis, postoperative pain, obesity, and tight abdominal binders (Kee et al., 2010).

NURSING POINTS OF CARE

METABOLIC ALKALOSIS

Nursing Assessment

- Obtain history of health problems related to metabolic alkalosis (e.g., peptic ulcer, vomiting, adrenocortical hormone abnormalities).
- Obtain baseline vital signs.
- Assess for signs and symptoms of metabolic alkalosis related to decreased calcium ionization (tingling of fingers and toes, dizziness, hypertonic muscles; respirations depressed as a compensatory action, atrial tachycardia).
- Obtain baseline values for ABGs and serum electrolyte, serum CO₂ content, and HCO₃⁻.

Key Nursing Interventions

1. Use safety precautions for hyperexcitability states.
2. Monitor the patient’s fluid I&O.
3. Monitor renal and hepatic function.
4. Monitor laboratory test results for changes (ABGs, potassium, chloride).
5. Monitor the patient for changes in vital signs, with particular attention to respirations and CNS.
6. Monitor for changes in cardiac rhythm, especially in patients taking cardiac glycosides.
7. Administer sodium chloride at prescribed rate. KCl may be used to replace both the Cl and K ions.
CLINICAL MANIFESTATIONS
Acute signs and symptoms include tachypnea; dyspnea; dizziness; seizures; warm, flushed skin; and ventricular fibrillation. Chronic signs and symptoms occur if $\text{PaCO}_2$ exceeds the body’s ability to compensate, and they include respiratory symptoms.

LABORATORY AND RADIOGRAPHIC FINDINGS
- **ABG values:**
  - **Acute:** pH less than 7.35, $\text{PaCO}_2$ greater than 42 mm Hg, $\text{HCO}_3^-$ greater than 26 mEq/L. **Chronic:** pH less than 7.35, $\text{PaCO}_2$ greater than 42 mm Hg, $\text{HCO}_3^-$ normal or slight increase
  - Serum $\text{HCO}_3^-$: Reflects acid–base balance; initial values normal unless mixed disorder is present
  - Serum electrolytes: Usually not altered
  - Chest radiography: Determines the presence of underlying pulmonary disease
  - Drug screen: Determines the quantity of drug if patient is suspected of taking an overdose

COMMON CAUSES OF RESPIRATORY ACIDOSIS
Acute:
- Pulmonary/thoracic disorders: Severe pneumonia, acute respiratory distress syndrome (ARDS), flail chest, pneumothorax, smoke inhalation
- Increased resistance to air flow: Upper airway obstruction, aspiration, laryngospasm, severe bronchospasm
- CNS depression: Sedative overdose, anesthesia

Chronic:
- Obstructive diseases: Emphysema, chronic bronchitis, cystic fibrosis, obstructive sleep apnea
- Restriction of ventilation: Kyphoscoliosis, hydrothorax, severe chronic pneumonitis, obesity–hypoventilation (pickwickian syndrome)
- Neuromuscular abnormalities: Spinal cord injuries, poliomyelitis, muscular dystrophy, multiple sclerosis
- Depression of respiratory center: Brain tumor, chronic sedative overdose

TREATMENT/COLLABORATIVE MANAGEMENT
The goal is to treat the underlying cause. Respiratory acidosis is treated by carrying out the following:
- **Restore normal acid–base balance:** Support respiratory function.
- **Administer bronchodilators or antibiotics for respiratory infections as indicated.**
- **Administer oxygen as indicated.**
- **Administer adequate fluids (2–3 L/day) to keep mucous membranes moist and help remove secretions.**
Respiratory Alkalosis: Carbonic Acid Deficit

Respiratory alkalosis usually is caused by hyperventilation, which causes “blowing off” of CO₂ and a decrease in H₂CO₃ content. Respiratory alkalosis can be acute or chronic.

**ETIOLOGY**

Acute respiratory alkalosis results from pulmonary disorders that produce hypoxemia or stimulation of the respiratory centers. Underlying causes of hypoxemia include high fever, pneumonia, congestive HF, pulmonary emboli, hypotension, asthma, and inhalation of irritants. Causes of stimulation of respiratory centers include anxiety (most common), excessive mechanical ventilation, CNS lesions involving the respiratory center, and salicylate overdose (an early sign).

**CLINICAL MANIFESTATIONS**

Respiratory alkalosis causes light-headedness, the inability to concentrate, numbness and tingling of the extremities (circumoral paresthesia), tinnitus, palpitations, epigastric pain, blurred vision, precordial pain (tightness), sweating, dry mouth, tremulousness, seizures, and loss of consciousness.
LABORATORY AND ECG FINDINGS

- ABG values: pH greater than 7.45, PaCO₂ less than 38 mm Hg, HCO₃⁻ less than 22 mEq/L
- Serum electrolytes: Presence of metabolic acid–base disorders
- Serum phosphate: May fall to less than 0.5 mg/dL
- ECG: Determines cardiac dysrhythmias

COMMON CAUSES OF RESPIRATORY ALKALOSIS

- Caused by hyperventilation “blowing off of CO₂”
- Hypoxemia: Pneumonia, hypotension, severe anemia, congestive HF
- Stimulation of pulmonary or pleural receptors: Pulmonary emboli, pulmonary edema, asthma, inhalation of irritants
- Central stimulation of respiratory center: Anxiety, pain, intracerebral trauma
- Hyperventilation, mechanical: Fever, sepsis (gram negative), hepatic disease (Kee et al., 2010)

TREATMENT/COLLABORATIVE MANAGEMENT

In respiratory alkalosis, the underlying disorder must be treated. Treatment of patients with respiratory alkalosis consists of the following:

1. Treat underlying cause of respiratory alkalosis.
2. Treat the source of anxiety (instruct patient to breathe slowly into a paper bag).
3. Administer a sedative as indicated.
4. Administer oxygen therapy if hypoxemia is causative factor.
5. Adjust mechanical ventilators: Check settings and make adjustments to ventilatory parameters in response to ABG results (Hinkle & Cheever, 2013).

Table 3-10 provides a summary of acute acid–base imbalances.

NURSING POINTS OF CARE

RESPIRATORY ALKALOSIS

Nursing Assessment

- Obtain a patient history of hysteria, fever, or severe infection.
- Check for signs and symptoms of respiratory alkalosis (light-headedness, numbness and tingling, tinnitus, occasional loss of consciousness) (Heitz & Horne, 2012).
- Obtain baseline vital signs.
- Obtain ABG and electrolyte values.

Continued
The Pediatric Patient

Physiological differences in pediatric patients, which include less body surface area, immaturity of renal structures, high rate of metabolism, and immaturity of the endocrine system in promoting homeostatic control, predispose this age group to various fluid and electrolyte imbalances. Pediatric clients are additionally at risk for acid–base imbalances because the transport system for ions and bicarbonate is weaker than in older children and adults (Kee et al., 2010).

Infants have proportionately more body fluid (70%–80% of body weight) than any other age group. Infants are at higher risk for FVD during times of increased external temperatures. In infants (children younger than 18 months), sunken or depressed fontanels can indicate FVD, and bulging fontanels can indicate FVE. In addition, in children, skin turgor begins to diminish after 3% to 5% of body weight is lost. Factors that increase insensible fluid loss are hyperthermia, increased activity, hyperventilation, radiant warmers, and phototherapy (Kee et al., 2010).

Assessment begins with observations of the infant’s/child’s general appearance and behavioral changes. The following assessments should be performed and documented in the medical records:

- Monitor vital signs according to the severity of the illness. Vital signs of seriously ill infants and children must be monitored every 15 minutes. With each temperature increase of 1°F, the metabolic need for oxygen increases by 7% and the respiratory rate increases by four breaths per minute (Kee et al., 2010).
- Assess skin and mucous membranes. The extremities often become cold and mottled with the presence of fever and severe FVD.
- Skin elasticity can be assessed by pinching the skin on the abdomen or inner thigh (dent test). Common areas for assessing edema include the extremities, face, perineum, and torso.
- Tears and salivation are decreased or absent with dehydration. Dehydration causes the fontanels and eyeballs to appear soft and sunken. With FVE the fontanels bulge and feel taut.
Tingling fingers and toes, abdominal cramps, muscle cramps, light-headedness, nausea, and thirst are important symptoms of electrolyte imbalances in infants and children.

Monitor weight daily. Small weight changes are crucial in fluid balance problems.

Monitor I&O. The immature development of the renal structures in the infant limits the kidney’s ability to concentrate urine and increases the infant’s risk for dehydration. Establish a baseline for normal output; normal output ranges for infants are 2 to 3 mL/kg/hr. Specific gravity should be evaluated (Kee et al., 2010).

Table 3-10 Summary of Acute Acid–Base Imbalances

<table>
<thead>
<tr>
<th>Condition</th>
<th>pH</th>
<th>$P_{aCO_2}$</th>
<th>$HCO_3^-$</th>
<th>How the Body Compensates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Respiratory acidosis</td>
<td>↓</td>
<td>↑</td>
<td>↑</td>
<td>Kidneys conserve $HCO_3^-$ and eliminate $H^+$ to increase pH</td>
</tr>
<tr>
<td>With compensation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Respiratory alkalosis</td>
<td>↑</td>
<td>↓</td>
<td></td>
<td>Normal</td>
</tr>
<tr>
<td>With compensation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metabolic acidosis</td>
<td>↓</td>
<td>↓</td>
<td>↓</td>
<td>Hyperventilation to blow off excess $CO_2$ and conserve $HCO_3^-$</td>
</tr>
<tr>
<td>With compensation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metabolic alkalosis</td>
<td>↑</td>
<td></td>
<td>↑</td>
<td>Hypoventilation to $CO_2$ or normal kidneys keep $H^+$ and excrete $HCO_3^-$</td>
</tr>
<tr>
<td>With compensation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Common Causes of Acid–Base Imbalance

- Respiratory acidosis: Asphyxia, respiratory depression, central nervous system depression
- Respiratory alkalosis: Hyperventilation, anxiety, pulmonary embolism (PE) (causing hyperventilation)
- Metabolic acidosis: Diarrhea, renal failure, salicylate overdose such as acetylsalicylic acid (aspirin)
- Metabolic alkalosis: Hypercalcemia, overdose on an alkaline substance such as antacid

- Knowledge of variations in serum electrolyte ranges for infants and children can help prevent complications.

NURSING FAST FACT!

Knowledge of variations in serum electrolyte ranges for infants and children can help prevent complications.
The Older Adult

Older adults are at higher risk for dehydration due to factors that include natural changes associated with aging. These include a decreased percentage of total body water, decreased muscle mass, decreased capacity to concentrate urine, and a decrease in the sensation of thirst.

Signs and symptoms of dehydration are often unreliable in older adults. A rapid weight loss over 1 to 2 weeks should signal the possibility of dehydration (Morley, 2015). Furthermore, laboratory results may not always be reliable indicators in older adults. For example, the blood urea nitrogen BUN to serum creatinine level (> 20) is a common measure of dehydration but is not reliable in older adults because a multitude of other factors may cause an elevation such as aging muscle loss, presence of renal/heart failure, glucocorticoids, and increased protein intake (Morley, 2015).

Cardiovascular and respiratory changes in the older adult combine to contribute to a slower response to the stress of blood loss, fluid depletion, shock, and acid–base imbalances (Kee et al., 2010).

**NURSING FAST FACT!**

Because the sensation of thirst is diminished in older adults, the attempt to reach homeostasis based on thirst is compromised (Hankins, 2010).

The older adult patient has a decreased ability to adapt to rapid increases in intravascular volume and can quickly develop fluid overload. Sodium and fluid overload is common in hospitalized older adult patients and can result in increased morbidity and mortality in surgical patients (Zarowitz & Lefkovitz, 2008). Dehydration and chronic hyponatremia can lead to confusional states that interfere with fluid intake in older adult people, who are very susceptible to dehydration.

**NURSING FAST FACT!**

Daily weight monitoring is standard practice for patients with HF as it leads to early recognition of excess fluid retention, which when reported can be offset with additional medication to avoid hospitalization from HF decompensation.
Hypokalemia is a common deficit experienced by older adults. Potassium is not conserved well at any age; however, older adults often receive diuretics and steroids, which tend to decrease serum potassium levels.

### Home Care Issues

- Home health care is commonly prescribed for adults with chronic illnesses such as diabetes mellitus, cardiorespiratory disorders, cancer, and GI disorders. The role of the home health care nurse includes assessment of the patient and family needs. Nursing diagnoses, outcomes, and interventions are planned based upon assessment findings. It is notable that polypharmacy is prevalent among older adults, therefore medication reconciliation, patient education, and evaluation of adverse/side effects is critical. Many home care patients are at risk for fluid and electrolyte imbalances due to medications as well as their medical diagnoses and dietary/nutritional issues. The home care nurse assesses for signs and symptoms of imbalances, monitors laboratory findings, and makes suggestions to the LIP for ongoing diagnostic tests based on assessment findings.

### Patient Education

- Teach patient risk factors for development of FVD or FVE.
- Explain to patient and family the reasons for I&O records.
- Teach the patient to keep track of oral liquids consumed.
- Assess the patient’s understanding of the type of fluid loss being experienced.
- Give verbal and written instructions for fluid replacement (drink at least 3 quarts of liquid).
- Teach the patient to increase fluid intake during hot days and in the presence of fever or infection, and to decrease activity during extreme weather.
- Teach how to observe for dehydration (especially in infants).
- Instruct the patient to seek medical consultation for continued dehydration.
- Teach appropriate use of laxatives, enemas, and diuretics.
- Inform the patient to notify the physician if he or she has excessive edema or weight gain (more than 2 lb) or increased shortness of breath.
- Provide literature on low-salt diets; consult with dietitian if necessary.
- Provide dietary education on sodium and potassium and teach to avoid adding salt while cooking; provide information on salt substitutes.

*Continued*
Patient Education—cont’d

- Teach to avoid caffeine because it acts as a mild diuretic.
- Provide written material and verbal instructions regarding any medications.
- Provide information on predisposing factors associated with specific electrolyte imbalances.
- Review indicators of digitalis toxicity, if appropriate.
- Provide information on dietary sources of electrolytes in deficit situations when appropriate.
- Provide information on over-the-counter medications (e.g., magnesium and aluminum hydroxide, antacids and phosphorus-binding antacids, laxatives, multivitamin and mineral supplements) when appropriate.
- Educate the patient with cancer about symptoms of hypercalcemia.
- Educate the patient on the high phosphorus content of processed foods, carbonated beverages, and over-the-counter medications when appropriate.

Nursing Process

The nursing process is a five- or six-step process for problem-solving to guide nursing action. Refer to Chapter 1 for details on the steps of the nursing process related to vascular access. The following tables focus on nursing diagnoses and nursing outcomes for patients with fluid, electrolyte, and acid–base imbalances. Nursing diagnoses should be patient specific and outcomes and interventions individualized. The Nursing Outcomes Classification (NOC) and Nursing Interventions Classification (NIC) presented here are suggested directions for development of outcomes and interventions.

Nursing diagnoses and interventions are specific to the underlying pathophysiological process. In addition, the following may be considered.
### Nursing Diagnoses Related to Fluid and Electrolyte Imbalance

<table>
<thead>
<tr>
<th>Deficient or excess fluid volume related to:</th>
<th>Electrolyte and acid–base balance, fluid balance, hydration</th>
<th>Fluid management, hypovolemia management, shock management: volume, fluid monitoring</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compromised regulatory mechanisms; active fluid volume loss or gain</td>
<td></td>
<td></td>
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</tbody>
</table>

**Risk for injury related to:**

**External:** alteration in cognitive and psychomotor functioning  
**Internal:** biochemical dysfunction  
Altered mental functioning, drowsiness, and weakness; sensory or neuromuscular dysfunction from hypophosphatemia-induced central nervous system disturbances  
Altered sensorium from primary hypernatremia or cerebral edema occurring with too rapid correction of hypernatremia  
Tetany—precipitation of calcium phosphate in the soft tissue and periarticular region of the large joints  
Sensory or neuromuscular dysfunction as a result of hypomagnesemia  
Tetany and seizures related to neurosensory alterations from severe hypocalcemia

**Deficient knowledge related to alteration in cognitive function; insufficient information**

Knowledge of diet, disease process, health behavior, health resources, medication, treatment regimen  
Teaching: disease process, learning facilitation

**Nutrition altered, less than body requirements, related to:**

Insufficient dietary intake  
From chronic alcoholism, IV fluid (including total parenteral nutrition) with lack of phosphate additive, magnesium related to history of poor intake, anorexia, or alcoholism  
Effects of vitamin D deficiency, renal failure, malabsorption, laxative use

**Perfusion, tissue ineffective (peripheral) related to:**

Aggravating factors

**Gas exchange, impaired related to:**

Alveolar–capillary membrane changes; ventilation–perfusion imbalance (hypercapnia, hypercarbia, hypoxemia, hypoxia)

**Perfusion, tissue, cardiac, decreased risk for related to:**

Hypoxemia, hypoxia

**Cardiac pump effectiveness, circulation status, tissue perfusion cardiac, tissue perfusion: cellular, vital signs**

Cardiac care  
Dysrhythmia management, vital signs monitoring, shock management: cardiac

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Sources: Ackley, Ladwig, & Makic, 2017; Bulechek, Butcher, Dochterman, & Wagner, 2013; Moorhead, Johnson, Maas, & Swanson, 2013.
Chapter Highlights

- Fluid is distributed in three compartments: intracellular (40%), intravascular (5%), and interstitial (15%). Water accounts for 60% of TBW for an average adult and 80% for full-term infants.
- Fluid is transported passively by filtration, diffusion, and osmosis.
- Electrolytes are actively transported by ATP on cell membranes and by the sodium–potassium pump.
- The osmolarity of IV solutions has the following ranges:
  - Isotonic solutions: 250 to 375 mOsm/L
  - Hypotonic solutions: Less than 250 mOsm/L
  - Hypertonic solutions: Greater than 375 mOsm/L
- The homeostatic organs that regulate fluid and electrolyte balance include the kidneys; heart and blood vessels; lungs; and adrenal, parathyroid, and pituitary glands.
- There are six areas to assess for fluid balance: neurological status; cardiovascular, respiratory, and integumentary systems; special senses; and body weight.
- Fluid imbalances fall into two categories:
  - FVD caused primarily by disorders of the GI system. Signs and symptoms reflect a dehydrated individual. Treatment is aimed at rehydration with isotonic sodium chloride.
  - FVE caused primarily by cardiovascular dysfunction, renal or endocrine dysfunction, and too-rapid administration of IV fluids. Signs and symptoms reflect fluid overload. Treatment is aimed at decreasing the sodium level, using diuretics to increase the excretion of fluids, and treating the underlying cause.
- The seven major electrolytes and their symbols are:
  - Cations: Sodium: Na⁺, potassium: K⁺, calcium: Ca²⁺, magnesium: Mg²⁺
  - Anions: Chloride: Cl⁻, phosphate: HPO₄⁻, bicarbonate: HCO₃⁻
- Key nursing interventions for electrolyte imbalances reflect collaborative practice and are specific to the imbalance.
- Key laboratory values include:
  - Sodium (Na⁺): 135 to 145 mEq/L
  - Potassium (K⁺): 3.5 to 5.0 mEq/L
  - Calcium (Ca²⁺): 4.5 to 5.5 mEq/L or 9 to 11 mg/dL
  - Magnesium (Mg²⁺): 1.5 to 2.5 mEq/L or 1.8 to 3.0 mg/dL
  - Phosphorus (HPO₄⁻): 2.5 to 4.5 mg/dL
  - Chloride (Cl⁻): 95 to 108 mEq/L
- Critical guidelines for potassium infusion include:
  - Never give potassium by IV push.
  - Concentrations of potassium greater than 60 mEq should not be given in a peripheral vein.
  - Concentrations greater than 8 mEq/100 mL can cause pain and irritation of peripheral veins, leading to phlebitis.
• Do not add potassium to a hanging container.
• Administer potassium at a rate not exceeding 10 mEq/hr through peripheral veins.
• Calcium and phosphate have a reciprocal relationship: When one is elevated, the other is decreased.
• Patients with calcium imbalances may need seizure precautions. The most dangerous symptom of hypocalcemia is laryngospasm.
• The four major acid–base imbalances in the body are respiratory acidosis (carbonic acid excess), respiratory alkalosis (carbonic acid deficit), metabolic acidosis (base bicarbonate deficit), and metabolic alkalosis (bicarbonate excess).
• Acid–base balance is maintained through three major reaction-specific buffer systems that regulate hydrogen ion concentration: the carbonic acid–bicarbonate system, the phosphate buffer system, and the protein buffer system.

Thinking Critically: Case Study

A 28-year-old woman who became ill on a cruise to the Bahamas was admitted to the hospital after 6 days of severe diarrhea and poor intake. She weighed 120 lb on admission (132 lb before illness). Her BUN was 40 mg/dL, and serum creatinine was 1.3 mg/dL. Her potassium level was 3.2 mEq/mL, and sodium was 133 mEq/mL. Her skin turgor was poor, and urine output was 15 mL/hr (specific gravity 1.030). Blood gases were pH 7.47 and HCO₃⁻ 30 mEq/L; BP was 120/80 mm Hg recumbent and fell to 98/60 mm Hg when the patient was upright. Her pulse was 110, weak, and regular, with respiratory rate of 14. Her reflexes were hyperactive, and she complained of “tingling of fingers.”

Case Study Questions
1. What percentage of body weight did she lose?
2. What concerns would the nurse have regarding the patient’s laboratory test results?
3. What nursing diagnoses would apply to this woman?
4. What nursing interventions would be implemented?
5. What collaborative orders would you anticipate?

References


Chapter 4
Parenteral Solutions

LEARNING OBJECTIVES
After completing this chapter, the reader will be able to:

1. Define terminology related to parenteral solutions.
2. Identify three indications for parenteral solution administration.
3. Differentiate between the effects of isotonic, hypotonic, and hypertonic fluids.
4. List the key elements of crystalloid solutions.
5. Differentiate between crystalloid and colloidal parenteral solutions.
6. Compare the indications for dextrose, sodium chloride, hydrating fluids, and balanced electrolyte fluids.
7. Identify the use of alkalinizing and acidifying fluids.
8. Identify indications for common colloidal solutions.
9. Apply formulas used to calculate the fluid needs of pediatric clients.
10. Describe why older adults are at increased risk for dehydration.

Glossary

Balanced solution Parenteral solution that contains electrolytes in proportions similar to those in plasma; also contains bicarbonate or acetate ion

Body surface area (BSA) The surface area of the body expressed in square meters; used in calculating pediatric dosages, fluid needs in burn patients, and determining radiation and chemotherapy doses

Caloric method Calculation of metabolic expenditure of energy, used in pediatric fluid maintenance and replacement

Catabolism The breakdown of chemical compounds by the body; an energy-producing metabolic process

Colloid A substance (e.g., blood, plasma, albumin, dextran) that does not dissolve into a true solution and is not capable of passing through a semipermeable membrane
Crystalloid  Solutes (e.g., electrolytes, dextrose) having the ability to form crystals; they easily mix and dissolve in a solvent, forming a solution where the crystalloids cannot be distinguished from the resulting solution.

Dehydration  A deficit of total body water; can involve one fluid compartment or all three

Hydrating solution  A solution of water, carbohydrate, sodium, and chloride used for the purposes of hydration and diuresis, and for assessing the adequacy of renal function

Hypertonic solution  A solution with an osmolarity higher than that of plasma, above 375 mOsm

Hypotonic solution  A solution with an osmolarity lower than that of plasma, usually below 250 mOsm

Isotonic solution  A solution with the same osmolarity as plasma, usually 250 to 375 mOsm

Maintenance therapy  Fluids that provide all nutrients necessary to meet daily patient requirements; usually water, glucose, sodium, and potassium

Normal saline  Solution of salt (0.9% sodium chloride)

Osmolality  The solute concentration in fluid as measured by weight and expressed as the number of milliosmols in 1 kg of solution

Osmolarity  The solute concentration in fluid as measured by the number of milliosmols per liter of solution

Parenteral therapy  Introduction of substances via a route other than the gastrointestinal tract; includes the IV, subcutaneous, intramuscular, and intraspinal routes

Plasma volume expander  Solutions with a relatively high molecular weight that increase the plasma volume by increasing the osmotic pressure

Replacement therapy  Replenishment of fluid and electrolyte and nutritional losses when maintenance cannot be met and when patient is in a deficit state

Solute  A substance dissolved in a solution

Solvent  A substance in which a solute is dissolved (e.g., water)

Introduction

The nurse is responsible for the administration of parenteral therapy, including parenteral solutions. Along with administering therapy, the nursing role includes assessing fluid volume status and monitoring the patient's response to interventions. Knowledge regarding the contents of parenteral solutions, their purpose and actions on the body, and their potential complications is imperative. The complex subject of fluids and electrolytes is covered in Chapter 3, which provides the requisite background knowledge for this chapter on parenteral solutions.
Foundations of Parenteral Solution Administration

Parenteral solutions are administered for the following reasons:

1. To maintain and meet daily fluid/electrolyte body fluid requirements
2. To replace present and ongoing fluid losses, and to correct any electrolyte imbalances
3. To act as a diluent for delivery of infusion medications

Factors affecting the choice, amount, and rate of parenteral solutions include the patient's renal and cardiac function, daily maintenance requirements, existing fluid and electrolyte imbalance, clinical status, and disturbances in homeostasis as a result of parenteral therapy.

Maintenance Parenteral Solution Support

Maintenance parenteral solution support provides nutrients that meet the daily needs of a patient for water, electrolytes, and dextrose. As the body’s primary fluid, water is essential for:

- transporting nutrients, gases, and waste in and out of the body’s cells
- facilitating the elimination of waste through the kidneys, gastrointestinal (GI) tract, skin, and lungs
- regulating body temperature through skin evaporation

(Crawford & Harris, 2011)

A typical patient profile for maintenance solution support is an individual who is allowed nothing by mouth (NPO), such as after a surgical procedure, or one whose oral intake is restricted for any reason. As discussed in the previous chapter, water and fluids are gained through fluid intake and metabolism of nutrients and are lost through the kidneys and GI system (sensible or measurable losses) and through the lungs and the skin (insensible losses, which are not measurable).

The amount of daily fluid intake needed for an adult patient with normal heart and kidney function is 1500 mL per square meter (m²) of body surface; on average, this amounts to about 2 to 3 liters per day. For example, a 6-foot-tall man weighing 187 lb (85 kg) has a body surface area (BSA) of about 2 m², so 1500 times 2 = 3000; therefore, he needs 3000 mL of fluids for maintenance therapy.

Solutions for maintenance therapy include water, daily needs of sodium and potassium, and glucose.

**NURSING FAST FACT!**

There are a number of online tools for calculating BSA. The patient’s height and weight are required. One helpful calculator website is from Cornell University (www-users.med.cornell.edu/~spon/picu/calc/bsacalc.htm).
Replacement Therapy

Replacement therapy is necessary for maintenance needs for fluid, electrolyte, or blood product deficits and also for replacing fluid losses and correcting electrolyte imbalances. Examples of conditions of patients needing replacement infusion therapy (and their replacement requirements) are:

- Hemorrhage (replacement of fluid volume, red blood cells, and plasma)
- GI fluid losses due to vomiting, diarrhea, high-output ostomies/fistulas (replacement of electrolytes and water losses)
- Starvation (replacement of water and electrolytes, nutrients)

During acute illness, fluids can become sequestered into a portion of the body from which it is not easily exchanged with the rest of the extracellular fluid (ECF), referred to as third spacing (Capriotti & Frizzell, 2016). The trapped fluid is sequestered and not available for functional use. Fluid can be sequestered from the intravascular space into body spaces (pleural or peritoneal effusions), or it can become trapped in the bowel by obstruction or in the interstitial space as edema after burns. Third-space shifts occur in conditions such as peritonitis, bowel obstruction, burns, some cancers, major surgery involving extensive tissue trauma, and sepsis.

A major consideration in differentiating the fluid volume deficit associated with third spacing from that associated with fluid lost through vomiting or diarrhea is that measurable fluid can be replaced using replacement therapy, whereas third-space fluid cannot; in addition, decreased body weight does not occur in third spacing. Accurate dosing of fluid therapy requires monitoring, and treatment is directed at correcting the cause of the third-space shift of body fluids and is tailored to the patient’s response.

When restoring ongoing losses (e.g., nasogastric tubes to suction, bleeding), critical evaluation of the source of the loss is ongoing, such as with draining fistulas, abscesses, nasogastric tubes, burns, and abdominal wounds. With such patients, there are often frequent changes in the types of solutions ordered, in the amounts of electrolytes ordered based on laboratory test results, and in the rate of infusion.

Aspects of assessment that contribute to decision making for the type and amount of fluid replacement therapy include:

- Evaluation of laboratory values including renal function and hydration status (serum creatinine, blood urea nitrogen, urine/serum osmolality), serum electrolytes, complete blood count, acid–base balance (blood gases), coagulation studies, serum glucose
- Accurate intake and output measurements. Output measurements will include urine, vomitus, and wound/ostomy/fistula drainage. Insensible loss is approximately 1000 mL per day (Capriotti & Frizzell, 2016).
- Physical assessment findings pertinent to fluid balance, including vital signs, weight, cardiorespiratory system, skin (turgor, presence of edema)
- Presence of comorbidities that are risk factors with fluid replacement (e.g., heart failure, renal insufficiency)
Many patients require potassium supplementation. Inadequate intake is a frequent cause of hypokalemia. Patients at greatest risk include those who are NPO, alcoholics, those post-bariatric and gastric surgery, those with eating disorders, and those under stress from tissue injury or wound infection (Capriotti & Frizzell, 2016).

Most hospitalized patients receiving additional saline or glucose infusions are prone to developing potassium deficiency. Excretion of potassium in their urine can increase to 60 to 120 mEq/day even with limited intake. Tissue injury significantly increases the loss of potassium. Normal dietary intake of potassium is 80 to 200 mEq/day. Potassium is usually included as part of replacement therapy. Potassium administration is contraindicated in conditions such as renal insufficiency, acute dehydration, azotemia, and hyperkalemia from any cause.

**Nursing Fast Fact!**

Recommended potassium administration rates should not usually exceed 10 mEq per hour or 200 mEq for a 24-hour period. When severe hypokalemia is a threat (serum potassium level less than 2.0 mEq per liter and electrocardiographic changes and/or muscle paralysis), rates up to 40 mEq per hour or 400 mEq over a 24-hour period can be administered very carefully when guided by continuous monitoring of the ECG and by frequent serum potassium determinations to avoid hyperkalemia and cardiac arrest (Baxter Healthcare Corp., 2017). Potassium is always diluted and never administered by IV push. Key nursing assessment: Check renal function and serum potassium level before administering potassium.

Carefully monitor replacement solutions with potassium for the following patients:

1. **Those with dysfunction of the:**
   - Renal system
   - Cardiovascular system
   - Adrenal glands
   - Pituitary gland
   - Parathyroid gland
2. **Those with existing deficits/excess of:**
   - Sodium
   - Calcium
   - Potassium
   - Calcium
   - Base bicarbonate
   - Blood volume (hypovolemic)

**Fluid Administration in Burn Resuscitation**

Patients who sustain burns require more fluids than any other trauma patients due to the pathophysiological consequences associated with the burn injury.
An increase in vascular permeability leads to fluids leaving the intravascular space and entering the interstitial space, resulting in edema, hypovolemia, and hemoconcentration. Prompt fluid resuscitation is essential to survival. The consequences of inadequate fluids include increased burn depth and longer periods of shock (Guilabert et al., 2016). The Parkland formula is widely used to calculate fluid resuscitation. However, based upon a review of the literature, researchers suggest that the amount of fluid administered in the first 24 hours should be somewhat higher than that based on the Parkland formula (Guilabert et al., 2016). The initial resuscitation fluid for the first 24 hours should be a balanced crystalloid fluid with Ringer's acetate preferred. Beyond 24 hours, colloidal fluids are often used; however, there is a lack of data regarding which colloidal fluid to use and when. Using an online calculator for the Parkland formula, fluid recommendations are calculated as follows for an adult patient who weighs 150 lb and has sustained nonsuperficial burns over 30% of the BSA:

This patient should receive 8165 mL of crystalloid fluid in the first 24 hours. The fluid should be administered at 510 mL per hour for the first 8 hours, followed by 255 mL per hour for 16 hours (http://reference.medscape.com/calculator/burn-injury-fluid-parkland).

**Osmotic Activity and Parenteral Solutions**

The osmotic activity of a solution may be expressed in terms of either its [osmolality](#) or its [osmolality](#). Although the terms are often used interchangeably, they do have different definitions.

- Osmolarity refers to the solute concentration in fluid by the number of milliosmols (mOsm) per liter of solution.
- Osmolality refers to the solute concentration in the fluid by weight and is expressed as the number of milliosmols (mOsm) in 1 kg of solution. Osmolality assesses the activity of all solutes present in a sample of plasma or urine. Osmolality is a better measure of the true physiological condition than is osmolarity because it takes into account a wider range of solutes as well as the movement of fluid between physiological compartments (Cockerill & Reed, 2012).

**NURSING FAST FACT!**

Osmolarity is generally used when referring to fluids outside the body (IV solutions). Osmolality is used for describing fluids inside the body, such as laboratory test values from urine or plasma (e.g., serum osmolality).

The term **tonicity** is related to a solution's osmolarity and refers to the ability of an extracellular solution to make water move into or out of a cell by osmosis. Tonicity is determined solely by effective solutes such as glucose that cannot
penetrate the cell membrane, thereby producing an osmotic force that pulls water into or out of the cell and causing it to change size.

Solutions to which body cells are exposed can be classified as isotonic, hypotonic, or hypertonic depending on whether they cause cells to swell or shrink. Cells placed in an isotonic solution, which has the same effective osmolality as intracellular fluids (ICFs; 280–295 mOsm/L) neither shrink nor swell. When cells are placed in hypotonic solution, which has a lower effective osmolality than ICFs, they swell as water moves into the cell. When cells are placed in a hypertonic solution, which has a greater effective osmolality than ICF, they shrink as water is pulled out of the cell. Administration of IV fluids is guided by the tonicity of the solution and falls into three categories: isotonic or iso-osmolar, hypotonic, and hypertonic. The effect of IV fluid on the body fluid compartments depends on how the osmolarity of the IV solution compares with the patient’s serum osmolality. IV fluids can change the fluid compartment in one of three ways:

1. Expand the intravascular compartment
2. Expand the intravascular compartment and deplete the intracellular and interstitial compartments
3. Expand the intracellular compartment and deplete the intravascular compartment

**NOTE:** See Chapter 3 to gain more information on osmolarity and to review diagrams of fluid shifts.

**Isotonic Fluids**

Isotonic solutions have an osmolarity of 250 to 375 mOsm/L. Blood and normal body fluids have an osmolarity of 285 to 295 mOsm/kg. These fluids will expand the ECF compartment. No net fluid shifts occur between isotonic solutions because the osmotic pressure gradient is the same inside and outside the cells. Many isotonic solutions are available. Examples include 0.9% sodium chloride, 5% dextrose in water, and lactated Ringer’s solution.

Isotonic solutions are commonly used to treat fluid loss, dehydration, and hypernatremia (sodium excess). Five percent dextrose solution is used for dehydration because it replaces fluid volume without disrupting the interstitial and intracellular environment. However, this solution becomes hypotonic when dextrose is metabolized; the solution should be used cautiously in patients with renal and cardiac disease because of the increased risk of fluid overload. This solution also does not provide enough daily calories and can lead to protein breakdown if used for extended periods of time (Crawford & Harris, 2011).

**Caution:** The danger with the use of isotonic solutions is circulatory overload. These solutions do not cause fluid shifts into other compartments. Another problem with overexpanding the vascular compartment is that the fluid dilutes the concentration of hemoglobin and lowers hematocrit levels.
Hypotonic Fluids

Hypotonic fluids have an osmolarity lower than 250 mOsm/L. The serum osmolality is lowered in the vascular space as body fluids shift out of blood vessels into cells and interstitial spaces. The resulting osmotic pressure gradient draws water into the cells from the ECF, causing the cells to swell. Hypotonic solutions are used for patients who have hypertonic dehydration, who require water replacement, and who have diabetic ketoacidosis after initial sodium chloride replacement. Examples of hypotonic solutions include 0.45% sodium chloride (half-strength saline), 0.33% sodium chloride, and 2.5% dextrose in water.

Whereas hypotonic solutions hydrate cells, they can deplete the circulatory system, resulting in hypovolemia and hypotension. Hypotonic solutions are not administered to patients at risk for increased intracranial pressure (can exacerbate cerebral edema) or to those with liver disease, trauma, or burns (Crawford & Harris, 2011).

Caution: Do not give hypotonic solutions to patients with low blood pressure because it will further a hypotensive state.

Hypertonic Fluids

Hypertonic fluids have an osmolarity of 375 mOsm/L or higher. The resulting osmotic pressure gradient draws water from the intracellular space, increasing extracellular volume and causing cells to shrink. Examples of hypertonic fluids include 5% dextrose in 0.45% sodium chloride, 5% dextrose in 0.9% sodium chloride, 5% dextrose in lactated Ringer’s, 10% dextrose in water, and colloids (albumin 25%, plasma protein fraction [PPF], dextran, and hetastarch), which are addressed later in this chapter.

Hypertonic fluids are used to replace electrolytes, to treat hypotonic dehydration, and to temporarily treat circulatory insufficiency and shock. When hypertonic dextrose solutions are used alone, they also are used to shift ECF from the interstitial fluid to the plasma (Crawford & Harris, 2011).

Caution: Hypertonic solutions are irritating to vein walls and may cause hypertonic circulatory overload. Some hypertonic solutions are contraindicated in patients with cardiac or renal disease because of the increased risk for heart failure and pulmonary edema. Give hypertonic solutions slowly to prevent circulatory overload.

Crystalloid Solutions

Crystalloids are solutes (e.g., electrolytes, dextrose) having the ability to form crystals. They easily mix and dissolve in a solvent, forming a solution in which the crystalloids cannot be distinguished from the resulting solution. Crystalloid solutions are capable of diffusing through semipermeable cell membranes due to small molecules. Crystalloid solutions are usually electrolyte solutions that are classified as isotonic, hypotonic, or hypertonic, as previously addressed. Types of crystalloid solutions include dextrose solutions, sodium chloride solutions, balanced electrolyte solutions, and alkalizing and acidifying solutions (Crawford & Harris, 2011).
Key Elements of Crystalloid Fluids

The key elements included in crystalloid parenteral fluids include water, carbohydrates (glucose), protein, vitamins, and electrolytes.

**Water**

The human body is a contained-fluid environment of water and electrolytes. Water accounts for about 60% of the body weight of the adult and 80% of the full-term infant. Holliday and Segar (1957) established that, regardless of age, all healthy persons require approximately 100 mL of water per 100 calories metabolized, for dissolving and eliminating metabolic wastes. This means that a person who expends 1800 calories of energy requires approximately 1800 mL of water for metabolic purposes. These water needs are increased in patients with water losses (e.g., respiratory rate >20 breaths/min, fever, diaphoresis, located in a low-humidity environment); in patients with decreased renal concentration ability; and in elderly people. Insensible loss is approximately 1000 mL per day (Capriotti & Frizzell, 2016).

**NURSING FAST FACT!**

Three main physiological mechanisms assist in regulating fluid homeostasis: osmoreceptors, antidiuretic hormone (ADH), and thirst. High plasma osmolality stimulates osmoreceptors in the thirst center in the hypothalamus, which stimulate thirst and also the release of ADH from the posterior pituitary gland (Capriotti & Frizzell, 2016). ADH stimulates water reabsorption from the kidneys by reducing the amount of water lost in urine, thus promoting reabsorption of water back into the circulation. In a healthy person, these mechanisms work together.

**NURSING FAST FACT!**

Thirst develops when there is as little as a 1% to 2% change in serum osmolality. Thirst is one of the earliest symptoms of hemorrhage and is often present before other signs of blood loss are apparent (Grossman & Porth, 2014).

**Carbohydrates (Glucose)**

Glucose, a nutrient included in maintenance, restoration, and replacement therapies, is converted into glycogen by the liver, which improves hepatic function. By supplying calories for energy, it spares body protein. Sources of carbohydrates include dextrose (glucose) and fructose. When glucose is supplied by infusion, all the parenteral glucose is bioavailable. The addition of 100 g of glucose per day minimizes starvation. Every 2 L of 5% dextrose in water contains 100 g of glucose.
Amino Acids
Amino acids (protein) are the body-building nutrients whose major functions include tissue growth and repair, replacing body cells, healing wounds, and synthesizing vitamins and enzymes. Amino acids are provided in parenteral nutrition (PN) formulations as synthetic crystalline amino acids. They are available in concentrations of 3% to 20%, with and without electrolytes. There are also specialty amino acid formulations that may be used with certain disease states (refer to Chapter 12).

Vitamins
Vitamins may be added to parenteral solutions. For patients who require PN, multivitamins are required as part of the PN solution (refer to Chapter 12). Vitamins are necessary for growth and maintenance, as well as for multiple metabolic processes. Vitamins cannot be synthesized by the body and must be provided in the diet. Some disease conditions alter vitamin requirements. Vitamin B complex is important in the metabolism of carbohydrates and in the maintenance of GI function, which is especially important in postoperative patients. Vitamin C promotes wound healing.

Electrolytes
Electrolytes are the major additives to parenteral fluids. Correction, as well as prevention, of electrolyte imbalances is important in preventing the serious complications associated with excess or deficit of electrolytes. There are seven major electrolytes in normal body fluids, and the same seven major elements are supplied in manufactured IV solutions (refer to Chapter 3 to review electrolyte functions and the consequences of low/elevated electrolyte levels). The electrolytes of major importance in parenteral therapy are potassium, sodium, chloride, magnesium, phosphorus, calcium, and bicarbonate or acetate ion (important for acid–base balance).

Crystalloid Physiological Initial and Therapeutic Responses

Therapeutic Response/Systemic Effects
The therapeutic response to crystalloid administration occurs as the fluid disperses through the ECF and ICF. The therapeutic response is predictable and is the reason for the choice of one fluid over another. The therapeutic response to isotonic solutions administered by the IV route is that the tonicity of the plasma remains unchanged. The 0.9% sodium chloride and lactated Ringer’s solutions remain isotonic even after they disperse into the interstitial spaces; therefore, the tonicity of the interstitial space is unchanged. The interstitial space is three times as large as the intravascular space; 75% of the fluid will be dispersed interstitially, and 25% will remain in the plasma.

Dextrose in water is an electrolyte-free solution. The solution of 5% dextrose in water is isotonic in the initial response, but because the dextrose is rapidly metabolized, what is left is free water that dilutes the ECF. The cells suddenly are suspended in a hypotonic environment, and osmosis will
occur, with the cells absorbing the fluid until the two compartments are isotonic.

Many crystalloid solutions are made up of a combination of dextrose and electrolyte solutions, most of which are hypertonic initially. The therapeutic response to these fluids can be predicted based on the tonicity of the solution. Once the cells use the dextrose, the remaining sodium chloride and electrolytes will be dispersed as isotonic electrolyte solution, hydrating only the ECF. The dispersion of the solution to ECF and ICF will be dependent on the osmolarity of the solution. Remember that 5% dextrose when added to other solutions rapidly is absorbed into the cells to be used for energy. The remaining electrolyte solution is dispersed between the ECF and ICF. The only true hypertonic crystalloid solutions are 3% and 5% sodium chloride. These remain consistently hypertonic and can cause severe cellular dehydration.

**NURSING FAST FACT!**

- The ICF compartment contains approximately 60% to 65% of the body’s fluid or 40% of the body’s weight.
- The ECF compartment, including interstitial and intravascular fluids, accounts for 35% to 40% of the body’s fluid or 20% of the body’s weight. (Pierce, Shen, & Thimmesch, 2016)

**Dextrose Solutions**

Carbohydrates can be administered by the parenteral route as dextrose, fructose, or invert sugar. Dextrose is the most commonly administered carbohydrate. The percentages of the solutions express the number of grams of solute per 100 g of solvent. Thus, a 5% dextrose in water (D5W) infusion contains 5 g of dextrose in 100 mL of water.

**NURSING FAST FACT!**

One milliliter of water weighs 1 g, and 1 mL is 1% of 100 mL. Milliliters, grams, and percentages can be used interchangeably when calculating solution strength. Thus, 5% dextrose in water equals 5 g of dextrose in 100 mL, and 1 L of 5% dextrose in water contains 50 g of dextrose (example: 250 mL of 20% dextrose in water solution contains 50 g of dextrose).

When carbohydrate needs are inadequate, the body will use its own fat to supply calories. Dextrose fluids are used to provide calories for energy, reduce catabolism of protein, and reduce protein breakdown of glucose to help prevent a negative nitrogen balance.
The monohydrate form of dextrose used in parenteral solutions provides 3.4 kcal/g. It is difficult to administer enough calories with 5% dextrose in water, which provides only 170 calories per liter. One would have to administer 9 L to meet calorie requirements, and most patients cannot tolerate 9000 mL of fluid in 24 hours! Concentrated solutions of carbohydrates in 20% to 70% dextrose are useful for supplying calories. These solutions, which contain high percentages of dextrose, must be administered slowly for adequate absorption and utilization by the cells.

Dextrose is a nonelectrolyte, and the total number of particles in a dextrose solution does not depend on ionization. Dextrose is thought to be the closest to the ideal carbohydrate available because it is well metabolized by all tissues. The tonicity of dextrose solutions depends on the particles of sugar in the solution. Dextrose 5% is rapidly metabolized and has no osmotically active particles after it is in the plasma. The osmolarity of a dextrose solution is determined differently from that of an electrolyte solution. Dextrose is distributed inside and outside the cells, with 8% remaining in the circulation to increase blood volume.

Dextrose in water is available in various concentrations, including 2.5% (25 g/L), 5% (50 g/L), 10% (100 g/L), 20% (200 g/L), 30% (300 g/L), 38.5% (385 g/L), 40% (400 g/L), 50% (500 g/L), 60% (600 g/L), and 70% (700 g/L). Dextrose is also available in combination with other types of solutions. Concentrations higher than 10% are given through central vascular access devices (Gorski et al., 2016). A general exception is the administration of limited amounts of 50% dextrose given slowly through a peripheral vein for emergency treatment of hypoglycemia.

**INDICATIONS**

- A diluent for administration of IV medications
- Provides calories and fluid replacement in concentrations 10% or less
- Provides calories as part of PN formulas (≥10%)
- Adjunctive treatment of hyperkalemia (using high concentrations of dextrose)
- Emergency treatment of hypoglycemia (25% or 50%)

**RISKS**

- Vein irritation, vein damage, and thrombosis may result when hypertonic dextrose solutions are administered in a peripheral vein. Considered a vesicant at concentrations >10% (Gorski et al., 2017).
- Solutions of 20% to 70% dextrose, when infused too rapidly, act as an osmotic diuretic and can pull interstitial fluid into plasma, causing severe cellular dehydration. Any solution of dextrose infused rapidly can place the patient at risk for dehydration. To prevent this adverse reaction, infuse the dextrose solution at the prescribed rate.
- Rapid infusion of 20% to 70% dextrose can also lead to transient hyperinsulinism reaction, in which the pancreas secretes extra insulin to metabolize the infused dextrose. Sudden discontinuation of any hypertonic
Dextrose solution may leave a temporary excess of insulin. Reduce the rate of administration gradually.

- Dextrose solutions cannot replace or correct electrolyte deficits, and continuous infusion of 5% dextrose in water places patients at risk for deficits in sodium, potassium, and chloride.
- Dextrose is never mixed with blood components because it causes hemolysis (pseudoagglutination; i.e., agglomeration) of the cells.

**NOTE:** Before adding any medication to a dextrose solution, check the compatibility information and/or consult with the pharmacist. Dextrose may also affect the stability of admixtures.

**NURSING FAST FACTS!**

- Do not “play catch-up” if the solution infusion is behind schedule. Make sure that the IV solution does not “run away” and that it does not infuse rapidly into the patient.

**Sodium Chloride Solutions**

Sodium chloride solutions are available as hypotonic—0.25% (1/4 sodium chloride) and 0.45% (1/2 sodium chloride); isotonic—0.9% (0.9% sodium chloride) and bacteriostatic isotonic 0.9% sodium chloride, which contains benzyl alcohol as a preservative; and hypertonic —3% and 5% concentrations. Sodium chloride 0.9% sodium chloride solution, commonly referred to as normal saline, has 154 mEq of both sodium and chloride, which is about 9% higher than normal plasma levels of sodium and chloride ions without other plasma electrolytes. Sodium chloride has a pH of 4.5 to 7 (Gahart, Nazareno, & Ortega, 2016).

Sodium chloride solutions should be used cautiously in patients with heart failure, edema, or hypernatremia because it replaces ECF and can lead to fluid overload.

**INDICATIONS**

- Provides ECF replacement when chloride loss is greater than or equal to sodium losses (e.g., a patient undergoing nasogastric suctioning)
- Treats patients with metabolic alkalosis in the presence of fluid loss (the 154 mEq of chloride helps compensate for the increase in bicarbonate ions)
- Treats patients with sodium depletion
- Initiates or terminates a blood transfusion (0.9% NaCl is the only solution to be used with any blood product)
- Used to assess patency of vascular access devices (VAD) and to lock VAD to prevent catheter occlusion (0.9% NaCl in prefilled syringes)
RISKS

- Provides more sodium and chloride than patients need, causing hypernatremia. The adult dietary sodium requirements are 90 to 250 mEq daily. Three liters of sodium chloride (0.9%) provides a patient with 462 mEq of sodium, a level that exceeds normal tolerance. To prevent this overload of electrolytes, assess for signs and symptoms of sodium retention.
- Continuous infusion of 0.9% sodium chloride is associated with increased risk of acidosis because sodium chloride provides one-third more chloride than is present in ECF. The excess chloride leads to loss of bicarbonate ions, leading to an imbalance of acid.
- May cause low potassium levels (i.e., hypokalemia) because of the lack of other important electrolytes over a period of time.
- Can lead to circulatory overload. Isotonic fluids expand the ECF compartment, which can lead to overload of the cardiovascular compartments.

NURSING FAST FACT!

During stress, the body retains sodium, which contributes to hypernatremia.

Hypotonic saline (0.45%) can be used to supply normal daily salt and water requirements safely. Hypertonic saline solution (3%–5%) is used only to correct severe sodium depletion and water overload.

Hypertonic saline can be dangerous when administered incorrectly. Nurses should follow these steps to ensure safe administration of hyperosmolar sodium chloride (3% and 5%).

- Check serum sodium level before and during administration.
- Administer only in monitored care settings (e.g., critical care unit).
- Monitor aggressively for signs of pulmonary edema.
- Administer only small volumes of hyperosmolar fluids.
- Use an electronic infusion device.

Dextrose Combined With Sodium Chloride

When sodium chloride is infused, the addition of 100 g of dextrose prevents the formation of ketone bodies. Dextrose prevents catabolism, which is the breakdown of chemical compounds by the body. Consequently, there is a loss of potassium and intracellular water.

Carbohydrates and sodium chloride fluid combinations are best used in cases of excessive loss of fluid through sweating, vomiting, or gastric suctioning.

INDICATIONS

- Temporarily treats patients with circulatory insufficiency and shock caused by hypovolemia in the immediate absence of a plasma expander.
• Provides early treatment of burns, along with plasma or albumin
• Replaces nutrients and electrolytes
• Acts as a hydrating solution to assist in checking renal function before replacement of potassium

Risks
• Same as for sodium chloride solutions (see previous section): hypernatremia, acidosis, and circulatory overload

Hydrating Solutions (Combinations of Dextrose and Hypotonic Sodium Chloride)

Solutions that contain dextrose and hypotonic saline provide more water than is required for excretion of salt and are useful as hydrating fluids. Hydrating fluids are used to hydrate general medical-surgical patients, to promote diuresis, and to assess the status of the kidneys before the initiation of maintenance solutions with electrolyte replacement. The establishment of urinary flow indicates that the kidneys have begun to function; the hydrating solution may then be replaced with a specific electrolyte solution. Carbohydrates in hydrating solutions reduce the depletion of nitrogen and liver glycogen and are also useful in rehydrating cells.

Hydrating solutions are potassium free. Potassium is essential to the body but can be toxic if the kidneys are not functioning effectively and therefore are unable to excrete the extra potassium.

Combination solutions can be used by hypodermoclysis, or subcutaneous route, for hydration in clients with poor venous access.

Indications
• Help assess the status of the kidneys before replacement therapy is started
• Hydrate patients in dehydrated states
• Promote diuresis in dehydrated patients

Risks
• Require cautious administration in edematous patients (e.g., patients with cardiac, renal, or hepatic disease)

Balanced Electrolyte Solutions

A variety of balanced electrolyte fluids are available commercially. Balanced fluids are available as hypotonic or isotonic maintenance and replacement solutions. Maintenance fluids approximate normal body electrolyte needs; replacement fluids contain one or more electrolytes in amounts higher than those found in normal body fluids. Balanced fluids also may contain lactate or acetate (yielding bicarbonate), which helps to combat acidosis and provides a truly balanced solution.

Table 4-1 provides a summary of electrolyte solutions, including osmolarity, pH, and electrolyte content, and Table 4-2 lists indications and precautions.

Text continued on page 190
## Table 4-1 Contents of Available IV Fluids

<table>
<thead>
<tr>
<th>Solution</th>
<th>Osmolarity</th>
<th>Dextrose, g/100 mL</th>
<th>pH</th>
<th>Cal/100 mL</th>
<th>Na</th>
<th>Cl</th>
<th>K</th>
<th>Ca</th>
<th>Mg</th>
<th>Acetate</th>
<th>Lactate</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dextrose in Water (D/W)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5% D/W</td>
<td>Hypertonic—252</td>
<td>5</td>
<td>4.8</td>
<td>17</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10% D/W</td>
<td>Hypertonic—505</td>
<td>10</td>
<td>4.7</td>
<td>34</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20% D/W</td>
<td>Hypertonic—1010</td>
<td>20</td>
<td>4.8</td>
<td>68</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50% D/W</td>
<td>Hypertonic—2526</td>
<td>50</td>
<td>4.6</td>
<td>170</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>70% D/W</td>
<td>Hypertonic—3532</td>
<td>70</td>
<td>4.6</td>
<td>237</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Sodium Chloride (NaCl)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.225% NaCl (1/4 strength)</td>
<td>Hypotonic—77</td>
<td>4.5</td>
<td>34</td>
<td>34</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.33% NaCl</td>
<td>Hypotonic—115</td>
<td>4.5</td>
<td>51</td>
<td>51</td>
<td></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>0.45% NaCl (1/2 strength)</td>
<td>Hypotonic—154</td>
<td>5.6</td>
<td>77</td>
<td>77</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.9% NaCl (full strength)</td>
<td>Isotonic—308</td>
<td>6.0</td>
<td>154</td>
<td>154</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3% NaCl</td>
<td>Hypertonic—1027</td>
<td>6.0</td>
<td>513</td>
<td>513</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5% NaCl</td>
<td>Hypertonic—1711</td>
<td>6.0</td>
<td>855</td>
<td>855</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.25% D and 0.9% NaCl</td>
<td>Isotonic—321</td>
<td>2.5</td>
<td>4.5</td>
<td>8</td>
<td>154</td>
<td>154</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Dextrose and Sodium Chloride (D/NaCl)**

<table>
<thead>
<tr>
<th>Solution Description</th>
<th>Isotonic</th>
<th>5</th>
<th>4.6</th>
<th>17</th>
<th>34</th>
<th>34</th>
</tr>
</thead>
<tbody>
<tr>
<td>5% D and 0.225% NaCl</td>
<td>321</td>
<td>5</td>
<td>4.6</td>
<td>17</td>
<td>34</td>
<td>34</td>
</tr>
<tr>
<td>5% D and 0.45% NaCl</td>
<td>406</td>
<td>5</td>
<td>4.6</td>
<td>17</td>
<td>77</td>
<td>77</td>
</tr>
<tr>
<td>5% D and 0.9% NaCl</td>
<td>560</td>
<td>5</td>
<td>4.4</td>
<td>17</td>
<td>154</td>
<td>154</td>
</tr>
</tbody>
</table>

**Balanced Electrolyte Solutions**

<table>
<thead>
<tr>
<th>Solution Description</th>
<th>Isotonic</th>
<th>6.5</th>
<th>130</th>
<th>109</th>
<th>4</th>
<th>3</th>
<th>28</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lactated Ringer’s solution</td>
<td>273</td>
<td>6.5</td>
<td>130</td>
<td>109</td>
<td>4</td>
<td>3</td>
<td>28</td>
</tr>
<tr>
<td>Ringer’s injection</td>
<td>309</td>
<td>5.5</td>
<td>147</td>
<td>156</td>
<td>4</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Normosol-R*</td>
<td>295</td>
<td>7.4</td>
<td>140</td>
<td>98</td>
<td>5</td>
<td>3</td>
<td>27</td>
</tr>
<tr>
<td>D5 and Normosol-M*</td>
<td>363</td>
<td>5.0</td>
<td>17</td>
<td>40</td>
<td>98</td>
<td>40</td>
<td>16</td>
</tr>
</tbody>
</table>

**Specialty Solutions**

<table>
<thead>
<tr>
<th>Solution Description</th>
<th>Isotonic</th>
<th>6.5</th>
<th>167</th>
<th>167</th>
<th>167</th>
<th>167</th>
<th>167</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/6 M Sodium lactate</td>
<td>335</td>
<td>6.5</td>
<td>167</td>
<td>167</td>
<td>167</td>
<td>167</td>
<td>167</td>
</tr>
<tr>
<td>10% Mannitol</td>
<td>549</td>
<td>5.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20% Mannitol</td>
<td>1098</td>
<td>5.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NaHCO₃</td>
<td>333</td>
<td>8.0</td>
<td>595</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Ca = calcium; Cal = calories; Cl = chloride; K = potassium; Mg = magnesium; Na = sodium; NaCl = sodium chloride.

*Hospira Pharmaceuticals.
### Table 4-2  Quick-Glance Chart of Common IV Fluids

<table>
<thead>
<tr>
<th>Solutions</th>
<th>Indications</th>
<th>Precautions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dextrose Solutions</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5% Dextrose</td>
<td>Spares body protein.</td>
<td>Possible compromise of glucose tolerance by stress, sepsis, hepatic and renal failure, corticosteroids, and diuretics.</td>
</tr>
<tr>
<td>10% Dextrose</td>
<td>Provides nutrition.</td>
<td></td>
</tr>
<tr>
<td>20% Dextrose</td>
<td>Provides calories.</td>
<td></td>
</tr>
<tr>
<td>50% Dextrose</td>
<td>Provides free water.</td>
<td></td>
</tr>
<tr>
<td>70% Dextrose</td>
<td>Acts as a diluent for IV drugs.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Treats dehydration.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Treats hyperkalemia.</td>
<td></td>
</tr>
<tr>
<td><strong>Sodium Chloride (NaCl) Solutions</strong></td>
<td>Replaces extracellular fluid (ECF) and electrolytes.</td>
<td>Fluid and/or solute overload, with potential congested states or pulmonary edema</td>
</tr>
<tr>
<td>0.225% NaCl</td>
<td></td>
<td>Calorie depletion</td>
</tr>
<tr>
<td>0.45% NaCl</td>
<td>Replaces sodium and chloride.</td>
<td>Hypernatremia or hyperchloremia</td>
</tr>
<tr>
<td>0.9% NaCl</td>
<td>Treats hyperosmolar diabetes.</td>
<td>Deficit of other electrolytes</td>
</tr>
<tr>
<td>3% NaCl</td>
<td>Acts as diluent for IV drug administration.</td>
<td>Can induce hyperchloremic acidosis because of a loss of bicarbonate ions.</td>
</tr>
<tr>
<td>5% NaCl</td>
<td>Used for initiation and discontinuation of blood products (0.9% NaCl).</td>
<td>Does not provide free water or calories.</td>
</tr>
<tr>
<td></td>
<td>Replaces severe sodium and chloride deficit.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Helps to correct water overload.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Acts as an irritant for intravascular devices.</td>
<td></td>
</tr>
<tr>
<td><strong>Combination Dextrose and Sodium Chloride Solutions</strong></td>
<td>Assesses renal function. Hydrates cells. Promotes diuresis.</td>
<td></td>
</tr>
<tr>
<td>5D/0.225% NaCl (hydration solution)</td>
<td>For temporary treatment of circulatory insufficiencyhydrating fluids.</td>
<td>Use with caution in patients with edema and in those with cardiac, renal, or liver disease.</td>
</tr>
<tr>
<td>5D/0.45% NaCl (hydration solution)</td>
<td>Replaces nutrients and electrolytes. Supplies some calories. Reduces nitrogen depletion. Used in place of plasma expanders.</td>
<td>Do not use in patients in diabetic coma.</td>
</tr>
<tr>
<td>5D/0.9% NaCl</td>
<td></td>
<td>Do not use in patients who are allergic to corn.</td>
</tr>
</tbody>
</table>
### Table 4-2 Quick-Glance Chart of Common IV Fluids—cont’d

<table>
<thead>
<tr>
<th>Solutions</th>
<th>Indications</th>
<th>Precautions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Balanced Electrolyte Solutions</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normosol-M and dextrose 5% Balanced maintenance solution</td>
<td>Parenteral maintenance of routine fluid and electrolyte requirements with minimal carbohydrate calories. Magnesium helps prevent iatrogenic Mg²⁺ deficiency. Provides free water, calories, and electrolytes. Provides routine maintenance. Relieves physiological stress leading to inappropriate release of ADH.</td>
<td>Fluid or solute overload, overhydration with congested states, or pulmonary edema&lt;br&gt;Dilution of serum electrolyte concentrations&lt;br&gt;Use with care in patients with congestive heart failure and severe renal insufficiency. Solutions with dextrose should be used with caution in patients with known subclinical or overt diabetes mellitus.</td>
</tr>
<tr>
<td>Normosol-R Balanced solution for replacement of acute losses of ECF in surgery, trauma, burns, or shock</td>
<td>Provides calories and electrolytes. Provides fluid and electrolyte replacement. Provides electrolytes. Provides calories. Replaces ECF losses and electrolytes. Sodium acetate provides an alternate source of bicarbonate by metabolic conversion in the liver.</td>
<td>Use with care in patients with congestive heart failure, with severe renal insufficiency, or in clinical states of sodium retention. Hyperkalemia&lt;br&gt;Use with caution in patients with metabolic or respiratory alkalosis. Fluid or solute overloading, overhydration, and congested states or pulmonary edema&lt;br&gt;Elderly have increased risk of developing fluid overload and dilutional hyponatremia.</td>
</tr>
<tr>
<td>5% D in Ringer’s injection</td>
<td>Provides calories. Spares body protein. Replaces ECF losses and electrolytes. Composition similar to plasma.</td>
<td>Contraindicated in patients with renal failure&lt;br&gt;Use with caution in patients with congestive heart failure. Tolerated well by patients with hepatic disease</td>
</tr>
<tr>
<td>5% Dextrose and lactated Ringer’s solutions (ionic composition similar to plasma)</td>
<td>Treats mild metabolic acidosis. Replaces fluid losses from burns and trauma. Contains bicarbonate precursor. Replaces fluid losses from alimentary tract. Rehydrates in all types of dehydration. Ionic composition similar to plasma.</td>
<td>Contraindicated in patients with lactic acidosis&lt;br&gt;Circulatory overload&lt;br&gt;May cause metabolic acidosis&lt;br&gt;Hypernatremia&lt;br&gt;Fluid overload&lt;br&gt;Contraindicated in patients with renal failure&lt;br&gt;Use with caution in patients with congestive heart failure. Composition similar to plasma&lt;br&gt;Tolerated well by patients with hepatic disease&lt;br&gt;Contraindicated in patients with lactic acidosis&lt;br&gt;Circulatory overload&lt;br&gt;May cause metabolic acidosis&lt;br&gt;Contains bicarbonate precursor</td>
</tr>
</tbody>
</table>
Several types of balanced electrolyte replacement fluids are available. Special fluids available from manufacturers for gastric replacement provide the typical electrolytes lost by vomiting or gastric suction. These isotonic fluids usually contain ammonium ions, which are metabolized in the liver to hydrogen ions and urea, replacing hydrogen ions lost in gastric juices. Lactated Ringer’s injection is considered an isotonic multiple-electrolyte solution.

Hypertonic multiple-electrolyte solutions are also used as replacement fluids. Usually 5% dextrose has been added, which raises the osmolarity of the solution.

*Ringer’s Solution and Lactated Ringer’s*

The Ringer’s solutions (i.e., Ringer’s injection and lactated Ringer’s) are classified as balanced or isotonic solutions because their fluid and electrolyte contents are similar to those of plasma. They are used to replace electrolytes at physiological levels in the ECF compartment and are very commonly used balanced solutions.

**Ringer’s Solution (Injection)**

First developed in the 1800s, Ringer’s injection is a fluid and electrolyte replenisher, which is used rather than 0.9% sodium chloride for treating patients with dehydration after reduced water intake or water loss. Ringer’s solution (injection) is similar to normal saline (i.e., 0.9% sodium chloride) but also includes potassium chloride, calcium chloride, and sodium bicarbonate. Ringer’s injection is preferred to normal saline for treating patients with dehydration after drastically reduced water intake or water loss (e.g., with vomiting, diarrhea, or fistula drainage). This solution has some incompatibilities with medications, so it is necessary to check drug compatibility literature for guidelines.

**NURSING FAST FACT!**

Ringer’s injection does not contain enough potassium or calcium to be used as a maintenance fluid or to correct a deficit of these electrolytes.

**Indications**

- Treatment of any type of dehydration
- Restoration of fluid balance before and after surgery
Replacement of fluids lost from dehydration, from GI losses, and fistula drainage

Used instead of lactated Ringer's when the patient has hepatic disease and is unable to metabolize lactate

May be used as blood replacement for a short period of time

**Risks**

- May exacerbate sodium retention, congestive heart failure, and renal insufficiency
- Contraindicated in renal failure

**Lactated Ringer's Solution**

This solution is also called Hartmann's solution, named after the physician who added lactate to Ringer's injection for the purpose of treating acidosis in the 1930s. Lactated Ringer's is a commonly prescribed solution, with an electrolyte concentration closely resembling that of the ECF compartment. Notably, there is also a Ringer's acetate which may be used in critically ill patients where there is concern about high levels of plasma lactate levels (Correa, Rocha, Pessoa, Silva, de Assuncao, 2015). The composition of Lactated Ringer's and Ringer's acetate is almost identical with the exception of the added buffer (lactate or acetate).

**NURSING FAST FACT!**

Lactated Ringer's solution has some incompatibilities with medications, so it is necessary to check drug compatibility literature for guidelines.

Lactated Ringer's is used for the following:

**Indications**

- Rehydration in all types of dehydration
- Restoration of fluid volume deficits
- Replacement of fluid lost as a result of burns
- Treatment of mild metabolic acidosis
- Treatment of salicylate overdose

**Risks**

- Three liters of lactated Ringer's solution contains about 390 mEq of sodium, which can quickly elevate the sodium level in a patient who does not have a sodium deficit.
- Lactated Ringer's solution should not be used in patients with impaired lactate metabolism, such as those with hepatic disease, Addison's disease, severe metabolic acidosis or alkalosis, profound hypovolemia, or profound shock or cardiac failure. In these conditions, serum lactate levels may already be elevated.
Alkalizing and Acidifying Infusion Fluids

Alkalizing Fluids

Metabolic acidosis can occur in clinical situations in which dehydration, shock, hepatic disease, starvation, or diabetes causes retention of chlorides, ketone bodies, or organic salts or in which too large an amount of bicarbonate is lost. An alkalizing fluid is used in treatment. Two IV fluids are available when excessive bicarbonate losses and metabolic acidosis occur: 1/6 molar isotonic sodium lactate and sodium bicarbonate injection (5%, 7.5%, 8.4%). The 7.5% and 8.4% solutions should be diluted with an equal amount of water for injection or diluted with a compatible IV solution (Gahart et al., 2016). The lactate ion must be oxidized to carbon dioxide in the body before it can affect the acid–base balance. Conversion of sodium lactate to bicarbonate requires 1 to 2 hours. Oxygen is needed to increase bicarbonate concentrations. The isotonic solution sodium bicarbonate injection provides bicarbonate ions in clinical situations of excessive bicarbonate losses.

Alkalizing fluids are used in treating vomiting, starvation, uncontrolled diabetes mellitus, acute infections, renal failure, and severe acidosis with severe hyperpnea (sodium bicarbonate injection).

The 1/6 molar sodium lactate solution is indicated for acidosis resulting from sodium deficiency; however, it is contraindicated in patients suffering from lack of oxygen and in those with hepatic disease. Patients receiving this fluid should be watched for signs of hypocalcemic tetany.

Acidifying Fluids

Metabolic alkalosis is a condition associated with an excess of bicarbonate and a deficit of chloride. Isotonic sodium chloride (0.9%) provides conservative treatment of metabolic alkalosis. Ammonium chloride is the solution used to treat metabolic alkalosis. Acidifying fluids are used for severe metabolic alkalosis caused by a loss of gastric secretions or pyloric stenosis.
An advantage is that the ammonium ion is converted by the liver to a hydrogen ion and ammonia, which is excreted as urea. However, a disadvantage is that ammonium chloride must be infused at a slow rate to enable the liver to metabolize the ammonium ion. In fact, rapid infusion can result in toxicity, causing irregular breathing and bradycardia.

**NURSING FAST FACT!**

Ammonium chloride must be used with caution in patients with severe hepatic disease or renal failure and is contraindicated in any condition in which a high ammonium level is present.

**NURSING POINTS OF CARE**

**CRYSTALLOID ADMINISTRATION**

**Nursing Assessment**
- History of present illness relative to need for maintenance/replacement solutions.
- Ability to ingest and retain fluids.
- Vital signs.
- Signs and symptoms of fluid imbalance.
- Urinary output for renal function prior to administration.
- Baseline laboratory data prior to administration.
- Review licensed independent practitioner (LIP) order for accuracy and match the solution to the order.

**Key Nursing Interventions**
1. Administer IV fluids at room temperature.
2. Administer IV solutions/medications at prescribed rate and monitor for results.
3. Monitor
   a. central venous pressure (CVP) and for evidence of fluid volume excess/deficit.
   b. laboratory test result values (e.g., serum protein levels, sodium, hemoglobin, and hematocrit).
   c. input and output (I&O).
   d. complications associated with vascular access devices (VADs) (phlebitis, erratic flow rates, infiltration).
4. Monitor VAD patency. Flush VAD before each infusion as part of the steps to assess catheter function and after each infusion to clear the infused medication from the catheter lumen to prevent contact between incompatible medications. Follow flushing and locking guidelines.
5. Replace fluid containers according to established organizational policies, procedures, and/or current practice guidelines.
Colloidal Solutions

Colloid solutions contain large molecules that are unable to pass through semipermeable membranes such as the capillary walls. When administered intravenously, colloids increase the osmotic pressure within the plasma space, drawing fluid in to increase intravascular volume. Colloid solutions are often called plasma or volume expanders. The protein or starch molecules in a colloid solution do not dissolve and do not form a true solution as they remain suspended and distributed within the fluid. Examples of colloidal solutions include albumin, dextran, and hydroxyethyl starches, mannitol, and gelatin, which are discussed below.

It is important to recognize that there has been a long-standing debate over the use of crystalloid versus colloid fluids in the critically ill (Pierce et al., 2016). Although colloid solutions continue to be used, it has been suggested that crystalloid solutions should be used preferentially (Hohertz, Seupaul, & Holmes, 2015). This recommendation is based upon meta-analyses of trials that have shown more adverse effects with colloids (e.g., nephrotoxicity, increased risk for bleeding) and also based upon the fact that they are more expensive. See the evidence-based practice box below.

A Cochrane meta-analysis included 78 randomized controlled trials comparing colloids (studies specifically included albumin, hydroxyethyl starch, modified gelatin, dextran) to crystalloids in patients requiring volume replacement. In patients who had trauma or burns or who were postsurgery, the researchers found that there was no evidence of a reduction in the risk of death with colloids versus crystalloids and that use of hydroxyethyl starch might increase mortality. Concluding that colloids are more expensive than crystalloids in conjunction with no improvement in survival with their use, the researchers state that it is difficult to justify continued use of colloids (Perel, Roberts, & Ker, 2013).

Albumin

Albumin is a natural plasma protein that is commercially extracted from donor plasma as a principal product of fractionation (dividing plasma into its component parts) and that is considered a blood product (Richardson, 2014; see Chapter 11). It supplies 80% of the osmotic activity of plasma. It is administered as PPF or as purified albumin. Normal serum albumin is composed of 96% albumin and 4% globulin and other proteins. Albumin is available as a 5% (isotonic) or 25% (hypertonic) solution. PPF is available only in a 5% solution. Five percent albumin is a commonly infused colloidal solution and is used primarily to increase plasma volume after sudden loss of intravascular volume, as seen in patients with hypovolemic shock from trauma or surgery. Both PPF and 5% albumin are isotonic solutions and therefore are osmotically equivalent to an equal volume of plasma. They cause a plasma volume increase, are used interchangeably, and share the same clinical uses. Albumin and PPF are supplied in glass bottles and,
depending upon the brand, albumin in 5% concentrations is available in units of 50-, 250-, 500-, and 1000-mL vials.

Albumin is also available in a 25% solution, which is very hypertonic, drawing about four times its volume from the interstitial fluid into the vascular compartment. Albumin in a 25% concentration is supplied in units of 20-, 50-, and 100-mL vials (Richardson, 2014).

Manufacturers recommend that the albumin solutions be used within 4 hours of opening; PPF should be administered immediately upon opening. Depending on the manufacturer, the solutions are sometimes supplied with an infusion set. If no administration set is provided, a standard administration set without a filter is used.

**NOTE:** Although albumin is made from human plasma, its manufacturing process reduces the risk for transmission of infectious agents.

**INDICATIONS**

- Hypovolemia with or without shock, with or without hemorrhage
- Use 5% for hypovolemia, 25% if adequate hydration in the presence of edema
- Hypoalbuminemia
- Maintains electrolyte balance and promotes diuresis in presence of edema

**RISKS**

- Allergic reactions (e.g., urticaria, flushing, chills, fever, headache)
- Circulatory overload (greatest risk with 25% albumin)
- Pulmonary edema
- May alter laboratory findings

**Dextran**

Dextran fluids are polysaccharides that behave as colloids. They contain no electrolytes. They are available as low-molecular-weight dextran (Dextran 40) and high-molecular-weight dextran (Dextran 70). Low-molecular-weight dextran (Dextran 40) is a rapid but short-acting plasma volume expander. It increases plasma volume by once or twice its own volume. It improves microcirculatory flow and prevents sludging in venous channels. It mobilizes water from body tissues and increases urinary output. The initial 500 mL may be given rapidly. The remainder of any desired daily dose should be evenly distributed over 8 to 24 hours (Gahart et al., 2016).

High-molecular-weight Dextran 70 approximates colloidal properties of human albumin. It dilutes total serum proteins and hematocrit values. It is used as adjunct treatment of impending shock or shock states related to burns, hemorrhage, surgery, or trauma (Gahart et al., 2016). The rate of administration is variable depending on indication, present blood volume, and patient response. The initial 500 mL may be given at a rate of 20 to 40 mL/min if the patient is hypovolemic. If additional high-molecular-weight dextran is required, the flow should be reduced to the lowest rate possible (Gahart et al., 2016).
It is important to monitor the patient’s pulse, blood pressure, and urine output every 5 to 15 minutes for the first hour of administration of dextran and then every hour after that.

These products are used when blood or blood products are not available but are not a substitute for whole blood or plasma proteins. Assessment of hydration status is important.

**INDICATIONS**
- Adjunct in treatment of shock

**RISKS**
- Possibility of hypersensitivity reactions (i.e., anaphylaxis)
- Dextran promotes tissue dehydration; hydration should be maintained with additional IV fluids
- Circulatory overload
- Increased risk of bleeding, as it may reduce coagulability of circulating blood

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**Table 4-3** Common Colloid Volume Expanders

<table>
<thead>
<tr>
<th>Solution</th>
<th>Osmolarity</th>
<th>Initial Volume Expansion</th>
<th>Duration of Expansion</th>
<th>Side Effects*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albumin 5%</td>
<td>290</td>
<td>70%–100%</td>
<td>16–24 hours</td>
<td>Rare Allergic reactions</td>
</tr>
<tr>
<td>Albumin 25%</td>
<td>310</td>
<td>200%–400%</td>
<td>16–24 hours</td>
<td>Rare Allergic reactions</td>
</tr>
<tr>
<td>Starches</td>
<td>308 mOsm/L</td>
<td>100%</td>
<td>8–24 hours</td>
<td>Hypersensitivity, Coagulation disorders, Metabolic acidosis</td>
</tr>
<tr>
<td>Hetastarch 6%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Starches</td>
<td>326 mOsm/kg</td>
<td>100%–150%</td>
<td>8–24 hours</td>
<td>Hypersensitivity, Coagulation disorders</td>
</tr>
<tr>
<td>Pentastarch 10%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dextran</td>
<td>280–324</td>
<td>100%–150%</td>
<td>1–2 hours</td>
<td>Anaphylactic reactions</td>
</tr>
<tr>
<td>Low molecular weight (Dextran 40)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dextran–high molecular weight (Dextran 70)</td>
<td>280–324</td>
<td>80%–140%</td>
<td>24 hours</td>
<td>Anaphylactic reactions</td>
</tr>
</tbody>
</table>

*Circulatory overload is a risk with all colloid volume expanders.

**NURSING FAST FACT!**

Dextran is contraindicated in patients with severe bleeding disorders, heart failure, and renal failure. It is important to draw blood for typing and crossmatching before administering dextran, as it interferes with laboratory crossmatching.
Hydroxyethyl Starches: Hetastarch and Pentastarch

Hetastarch (hydroxyethyl glucose) is a synthetic colloid made from starch. It is available as a 6% solution in a 500-mL container, diluted in isotonic sodium chloride or in lactated electrolyte solution. The hydroxyethyl starches are classified as plasma volume expanders. Hetastarch is similar in its plasma volume expansion properties to 5% human albumin. Other hydroxyethyl starches include pentastarch (rx.com, 2017) and Voluven®, a 6% hydroxyethyl starch injection, for the prevention and treatment of dangerously low blood volume (Voluven, 2014).

INDICATIONS

- Treatment of hypovolemia
- Effects of volume expansion last 24 to 36 hours (Gahart et al., 2016).

RISKS

- Severe allergic reactions, including anaphylaxis
- Circulatory overload
- Anemia and/or bleeding as a result of hemodilution and/or factor VIII deficiency, and other coagulopathies, including disseminated intravascular coagulopathy (DIC)
- Metabolic acidosis

Mannitol

Mannitol is a sugar alcohol substance that is available in concentrations of 5%, 10%, 15%, 20%, and 25%. Classified as an osmotic diuretic, mannitol is distributed to the extracellular space, causing the movement of water to the extracellular and vascular spaces. Depending upon the concentration, the osmolarity ranges from 275 to 1375 mOsm/L. No further dilution of this product is necessary; however, any crystals present in the solution must be completely dissolved before administration (Gahart et al., 2016).

INDICATIONS

- Promotion of diuresis in the prevention/treatment of the oliguric phase of acute renal failure
- Excretion of toxic substances in the body
- Reduction of intracranial pressure and cerebral edema
- Reduction of intraocular pressure
- Reduction of generalized edema

RISKS

- Fluid and electrolyte imbalances are the most common and may be severe.
- May induce dehydration with hyperkalemia, hypokalemia, or hyponatremia.
- The 20% and 25% concentrations are considered vesicant solutions, capable of causing skin necrosis upon extravasation (Gorski et al., 2017).

Table 4-3 provides a summary of characteristics of common colloidal solutions.
NOTE: Mannitol solution requires cautious use in patients with an impaired cardiac or renal system. It is contraindicated in the presence of anuria, severe pulmonary and cardiac congestion, and intracranial bleeding. A test dose may be required for these patients (Gahart et al., 2016).

Gelatins

Gelatins are proteins formed upon the boiling of animal connective tissue. They dissolve in hot water and form a jelly when cooled. They are high-molecular-weight proteins formed from hydrolysis of collagen (e.g., Gelofusine®). Gelatin administration results in about 70% to 80% volume expansion, but it has a shorter duration of action as compared to albumin and starches (Mitra & Khandelwal, 2009). Gelatins have no preservatives, and all gelatins have a recommended shelf life of 3 years when stored at temperatures less than 30°C. Gelatin is rapidly excreted by the kidney following infusion.

INDICATIONS
- Hypovolemia due to acute blood loss
- Priming heart–lung machines

RISKS
- Anaphylactic reactions
- Dilutional coagulopathy

NURSING POINTS OF CARE

COLLOID ADMINISTRATION

Nursing Assessment
- History of allergic reactions.
- Ability to ingest and retain fluids.
- Vital signs.
- Signs and symptoms of fluid imbalance.
- Urinary output for renal function prior to administration.
- Review baseline laboratory data prior to administration.
- Review licensed independent practitioner (LIP) order for accuracy and match the solution to the order.
Key Nursing Interventions
1. Monitor for signs and symptoms of allergic/anaphylactic reaction.
2. Administer IV fluids at room temperature.
3. Administer IV solutions at prescribed rate and monitor for results.
4. Monitor
   a. CVP and for evidence of fluid volume excess/deficit.
   b. laboratory test result values (e.g., serum protein levels, sodium, hemoglobin, and hematocrit).
   c. input and output (I&O).
   d. complications associated with vascular access devices (VADs) (phlebitis, erratic flow rates, infiltration).
   e. for the need for additional fluid in dehydrated patients.
   f. for bleeding postinfusion.
5. Monitor VAD patency. Flush VADs prior to each infusion as part of the steps to assess catheter function and after each infusion to clear the infused medication from the catheter lumen to prevent contact between incompatible medications. Follow flushing and locking guidelines.
6. Replace fluid containers according to established organizational policies, procedures, and/or current practice guidelines.

AGE-RELATED CONSIDERATIONS
The Pediatric Client
Factors Affecting Fluid Needs in Pediatric Clients
A common cause of increased fluid and calorie needs in children is temperature elevation. A one-degree increase in temperature increases a child’s calorie needs by 12% (Doellman, 2014). In children, loss of GI fluids, ongoing diarrhea, and small-intestinal drainage can seriously affect fluid balance.

NURSING FAST FACT!
To ensure accuracy in determining fluid needs, most pediatric patients should be on strict I&O monitoring, including diaper weighing for infants. When weighing an infant’s diaper, consider the weight of the diaper before it was wet. The weight difference between a dry and a wet piece of linen represents the amount of liquid that it has absorbed. The weight of the fluid measured in grams is the same as the volume measured in milliliters.

There are three general methods for assessment of 24-hour maintenance of fluids in the pediatric client: BSA, weight, and metabolic rate. It is important to recognize that these
are general formulas and that certain variables exist that increase fluid requirements, including elevated temperature, stress, burns, and surgery (Doellman, 2014).

1. Based upon BSA
   - Recommended for children at 10 kg of body weight or greater
   - Maintenance requirements based on BSA: 1200 to 1500 mL/m² (Doellman, 2014)
   - A helpful calculator for pediatric BSA calculation can be found on the following website: www.rch.org.au/genmed/clinical_resources/Body_surface_area_BSA_calculator
   - A nomogram that can be used to determine the BSA of a patient is called the meter square method. To use this method, draw a straight line between the point representing the patient’s height on the left vertical scale and the point representing the patient’s weight on the right vertical scale. The point at which the line intersects indicates the BSA in square meters.

2. Based upon weight
   - The weight method uses the child’s weight in kilograms to estimate fluid needs.
   - Fluid requirements include:
     - 100 mL/kg for the first 10 kg of body weight
     - 50 mL/kg for next 10 kg
     - 20 mL/kg for each kg over 20 kg (Doellman, 2014)
   - A helpful calculator for pediatric calculation based upon weight can be found on the Medscape website (http://reference.medscape.com/calculator/maintenance-fluid-calculation-child)
   - Example: A child weighs 12 kg (26.4 lb). According to the above calculator website, this child requires 1100 mL/24 hours of fluid, which is a rate of 46 mL/hour.
   - Using basic math, the same result is obtained: Multiply 100 mL/kg × 10 kg = 1000 mL; multiply 50 mL/kg × 2 kg = 100. 1000 + 100 = 1100 mL/24 hours.

3. Based upon metabolic rate
   - 100 mL water needed for every 100 calories consumed
   - Caloric expenditure related to weight as follows:
     - 2 to 10 kg: 10 calories per kg
     - 10 to 20 kg: 50 calories for each kg over 10
     - >20 kg: 20 calories per kg
   (Doellman, 2014)

The Older Adult
While dehydration is a common concern among older adults, it is also recognized that fluid volume excess can be a problem and it is a common cause of postoperative morbidity and mortality in older adults (El-Sharkawy, Sahota, Maughan & Lobo, 2014). Older adults are predisposed to water retention and related electrolyte abnormalities, especially during times of stress such as before, during, and after surgery. In relation to specific perioperative fluid replacement, the risk for acidosis and other electrolyte abnormalities is increased when 0.9% sodium chloride is used as fluid replacement as compared to balanced crystalloid fluids. Because total body water is reduced by 10–15% due to lean body mass and there is reduced glomerular filtration rate and decreased ability to concentrate urine, the older adult is prone to fluid retention and fluid overload. The nurse’s accuracy in measuring and recording the intake and output is critical, providing the LIP with information to guide fluid replacement needs. Careful attention to fluid balance is associated with shorter lengths of hospital stay and decreased postoperative complications (El-Sharkawy et al., 2014).
Home Care Issues

Among the older adult population, a significant risk is that of dehydration, affecting 20% to 30% of older adults (Miller, 2015). Although most patients with early signs of dehydration can be managed with increasing oral intake, those with moderate dehydration may benefit from infusion therapy at home (Gorski, 2017). In addition to the older and chronically ill population, other home-care patient populations that may require infusion fluid replacement to prevent dehydration include pregnant women with hyperemesis gravidarum and patients who are undergoing chemotherapy. Home treatment has been found to be successful in reducing the risk for rehospitalization and emergency room visits (Konrad et al., 2016). Although IV fluid administration is more common, subcutaneous infusion is an alternative when administering isotonic fluids (Chapter 10). This is called hypodermoclysis. Hypodermoclysis generally is indicated as a short-term infusion therapy, typically for 2 to 3 days or less. Primarily used in the older adult with dehydration, it is recognized as a relatively easy, low-risk, and cost-effective method for delivery of hydration fluids in patients with mild to moderate dehydration (Caccialanza, Constans, Cotogni, Zaloga, & Pontes-Arruda, 2016).

Patient Education Topics

- Reason for parenteral fluid therapy (e.g., replacement fluid, vitamins, nutrition, volume replacement).
- Signs and symptoms of complications (e.g., IV site symptoms such as burning, redness, or any discomfort; adverse reactions to fluid replacement such as allergic reactions).
- Need for increased oral intake if appropriate.
- Sodium and fluid restriction if appropriate.
- Reason for daily weights.
- Signs and symptoms of dehydration and fluid overload.
- Change positions slowly if any dizziness or light-headedness occurs (e.g., in presence of dehydration).

Nursing Process

The nursing process is a five- or six-step process for problem-solving to guide nursing action. Refer to Chapter 1 for details on the steps of the nursing process related to vascular access. The following table focuses on nursing diagnoses, nursing outcomes classification (NOC), and nursing interventions classification.
NIC) for patients with parenteral fluid needs. Nursing diagnoses should be patient specific, and outcomes and interventions individualized. The NOC and NIC presented here are suggested directions for development of outcomes and interventions.

### Chapter Highlights

- The three main objectives of parenteral solution administration are to:
  - Maintain and meet daily fluid/electrolyte body fluid requirements
  - Replace present and ongoing fluid losses and correct any electrolyte imbalances
  - Act as a diluent for delivery of infusion medications
- Solutions have an osmolarity that is hypotonic, isotonic, or hypertonic:
  - Hypotonic is 250 mOsm/L or below.
  - Isotonic ranges from 250 to 375 mOsm/L.
  - Hypertonic is above 375 mOsm/L.
- Infusates are categorized as:
  - *Crystallloids*: Solutions that are considered true solutions and whose solutes, when placed in a solvent, mix, dissolve, and cannot be distinguished from the resultant solutions. Crystalloids are able to move through membranes. Examples are dextrose and sodium chloride solutions and lactated Ringer's solution.
  - *Colloids*: Substances whose particles, when submerged in a solvent, cannot form a true solution because their molecules cannot dissolve but remain suspended and distributed in the fluid. Examples include dextran, albumin, mannitol, hetastarch, and gelatins.
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Thinking Critically: Case Study

Over a 16-hour period of time, a 6-year-old child was inadvertently given 800 mL of 3% sodium chloride solution instead of the prescribed 0.33% sodium chloride. She developed lethargy, convulsions, and coma before the error was discovered. Despite resuscitative efforts, the child died.

Case Study Questions

1. Identify the mEq of each electrolyte in the IV solutions.
2. Identify the osmolality/tonicity of each of the electrolyte solutions.
3. Refer to Chapter 1 on legal aspects for factors involved in malpractice. Who was liable?
4. What types of safeguards should be in place for the pediatric patient receiving IV fluids? (Refer to Chapter 6 for pediatric peripheral infusions.)

Media Link: Chapter post tests and answers are provided on DavisPlus, along with case studies and critical thinking activities.

References


Chapter 5
Infusion Equipment

LEARNING OBJECTIVES
After completing this chapter, the reader will be able to:

1. Define terminology related to I.V. equipment.
2. Identify types and characteristics of solution containers.
3. Identify types and characteristics of administration sets.
4. Discuss risk factors associated with the use of add-on devices including needleless connectors.
5. Describe the purpose of, and indications for, medication and solution filtration.
6. Discuss the rationale for and options for catheter stabilization.
7. Differentiate between site protection and joint protection.
8. Describe technologies used in vein visualization.
9. Describe the use of infiltration detection technology.
10. Identify the three main types of peripheral I.V. catheters.
11. Identify the different types of flow-control devices.
12. Discuss the benefits of “smart pump” technology.
13. Describe the nurse’s role in product selection, evaluation, and problem reporting.

Glossary

**Backcheck valve**  A device that functions to prevent retrograde solution flow

**Cannula** A flexible tube that may be inserted into a duct, cavity, or blood vessel to deliver medication or drain fluid. It may be guided by a sharp, pointed instrument (stylet); also called a catheter.

**Catheter (I.V.)** A cannula inserted into a vein to administer fluids or medications or to measure pressure

**Drip chamber** Area of the I.V. administration set usually found under the spike where the solution drips and collects before running through the I.V. tubing

**Drop factor** The number of drops needed to deliver 1 mL of fluid

**Elastomeric pump** A portable infusion device with a balloon (elastomeric reservoir) made of soft rubberized material that is inflated with medication to a predetermined volume; when the tubing is unclamped, positive pressure is exerted to deliver the infusion

**Electronic infusion device** An infusion pump powered by electricity or battery; programmed to regulate the I.V. flow rate
Filter  A special porous device used for eliminating certain elements, as in particles of a certain size in a solution

Gauge  Size of cannula opening; a standard of measurement

Hub  Female connection point of an I.V. catheter where the I.V. administration set or syringe is attached

Infusate  Refers to medications or solutions administered via an infusion

Lumen  The space within a tubular structure, such as an artery, vein, or catheter

Luer-lock  A design that incorporates a threaded sleeve on a male Luer

Macrodrip  In I.V. therapy, an administration set that delivers measured amounts of I.V. solutions at a specific flow rate based on the size of the drops of the solution

Microdrip  In I.V. therapy, an administration set that delivers small amounts of I.V. solutions; drop factor of 60 drops/mL

Midline catheter  A longer peripheral catheter that is placed in a peripheral vein, generally inserted about the antecubital fossa, with the catheter tip residing level at or near the level of the axilla and distal to the shoulder; in infants, a midline catheter may be placed in a scalp vein with the tip terminating in the jugular vein above the clavicle or in the leg with the tip below the inguinal crease

Multichannel pump  Electronic infusion device that delivers multiple drugs or solutions simultaneously or intermittently from bags, bottles, or syringes

Needleless connector  A device attached to the hub of the peripheral I.V. catheter or central vascular access device that allows the tip of a syringe or male Luer end of the I.V. administration set to be attached

Over-the-needle catheter  A device that consists of a needle with a catheter sheath; the needle is removed, leaving a plastic catheter in place; the most common type of peripheral I.V. catheter

Patient-controlled analgesia (PCA)  A drug delivery system that dispenses a preset intravascular dose of a narcotic analgesic when the patient pushes a switch on an electric cord

Port  Point of entry

Primary administration set  Device used for delivery of parenteral solutions

psi  Pounds per square inch; a measurement of pressure: 1 psi equals 50 mm Hg or 68 cm H₂O

Radiopaque  Material used in I.V. catheter that can be identified by radiographic examination

Secondary administration set  Administration set that has short tubing used for delivery of 50 to 150 mL (or sometimes greater volumes of up to 500 mL) of infusion attached to primary administration set for intermittent delivery of medication or solutions

Stylet  Needle or guide that is found inside a catheter; used for vein penetration and removed after catheter insertion

Syringe pump  Piston-driven pumps that provide precise infusion by controlling the rate of drive speed and syringe size
Introduction

Infusion therapy involves the use of a variety of supplies and equipment and often complex technology. Included are single-use devices, such as disposable solution containers, tubing, and catheters, and durable medical equipment including infusion pumps, I.V. poles, and visualization technologies such as ultrasound units. Nurses must be well educated and competent in the clinical application and proper use of equipment. Furthermore, the nurse should participate in the decision-making process of equipment acquisition. Referring back to Chapter 2, remember that the U.S. Occupational Safety and Health Administration (OSHA) Bloodborne Pathogen standard actually requires that staff have input into safe controls to reduce exposure. There is a relationship between the industry that manufactures the equipment, the health-care providers, and the patient that is collaborative and mutually dependent. The public holds industry, medical institutions, and professionals accountable for the safe and effective delivery of health care. Medical products and equipment are the collective responsibility of industry and medical professionals.

Solution Containers

Solution containers for use with general hydration/electrolyte solutions, medications, blood products, and nutritional products are made of either plastic or glass. Although today the use of glass containers is less common, glass is still used for medications or solutions that are not compatible with the chemicals or properties of plastic (Fig. 5-1). The history of sterile evacuated glass containers dates back to 1929. In 1950, plastic containers became accessible for the storage and delivery of blood products. Today, plastic containers are used the majority of the time for administering solutions and blood products.

Glass Containers

Glass containers available in the United States are made not just of glass but of a combination of glass, plastic, rubber, and metal. Because glass does not collapse, venting is required to allow air to enter the bottle during infusion. A vented administration set must be used with glass/semirigid containers. There are also “universal” administration sets that can be used with both rigid and plastic containers; the vent is either open or closed depending on the type of container (Fig. 5-2).

The closed glass system has a “rubber”-type stopper that is covered with a removable seal. This seal must be removed, and the bottle is used immediately to ensure sterility.

Checking the Glass Solution Containers for Clarity

To ensure safety in the administration of solutions, the clarity of the solution and the expiration date are checked before the glass container is connected to the administration set. To check a glass container, hold the glass bottle up to
**Figure 5-1** Comparison of glass and plastic infusion delivery systems.

**Figure 5-2** (A) Universal spike (closed; used with flexible plastic infusion containers); (B) Universal spike (open; used with glass, semi-rigid infusion containers).
the light and check for flashes of light, floating particles, or discoloration. The solution should be clear; if it is not, mark the container as contaminated and return it to the pharmacy. An unusual occurrence report should be completed per the organizational policy (see Chapter 1).

**Advantages**
- Crystal clear; allows good visualization of contents
- Graduations on glass easy to read
- Inert; has no plasticizers

**Disadvantages**
- More easily broken during transport
- Particulate matter due to coring
- Cumbersome disposal

**Note:** Once the glass system is opened by a pharmacist during introduction of an admixture, it is sealed with a tamperproof closure to prevent alteration of the infusate. Always check the closure for integrity; if the closure is torn, it should not be used and should be returned to the pharmacy.

**Plastic Containers**
Most commonly, infusate solutions are packaged in flexible or semirigid plastic containers (Fig. 5-3). Flexible plastic containers have several unique features. The entire structure that comes in contact with the fluid, including the closure, is made of the same material. The most common plastic used in solution containers is polyvinylchloride (PVC). However, some drugs adsorb, or adhere, to the surface of the plastic container, which has led to the development of new plastics such as polyolefin and ethyl vinyl acetate.

**Note:** Di(2-ethylhexyl) phthalate (DEHP), a plasticizer, is added to PVC to make solution containers soft and pliable. However, DEHP is a known toxin and can seep from the plastic into the bloodstream, particularly with certain types of solutions. DEHP is lipophilic and leaches into lipid-based solutions. The greatest risk of exposure to DEHP occurs with neonatal patients. Exposure is associated with disorders of reproductive development. In general, the trend is moving away from PVC medical products. During PVC production and during disposal (i.e., incineration), dioxin, a well-known carcinogen, is released.

**EBP** DEHP concentrations significantly increased in 17 of 22 children after a 12-hour infusion of parenteral nutrition. There were no traces of DEHP in a control group of 20 children (Kambia et al., 2013).
Plastic solution containers containing premixed solutions (e.g., 0.9% NaCl, 5% dextrose in water) are provided in 1000-mL and 500-mL bags for primary infusions and in 50- to 250-mL bags for secondary infusions or smaller-volume primary infusions. Larger plastic containers, up to 4000 mL, are available for mixing large-volume infusions, such as parenteral nutrition solutions. Plastic containers are flexible and collapsible and do not need air to replace fluid flowing through them.

**Figure 5-3** Plastic infusion system. Large-volume flexible plastic container (A) and secondary solution container of 50 mL (B). (Courtesy of Baxter Healthcare Corp., Round Lake, IL.)
from the container. A nonvented administration set is used with plastic contain-
ers because they collapse as they empty. Depending on the manufacturer, there
may be one or two extensions or entry ports protruding from the bottom of the
bag. If two ports protrude, one is the administration set port, encased in a pro-
tective and easily removable plastic pigtail that protects the port until it is spiked
with the administration set. The second extension is an injection port for adding
medication. A membrane seals both the medication and the administration ports
of the container, and entry of air into this system is prevented. Spiking the plas-
tic container is accomplished by a simple twisting motion (Fig. 5-4). Because
the plastic can be easily perforated during use, careful attention should be paid
to the integrity of this container during preparation and infusion delivery.

**Advantages**

- Closed system
- Flexible
- Lightweight
- Easier storage

**Disadvantages**

- More easily punctured
- Fluid level difficult to determine
- Composed of plasticizers
- Not completely inert (potential for leaching)

![Figure 5-4](Image)

*Figure 5-4*  Spiking an I.V. container. (Courtesy of Baxter Healthcare Corp., Round
Lake, IL.)
Semirigid Containers

Semirigid containers made of polyolefin contain no plasticizers, have fluid level marks that are easier to read, and are impermeable to moisture. However, semirigid containers crack more easily and are not as tolerant to temperature extremes. Semirigid containers must be vented to add air to the infusion system because they do not collapse.

Checking the Plastic Container for Clarity

The plastic container should be held up to the light and checked for clarity. If there is any discoloration, or if any particles are floating in the solution, it should not be used and should be considered potentially contaminated. Squeeze the plastic container to check for pinholes and thus leakage and loss of integrity. Check the expiration date on the label to ensure patient safety, and be sure the outer wrap of the plastic system is free of pooled solution. Any abnormalities should result in the return of the container and unusual occurrence reporting to the pharmacy per the organizational policy.

NURSING FAST FACT!
Always read the information provided on the solution bag.

Use-Activated Containers

Use-activated containers (Fig. 5-5) consist of a solution (e.g., dextrose 5% in water) and a separate compartment with a premeasured drug and diluent that is mixed just prior to administration. Although more expensive, these containers are useful for infusions that have a short shelf life after admixture. They are used in all settings, including outpatient and home care.

To activate the container, the container seal or diaphragm is ruptured by compressing opposing parts or applying pressure to rupture the internal reservoir. It is important to complete this step correctly to ensure that all of the medication is added to the solution.

The Syringe as a Solution Container

Syringes are also solution containers. Prefilled flush syringes of heparin and saline are used in all settings. Of note, the syringes used most often are packaged in “clean” wrap, also known as a sterile fluid pathway, which means that the inside of the syringe and the flush solution are sterile. If the flush syringe needs to be dropped onto a sterile field, it is important to ensure that the flush syringe is packaged in sterile wrap versus a sterile fluid pathway (see Fig. 5-6).

Medications may also be provided in syringes, such as used with syringe pumps, discussed later in this chapter, and delivered via an I.V. bolus method.
Figure 5-5  Medication Additive System®. (Courtesy of Baxter Healthcare Corp., Round Lake, IL.)

Figure 5-6  Sterile-wrapped 0.9% sodium chloride syringe.
Infusion Pump Specific

Some containers are specific and applicable for use with only a single, unique type of infusion pump.

Administration Sets

The tubing choices or administration sets are manufactured with varying materials. The common types are PVC or non-PVC (e.g., polyolefin). Administration set choices include:

1. PVC with DEHP: Historically used for a majority of administration sets; however, not compatible with lipids and some drugs. The trend is toward PVC/DEHP alternatives.
2. PVC without DEHP: Required for administration of lipids and some drugs.
3. Non-PVC lined (polyethylene lined): Inner lumen is lined with non-PVC material; used for administration of nitroglycerin or paclitaxel.
4. Non-PVC: Is more rigid plastic than PVC; may not be compatible with some I.V. infusion pumps.

Basic Components of Administration Sets

The most frequently used administration sets (primary, secondary, Y-set) among manufacturers have the same basic components but may vary in drop factor (Fig. 5-7).

The basic components include:

1. Spike: The spike is a sharply tipped plastic tube designed to be inserted into the solution container. It is connected to the flange, drop orifice, and drip chamber.
2. Flange: The flange is a plastic guard that helps prevent touch contamination during insertion of the spike.
3. Drop orifice: The drop orifice is an opening that determines the size and shape of the fluid drop. The size of this drop orifice determines the drop factor.
4. Drip chamber: The drip chamber is a pliable, enlarged clear plastic tube that contains the drop orifice and allows for visualization of the falling drops. It is connected to the tubing.
5. Tubing: The plastic tubing connects to the drip chamber. Depending on the manufacturer, the tubing may have a variety of clamps, ports, connectors, or filters built into the system.
6. Clamp: The flow clamp control device operates on the principle of compression of the tubing wall. The roller clamp is found on all standard administration sets and controls flow rate by occluding the tubing as the clamp is tightened. Some sets also include a slide or pinch clamp; such clamps are used only as on-off controls and are never used to regulate the flow. Be sure to check the manufacturer’s instructions for use.
7. **Injection ports:** Needleless injection ports serve as an access into the tubing and are located at various points along the administration set. Usually the ports are used for medication administration. They are accessed with a blunt plastic cannula, the plastic tip of a syringe, or the male end of the administration set. Such ports are always disinfected prior to any access.

8. **Backcheck valve:** A one-way valve that allows the solution to flow in one direction; it is most often used with a secondary administration set, thus allowing the primary solution to resume after the piggyback is completed.

9. **Male Luer end:** The end of the administration set that is attached to the I.V. catheter, a needleless connector (NC), or injection port.

10. **Final filter:** A final filter removes foreign particles from the infusate. It may be an integral part of the administration set (preferred), or it may be added on separately.
Primary Continuous

Primary continuous administration sets are defined as the main administration sets used to deliver solutions and medications (Fig. 5-8). These administration sets are available as vented or nonvented. As previously discussed, vented sets allow air to enter the container, and they are used with glass and semi-rigid containers. Nonvented sets have a straight spike pin without an air vent device and are used with collapsible plastic containers. The tubing of the set distal to the drip chamber terminates in a male Luer end that connects to the vascular access device (VAD) hub or a needleless connector attached to the VAD. Primary sets are available in macrodrip form (10–20 drops/mL) or in microdrip form (60 drops/mL).

Primary sets may have injection ports, backcheck valves and, often, inline filters. The drop factor is clearly specified on the packaging of each administration set as well as in the accompanying literature (Fig. 5-9). The microdrip set, also called a minidrip or pediatric set, is used when small amounts of fluid or slower rates are required.

The backcheck valve is a device that functions to prevent retrograde flow of the fluid. When the fluid is flowing in the proper direction, from the bag to the patient, the valve is open. If the fluid is flowing in the wrong direction, from the patient toward the solution container, the valve closes. Backcheck valves are required with secondary medication administration. The secondary administration set (“piggyback”) is attached to the injection port on the upper third of the primary administration set. The backcheck valve is located between the

Figure 5-8  Primary administration set. (Courtesy of Baxter Healthcare Corp., Round Lake, IL.)
primary fluid container and the upper injection port; this prevents the secondary medication from flowing into the primary infusion container. The primary container must hang lower than the secondary container. Backcheck valves are inline components of many primary administration sets.

**INS Standard** Primary and secondary continuous administration sets used to administer solutions other than lipid, blood, or blood products are changed no more frequently than every 96 hours. The administration set is changed immediately upon suspected contamination or when the integrity of the product or system has been compromised (Gorski et al., 2016a, p. S84).

**Secondary**
A secondary administration set is defined as an administration set attached to the primary administration set for a specific purpose, usually to administer medications; it is commonly called the piggyback set. The piggyback set
short tubing with a standard drop factor of 10 to 20 drops/mL. These sets are widely used for the administration of multiple intermittent medications, such as antibiotics, to patients. They are connected with a needleless adapter into an injection port immediately distal to a backcheck valve of the primary tubing. In setting up the piggyback set, the primary infusion container is positioned lower than the secondary container, using the extension hook provided in the secondary line packaging (see Fig. 5-10). The secondary set should remain connected to the primary tubing with both being changed no more often than every 96 hours. If it is disconnected from the primary tubing, it is treated as a primary intermittent set (below) (Gorski et al., 2016a).

**Primary Intermittent**

The primary intermittent set is defined as an administration set that is connected and disconnected with each use. The set itself is generally the same one used

![Figure 5-10](image-url) Secondary administration set. Note check valve (also called backcheck valve), which acts to prevent retrograde solution flow.
for a continuous primary infusion. The set may be connected to the NC of the patient's VAD with each use, or it may be connected to another primary continuous set. It is important to recognize that with every connection and disconnection, there is risk for contamination at the catheter hub, the NC, and the male Luer end of the administration set, which increases risk for bloodstream infection (Gorski et al., 2016a). Because of the contamination risk, aseptic technique with access and careful attention to protecting the male Luer end of the set with a new, sterile compatible covering device after each use are critical. An example of an antimicrobial product used for this purpose is shown in Figure 5-11.

**INS Standard** Primary intermittent administration sets are changed every 24 hours (Gorski et al., 2016a, p. S84).

**Metered Volume Chamber**

Used less often today due to preference for infusion pumps and syringe pumps, the metered volume chamber set is used for intermittent administration of measured volumes of fluid with a calibrated chamber. These sets are calibrated in much smaller increments than other infusion devices, which limits the amount of solution available to the patient (usually for safety reasons). Most chambers hold 100 to 150 mL of solution, but neonatal chambers may hold only 10 to 50 mL. The volume-controlled set is used most frequently for pediatric patients and critically ill patients when small, well-controlled delivery of medication or solution is required (Fig. 5-12).

**Primary Y**

The primary Y administration set is used for rapid infusion or for administration of more than one solution at a time. Each leg of the Y set is capable of being the primary set. The Y set has two separate spikes with a separate drip chamber and short length of tubing with individual clamps. Primary Y sets are made up of large-bore tubing; the purpose of this tubing is to infuse large amounts of fluid in acute situations. Use of the primary Y set is associated with the risk for air embolism because air can be drawn into the administration set if one container is allowed to empty.

![Figure 5-11](Dual Cap System™. Antimicrobial protection for end of intermittently used I.V. administration sets and for the needleless connector. (Courtesy of Catheter Connections, Salt Lake City, UT.)}
Blood Component

Blood is administered only with administration sets specifically designed for this use. These sets, designed for the viscous properties of blood, allow for rapid flow as needed and can provide a dual line (Y tubing) for infusion of 0.9% sodium chloride before, during, and after the transfusion. Blood transfusions are administered via a gravity infusion and also via an electronic infusion device (EID), if it is listed as an indication for use. Most blood administration Y sets contain in-line filters with a pore size of 170 to 260 microns and have a drop factor of 10 to allow for the safe infusion of blood cells (Fig. 5-13) (Maynard, 2014).

**INS Standard** Change the transfusion administration set and filter after the completion of each unit or every 4 hours; if more than one unit of blood component can be infused within 4 hours, the transfusion set can be used for the 4 hour period (Gorski et al., 2016a, p. S85).

Lipid

Lipids or fat emulsions are supplied in glass or non-DEHP plastic containers. Lipid-containing solutions are known to leach DEHP from bags and tubing.

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**Figure 5-12** Volume chamber control set for intermittent infusion. (Courtesy of Baxter Healthcare Corp., Round Lake, IL.)

**Figure 5-13** Diagram of Y administration set used for blood administration. (Courtesy of Baxter Healthcare Corp., Round Lake, IL.)
made of PVC; therefore, they must be administered through DEHP-free administration sets (Gorski et al., 2016a, p. S85).

**Specialty Sets: Pump/Medication Specific**

The pump-specific administration set is made specifically for use with the EID for which it is designed. These sets may or may not allow priming of the set outside of the EID. For specifics on each pump administration set, see the literature that accompanies each EID.

Some drugs (e.g., nitroglycerin, insulin) are readily adsorbed into many plastics, including PVC plastics, which affects the accuracy of drug dosage delivery. Use of non-PVC administration sets and glass containers is recommended. For example, paclitaxel leaches DEHP from both plastic infusion containers and PVC-containing plastic containers, so it should be administered in glass containers or in polypropylene or polyolefin containers and polyethylene-lined administration sets (Gahart, Nazareno, & Ortega, 2016). Special-administration non-DEHP sets are also used for propofol infusions. The administration set should be replaced every 6 to 12 hours, in accordance with the manufacturer's recommendations (Gorski et al., 2016a, p. S85).

**INS Standard**  When units of intravenous fat emulsion (now referred to as lipid injectable emulsion [ILE]) are administered separately, the administration set is changed every 12 hours and with every new container (Gorski et al., 2016a, p. S85).

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**NURSING FAST FACT!**

It is important that all administration sets be changed using aseptic technique, that they be of Luer-lock design, and that they be anti–free flow.

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**Add-On Devices**

A variety of “add-on devices” are used with infusion therapy. They are defined as additional components added to the administration set or VAD. Add-on devices include the following:

- Extension sets
- Stopcocks
- Manifold sets
- NCs
- Filters

In general, add-on devices are used only when clinically indicated for a specific purpose and should be of a design that ensures a secure junction, reduces manipulation, and reduces the risk of disconnection (Gorski et al., 2016a).
Extension Sets

Extension tubing may be added to the administration set or VAD. Extension sets may be straight or in a Y configuration, or may have multiple entries. Straight extension sets may be connected to the VAD with a NC added to the end of the set to increase the length (Fig. 5-14). This is common with home-care patients, for whom the extra length allows easier access to scrub the NC and self-infuse a medication. Y-configured extension sets usually have a clamp on both segments and can be added to allow simultaneous or separate administration of solutions. Multientry extension sets may have three or more “pigtails” allowing entry into the infusion system. Both Y-configured and multientry sets may have clamps, additional injection ports, or backcheck valves (Alexander, Gorski, Corrigan, & Phillips, 2014). When used with power-injectable catheters, an extension set with such capability must be used (Fig. 5-15).

A catheter connection device such as a J loop or T connector added to the peripheral I.V. catheter makes it easier to convert from a continuous to an intermittent infusion with less manipulation at the catheter insertion site.

Stopcocks

A stopcock is a device that controls the direction of flow of an infusate through manual manipulation of a direction-regulating valve. A stopcock is usually a three- or four-way device. A three-way stopcock connects two lines of fluid to a patient and provides a mechanism for either one to run to the
patient (similar to a faucet). With a four-way stopcock, the valve can be manipulated so that one or both lines can run to the patient, either alone or in combination.

The general use of stopcocks for administration of medications or I.V. infusions and for collection of blood samples creates a potential portal of entry for microorganisms and should be avoided for this reason (Gorski et al., 2016a). When the stopcock portals are uncapped, they are vulnerable to touch contamination. The stopcock itself is small and requires handling in such a way that sterility can easily be compromised. Syringes are frequently attached to I.V. push administration, and the portal is poorly protected after use. If stopcocks must be used, a stopcock or manifold with an integrated NC rather than a solid cap should be used (Gorski et al., 2016a, p. S72). Aseptic technique is followed for all add-on device changes.

**INS Standard** Change the add-on devices with new VAD insertion, with each administration set replacement, or as defined by the organization, and whenever the integrity of the product is compromised or suspected of being compromised (Gorski et al., 2016a, p. S72).

**NURSING FAST FACT!**

Caution should be exercised when using a stopcock because of the risk of contamination of the I.V. system and therefore increasing the risk for a bloodstream infection.

**Needless Connectors**

An NC is attached to the hub of the PIV catheter or central vascular access device (CVAD), allowing the tip of a syringe or male Luer end of the I.V. administration set to be attached. Although *needleless connector* is the current term recommended by INS, other commonly used terms are *injection caps, injection ports,* and *valves*. NCs allow for venous access without removal of the connector, thus maintaining a closed infusion system. Many types of NCs are available,
and it is important to understand how they work and what the implications are related to flushing technique. NCs are classified into two broad categories as defined by INS (Gorski et al., 2016a):

- Simple: A simple device has no internal mechanisms so that fluid flows straight through the internal lumen. Simple devices include those with a split septum, which opens when a blunt plastic cannula attached to the syringe or administration set is passed through the septum (Fig. 5-16).
- Complex: These include mechanical valves with an internal mechanism that controls the flow of fluid through the device, allowing both infusion and aspiration of blood.

NCs can be further classified based on function, as follows:

- Negative-displacement NC: Blood is pulled back into the catheter lumen (reflux) when I.V. tubing or a syringe is disconnected before the tubing is clamped, or when an infusion container runs dry. A positive fluid displacement technique is required to overcome blood reflux with negative fluid displacement connectors. This is accomplished when pressure is maintained on the flush syringe while the catheter clamp is being closed. Negative fluid displacement connectors are less commonly used today.
- Positive displacement NC: With these devices, an internal reservoir within the NC holds a small amount of fluid. When the syringe or I.V. tubing is disconnected, fluid is pushed out to overcome blood reflux. Important to the use of positive NCs is clamping the catheter after syringe/tubing disconnection to allow positive fluid displacement.
- Neutral NC: Blood reflux is prevented during connection and disconnection of I.V. tubing or syringes. The function of a neutral displacement device is not dependent on clamping technique. The catheter can be clamped either before or after disconnection.

Figure 5-16 Split septum needleless connectors. A, INTERLINK. (Courtesy of Baxter Healthcare Corp., Round Lake, IL) B, BD Q-Syte™ Luer Access Split Septum. (Courtesy and © Becton, Dickenson and Company)
An example of a “complex” NC is shown in Figure 5-17. Some NCs contain an antimicrobial barrier.

**NURSING FAST FACT!**

Blood reflux, and thus the risk for catheter occlusion, is dependent on proper flushing technique based on whether the connector is a positive or negative fluid displacement device. Refer to Chapter 6 for steps in flushing and locking. It is important that all nurses understand which type of device is being used.

**NURSING FAST FACT!**

For all catheters that are supplied with a clamp, the clamp should be closed when it is not in use to prevent the risk of air embolism or exsanguination with accidental dislodgement of the needleless connector.

**Infection Prevention Concerns With NCs**

Important aspects of infection prevention related to NCs include the frequency of changing the device and attention to aseptic technique when accessing the connector. NCs are a known source of contamination via the intraluminal route (i.e., through the lumen of the catheter), and failure to disinfect the NC before access is an important problem and area of concern (Moureau & Flynn, 2015). It is critically important that NCs are disinfected before each and every access (Gorski et al., 2016a). Acceptable disinfectants include 70% alcohol, alcoholic chlorhexidine, and povidone iodine. Although there is no consensus on the duration of disinfection (i.e., “scrubbing”) time, studies have reported 5 to 60 scrub times (Gorski et al., 2016a). It is important that the disinfectant be allowed to dry before a syringe or I.V. tubing is connected to the NC. Of note, there is a chlorhexidine/ alcohol disinfectant

![Figure 5-17 Example of a complex needleless connector (NC). ONE-LINK neutral displacement NC. (Courtesy of Baxter Healthcare Corp., Round Lake, IL.)](image)
wipe that is available for NC disinfection with a recommended 5 second scrub followed by a 5 second dry time.

- Change the NC no more frequently than 96-hour intervals, as changing more often adds no benefit and has been shown to increase the risk of central line–associated bloodstream infection (Gorski et al., 2016a).
- Additionally, the NC should be changed in the following circumstances:
  - When it is removed for any reason
  - If residual blood or debris is present
  - Prior to drawing a blood sample for culture
  - Upon contamination
  - According to organizational policies and procedures
- In home care, NCs are routinely changed at least every 7 days with intermittent infusions and more often based on INS criteria (Gorski, 2017).

**Passive Disinfection Caps and NCs**

There is increasing use of passive disinfection caps. These are plastic caps that contain a sponge saturated with 70% alcohol and that are placed on the end of the NC in between intermittent infusions, thus protecting the end and providing continuous disinfection. The advantages of their use include reduced contamination and elimination of “human factor” issues that require nurses to have disinfection supplies at the bedside and to use them consistently; the caps provide the nurse with an easy-to-use solution (Moureau & Flynn, 2015). If they are left in place for a certain length of time, based on manufacturer guidelines, the NC does not require scrubbing prior to the initial access (Figs. 5-11 and 5-18). However, the INS suggests that a 5- to 15-second disinfectant scrub be done with each subsequent entry through

![Figure 5-18](image-url) **Figure 5-18** Curos® alcohol disinfection cap, which is discarded upon catheter access and replaced upon completion of infusion. (Courtesy of 3M, St. Paul, MN)
the NC (Gorski et al., 2016a). It is important that the disinfection cap is discarded after removal and that a fresh cap is placed after completion of the intermittent infusion.

Filters
Filters may be used during the infusion of I.V. solutions to prevent the administration of any particulate matter, air, microorganisms, or endotoxins that may be in the infusion system. Unwanted matter is present in all types of solutions, and the United States Pharmacopeia (USP) has set standards regarding the amount of particulate matter allowable. The addition of medications and administration sets potentially increases the amount of particulate matter. Organ damage from particles includes capillary blockage; activation of platelets, neutrophils, and endothelial cells that can result in microthrombi; and deterioration of the microcirculation (Boehne et al., 2013). Pulmonary capillaries are the first anatomic filter for particulate matter. It is likely that even 1 L of I.V. fluid could introduce enough particles to occlude significant areas of pulmonary circulation (Hadaway, 2010). Filtration in critically ill patients is an important area of current research.

In a review of the literature related to air in infusion systems, the authors concluded that although air embolism is a relatively rare event, patients may be at risk from even small air bubbles (Wilkins & Unverdorben, 2012). Persons who have right-to-left cardiac shunts (e.g., patent foramen ovale) are at risk from even small volumes of air, and in this situation, air-eliminating filters (0.2 micron) should be used in accordance with INS (Gorski et al., 2016a). The prevalence of patent foramen ovale is up to 27% in the general population and is generally asymptomatic (Wilkins & Unverdorben, 2012). Knowing this, nurses should take all steps to remove air from the line and syringes. Air should be aspirated from stopcocks, NCs, and syringes as well as from administration sets. Although there is a lack of data demonstrating benefits in air embolism prevention, some suggest that an air-eliminating filter should be used whenever possible (Wilkins & Unverdorben, 2012).

Current recommendations for filtration include blood transfusions, parenteral nutrition solutions (i.e., lipid-containing), lipid injectable emulsions, intraspinal infusions, and specific medications/solutions as recommended by the manufacturer (e.g., certain biologicals) (Gorski et al., 2016a).

EBP The science continues to evolve regarding the effect of particulate matter on capillary endothelium and the effect of microbubbles of air in causing cerebral and pulmonary ischemia (Gorski et al., 2016a, p. 570). In a Cochrane systematic review that included four studies with 704 infants, the researchers found insufficient evidence to recommend filtration to prevent mortality and morbidity in neonates (Foster, Richards, Showell, & Jones, 2015). In a randomized trial involving critically ill children, subjects were randomly assigned to a control group ($n = 406$) or a filter group ($n = 401$). Inline filtration was used with 1.2-micron filters for lipid-containing solutions and 0.2-micron filters for aqueous solutions. There was a significant...
Filters are available as add-on devices or as inline components as an integral part of the administration set. Advantages to the inline filter include reduced risk for contamination and no risk of filter-tubing separation. Disadvantages include the need for an entire administration set change should the filter clog. The location of the filter may also be a disadvantage. If the filter is located at the upper portion of the tubing, it retains only substances that enter the tubing above the filter. Add-on filters can be easily changed if they become clogged and can be placed at the distal end of the tubing. As with all infusion procedures, attention to aseptic technique is critical when manipulating the infusion system.

Inline filters are available in a variety of forms, sizes, and materials. Common filter sizes used with common I.V. solutions and medications are:

- 0.2 micron: Most common, air eliminating, bacterial retentive
- 0.45 micron: Remove fungi or bacteria, may be air eliminating
- 1.2 micron: Used with three-in-one parenteral nutrition solutions and lipid emulsions

Examples of filters are shown in Figures 5-19, 5-20, and 5-21.

**INS Standard** Locate add-on bacteria- and particulate-retentive and air-eliminating membrane filters as close to the VAD hub as possible (Gorski et al., 2016a, p. S71).

**Membrane Filters**

Membrane filters are screen filters with uniformly sized pores. Filters range in size from 170 microns (largest) to 0.2 micron (smallest). They allow liquids but not particles to pass through. The finer the membrane, the more fully it will filter the liquid. A 5-micron screen will retain on the flat portion of the membrane all particles larger than 5 microns. A 0.2-micron filter is used to retain bacteria, fungi, and air. A 0.2-micron air-venting filter automatically vents air through a nonwettable (hydrophobic) membrane and permits uniform high-gravity flow through a large wettable (hydrophilic) membrane.

To be effective, an infusion membrane filter must have the ability to:

- Maintain high flow rates.
- Automatically vent air.
- Retain bacteria, fungi, particulate matter, and endotoxins.
- Tolerate pressures generated by infusion pumps.
- Act in a nonbinding fashion to drugs.
Figure 5-19  Posidyne® ELD 0.2-micron filter with 96-hour bacterial and endotoxin retention. (Illustration courtesy of PALL CORPORATION. Copyright PALL CORPORATION, 2015.)

Figure 5-20  Lipopor™ TNA filter set for total nutrient admixture administration with 1.2-micron air- and particle-eliminating filter. (Illustration courtesy of PALL CORPORATION. Copyright PALL CORPORATION, 2015.)
A 0.2-micron filter is contraindicated with administration of blood or blood components and lipid emulsions. Other contraindications include the administration of low-volume medications (total amount <5 mL over 24 hours), I.V. push medications, medications with pharmacological properties that are altered by the filter membrane, and medications that adhere to the filter membrane.

All filters have a certain pressure value at which they will allow the passage of air from one side of a wetted hydrophilic membrane to the other. Filters are also rated according to the pounds per square inch (psi) of pressure they can withstand. The filter should withstand the psi exerted by the infusion pump, or rupture may occur. If the psi rating of the housing is less than that of the membrane, excess force will break the housing.

**Blood Filters**

In accordance with the American Association of Blood Banks, blood components must be transfused through special tubing with a filter designed to remove blood clots and potentially harmful particles (Maynard, 2014). Blood administration sets have a standard clot filter of 170 to 260 microns. These filters are intended to remove coagulated products, microclots, and debris resulting from collection and storage. Commercially available filters include the standard clot filter, the microaggregate filter, and the leukocyte reduction filter. Refer to Chapter 11 for information related to filtration in transfusion therapy.
Catheter Stabilization Devices

The INS uses the term *engineered* stabilization devices, defined as devices or systems, placed subcutaneously or topically, specifically designed and engineered to control movement at the VAD catheter insertion site (Gorski et al., 2016a, p. S149). Attention to catheter stabilization is important because limiting movement of the catheter in and out of the insertion site (called pistoning) reduces the risk of accidental dislodgement and other complications such as infiltration, phlebitis, and infection (Alekseyev et al., 2012). Catheter stabilization is pertinent to both central and peripheral VADs. Historically, nonsterile tape was used to secure PIV catheters, and most often sutures were used to secure central lines. Because the use of sutures is associated with increased risk for infection and health-care provider needlestick injury, sutures should not be used (Gorski et al., 2016a). Because tape is not effective as a defined stabilization device, its use also is not recommended.

A variety of catheter-stabilization products are on the market as well as claims of several types of catheter securement dressings. A common type of product consists of an adhesive pad and a mechanism for holding the catheter to the pad (Fig. 5-22). Other options include bordered transparent semipermeable membrane securement dressings and tissue adhesives (Gorski et al., 2016a). The use of tissue adhesives is a new stabilization strategy. In essence, this is the

![Figure 5-22 StatLock® PICC Plus Catheter stabilization device. (© 2013 C.R. Bard, Inc. Used with permission.)](image)
use of a “glue” at the catheter entrance site in conjunction with a standard transparent dressing (Bugden et al., 2016; Marsh et al., 2015).

A novel stabilization product used with peripherally inserted central catheter (PICC) stabilization is a small metal anchor that is placed beneath the skin in the subcutaneous tissue. Advantages of this product are that replacement is unnecessary, site antisepsis is simple, and it has no adhesives, which can be an issue for some patients. This product was found to be efficacious in a small study of 68 inpatients and outpatients in three different institutions (Fig. 5-23) (Egan, Siskin, Weinmann, & Galloway, 2013).

EBP In an integrative review of the literature, a group of nurses reviewed research studies or outcomes-based studies addressing catheter stabilization. A total of 13 studies met the study inclusion criteria and were classified, summarized, and analyzed. A major limitation is that most of the published studies were descriptive in nature; in addition, few were randomized. Although the authors concluded that a decrease in complication rates was associated with the use of specific I.V.-stabilization devices as compared with tape and surgical strips, they also identified the need for further research in this area, including randomized clinical trials (Alekseyev et al., 2012). In a Cochrane systematic review that included a comparison of securement devices for CVADs, there was inadequate evidence to make recommendations for CVAD securement (Ullman et al., 2015). While making a recommendation to “consider” use of an engineered stabilization device to secure VADs, the INS acknowledged that evidence is limited due to small, descriptive studies and lack of high-quality randomized trials (Gorski et al., 2016a, p. S73).

Figure 5-23 Catheter stabilization device, securAcath®. Metal anchor of device sits in subcutaneous tissue. (Courtesy of Interrad Medical, Plymouth, MN.)
Site Protection and Joint Stabilization Devices

Site protection refers to the use of methods or products that protect the catheter site. Examples include clear plastic site protectors placed over the site, used most often with children, and mittens. Such strategies may be necessary with patients who exhibit confusion or other cognitive deficits. Hiding or camouflaging the site may reduce inadvertent manipulation at the I.V. site (Fig. 5-24).

Although areas of joint flexion should be avoided with PIV placement (see Chapter 6), at times this is not possible. An arm board should be used and applied in a manner that allows ongoing visual assessment of the catheter and vein path. Arm boards should be padded as needed and should support the area of flexion and maintain a functional position for the VAD (Gorski et al., 2016a). Wooden tongue depressors specifically should not be used in preterm infants and immunocompromised patients. Joint-stabilization and site-protection devices should be applied in a manner that preserves circulation, prevents skin impairment and nerve pressure, and provides the ability to visually inspect and assess the VAD site (Gorski et al., 2016a).

Peripheral I.V. Catheters

A peripheral I.V. catheter has a tip that terminates in the peripheral vasculature. The INS uses the term short peripheral catheters (SPC) to differentiate from mid-line peripheral catheters (Gorski et al., 2016a). It is notable that today, there are

Figure 5-24 I.V. House UltraDressing®, which consists of flexible fabric with thumb holes and a polyethylene dome that wraps around the patient's hand after an I.V. is started. This provides site protection and prevents accidental snagging of the loop or catheter hub. (Courtesy of I.V. House, Inc., Chesterfield, MO.)
increasing varieties and technologies in peripheral I.V. catheters. Often referred to in marketing information as “extended dwell” catheters, these catheters are longer than an SPC and shorter than a midline. Placement techniques include either a traditional over-the-needle insertion technique or an advanced placement techniques such as modified or accelerated Seldinger technique (described below), often in conjunction with ultrasound guidance. These “long” peripheral catheters fit in between the categories of the SPC and midline peripheral catheters. The 3 major options of peripheral catheters include:

1. The stainless steel winged needle, often called a “scalp vein needle” or a “butterfly.” Flexible plastic wings extend from either side of the needle hub, and a short length of tubing is attached to the needle. This type of device is usually indicated for obtaining blood. It may be used for single-dose I.V. medication administration and then promptly removed. It is not left in place due to the high risk for infiltration. Stainless steel needles are available in the following gauges (odd-numbered): 17, 19, 21, 23, 25, and 27.

2. The over-the-needle catheter leaves a plastic-type catheter in place and is the most common type of placement method.

3. The midline catheter is a longer peripheral catheter (e.g., 3-4 inches) that is placed in a peripheral vein, generally inserted about the antecubital fossa, with the catheter tip residing level at or near the level of the axilla and distal to the shoulder; in infants, a midline catheter may be placed in a scalp vein with the tip terminating in the jugular vein above the clavicle, or in the leg with the tip below the inguinal crease (Gorski et al., 2016a).

Catheters have radiopaque material or stripping added to ensure radiographic visibility. Radiopacity aids in the identification of a catheter embolus, which is a rare complication. The hub of a cannula is plastic and color coded to indicate the length and gauge.

Catheters are made of various biocompatible materials such as steel polytetrafluoroethylene (Teflon), polyurethane, silicone, and Vialon. Teflon is considered the most thrombogenic and silicone the least thrombogenic (Alexander et al., 2014).

**INS Standard** The catheter selected shall be of the smallest outer diameter with the fewest number of lumens and is the least invasive device needed for the prescribed therapy (Gorski et al., 2016a, p. S51).

**Over-the-Needle Catheters**

The most widely used infusion device is the over-the-needle catheter, which consists of a flexible catheter with a rigid needle or stylet that is used as a guide to puncture and insert the catheter into the vein. The stylet connects with a clear chamber that allows for visualization of blood return, indicating successful venipuncture. The hub of the catheter is plastic and color coded to indicate length and gauge. Figure 5-25 shows examples of over-the-needle catheters.
The point of the stylet extends beyond the tip of the catheter. After venipuncture, the needle (stylet) is withdrawn and discarded, leaving a flexible catheter within the vein. Safety catheters should be used as discussed below.

**Catheter Features**

**Flashback Chambers**

The flashback chamber is a small space at the hub of the stylet. When the stylet punctures the vein during catheter insertion, the increased pressure in the vein is immediately relieved into the catheter stylet with a flow of blood in the flashback chamber. This allows the nurse to see that blood return is continuing as the catheter is advanced and secured. The safest catheters use a flashback chamber that allows the rapid return of blood but prohibits any blood spillage.

**Figure 5-25** Over-the-needle catheters. A, BD Insyte™ Autoguard™ BC Shielded I.V. Catheter. B, Nexiva™ closed I.V. catheter system. (Courtesy and © Becton, Dickenson and Company) C, Catheter with passive safety technology (Courtesy of B. Braun, Bethlehem, PA.)
Blood Control
Exposure to blood from the hub of the catheter after stylet removal is a risk for the nurse. Technology within the hub of the catheters that stops the flow of blood out of the catheter on removal of the stylet allows the nurse to place an NC on the hub of the catheter without being exposed to blood. The risks of mucocutaneous transmission of blood and body fluids are addressed in Chapter 2.

Addition of Wings
Adding wings to the design of I.V. catheters and scalp vein needles can improve insertion technique and catheter stabilization. The wings are usually flexible plastic protrusions from the hub of the device. Winged catheters may provide more control when the catheter is manipulated, thereby improving insertion success.

Color Coding
SPCs are color coded based on international color-coding standards. Universal color-coding standards allow visual recognition of the catheter gauge size. This standard has not been applied to gauge sizes of midline catheters or CVADs.

- Violet: 26-gauge
- Yellow: 24-gauge
- Blue: 22-gauge
- Pink: 20-gauge
- Green: 18-gauge
- Gray: 16-gauge

Needle Protection: Active and Passive Sharps Safety
Two categories of safer needle devices incorporate prevention techniques for I.V. catheters: active design and passive design.

Active-design safety needles require health-care workers to activate a safety mechanism after use to protect against accidental needlesticks. The user can bypass these safety mechanisms, leaving him or her at risk for injury. If a nurse forgets to activate the safety mechanism, or if the safety mechanism fails to activate once the needle is removed from the patient, the nurse is at risk. The passive design deploys automatically during use such as a needle that becomes blunt ended upon withdrawal (e.g. Fig. 5-25C).

INS Standard Consider the use of passive safety-engineered devices for needlestick injury prevention (Gorski et al., 2016a, p. S40).

Dual-Lumen Peripheral Catheters
The dual-lumen peripheral catheter is available in a range of catheter gauges with corresponding lumen sizes. Two totally separate infusion channels exist, making it possible to infuse two solutions simultaneously. Dual-lumen catheters are also available as midline catheters.
Midline Catheters

Midline catheters are PIV catheters designed for intermediate-term therapies that are appropriate for peripheral administration (e.g., antibiotics, fluid replacement). They are widely used today. Current recommendations suggest selection of a midline for infusions anticipated to take up to 14 days (Chopra et al., 2015). While guidelines suggest placement based on 14 days of need, in many cases midline catheters remain functional for longer periods of time and are removed based upon clinical indications (e.g., infiltration, phlebitis) or when no longer needed for infusions.

The catheter is placed midline in the antecubital region in the basilic, cephalic, or median antecubital site and is then advanced into the larger vessels of the upper arm for greater hemodilution. The catheter is placed using aseptic technique with consideration given to the use of maximum sterile barrier precautions (cap, mask, sterile gown/gloves and a full sterile body drape for the patient). Ultrasound guidance is used for vein identification and selection and insertion techniques include a modified Seldinger technique or an accelerated or all-in-one Seldinger technique are used.

- **Modified Seldinger technique (MST):** Using ultrasound to locate the vein, venipuncture is made using a micropuncture needle; a guidewire is inserted several inches into the vein through the needle; the guidewire is secured to prevent embolism, and the needle is removed; a dilator and introducer sheath are threaded over the guidewire and advanced into the skin (the opening of the skin may be slightly enlarged with a scalpel to accommodate the dilator) and into the vein; the guidewire and dilator are removed, and the catheter is threaded into the introducer and advanced. The sheath is then withdrawn, broken, and peeled apart (Gorski et al., 2016b)

- **Accelerated Seldinger technique:** An integrated all-in-one placement technique. The needle is placed in the vessel, the guidewire is advanced, and the dilator and sheath (or catheter) are inserted over the needle and guidewire (Adams, Little, Vinsant, & Khandelwal, 2016; Dumont, Getz, & Miller, 2014).

Visualization Technology

The use of visualization technology has improved the practice of I.V. access and infusion therapy for patients who are in need of I.V.s but have veins that can be

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**NURSING FAST FACT!**

Controversy still exists regarding simultaneous infusions of known incompatible solutions or medications through a dual-lumen peripheral catheter because of the limited hemodilution achievable in any peripheral vein.
neither seen nor palpated. The transilluminator works by directing a high-intensity cool light down into the subcutaneous tissue and creating a uniform area of or- angelike reflection from the fatty tissue. The light is flush with the skin; by moving the light around the extremity, a dark line can be seen. The vein’s deoxygenated blood absorbs the light, whereas the fatty tissue reflects the light (Fig. 5-26).

Near-infrared (nIR) imaging devices are increasingly used to visualize veins. Veins can be visualized to about 10 mm below the skin surface. Bifurcations and venous valves may be identified, and the venous pathway can be seen (Gorski et al., 2016a). The use of nIR is especially useful in identifying veins in the forearm. In a study of volunteer subjects (n = 768 observations in 384 subjects), researchers found that nIR technology increased the visibility of veins in subpopulations of African American and Asian ethnicity and in those with obesity compared to normal, unassisted eyesight (Chiao et al., 2013) (Figs. 5-27 and 5-28).

Ultrasound allows for real-time imaging of selected blood vessels and nearby anatomic structures before and during placement of midline catheters and PICCs as well as during short peripheral catheter placement. Ultrasound is increasingly used with short peripheral catheter insertion and is associated with fewer venipuncture attempts in both adults and children (Gorski et al., 2016a). The use of ultrasound allows for placement in deeper veins, but longer catheters must be used to ensure that the catheter adequately resides in the vein; otherwise, the risk of infiltration/extravasation is increased. Ultrasound-guided

![Image of transillumination device Veilite®](image-url)
catheter insertion requires training. A thorough understanding of the vascular system and the veins accessed (e.g., basilic, brachial, and cephalic) is required.

EBP A randomized controlled trial compared ultrasound-guided short peripheral catheter (SPC) insertion to usual placement using palpation in patients with difficult venous access. Emergency room nurses who were trained in the use of ultrasound were 2.52 times more likely to be successful in SPC insertion using ultrasound (76% success rate) as compared to usual placement using palpation (56% success rate) (Bahl, Pandurangadu, Tucker, & Bagan, 2016).

Infiltration Detection Technology
The ability to continually monitor an SPC site for infiltration or extravasation is recently available technology. A receptacle is placed near the SPC site and is connected to a cable that includes a non-invasive optical sensor. The cable attaches to a monitor, which is mounted on the I.V. pole (Fig. 5-29). The sensor
cable delivers the light signals from the monitor to the patient’s skin through the sensor head. The sensor head transmits the reflected light from the tissue back to the patient monitor through the sensor cable. If fluid accumulates in the subcutaneous tissue outside of the vein (i.e., evidence of infiltration/extravasation), there are changes in the scattering of light as detected by the sensor and the monitor alerts the nurse to check the I.V. site.

Central Vascular Access Devices (CVAD)

The reader is referred to Chapter 8 for information related to types of CVADs, catheter materials, features, sizes, and catheter placement technology.

Flow-Control Devices

Historically, control of the I.V. rate was regulated primarily with a roller clamp, which the nurse adjusted manually on the administration set. Although roller clamp rate control is still useful in certain circumstances, numerous mechanical infusion devices and EIDs are available for maintaining an accurate infusion rate. The term flow-control device refers to any instrument used to regulate infusion flow rate; the main categories include manual devices (e.g., roller clamp) and mechanical infusion devices and EIDs (Gorski et al., 2016a).

**INS Standard**  Factors to be considered in the choice of a flow control device include patient age, condition, prescribed infusion therapy, and care setting (Gorski et al., 2016a, p. S48).
Manual Flow Control

Manual flow control includes use of the roller clamp of the I.V. tubing or, alternatively, use of a “manual flow regulator” in lieu of the roller clamp. The manual flow regulator allows the nurse or patient to set the flow rate in milliliters per hour. Advantages may include easier regulation, more consistent flow, less drifting of flow compared to using the roller clamp, and less risk of accidental free
flow. However, the accuracy is about the same as with the roller clamp (±10%). Manual flow regulators are set to deliver specified volumes of fluid per hour. They are available as dials, with clocklike faces, or as barrel-shaped devices with cylindrical controls (Fig. 5-30). Flow markings on the dials help to approximate the drops per minute based on the set drop factor. Because these devices are gravity based, it is important to recognize that a number of factors affect the accuracy of the flow, such as patient position change or decreased volume in the solution container. Flow rate should be verified by counting the drops. These devices are not a replacement for an EID but are useful in certain situations where some variation in flow rate is not critical. Examples include home infusions of subcutaneous fluids or certain antibiotics.

**NURSING FAST FACT!**

When using a manual flow regulator, always verify the flow rate by counting the drops.

**NURSING FAST FACT!**

1 psi and 50 mm Hg exert the same amount of pressure.

**Mechanical Infusion Devices (Nonelectric)**

Mechanical infusion devices use no electricity and utilize various methods to infuse therapies. Certain devices, considered variable pressure, utilize a stretched elastomer or compressed spring to create the force required to infuse, with the decreasing force leading to decreasing flow rates throughout the infusion. Another device uses a constant pressure mechanism that maintains flow rate until acted upon through feedback, based on the increasing pressure in the area that the infusion is entering the patient, leading to a decrease in flow rate and reduction in site reactions (Fig. 5-31 A and B). Tubing diameter and length have a determining influence on the device’s initial flow rate. Such constant pressure devices can be used to administer both subcutaneously or intravenously. These types of flow-control devices are widely used in non–acute care settings.

The elastomeric pump system is a portable, single-use device with an elastomeric reservoir, or balloon. The balloon, which is made of a soft rubberized material capable of being inflated to a predetermined volume, is encapsulated inside an outer case that may be a soft- or hard-shelled transparent container. The pump includes preattached tubing, an inline filter, and built-in clamp. When the reservoir is filled, the balloon exerts positive pressure to administer the medication with an integrated tubing that controls the flow rate (Fig. 5-32). Used most often in home or outpatient settings, the elastomeric pump is used to deliver a variety of infusion therapies including I.V. antibiotics, chemotherapy, and analgesics.
ADVANTAGES

- Portability
- Simplicity
- Patient education is simplified; many patients learn in one to two teaching sessions

Figure 5-30 Manual flow regulator.

Figure 5-31 A, Freedom 60 mechanical syringe device. A syringe is loaded into this portable spring-loaded device. It is used for I.V. and subcutaneous infusions. B, Specialty infusion tubing for subcutaneous infusions. (Courtesy of RMS Medical Products, Chester, NY.)
Disadvantages

- Cold infusates slow infusion rate; infusion solutions should be at room temperature.
- Viscosity of fluid will have an inverse effect on flow rate.
- Atmospheric pressure can affect flow accuracy.
- More costly.
- Limited number of medications compatible with system.

**Nursing Fast Fact!**

Allow elastomeric infusion pumps to warm after storage and before infusion to improve accuracy in the flow rate.

Electronic Drip Monitor

This is a newer device that is placed around the drip chamber to monitor the flow rate. The nurse selects the administration set drop/mL factor (as listed on the administration set box) and adjusts the roller clamp to the right drop rate, and the device monitors the rate. An alarm sounds if the drip rate changes (Fig. 5-33).

*Figure 5-32* Elastomeric infusion pump. Eclipse™ elastomeric pump. (Courtesy of Halyard Health, Alpharetta, GA.)
Electronic Infusion Devices

EIDs are powered by electricity or battery and are programmed to regulate the I.V. flow rate in milliliters per hour. EIDs include positive-pressure infusion pumps. The normal pumping pressure is slightly lower than the occlusion pressure. Some pumps have a preset or fixed occlusion pressure, whereas others allow the nurse to change the occlusion pressure.

It is important to recognize that occlusion pressures are a safety feature, and nurses should be cautious when changing the pressure to avoid setting off alarms (Hadaway, 2010). Sometimes it may be appropriate to increase the pressure, such as with high-volume high-pressure infusions, arterial infusions, and those delivered in a hyperbaric chamber. Positive-pressure infusion pumps average 10 psi, with up to 15 psi considered to be safe, although newer technology has the psi set as low as 0.1 psi. Pressures greater than 15 to 20 psi should be used with extreme caution.
EIDs are used in I.V. infusions as well as with subcutaneous, arterial, and epidural infusions. These devices provide an accurate flow rate, are easy to use, and have alarms that signal problems with the infusion. However, regular assessment, responsibility, and accountability for safe infusion still lie with the nurse. To use these devices effectively, the nurse should know (1) indications for their use, (2) their mechanical operation, (3) how to troubleshoot, (4) their psi rating, and (5) safe usage guidelines.

**Volumetric Pumps**

Volumetric pumps calculate the volume delivered by measuring the volume displaced in a reservoir that is part of the disposable administration set. The pump calculates every fill and empty cycle of the reservoir. The reservoir is manipulated internally by a specific action of the pump. The industry standard for the accuracy of electronic volumetric infusion pumps is ±5%, although some have even better accuracy of ±2% (Hadaway, 2010). Volumetric pumps require pump-specific administration sets.

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**NURSING FAST FACT!**

To ensure safe, efficient operation, review the literature that accompanies the pump to become familiar with its operation. Observe all precautions.

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**NURSING FAST FACT!**

All infusion pumps should have an “anti-free flow” alarm to prevent inadvertent free-flowing solution.

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**Peristaltic Pumps**

*Peristaltic* refers to the controlling mechanisms: A peristaltic device moves fluid by intermittently squeezing the I.V. tubing. The device may be rotary or linear. In a rotary peristaltic pump, a rotating disc or series of rollers compresses the tubing along a curved or semicircular chamber, propelling the fluid when pressure is released. In a linear device, one or more projections intermittently press the I.V. tubing. Peristaltic pumps are used primarily for infusion of enteral feedings.

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**Ambulatory EIDs**

Ambulatory EIDs are lightweight, compact infusion pumps. They have been a significant breakthrough for patients requiring home infusion therapy, allowing the patient freedom to resume a normal life. Ambulatory EIDs are capable of delivering most infusion therapies, including continuous infusions (e.g., chemotherapy and inotropes), intermittent antibiotic therapy, analgesic infusions with patient-controlled analgesia (PCA), and continuous infusions with
tapering functions (e.g., parenteral nutrition) (Fig. 5-34). For intermittent antimicrobial infusions, a “keep vein open rate” is programmed to maintain flow between the drug administrations. Features include programmable memory, lockout functions for safety, and alarms. “Smart pumps” that include drug libraries are available. Ambulatory pumps function on a battery system that requires recharging or replacement of disposable batteries. The pump, along with the infusion container, is placed in a pouch or backpack, providing the patient with full mobility during the infusion.

**Electronic Syringe Pumps**

Electronic syringe pumps use a traditional syringe as the solution container, which is filled by the pharmacy with prescribed medication and positioned in a special pump designed to hold it. Syringe pumps are valuable for critical infusions of small doses of high-potency drugs. They are precisely accurate delivery systems that can be used to administer very small volumes. Some models

**Figure 5-34** Ambulatory pump: 6000CMS Ambulatory electronic infusion device. Capable of infusion modes including continuous infusion, patient-controlled analgesia, patient-controlled epidural analgesia, subcutaneous infusion, total parenteral nutrition, and intermittent infusions. (Courtesy of Moog Medical Devices Group, Salt Lake City, UT.)
have program modes capable of administration in milligrams per kilogram per minute, micrograms per minute, and milliliters per hour.

These pumps are used most frequently for delivery of antibiotics and small-volume parenteral therapy. Syringe pump technology is available for PCA infusion devices. Syringe pumps are used frequently in the areas of anesthesia, oncology, pediatrics, home care, and obstetrics.

The volume of the syringe pump is limited to the size of the syringe; a 60-mL syringe is usually used. However, the syringe can be as small as 5 mL. The tubing usually is a single, uninterrupted length of kink-resistant tubing with a notable lack of Y injection ports (Fig. 5-35).

**Patient-Controlled Analgesia Pumps**

PCA pumps are used for pain management across all care settings including acute care, long-term care, hospice, and home. PCA pumps can be used to deliver medication via the I.V., subcutaneous, and intraspinal routes. These pumps are distinct from other EIDs in that a remote bolus control allows the patient to deliver a bolus of medication at set intervals by pressing a button on a cord. PCA pumps are available in ambulatory or pole-mounted models and, as mentioned earlier, PCA technology is available with syringe pumps as well.

The PCA pump can be programmed to deliver a continuous infusion, a demand infusion, or both. All three afford pain control with varying degrees of patient interaction. Some pumps offer oxygen saturation monitoring, which sets off alarms and potentially stops the infusion in the event of hypoxemia.

- The continuous infusion is designed for patients who need maximum pain relief without the need for on-demand dosing. May be used for intraspinal infusions, and for patients unable to use the demand function.
- The demand-mode infusion dose is delivered by intermittent infusion when a button attached to the pump is pushed. The demand dose can be used alone or with a continuous basal type of infusion.
- The basal mode refers to the continuous delivery of pain medicine in conjunction with the demand mode. Should the patient require additional pain medication, for example, as associated with increased activity or a painful procedure, the demand dose is delivered in conjunction with

![Perfusor® Space Syringe Pump. (Courtesy of B. Braun, Bethlehem, PA.)](image)
the basal rate. This mode is often used in palliative care and hospice settings for patients with chronic pain. (Alexander et al., 2014).

**NURSING FAST FACT!**
PCA pumps are designed with a special key or locking device for security of the medications.

**INS Standard** Assess the patient for the appropriateness of PCA therapy and the patient’s comprehension of, and ability to participate in, the intended therapy (Gorski et al., 2016a, p. S131).

**Multichannel Pumps**
Multichannel pumps can deliver several medications and fluids simultaneously at multiple rates from bags, bottles, or syringes. They are often used in critical care settings. Multichannel pumps (usually with two to four channels) require manifold-type sets to set up all channels, whether or not they are in use; each channel must be programmed independently (Fig. 5-36).

**Smart Pumps**
Smart pumps are EIDs with an imbedded computer system. The computer software is aimed at reducing drug dosing errors through the presence and use of a drug library. The Institute for Safe Medication Practices ([ISMP], 2017) recommends the use of EIDs with dose-error reduction software for all high-alert medication infusions. The majority of health-care facilities use smart pump technology.

![Figure 5-36 Alaris® multichannel pump. (Courtesy and © Becton, Dickenson and Company)
but “we are all over the spectrum in terms of our compliance with the software and the use of various safety attributes” (Phelps, 2017, p. ix).

The drug library must be individualized to the organization’s medications and dosing limits. The organization must also make decisions related to whether the programmer (e.g., nurse) can override the dosing limits. Features of smart pumps are listed in Table 5-1.

Smart pumps are not without limitations. The accuracy of information entered into the smart pump (e.g., patient weight) is dependent on correct data. If the nurse bypasses the drug library and manually enters the infusion rate and volume, the dose-error reduction software will not be able to identify potential errors. The implementation of independent double-checking of drug prescription and data entry remains important for certain high-risk medications. Smart pumps do not detect errors related to wrong patient selection, wrong drug library selection, or to bypassing the drug library (Phelps, 2017). Smart pump technology is incorporated into the pumps shown in Figures 5-35 and 5-36.

**INS Standard** Consider use of smart pumps with dose-error reduction software as they are associated with reduced risk for infusion-related medication errors including error interceptions (e.g., wrong rate) and reduced adverse drug events (Gorski et al., 2016a, p. S48).

**NURSING FAST FACT!**

Because of the many pumps on the market, it is important to refer to the manufacturer’s directions for setup and troubleshooting guidelines of each EID.

<table>
<thead>
<tr>
<th>Table 5-1 Smart Pump Features</th>
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<td><strong>Feature</strong></td>
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<td>Drug library</td>
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<td>Soft limit</td>
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<td>Hard limit</td>
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<td>Clinical advisory</td>
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<td>Data logs</td>
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<td>Continuous display</td>
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<td>Wireless technology</td>
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Electronic Infusion Devices: Pump Programming

EIDs must be programmed based on the parameters of the specific infusion therapy. The nurse typically programs the pump at the bedside. In some settings, such as home care, the pharmacist most often enters the program prior to dispensing the EID to the home. Parameters include:

- **Rate**: Amount of time over which a specific volume of fluid is delivered. Infusion pumps deliver in increments of milliliters per hour. The most common rate parameters for regular infusion pumps are 1 to 999 mL/hr. Many newer pumps are capable of setting rates that offer parameters of 0.1 mL in increments of 0.1 to 99.9 mL, then in 1-mL increments up to 999 mL. Many newer pumps are capable of setting rates that satisfy both regular infusion and microinfusion needs.

- **Volume infused**: Measurement that tells how much of a given solution has been infused. This measurement is used to monitor the amount of fluid infused in a shift. It can also be used in home health to monitor the infusion periodically during the day or over several days. The “counter” is generally returned to 0 at the beginning of each shift.

- **Volume to be infused**: Usually the amount of solution hanging in the solution container. A pump is designed to sound an alarm when the volume to be infused is reached.

- **Tapering or ramping**: These terms are used to describe the progressive increase or decrease of the infusion rate. Tapered infusion rates are often used with parenteral nutrition infusions that are administered over part of each day (e.g., 14 hours per day). Tapering at the beginning or end of the infusion allows a more gradual infusion, allowing the body to adjust to high glucose and electrolyte concentrations. The pump mathematically calculates the ramping rate once the duration of infusion and total volume to be infused are entered into the program.

- **Timed infusion**: This refers to an infusion governed by a 24-hour clock within the device. With timed infusion, the device must have a sufficient internal backup battery to maintain the clock accurately at all times. Timed infusions are used for ramping and tapering, automatic piggybacking, and intermittent dosing.

Alarm Terminology

- **Air-in-line**: Designed to detect air in the line and may include air detection and air removal.

- **Occlusion**: Detects absence of fluid flowing upstream (between pump and the infusion container) or downstream (between the patient and the pump).

- **Infusion complete**: Alarm triggered by a preset volume limit (“infusion complete”). These alarms are helpful in preventing the fluid container from running dry because they can be set to sound before the entire solution container is infused.
**Low battery or low power**: Gives the user ample warning of the pump’s impending inability to function. A low-battery alarm means that the batteries need to be replaced or that an external power source needs to be connected. As a protective measure, when low-battery and low-power alarms are continued over a preset number of minutes, the pumps usually convert to a keep-vein-open (KVO) rate. The preset KVO rate is usually between 0.1 and 5 mL.

**Nonfunctional or malfunctional**: Alarm that means the pump is operating outside parameters and that the problem cannot be resolved. When this alarm sounds, the pump should be disconnected from the patient and returned to biomedical engineering or to the manufacturer for evaluation. The alert signifying a nonfunctional alarm may be worded in many ways, depending on the manufacturer.

**Not infusing**: Indicates that all of the pump infusion parameters are not set. This feature prevents tampering or accidental setting changes. The pump must be programmed or changed and then told to “start.”

**Tubing**: Ensures that the correct tubing has been loaded into the pump. If tubing is incorrectly loaded, this alarm will sound.

**Door**: Indicates that the door that secures the tubing is not closed. Cassette pumps may give a “cassette” alarm if the cassette is unable to infuse within device operating parameters.

**NURSING FAST FACT!**

In a number of EIDs, the pressure is “user” selectable from 0.10 to 10 psi. Occlusion alarms at low psi settings are common because the pumps are sensitive to even slight changes in pressure and very small I.V. catheter or patient movement. Many of the current EIDs infuse fluids using very low infusion pressures, often lower than the pressure of a gravity delivery. These devices are not, however, designed to detect infiltrations. When an infiltration occurs, the inline pressure may actually drop; therefore, the EID will not detect the infiltration. Visual monitoring of the I.V. site by the nurse is mandatory for patients with EIDs.

**Infusion Pump Safety**

Because better infusion pump design and engineering can reduce infusion pump problems, the U.S. Food and Drug Administration (FDA) launched an initiative in 2010 to address safety issues related to infusion pumps. From 2005 through 2009, the FDA received approximately 56,000 reports of adverse events associated with the use of infusion pumps, including numerous injuries and deaths (FDA, 2010). These adverse event reports and associated device recalls have not been isolated to a specific manufacturer, type of infusion pump, or use environment; rather, they have occurred across the board. Causes of these adverse events include user errors and deficiencies in design and engineering, such as software defects and mechanical and electrical failures. The FDA provides guidance to the nurse to reduce infusion pump risks (Table 5-2).
Table 5-2 Infusion Pump Risk Reduction Strategies for Clinicians

| Plan ahead | Have a backup plan in case of an infusion pump failure that details:  
|            | • How to obtain a working infusion pump and infusion tubing quickly when caring for high-acuity patients.  
|            | • How to handle high-risk infusions when the infusion pump fails. This may include staying with and closely monitoring the patient while another staff member obtains a working infusion pump if one is not readily available.  
|            | • How to handle infusions when the infusion pump fails in vulnerable patient populations (e.g., individuals sensitive to fluid overload). This may include clamping and disconnecting the infusion tubing from the patient to prevent overinfusion prior to obtaining a new infusion pump.  
|            | Participate in educational activities designed to promote the safe use of infusion pumps. Consider a secondary method of checking the expected volume infused, such as a time strip indicator or a buretrol.  
| Label      | Label the infusion pump channels with the name of the medication or fluid if your infusion pump does not display the name.  
| Check      | Label the infusion pump tubing at the port of entry with the medication or fluid name.  
| Use        | Verify that the infusion pump is programmed for the right dosage, at the right rate and volume to be infused. This is especially important at a change of shift, when any change is made to the infusion pump settings, when a new bag of medication/fluid is hung, or when new infusion tubing is primed.  
|            | Obtain an independent double-check of infusion pump settings by a second clinician per your hospital/facility policy when infusing high-risk medications (e.g., insulin, heparin, vasoressors, Diprivan, total parenteral nutrition, morphine, etc.). An independent double-check involves two clinicians separately checking (alone and apart from each other, then comparing results) the infusion settings in accordance with the physician’s order.  
|            | Monitor for signs of overinfusion or underinfusion of high-risk medications by using other patient monitoring systems, such as cardiac monitoring, pulse oximetry, end-tidal CO₂ measurement, and glucose meters, when applicable.  
|            | Monitor the patient and infusion per your facility’s protocol.  
| Use        | Use available resources, such as your Clinical/Biomedical Engineering Department, your area’s “super-users,” and infusion pump instructions or troubleshooting guides when experiencing problems with an infusion pump.  
|            | Use the drug library when applicable. Promptly respond and pay close attention to displayed alerts and cautions.  
|            | Use the “five rights” for safe medication administration: the right patient, the right drug, the right dose, the right route, and the right time.  
| Report problem | Remove from use, tag with the specific problem and clinician contact information, and sequester any infusion pump that shows signs of breakage or damage, including small chips or cracks, if an unexplained alarm occurs or if the pump does not function as expected.  
|            | Follow your hospital/facility protocol for reporting events where the infusion pump may have caused or contributed to a death or serious injury. You are also encouraged to report any other infusion pump safety concerns through your hospital/facility protocol.  
|            | You are encouraged to file a voluntary report with the U.S. Food and Drug Administration (FDA) for any pump problem that you may encounter.  
|            | Health Insurance Portability and Accountability Act of 1996 (HIPAA) restrictions do not apply to reports submitted to the FDA.  

Source: www.fda.gov/MedicalDevices/ProductsandMedicalProcedures/GeneralHospitalDevicesandSupplies/InfusionPumps/ucm205406.htm
Choosing a Flow-Control Device

A number of factors go into selecting the best device for any given infusion. Factors include the patient’s age, acuity, and mobility; severity of the illness; type of infusion; dosing; the health-care setting; and the potential for adverse effects of the infusion therapy (Gorski et al., 2016a). Some general guidelines are presented in Table 5-3. For the many patients who are discharged home with infusion therapy needs, careful consideration is given to the safest method. Factors in the decision-making process include the type of infusion, the frequency of administration, infusion rate requirements, drug stability in solution, patient safety and lifestyle concerns, patient preference, and reimbursement (Gorski, 2017). Patient safety is maximized by teaching the patient and family how to administer the infusion therapy, how to use an infusion pump, how to identify potential problems, and when/whom to call with problems.

NURSING POINTS OF CARE

USE AND MANAGEMENT OF INFUSION EQUIPMENT

Focused Assessment
- Appropriate supplies and equipment
- Appropriate VAD for anticipated duration and type of therapy
- Appropriate type of flow-control device

Key Nursing Interventions
1. Select and prepare the appropriate administration set and appropriate add-on devices.
2. Use filters when clinically indicated and appropriate (e.g., blood, parenteral nutrition, lipids).
3. Inspect fluid containers, administration sets, and cannulas for integrity before use.
4. Employ all necessary infection prevention interventions (aseptic technique, NC disinfection, protection of male Luer end of administration set with intermittent infusions, minimal use of add-on devices unless clinically indicated).
5. Follow the manufacturer’s directions for the setup and maintenance of EIDs and other flow-control devices and any other technology that is being used (e.g., visualization devices).
6. Set alarm limits on equipment as appropriate.
7. Monitor the patient and the infusion system for:
   a. Integrity of the infusion equipment.
   b. Patient’s ability to move (i.e., transfer/ambulate) safely with infusion.
   c. Alarms: Respond in a timely manner.
8. Change solution container, administration set, and add-on device in accordance with INS Standards.
Product Selection and Evaluation, and Problem Reporting

Product Selection and Evaluation
The nurse plays an important role in product selection and evaluation. Ongoing evaluation of new products and those products in current use is important in the delivery of high-quality patient care. Participation in product evaluation is an ongoing responsibility of nurses and other clinicians.

Product Problem Reporting
The FDA regulates products in the United States, including over-the-counter and prescription drugs and pharmaceuticals, food, cosmetics, veterinary products, biological devices, and medical devices. A medical device is defined as any instrument, apparatus, or other article that is used to prevent, diagnose, mitigate, or treat a disease or to affect the structure or function of the body, with the exception of drugs.

Inappropriate use of medical devices may contribute to adverse events. The act of “jerry-rigging” or otherwise manipulating a device to overcome a small problem can result in liability for problems arising from use of that equipment in the institution. For example, as discussed earlier in relation to smart infusion pumps, the problem of bypassing the drug library is a concern because the computer software will not be able to identify potential errors. The responsibility shifts to the institution when a practitioner interferes with the design/use of a piece of equipment.

Nurses use many medical devices and are usually the primary reporters of device problems. The Safe Medical Devices Act of 1990 imposed significant reporting requirements on the medical device industry and users of medical devices. Medical device reporting is the mechanism for the FDA to receive information about adverse events from manufacturers and user facilities (e.g., hospitals and nursing homes). As discussed earlier, the reporting of adverse events associated with infusion pumps led to the FDA’s 2010 initiative to improve infusion pump safety. Any deaths related to the medical device must be

Table 5-3 Guidelines for Selecting a Flow-Control Device

<table>
<thead>
<tr>
<th>Type of Infusion</th>
<th>Flow-Control Device</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower-risk infusions (e.g., antibiotics, simple fluid administration)</td>
<td>Simple roller clamp</td>
</tr>
<tr>
<td></td>
<td>Manual flow regulators</td>
</tr>
<tr>
<td></td>
<td>Elastomeric devices</td>
</tr>
<tr>
<td></td>
<td>Spring-based devices</td>
</tr>
<tr>
<td>Infusions that require precise flow control (e.g., parenteral nutrition, vasoactive medications, opioid infusions)</td>
<td>Electronic infusion devices (EIDs)</td>
</tr>
<tr>
<td>Same as above</td>
<td>EIDs with dose-error reduction software</td>
</tr>
<tr>
<td>High-alert medication infusions</td>
<td></td>
</tr>
</tbody>
</table>

References: Gorski et al., 2017; ISMP, 2017.
reported to both the FDA and the device manufacturer, whereas serious injury (life-threatening, permanent functional impairment/body structure damage, intervention required to prevent damage) must be reported to the device manufacturer (FDA, 1996).

Nurses play a critical role in reporting adverse events. Certainly, not all medical device problems are serious as defined by the FDA, but many are significant to clinical practice. The following are examples of medical device problems related to infusion therapy practice:

- Loose or leaking catheter hubs
- Defective infusion pumps
- Misleading labeling
- Inadequate packaging
- Cracked or leaking I.V. solution bag

When a device failure is noted, it is important to follow the following steps:

1. Identify previously recorded lot numbers and expiration dates of products.
2. If possible, retain sample and return to manufacturer to aid in investigation of failure.
3. Complete an unusual occurrence report.
4. Inform the supervisor.
5. Notify the risk management department.

It is the responsibility of the organization's risk management department to notify the manufacturer and the FDA. Completion of these steps satisfies the legal requirement of identifying and reporting products that may have caused a patient harm.

**INS Standard** Infusion equipment and supplies are inspected for product integrity and functionality before, during, and after use as determined by verification of inspection or expiration date and visual inspection of the product. If a product is expired, its integrity compromised or found defective, the clinician removes it from patient use, labels it as expired or defective, and reports it according to organizational policies and procedures (Gorski et al., 2016a, p. S32).

**Websites**
www.fda.gov/MedicalDevices/Safety/ReportaProblem/default.htm#1
www.ecri.org/PatientSafety
Home Care Issues

Equipment and supplies used in home infusion therapy include:

- Vascular access devices (VADs) or alternative infusion devices such as subcutaneous access devices or intraspinal catheters: common VADs used in home-care peripherally inserted central catheter (PICC) and midline peripheral catheters
- Infusion administration supplies: I.V. administration sets, needleless connectors, alcohol wipes, site care kits including antiseptic agent, sterile gloves, mask, dressings, and tape
- Infusion delivery systems: syringe pumps, elastomeric infusion pumps, ambulatory pumps
- Premixed medications including prefilled saline/heparin syringes for flushing

Ambulatory infusion pumps are designed to allow the patient maximum portability and freedom of movement. The aim is small, quiet, lightweight infusion pumps with pouches that enclose both the pump and the infusion container. Equipment and supplies used at home offer safety features, as the patient or a caregiver is expected to participate in the patient’s care.

It is important to assess factors that affect the patient’s ability to learn how to use and safely manage life with an infusion pump. Various factors may affect the ability to learn, including physical status (e.g., pain, weakness, fatigue), mental status (e.g., stress, diagnosis), manual dexterity and coordination, cognition (e.g., forgetfulness), willingness to learn, and literacy. Problematic issues should be addressed in the plan of care; involvement of a willing caregiver may be appropriate. Environmental factors may affect learning and success of home infusion therapy. Some examples include the following:

- Poor lighting affects ability to see pump display.
- Noise and/or hearing impairment affects ability to hear alarms.
- Clutter may affect ability to maneuver within home and to protect pump from food and drink.

The home-care nurse must address such challenges and consider ways to mitigate home/patient limitations (Gorski, 2017).

NOTE: Reimbursement is an important issue to be addressed while planning for home care. The home-care agency and the home infusion pharmacy are resources for reimbursement questions and will assess and verify reimbursement sources, and potential patient co-payments, before providing home care. There may be limits on the number of home visits that the insurance company will cover.
Patient Education

Patient education in all care settings is necessary for patient safety and for decreasing anxiety related to the use of equipment. Document the patient and family understanding of the education. The following are important in equipment education:

- Preparation and administration of therapy.
- Expected patient outcomes and any potential problems associated with using the equipment.
- How to operate equipment, as appropriate, followed by return demonstrations.
- Pump alarms and actions to take.
- Using the demand dose function with PCA pumps for pain control.
- For home-care patients: 24-hour telephone number (home-care agency, home infusion pharmacy) to call about problems or issues related to the infusion or access device.

Nursing Process

The nursing process is a six-step process for problem-solving to guide nursing action. Refer to Chapter 1 for details on the steps of the nursing process. The following table focuses on nursing diagnoses, nursing outcomes classification (NOC), and nursing interventions classification (NIC) for patients using infusion equipment. Nursing diagnoses should be patient specific and outcomes and interventions individualized. The NOC and NIC presented here are suggested directions for development of outcomes and interventions.

<table>
<thead>
<tr>
<th>Nursing Diagnoses Related to Management of Infusion Equipment</th>
<th>Nursing Outcomes Classification (NOC)</th>
<th>Nursing Interventions Classification (NIC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anxiety (mild, moderate, or severe) related to:</td>
<td>Anxiety level, anxiety self-control, coping</td>
<td>Anxiety reduction techniques</td>
</tr>
<tr>
<td>Situational crises (new equipment technology); role function; environment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deficient knowledge related to: Equipment:</td>
<td>Knowledge: Treatment procedure; treatment regimen (equipment use)</td>
<td>Teaching: demonstrate equipment with return demonstration, assess ability and readiness to learn</td>
</tr>
<tr>
<td>Unfamiliarity with information resources, cognitive limitation, and information misinterpretation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Injury, risk for (external) related to: Physical environmental conditions: physical barrier (e.g., infusion pump/pole)</td>
<td>Patient safety behavior</td>
<td>Patient identification</td>
</tr>
<tr>
<td>Safe home environment Knowledge: fall prevention</td>
<td>Effectiveness of communication</td>
<td></td>
</tr>
<tr>
<td>Medication safety Education on equipment</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Ackley, Ladwig, & Makic, 2017.
Chapter Highlights

- Solution containers include glass containers, plastic containers, syringes, and infusion pump–specific containers.
- Administration sets include primary continuous and secondary sets and a variety of specialty sets for specific types of infusions (e.g., infusion pump specific, lipids, blood administration, nitroglycerin).
- Add-on devices include extension sets, stopcocks, catheter connection devices (e.g., J loop), manifolds, filters, and needleless connectors. Their use should be based on need, as their use is associated with increased manipulation of the infusion system (risk for contamination/infection) and increased risk for disconnections.
- Needleless connectors include negative and positive displacement NCs and neutral NCs. It is important to understand the type of NC used to reduce the risk for blood reflux and thus thrombotic occlusion. Disinfection of NCs is an important problem. They must be disinfected prior to each access. Disinfection caps may be placed on the NC for continuous disinfection.
- Filters may be used to remove particulate matter, air, microorganisms, and endotoxins. They are routinely used in blood transfusions, intraspinal infusions, and with parenteral nutrition and lipid infusions.
- Peripheral I.V. catheters include:
  - Stainless steel winged needles: for single-dose infusions; odd-numbered gauges
  - Over-the-needle SPCs: most common type of device used; even-numbered gauges
  - Midline catheters: used for peripherally compatible infusion therapies expected to last for longer than 1-2 weeks
  - Long peripheral catheters, between an SPC and a midline, that may be placed via different techniques such as modified or accelerated Seldinger
- Flow-control device refers to any instrument used to regulate infusion flow rate; the main categories include manual devices (e.g., roller clamp), mechanical and electronic infusion devices (EID).
  - Mechanical infusion devices: nonelectric methods such as mechanical flow devices and elastomeric infusion pumps.
  - EIDs are used in I.V. infusions as well as with subcutaneous, arterial, and epidural infusions, providing an accurate flow rate and alarms that signal problems with the infusion.
  - Multichannel pumps: EIDs that can deliver several medications and fluids simultaneously.
  - Ambulatory infusion pumps: EIDs that can be carried in a pouch; used primarily in home infusion therapy.
  - Smart pumps: EIDs with an embedded computer system, including a drug library.
- The nurse plays an important role in product selection and evaluation. Participation in product evaluation is an ongoing responsibility of nurses and other clinicians.
• Nurses use many medical devices and are usually the primary reporters of device problems.

The Safe Medical Devices Act of 1990 imposed significant reporting requirements on the medical device industry and users of medical devices. Medical device reporting is the mechanism for the FDA to receive information about adverse events from manufacturers and user facilities (e.g., hospitals and nursing homes).

**Thinking Critically: Case Study**

A 45-year-old postoperative hysterectomy patient has an order to convert her continuous I.V. to a Luer-activated needleless connector.

**Case Study Questions**

1. What are the steps in flushing this device? Note: Refer to Chapter 6 for procedure.
2. What infection prevention technique should be used prior to accessing the needleless connector with each catheter access?

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**References**

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Chapter 6
Peripheral I.V. Catheters:
Initiation and Maintenance
of Peripheral Infusion Therapy

LEARNING OBJECTIVES
After completing this chapter, the reader will be able to:

1. Define the terms related to peripheral venous access.
2. Describe pertinent anatomy and physiology related to skin and to the venous system.
3. Differentiate between a short peripheral I.V. catheter and a midline catheter.
4. Identify peripheral veins appropriate for venipuncture in infants, children, and adults.
5. Explain the use of visualization technologies in vein identification.
6. Describe pharmacological and nonpharmacological strategies used to reduce pain during peripheral I.V. catheter insertion.
7. Discuss cultural implications relative to peripheral catheter placement.
8. Discuss the importance of skin preparation and adherence to aseptic technique in reducing the risk for infection.
9. Calculate a drop rate for a gravity infusion.
10. Outline key areas for documentation related to peripheral infusion therapy.
11. Summarize anatomic and physiological characteristics in neonates, children, and older adults that impact catheter placement and infusion therapy.
12. List the 16 steps of the Phillips’ approach for initiating peripheral-short infusion therapy.

Glossary

Bevel Slanted edge on opening of a needle or cannula device
Cannulation Introduction of a tube (e.g., I.V. catheter) through a passage (e.g., vein)
Dermis  The layer of the skin immediately below the epidermis; composed of connective tissue, blood vessels, nerves, muscles, lymphatics, hair follicles, and sebaceous/sweat glands

Distal  Farther from the heart; farthest from the point of attachment (below the previous site of cannulation)

Drop factor  The number of drops needed to deliver 1 mL of fluid

Endothelium  The single layer of cells lining the blood vessels and heart

Epidermis  The outermost layer of skin covering the body, which is composed of squamous cells and is devoid of blood vessels

Gauge  Size of a cannula (catheter) opening; gradual measurements of the outside diameter of a catheter

Macrodrop  I.V. tubing with a drop factor of 10 to 20 drops/mL

Microabrasion  Superficial break in skin integrity that may predispose the patient to infection

Microdrop  I.V. tubing with a drop factor of 60 drops/mL

Midline Catheter  A longer peripheral catheter placed in the peripheral veins, generally inserted above the antecubital fossa, with the catheter tip inserted via the basilic, cephalic, or brachial vein and the tip located below the axillary line. In infants, a midline may be placed in a scalp vein with the tip terminating in the external jugular vein.

Palpation  Examination by touch

Peripheral intravenous catheter (PIV)  General term used to describe a catheter inserted into the peripheral veins for delivery of short-term infusion therapies; includes “short” peripheral catheter (SPC), long peripheral catheters, and midline peripheral catheters

Prime  To flush the air from the administration set or any add-on devices (e.g., needleless connector) with a solution before use

Proximal  Nearest to the heart; closest point to attachment (above the previous site of cannulation)

Purpura  Discolorations on skin that do not blanch; may be caused by bleeding underneath skin

Spike  A sharp object (piercing pin) used to puncture an object (e.g., a bag of I.V. fluid), permitting fluids within the object (bag) to flow out

Transillumination  Passage of light through a solid or liquid substance for diagnostic examination


text

Introduction

The peripheral intravenous catheter (PIV) is the most commonly used invasive device among hospitalized patients. As discussed in the previous chapter, peripheral catheters traditionally included both the “short” peripheral catheter (SPC) and the midline peripheral catheter, and both of these devices are addressed in this chapter. It is also important to understand that there are an increasing number
of PIV products, including those that fall between the SPC and the midline, sometimes called “extended dwell” catheters in marketing information. These catheters, along with midlines, are generally placed by specially trained nurses or other clinicians who are often part of an infusion or vascular access team. Placement techniques include either a traditional over-the-needle insertion technique or an advanced placement technique such as modified or accelerated Seldinger technique (described in Chapter 5), often in conjunction with ultrasound guidance. Longer peripheral catheters are generally required for peripheral access in deeper veins of the upper arm in order to have a sufficient length of catheter within the vein (Gorski et al., 2016a). They are also increasingly placed in forearm veins.

The SPC is commonly placed by non-specialty nurses across all health care settings, and the risks associated with peripheral access are often underestimated. Based upon a review of the literature, peripheral I.V. catheters “fail” 35% to 50% of the time (Helm, Klausner, Klemperer, Flint, & Huang, 2015) with complications that lead to pain, patient dissatisfaction, depletion of venous access, and the cost of treating minor and major complications. The incidence of such complications is decreased when attention is paid to device and site selection, proper skin antisepsis, adherence to aseptic technique, and ongoing monitoring as addressed in this chapter.

**Anatomy and Physiology Related to I.V. Practice**

Placement of peripheral intravenous (PIV) catheters requires the nurse to understand the anatomy and physiology of the skin and venous system and physiological responses of veins to heat, cold, and stress. It is also important to become familiar with skin thickness and consistency at various sites to perform venous access proficiently.

**Skin**

The skin is the largest organ of the body, and it performs major functions including protection, temperature regulation, metabolism, sensation, synthesis (e.g., synthesis vitamin D), and communication (Baranoski, Ayello, Tomic-Canic, & Levine, 2012). The skin consists of two main layers, the epidermis and the dermis, which overlie the subcutaneous tissue, which is also called the hypodermis. The epidermis, composed of squamous cells that are less sensitive than underlying structures, is the first line of defense against infections. It is thin, varying between 0.05 and 1.0 mm, and is an avascular layer (Thayer, 2012). The epidermis repairs and regenerates itself every 28 days (Baranoski et al., 2012). Two types of cells are common to the epidermis: Merkel and Langerhans. Merkel cells are receptors that transmit stimuli to axons through a chemical synapse. Langerhans cells are believed to play a significant role in cutaneous immune system reactions. The epidermis is thickest on the palms of the hands and soles of the feet and is thinnest on the inner surfaces of the extremities. Thickness varies with age and exposure to the elements, such as wind and sun.
It is also important to recognize that there are many microbes that live on the epidermis including *Staphylococcus*, *Corynebacterium*, *Propionibacterium*, and many others. These normal flora are protective through competitively inhibiting less desirable organisms (Thayer, 2012).

**NURSING FAST FACT!**

Prior to placing any vascular access device, skin antisepsis and hand hygiene are critical steps in minimizing skin microbes (of both patient and health-care provider) and in preventing device-associated infection.

The dermis, a much thicker layer, is located directly below the epidermis. The dermis consists of blood vessels, hair follicles, sweat glands, sebaceous glands, small muscles, and nerve endings. As with the epidermis, the thickness of the dermis varies with age and physical condition. The skin is a special-sense touch organ, and the dermis reacts quickly to painful stimuli, temperature changes, and pressure sensation. As a result of the extensive network of nerves in the dermal layer, the patient feels pain during the venipuncture procedure.

The hypodermis, or subcutaneous tissue, attaches the dermis to underlying structures. Its function is to promote an ongoing blood supply to the dermis (Baranoski et al., 2012). The hypodermis consists primarily of adipose tissue, which provides a cushion between the layers of the skin, bones, and muscles (Fig. 6-1).
Sensory Receptors

There are five types of sensory receptors, four of which are important in relation to infusion therapy. The sensory receptors transmit along afferent fibers. Many types of stimulation, such as heat, light, cold, pain, pressure, and sound, are processed along the sensory receptors. Sensory receptors related to infusion therapy include:

1. Mechanoreceptors, which process skin tactile sensations and deep tissue sensation (e.g., palpation of veins, placement of dressings, tape placement and removal)
2. Thermoreceptors, which process cold, warmth, and pain (e.g., warm compresses)
3. Nociceptors, which process pain (venipuncture)
4. Chemoreceptors, which process osmotic changes in blood and decreased arterial pressure (decreased circulating blood volume)

NURSING FAST FACT!

To decrease pain during venipuncture, keep the skin taut by applying traction and move quickly through the skin layers.

Nerves

When planning to place a PIV, it is important to recognize that certain sites are associated with a greater risk for nerve injury that can result in permanent damage. These sites include:

- The cephalic vein at the wrist due to proximity to the radial nerve. The radial artery, radial nerve, and cephalic vein are very superficial in this area. Anatomic studies of the wrists/forearms of cadavers demonstrated that the radial nerve can be found in variable locations along the cephalic vein and that the nerve crosses over the vein up to three times in the first several inches above the thumb (Samarakoon et al., 2011; Vialle et al., 2001). These researchers suggest that the cephalic vein above the styloid process of the radius should be avoided for the first 8 to 12 centimeters (~3–5 inches).
- The antecubital fossa due to proximity to the median, anterior interosseous, and antebrachial nerves. The median nerve is the largest nerve
in the arm; it is located in the center of the antecubital fossa. Placement of a PIV into the antecubital area, along with phlebotomy procedures, can result in nerve damage.

- The palm side of the wrist due to proximity to the median nerve, which advances from the antecubital fossa down the central inner aspect of the forearm into the inner aspect of the wrist, branching into the palm of the hand (Drake, Vogl, & Mitchell, 2015).

### Venous System

Two series of blood vessels distribute blood to the capillaries (via the arteries) and return blood to the heart (via the veins): pulmonary and systemic. The systemic circulation, particularly the veins of the systemic circulation, is the focus of PIV placement and infusion therapy.

The walls of arteries and veins consist of three layers: the tunica intima (innermost layer), the tunica media (middle layer), and the tunica adventitia (outer layer) (Capriotti & Frizzell, 2016) (Fig. 6-2). Veins are thinner and less muscular than arteries (Table 6-1). The wall of a vein is only 10% of the total diameter of the vessel, compared with 25% of the artery. Thus the vein can distend easily, allowing for storage of large volumes of blood under low pressure. Approximately 75% of the total blood volume is contained in the veins.

#### Tunica Adventitia

The outermost layer, called the tunica adventitia, consists of connective tissue that surrounds and supports a vessel. The blood supply of this layer, called the vasa vasorum, nourishes both the adventitia and media layers. Sometimes during venipuncture, you can feel a “pop” as you enter the tunica adventitia.

#### Tunica Media

The middle layer, called the tunica media, is composed of muscular and elastic tissue with nerve fibers for vasoconstriction and vasodilation. The tunica media in a vein is not as strong and rigid as it is in an artery, so it tends to collapse or

---

**Figure 6-2** Anatomy of a vein. (Courtesy of Medical Economics Publishing, Montvale, NJ, with permission.)
distend as pressure decreases or increases. Stimulation by change in temperature or mechanical or chemical irritation can produce a response in this layer. For instance, cold blood or solutions can produce spasms that impede blood flow and cause pain. Application of heat promotes dilation of the vein, which can relieve a spasm or improve blood flow.

### Tunica Intima

The innermost layer, called the tunica intima, has one thin layer of cells, the **endothelium**. The surface is smooth, allowing blood to flow through vessels easily. The endothelial cells of the tunica intima can be easily damaged by various I.V. insertion- and care-related factors, such as too rapid catheter advancement, insertion of a catheter too large for the vein, catheter motion caused by inadequate catheter stabilization, microorganisms entering the vein during cannulation because of inadequate site antisepsis, and infusion of irritating solutions (see Chapter 9 for complications).

Valves can be found in most veins, except very small and very large ones. Valves, made up of endothelial leaflets, help prevent the distal reflux of blood. Valves occur at points of branching, producing a noticeable bulge in the vessel when veins are distended, for example, when a tourniquet is applied. There are no diagrams listing specific locations for valves within superficial veins used for venipuncture because there is great variation among individual patients. The significance of valves may be recognized when blood withdrawal is attempted. The valves may compress and close the vein lumen during the process of aspiration, thus not allowing a blood return.

Blood flow via the veins is slower in the periphery and increases in turbulence in the larger veins of the thorax. This increased flow rate is an important aspect in administering hypertonic fluids because they should be administered in larger veins. The following is the amount of blood flow in milliliters per minute through each of the major veins used to deliver I.V. solutions:

- Cephalic and basilic veins: 45 to 95 mL/min
- Subclavian vein: 150 to 300 mL/min
- Superior vena cava: 2000 mL/min

<table>
<thead>
<tr>
<th>Table 6-1</th>
<th>Comparison of Artery and Vein</th>
</tr>
</thead>
<tbody>
<tr>
<td>Artery*</td>
<td>Vein*</td>
</tr>
<tr>
<td>Thick-walled</td>
<td>Thin-walled</td>
</tr>
<tr>
<td>Wall is 25% of total diameter</td>
<td>Wall is 10% of total diameter</td>
</tr>
<tr>
<td>Pulsates</td>
<td>Greater distensibility</td>
</tr>
<tr>
<td>Lacks valves</td>
<td>Valves present</td>
</tr>
</tbody>
</table>

*Has three tissue layers: tunica intima, tunica media, and tunica adventitia.*
**Veins of the Hands and Arms**

The venous system of the hands and arms is abundant, with acceptable veins for PIV catheter placement (Figs. 6-3 and 6-4). Veins used for insertion of PIV catheters are the superficial veins in the hand and forearm.

- The *metacarpal* veins located on the dorsum of the hand are easily visualized, palpated, and accessible. Their use may be limited because of excessive fat in infants and loss of subcutaneous tissue and skin turgor in older adults. Use of the metacarpal veins is not a first choice, especially when it is expected that the patient will require several days of infusion therapy.
- The *cephalic* vein follows along the radius side of the forearm; it is a larger vein and relatively easy to access. The *accessory cephalic* vein branches off the cephalic vein along the radius.
- The *basilic* vein follows along the ulnar side of the forearm to the upper arm; it is easily palpated but moves more easily, so it is important to stabilize the vein with traction during access.
- The antecubital veins, including the *median cephalic* (radius side), *median basilic* (ulnar side), and *median cubital* (in front of elbow), are located in the bend of the elbow. These large veins should be reserved for blood sampling and emergency, rather than routine placement of a PIV.

*Figure 6-3* Superficial veins of the dorsum of the hand. (Courtesy and © Becton, Dickenson and Company.)
Table 6-2 summarizes information on identifying and selecting the most effective I.V. site for clinical situations.

**Approaches to Venipuncture: Phillips’ 16-Step Peripheral-Venipuncture Method**

Performing a successful venipuncture requires mastery and knowledge of infusion therapy as well as psychomotor clinical skills. The Phillips’ 16-step venipuncture method, outlined in Table 6-3 and explained in detail in this chapter, is an easy-to-remember step approach for beginning practitioners.

**NOTE:** Current INS Standards (Gorski et al., 2016a) are integrated throughout the 16 steps.

**Precannulation**

Before initiating the I.V. cannulation, you must follow steps 1 through 5: (1) check the order from the licensed independent practitioner (LIP) (e.g., physician/nurse practitioner), (2) perform hand hygiene, (3) prepare the equipment, (4) assess and prepare the patient, and (5) select the vein and the site of insertion.

**Figure 6-4** Superficial veins of the forearm. (Courtesy and © Becton, Dickenson and Company.)
### Table 6-2 Selecting an Insertion Site for Superficial Veins of Dorsum of Hand and Arm

<table>
<thead>
<tr>
<th>Vein and Location</th>
<th>Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Digital</strong></td>
<td></td>
</tr>
<tr>
<td>Along the fingers</td>
<td><em>Avoid</em> use because of small size and in areas of flexion because of increased risk for infiltration.</td>
</tr>
<tr>
<td><strong>Metacarpal</strong></td>
<td></td>
</tr>
<tr>
<td>Dorsum of the hand formed by union of digital veins between the knuckles</td>
<td>Usually easily visualized&lt;br&gt;Not a first choice&lt;br&gt;Small veins that should be avoided if infusing irritating antibiotics, potassium chloride, or chemotherapeutic agents or if using high rates of infusion</td>
</tr>
<tr>
<td><strong>Cephalic</strong></td>
<td></td>
</tr>
<tr>
<td>Radial portion of the lower arm along the radial bone of the forearm</td>
<td>Large vein, easy to access&lt;br&gt;<em>Avoid</em> area of cephalic vein for about 3-5 inches above the thumb due to risk for nerve damage</td>
</tr>
<tr>
<td><strong>Basilic</strong></td>
<td></td>
</tr>
<tr>
<td>Ulnar aspect of the lower arm</td>
<td>Difficult area to access because of location&lt;br&gt;Large vein, easily palpated, but moves easily (&quot;rolling vein&quot;); stabilize with traction during venipuncture. Often available after other sites have been exhausted.</td>
</tr>
<tr>
<td><strong>Accessory Cephalic</strong></td>
<td>Medium to large size and easy to stabilize&lt;br&gt;May be difficult to palpate in persons with large amounts of adipose tissue. Short length may prohibit cannula use.</td>
</tr>
<tr>
<td><strong>Median Antebrachial</strong></td>
<td><em>Avoid</em> because area has many nerve endings and infiltration occurs easily.</td>
</tr>
<tr>
<td><strong>Median Basilic</strong></td>
<td>Should be reserved for blood draws for laboratory analysis only, unless an emergency situation&lt;br&gt;Uncomfortable placement site because arm is extended in unnatural position&lt;br&gt;Area difficult to splint with arm board</td>
</tr>
<tr>
<td><strong>Median Cubital</strong></td>
<td>Same as above</td>
</tr>
</tbody>
</table>
Step 1: Authorized Prescriber’s Order

An order by an LIP is required to initiate infusion therapy. The order should be clear, concise, and complete. It is also essential that the nurse understand the rationale for the order before proceeding. The order should include:

- Date and time
- Infusate (medication/solution)
- Route of administration
- Dosage
- Volume to be infused
- Rate of infusion
- Duration of infusion
- Signature of authorized prescriber

Evaluation: Appropriateness of Peripheral I.V. or Midline Catheters

At the time of receiving the order, there is opportunity to evaluate whether a peripheral catheter is the best option for the prescribed infusion therapy. One key point related to vascular access device (VAD) selection is that the least invasive VAD that has the greatest likelihood of reaching the end of the planned infusion therapy with the fewest number of replacements and the lowest rate of complications should be selected (Gorski et al., 2016b). A PIV catheter is a less invasive device compared with a central VAD and is often a good choice. However, the anticipated type and duration of infusion therapy
may make the initial choice of a central line (Chapter 8) appropriate, as some infusion therapies are not appropriate for peripheral administration. INS recommendations state that short PIVs or midline catheters should not be placed for administration of continuous vesicant therapy, parenteral nutrition, or infusates with an osmolarity greater than 900 mOsm/L (Gorski et al., 2016a, p. S51).

Today, there is increasing use of midline catheters across all health-care settings. These catheters are generally placed in the upper arm via the basilic, cephalic, or brachial vein, and the internal catheter tip is located at or near the level of the axilla and distal to the shoulder (Gorski et al., 2016a, p. S152). Advantages of midline catheters include longer dwell times due to placement in larger veins, which allows for improved hemodilution of infusates. Typical infusates include antimicrobial drugs, fluid replacement, and analgesics. Midline catheters are generally placed by nurses who are specially trained in placement using ultrasound.

When peripheral administration is appropriate, consensus-based recommendations (Chopra et al., 2015) provide suggestions for short PIVs and midlines based upon the following time frames:

- Choose a short PIV for 5 or fewer days of infusion
- Choose a midline catheter for infusions anticipated to last up to 14 days. Although guidelines suggest placement based on 14 days of need, in many cases midline catheters remain functional for longer periods of time and are removed when clinically indicated (e.g., infiltration, phlebitis) or when no longer needed for infusions.

**Step 2: Hand Hygiene**

Appropriate and adequate hand hygiene is one of the most important steps in reducing the risk for VAD-related infections. Hand hygiene is performed both before and after palpating catheter insertion sites and inserting, replacing, accessing, repairing, or dressing an intravascular catheter (see Chapter 2 for more information).

**Step 3: Equipment Collection and Preparation**

In preparation for short PIV placement and delivery of a primary or secondary solution:

- Gather ordered medication/solution, appropriate administration set, catheters, stabilization device, dressing, gloves, and skin antiseptic solution. Prepackaged PIV start kits provide the advantages of most of the needed supplies (antiseptic, dressing, gloves, tourniquet, tape) in clean packaging.
- Inspect the infusate container. In today's practice, two types of infusion containers are available: glass and plastic (rigid or soft). Glass containers are used infrequently and primarily with medications that can be absorbed by plastic.
To check the glass container:
- Hold the container up to the light to inspect for cracks as evidenced by flashes of light.
- Rotate the container and look for particulate contamination and cloudiness.
- Inspect the seal and check the expiration date.

To check a plastic container:
- The outer wrap of the plastic container should be dry.
- Gently squeeze the soft plastic infusion container to check for breaks in the integrity of the plastic; squeeze the system to detect pinholes.
- Inspect the solution for any particulate contamination. Check the expiration date.

If the order is for an intermittent infusion device:
- Gather catheters, start kit, stabilization device, needleless connector, and a prefilled syringe of sodium chloride for PIV catheter flushing.

Choose the correct administration set to match the solution delivery system. For the closed glass container, a vented administration set must be used; for the plastic container, a nonvented set should be used (see Chapter 5 for more detailed information on I.V. equipment). The solution container is “spiked” and “primed” just prior to placement of the PIV. Spiking and priming are shown in Figure 6-5.

Figure 6-5  A, Spiking; and B, priming plastic system.
Step 4: Patient Identification and Psychological Preparation

The 2017 National Patient Safety Goals by the Joint Commission (2017) state that the clinician must use at least two patient identifiers (neither to be the patient’s room number) whenever providing treatments or procedures. Examples of patient identifiers include name, an assigned identification number, and birth date. The use of bar-coding medication administration systems, where the patient’s wristband is scanned for appropriate identification, is now commonplace with 88% of U.S. hospitals implementing such technology in 2014 (Pedersen, Schneider, & Scheckelhoff, 2015).

Psychological preparation includes patient education prior to PIV placement and should address the purpose of placement and expectations in terms of the procedure. Instruct the patient regarding what type of medication/solution was ordered by the LIP and why it was ordered, any mobility limitations, and signs and symptoms of potential complications. Provide the opportunity for the patient to ask any questions. Evaluate the patient’s psychological preparedness for the PIV procedure before venous access. Consider aspects such as autonomy, handedness, and independence, along with invasion of personal space when I.V. placement is necessary. Often the patient has a fear of pain associated with venipuncture or the memory of a previously negative encounter related to necessity of the therapy. Make sure to assess and document fears and preferences related to pain management.

It is important to make sure that the patient is in a comfortable position, that privacy is ensured, and that the environment is conducive for the nurse to maintain aseptic technique and place the PIV. Good lighting for venous assessment and PIV placement is essential. When placing a PIV in the home setting, creating a good environment can be challenging. Often, the kitchen table works well because the lighting is good and the surface can be cleaned for placement of supplies.

Step 5: Site Selection, Vein Dilation, and Visualization Technologies

Site Selection

Site selection is based on a thorough assessment of the patient’s condition, age, diagnosis, vascular condition, history of previous access devices, and type and anticipated duration of therapy.

Expected outcomes in relation to appropriate site placement include the following:

- The site must tolerate the rate of flow (e.g., high flow rates, use larger veins).
- The site must be capable of delivering the medications or solutions ordered.
- The site must tolerate the gauge of cannula needed.
- The patient must be comfortable with the site chosen.
- The site must be one that least limits the patient’s activities of daily living.
- The site must be one with reduced risk for complications (e.g., avoid areas of flexion).
Traditional practice has been to begin placement of the PIV in the hand and then move up the arm for subsequent placements and to rotate sites based upon an established time frame, for example, every 96 hours. Today, research supports site rotation based upon clinical indications and new recommendations in the site selection process. Current INS recommendations are to “use the venous site most likely to last the full length of the prescribed therapy using the forearm to increase dwell time, decrease pain during dwell time, promote self-care, and prevent accidental removal and occlusions” (Gorski et al., 2016a, p. S54). Advantages to forearm placement include the presence of larger veins, where there is better hemodilution of the infusion solution (especially advantageous with irritating fluids such as potassium chloride and certain antibiotics) and thus less irritation to the vein wall, less movement (i.e., away from an area of flexion), ease of stabilization, and less interference with activities of daily living. Some guidelines in vein choice include the following:

1. For pediatric infusion, additional site selection can include the veins of the scalp and lower extremities (see the section in this chapter on Pediatric Infusion Therapy).
2. When subsequent PIV placement is required, placement should always be above the previously placed PIV.
3. Consideration should be given to use of visualization technologies that aid in vein identification including transillumination, near-infrared (nIR), and ultrasound (discussed later in this chapter and also in Chapter 5).
4. Areas to avoid include:
   a. Veins of the lower extremities; these should not be used in the adult population because of risk of embolism and thrombophlebitis
   b. Compromised veins, such as those that are hard and sclerosed
   c. Areas of flexion, such as the wrist or elbow, because of increased risk of infiltration and phlebitis; in the case of the antecubital fossa, PIV placement interferes with blood sampling, is associated with risk for nerve injury, and may prevent the use of those veins if a peripherally inserted central catheter (PICC) or midline catheter is required (Fig. 6.6)
   d. Cephalic vein above the thumb because of the potential for nerve damage
   e. The ventral surface (inner aspect) of wrist because of pain on insertion and possible nerve damage
   f. The affected extremity when there is evidence of cellulitis, presence of an arteriovenous fistula, history of axillary lymph node dissection (e.g., breast surgery), affected extremity from a stroke, or history of radiation therapy to that side

If there has been an inadvertent infiltration or extravasation of infusate(s), there should be further evaluation to determine the continued appropriateness of a PIV for the prescribed infusion therapy (e.g., infusate characteristics such as irritants or vesicants, extended need for infusion therapy). A central line may
be a better option in some circumstances. Some additional considerations include the following:

1. Blood pressure cuffs or tourniquets should not be used during periods of infusion on an extremity with an indwelling peripheral catheter.
2. Although PIVs are not used routinely for blood drawing and evidence is limited regarding the impact of dwell time with blood sampling, laboratory test results have shown PIVs to be reliable for many routine blood tests, including coagulation studies. Use of PIVs for blood draws, and thus avoidance of venipuncture for blood draws, is considered for pediatric patients, those who require serial laboratory tests, those with risk for bleeding, and those with difficult vascular access (Gorski et al., 2016a, p. S87) (See also Chapter 7).

The following factors help nurses make appropriate choices for site selection and are part of the nursing process—assessment.

1. *Condition of the vein:* A soft, straight vein is the ideal choice for venipuncture. Palpate the vein by moving the tips of the fingers down the vein to observe how it refills. When a patient is hypovolemic, peripheral veins collapse more quickly than larger veins.
2. *Patient age:* Infants do not have the accessible sites that older children and adults have because of the infants’ increased body fat. Scalp veins may be used in infants less than 18 months old. Veins in elderly persons
are usually fragile, so approach venipuncture gently and evaluate the need for a tourniquet. The dorsal metacarpal veins in elderly patients are a poor choice because blood extravasation (i.e., hematoma) occurs more readily in small, fragile veins.

3. **Patient preference:** Consider the patient’s personal feelings when determining the catheter placement site. Evaluate the extremities, taking into account the dominant hand.

4. **Patient activity:** Ambulatory patients who use crutches or a walker will need cannula placement above the wrist so that the hand can still be used.

5. **Patients receiving anticoagulation therapy:** Local ecchymoses and hemorrhagic complications are avoided when the nurse is aware that the patient is taking anticoagulant drugs. Venous distention can be accomplished with minimal tourniquet pressure. Use the smallest catheter that will accommodate the vein and deliver the ordered infusate. The dressing must be removed gently using alcohol or adhesive remover. On discontinuation of infusion therapy for patients on anticoagulation therapy, direct pressure should be applied over the site until bleeding has stopped.

**EBP** In studies examining factors associated with *S. aureus* bacteremia and PIVs, patients were more likely to have an infection if the PIV was placed in the antecubital fossa and if it was placed in the emergency department or an outside hospital (Davis, 2014; Stuart et al., 2013; Trinh, 2011).

**NURSING FAST FACT!**

If the veins are fragile or if the patient is taking anticoagulants, avoid using a tourniquet; constricted blood flow may overdistend fragile veins, causing vein damage, vessel hemorrhages, or subcutaneous bleeding.

6. **Patient with allergies:** Determine whether a patient has allergies. For example, iodine allergies must be identified because iodine is contained in some products used for skin antisepsis (povidone iodine). Other allergies of concern to delivery of safe patient care include allergies to lidocaine, medications, foods, animals, latex, and environmental substances.

Table 6-4 provides tips for peripheral vein selection.

**NURSING FAST FACT!**

Always question the patient regarding allergies before administering medications, especially those given by I.V. route. Ask patients about any history of latex allergy.
Cultural and Ethnic Considerations: Performing Infusion Therapy

It is an expectation that nurses deliver culturally sensitive care free of inherent biases based on gender, race, and religion. The American Nurses Association (ANA) Standards of Care address culture as follows:

- Under Standard 3, Outcomes Identification, one of the competencies states, “formulates culturally sensitive expected outcomes derived from assessments and diagnoses” (ANA, 2015, p. 57).
- Under Standard 5, Implementation, one of the competencies addresses healthcare delivery focused on the needs of consumers “and addresses and advocates for needs of diverse populations across the lifespan” (ANA, 2015, p. 61).

Based upon the Giger and Davidhizar (Giger, 2017) model, each individual is accepted as unique and assessed in terms of six cultural dimensions that are evident in all cultural groups:

1. Communication: Language, voice quality, pronunciation, use of nonverbal communication
2. Space: Comfort in conversation, proximity, body movement, perception of space
3. Social organization: Ethnicity, family role function, work, leisure, church, friends
4. Time: Definitions, social/work time, time orientation
5. Environmental control: Health practices, values, definition of health and illness
6. Biological variations: Skin color, body structure, nutritional preferences

In preparing to perform care for patients from different cultures, it is important to remember the following (ANA, 2015; Campinha-Bacote, 2011; Douglas et al., 2011):

- Learn as much as possible about the patient’s cultural customs and beliefs. Encourage the patient to share cultural interpretations of health, illness, and health care.
- Plan care based on cultural assessment and communicated needs.
- Identify sources of discrepancy between the patient’s and your own concepts of health and illness and recognize that they may not be the same.
- Understand that respect for the patient and his or her communication needs is central to the therapeutic relationship.
- Ask permission before you touch the patient.
- Provide resources for translation and interpretation and learn how to effectively work with translators.
- Provide written materials (e.g., patient educational tools, pain scales) in the patient’s preferred language.
- Be alert to words the patient seems to understand and use them frequently.
- Keep messages simple and repeat them.
- Avoid using technical medical terms and abbreviations.

Vein Distention

Most often a tourniquet is used to promote venous distention both as part of the venous assessment process and as part of actual preparation for venipuncture. Factors affecting the capacity for dilation are blood pressure, presence of valves, sclerotic veins, and multiple previous I.V. sites.
Methods to promote venous distention include:

1. **Gravity:** Position the extremity lower than the heart for a minute or two.
2. **Clenching/pumping fist:** Instruct the patient to open and close his or her fist. Squeezing a rubber ball or rolled washcloth works well.
3. **Stroking the vein:** Lightly stroke the vein downward or use light, gentle tapping with index finger to cause dilation of vein.
4. **Warm compresses:** For patients with difficult venous access, application of heat is associated with improvement in cannulation and with less time to gain access; dry heat may be more effective than moist heat (Emergency Nurses Association, 2015).
5. **Blood pressure cuff:** This is an excellent choice for vein dilation. Pump the cuff up slightly (e.g., about 30 mm Hg).

**NURSING FAST FACT!**

When using a blood pressure cuff, care must be exercised not to start the I.V. too close to the cuff, which causes excessive back pressure.

6. **Tourniquet:** Apply the tourniquet 5 to 6 inches above the venipuncture site. It is important that the tourniquet be applied to impede venous flow but not arterial flow; an arterial pulse should be easily palpable distal to the tourniquet. Tourniquets should be applied loosely or not used at all in patients who are at risk for bleeding, who have fragile skin/veins, or who have compromised circulation (Gorski et al., 2016a, p. S64).

**NURSING FAST FACT!**

Tourniquets are single-patient use and should be latex free.
Visualization Technology

In the 2016 INS Standards of Practice, a new Standard entitled Visualization Technology was added (Gorski et al., 2016a). Increasingly, the use of technology is employed to increase PIV cannulation success and decrease the number of cannulation attempts, especially in patients who have difficult venous access. For placement of midline catheters, ultrasound is routinely used for vein identification. Three categories of visualization technology are also described in Chapter 5 and include:

- **Transillumination**: Simply defined as shining a light through tissues. An example is a small, portable battery-operated device that is available for imaging subsurface veins and some structures; this side-transillumination method shines light into the skin from outside the field of view so that the light is pointed toward the center at a depth of approximately 2 cm. Figure 6-7 shows techniques for transillumination. The depth of visualization of veins is between 3 and 6 mm depending on the color of the light used. Advantages to such a device include vein location in darker-skinned and obese patients and in children. Table 6-5 provides information on how to use a transilluminator or penlight.

- **nIR**: Hands-free devices capture an image of the veins and reflect it back to the skin’s surface or to a screen. Superficial veins for PIV placement can be visualized to about 10 mm below the skin surface. Bifurcations and valves may be identified, and the venous pathway can be seen (Gorski et al., 2016a, p. S45). nIR may be a valuable tool, especially for placement of SPCs in the forearm (Fig. 6-8).

- **Ultrasound**: Ultrasonography uses sound waves to locate human bodily structures. The use of ultrasound to identify veins in placement of central VADs and midline catheters is standard practice. The use of ultrasound by nurses to place PIV catheters is increasing, especially for patients with difficult venous access. Venous access is generally difficult in obese patients, and use of ultrasound is associated with improved success rate in this special patient population (Houston, 2013) (see also Chapter 5).

**EBP Evidence-based practice guidelines from the Emergency Nurses Association (2015)**

Recommend the use of ultrasound-guided PIV placement in both adult and pediatric patients with difficult venous access, based on high-level evidence. Ultrasound technique can be performed effectively by nurses, physicians, and emergency department technicians. There was inadequate evidence to support the use of transillumination and near-infrared light. INS acknowledges conflicting evidence for these methods but recommends their consideration in patients with difficult venous access (Gorski et al., 2016a). Research regarding the efficacy of visualization technologies, especially near-infrared use, continues to emerge.
Chapter 6  Peripheral I.V. Catheters

Figure 6-7  Transillumination techniques. A, Tangential lighting using flashlight to illuminate veins of dark-skinned individual. B, Veinlite LED-assisted vein finder. C, Veinlite LED-assisted vein finder. (Courtesy of Translite LLC, Sugar Land, TX.)

<table>
<thead>
<tr>
<th>Table 6-5  Transillumination</th>
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</table>

- Take precautions in patients with alterations in skin surfaces caused by lesions, burns, or a disease process. Patients with altered skin integrity are often photosensitive and need additional protection of their already damaged tissue. This indirect lighting does not flatten veins or cause damage to the skin.
- Use a light directed toward the side of the patient’s extremity to illuminate veins and provide a guide for venipuncture.
- Refer to manufacturer’s guidelines for specific product use.
- Turn down the light in the room.
- Use penlight on the side of the forearm to illuminate any veins.
To enhance vein location, use adequate lighting. Bright, direct overhead examination lights may have a “washout” effect on veins. Instead, use side lighting, which can add contour and “shadowing” to highlight the skin color and texture and allow visualization of the vein shadow below the skin.

**Cultural and Ethnic Considerations: Skin Color**

Skin color is a significant biological variation in terms of infusion nursing practice. When caring for patients with highly pigmented skin, establish the baseline color with good lighting.

Table 6-6 presents a summary of tips for difficult venous access.

**Table 6-6 Techniques to Assist With Difficult Venous Access**

- Alterations in skin surfaces: Use tangential lighting.
- Obesity: Use ultrasonography to locate and cannulate veins.
- Edema: Displace edema with digital pressure.
- Fragile veins: Maintain traction using one-handed technique. Be gentle.
Cannulation

Cannulation involves steps 6 through 11: Paying attention to pain management, selecting the appropriate catheter, gloving, preparing the site, using direct or indirect entry into the vein, stabilizing the catheter, and managing the dressing.

**Step 6: Attention to Pain Management**

Reducing pain during PIV placement is an important aspect of infusion nursing practice. Patient satisfaction is maximized and fear and anxiety are reduced when pain management is addressed. The INS Standards (Gorski et al., 2016a, p. S63) state that local anesthetic agents should be a consideration. Local anesthetic agents include topical vasoconstrictors, intradermal injections (e.g., lidocaine), iontophoresis, pressure-accelerated lidocaine, and topical transdermal agents. Additional interventions include cognitive and behavioral strategies such as distraction and positioning.

**NOTE:** The duration required for anesthetic agents varies depending on the agent used.

**INTRADERMAL INJECTIONS**

Accepted forms of intradermal anesthesia used with I.V. insertion include lidocaine and bacteriostatic normal saline with a benzyl alcohol preservative. The benzyl alcohol is an opium alkaloid that possesses antiseptic and anesthetic properties. Lidocaine has been used in clinical practice since 1948 and is one of the safest anesthetics. Lidocaine is an amide that works by stopping impulses at the neural membrane. The anesthetized site is numb to pain, but the patient perceives touch and pressure and has control of his or her muscles. The anesthetic becomes effective within 15 to 30 seconds and lasts 30 to 45 minutes. Lidocaine can cause a slight burning sensation with initial needle insertion; when the lidocaine is buffered with sodium bicarbonate, this discomfort is reduced. However, buffered lidocaine is not commercially available and must be compounded by the pharmacy, which makes it more costly (Ganter-Ritz, Speroni, & Atherton, 2012). The nurse must have knowledge of the actions and side effects associated with lidocaine. A history of previous allergies precludes the administration of lidocaine.

The procedure for using 1% lidocaine (without epinephrine, buffered lidocaine preferred) before venipuncture is as follows:

1. Review the authorized prescriber's order or the clinical procedure in the facility for use of lidocaine prior to venipuncture.
2. Check for patient allergy and lidocaine sensitivity.
4. Select a suitable vein.
5. Draw up 0.3 mL of 1% lidocaine in a 1-mL TB syringe.
6. Don gloves.
7. Prep the site with antiseptic solution (e.g., chlorhexidine/alcohol for 30 seconds) and allow the site to dry.
8. Insert the needle bevel up intradermally lateral to intended site.
9. Inject the lidocaine to form a wheal at intended insertion site.
10. Continue with Phillips’ step 7 in starting the I.V. (Fig. 6-8).

**Transdermal Anesthetics**

Topical analgesic creams and patches are available by prescription (e.g., EMLA, which contains lidocaine and prilocaine) and over the counter (e.g., ELA-Max). Although transdermal creams are effective, the disadvantage is the time duration until an anesthetic effect (up to 1 hour).

Follow these steps when applying a transdermal cream:

1. Check for allergies to lidocaine.
2. Don gloves.
3. Prepare the intended venipuncture site by washing with mild soap and water.
4. Apply an amount of cream according to the manufacturer’s directions.
5. Place a transparent dressing over the cream.
6. Leave the dressing in place for the recommended time period (usually 45–60 minutes).
7. Remove the occlusive dressing, if one is used; remove the cream by wiping with a clean gauze or tissue. Perform any additional skin preparation or cleaning.

**Iontophoresis**

Iontophoresis refers to the use of a small external electric current to deliver water-soluble, charged drugs into the skin.

**Nonpharmacological Interventions**

The literature addresses contextual, cognitive, and behavioral interventions, particularly in the pediatric population (Ali, McGrath, & Drendel, 2016). Contextual strategies include parental presence and modification of the environment (e.g., low lighting and noise). There is strong evidence for the use of cognitive strategies such as distracting with music, watching cartoons, or playing with toys. Behavioral strategies for neonates and term infants include...
sucrose (e.g., provided on a pacifier) for procedural-based pain including venipuncture (Stevens, Yamada, Ohlsson, Haliburton, & Shorkey, 2016). Reduced pain with PIV placement in pediatric patients was demonstrated in a randomized trial with the use of a vibrating cold device that is applied over a cold pack (Potts, Davis, Elci, & Fein, 2017). Based upon the “gate control” theory, nonpainful input (e.g., cold treatment, vibration) closes the gate to painful input from the venipuncture, preventing pain from traveling up the spinal cord to the brain (Capriotti & Frizzell, 2016).

**Step 7: Catheter Selection**

PIV catheters are available in a variety of gauge sizes and lengths. Recommendations include selecting the smallest-gauge catheter appropriate for the prescribed therapy (Gorski et al., 2016a, p. S51). Small-gauge catheters take up less space in the vein, allowing for blood flow around the catheter; they also cause less trauma when inserted. If a larger-gauge catheter is required, as with emergent care or blood transfusions, a larger vein should be chosen. A 20- to 24-gauge catheter is used for blood transfusions based on the size of the veins. In general, for most applications, a 22- or 24-gauge catheter is selected. Only safety-engineered PIV catheters should be used (see also Chapter 5).

**INS Standard** The VAD selected shall be of the smallest outer diameter with the fewest number of lumens and is the least invasive device needed for the prescribed therapy (Gorski et al., 2016a, p. S51).

Of note, short peripheral catheters are color coded according to an international standard (Table 6-7); midline and central VADs are not.

The tip of the catheter should be inspected for integrity before venipuncture. Note the presence of burrs on the needle, peeling of catheter material, or other abnormalities.

**Step 8: Gloving**

Clean gloves are worn during PIV catheter placement while making sure that the intended insertion site is not touched after skin antisepsis. Should there be a need to repalpate the vein after skin antisepsis, sterile gloves are required.

<table>
<thead>
<tr>
<th>Table 6-7</th>
<th>Catheter Gauge and International Color Codes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gauges</td>
<td>Color Code</td>
</tr>
<tr>
<td>16-gauge</td>
<td>gray</td>
</tr>
<tr>
<td>18-gauge</td>
<td>green</td>
</tr>
<tr>
<td>20-gauge</td>
<td>pink</td>
</tr>
<tr>
<td>22-gauge</td>
<td>blue</td>
</tr>
<tr>
<td>24-gauge</td>
<td>yellow</td>
</tr>
<tr>
<td>26-gauge</td>
<td>violet</td>
</tr>
</tbody>
</table>
INS Standard  Standard precautions are used during all infusion procedures that potentially expose the clinician to blood and body fluids, secretions except sweat, nonintact skin, and mucous membranes that may contain transmissible infectious agents (Gorski et al., 2016a, p. S41).

Step 9: Site Preparation

Several steps are involved in site preparation. If the site is visibly dirty, the skin should be washed with soap and water. If there is excess hair at the site, hair can be clipped using a scissors or disposable-head surgical clippers. Shaving is not recommended because of the potential for microabrasions, which increase the risk of infection.

One of the most critical steps in reducing the risk of infection is site preparation using an antiseptic solution. Skin preparation is important because bacteria on the skin at the insertion site can travel along the external surface of the catheter during PIV catheter insertion. The preferred antiseptic for PIV skin antisepsis is alcoholic chlorhexidine solution; if there is a contraindication, 70% alcohol, tincture of iodine, or an iodophor may be used. Chlorhexidine/alcohol solution has a residual effect on the skin for up to 48 hours. It is important that the skin be allowed to fully dry prior to venipuncture. If not, antiseptic can be tracked into the vein during insertion, which can cause phlebitis or vein inflammation (as discussed in Chapter 9). Allow to air-dry; never blow on, fan, or wipe the site!

NOTE: Antiseptics should be provided in a single-use package.
Chlorhexidine solution is applied using a back-and-forth method for at least 30 seconds and allowed to dry (Fig. 6-9). Povidone iodine must remain on the skin and be allowed to fully dry (about 1.5 to 2 minutes) for adequate skin antisepsis.

NOTE: Alcohol should not be applied after the application of povidone-iodine preparation because alcohol negates the effects of povidone-iodine.

NOTE: Chlorhexidine preparations are used with caution in premature infants and those younger than 2 months due to risks including skin irritation and chemical burns. Povidone-iodine may be used but once dried, it is removed with sterile normal saline or sterile water to prevent absorption of the product through the skin (Gorski et al., 2016a). This is because iodine absorption through the skin may impact thyroid function in infants. However, chlorhexidine preparations are commonly used due to their effectiveness in skin antisepsis and they were reported as the primary skin antiseptic agent used in neonatal intensive care units (Sharp, 2014).

Step 10: Vein Entry
Venipuncture can be performed using a direct (one-step) or indirect (two-step) method. The direct method is appropriate for small-gauge needles and for fragile hand veins or rolling veins. It carries an increased risk of causing a hematoma. The indirect method can be used for all venipunctures. Procedures Display 6-1 at the end of this chapter describes the steps to initiate a peripheral-short infusion by a direct or an indirect technique.

Traction is important to maintain stability of the vein in either a direct or an indirect approach (Fig. 6-10). Figures 6-11 and 6-12 show diagrams of inserting a catheter into a vein, threading the cannula (catheter) into the vein, and removing the stylet.

Figure 6-9 Skin antisepsis prior to peripheral I.V. catheter placement. A, Chloraprep Sepp, which contains 0.67 mL of 2% chlorhexidine gluconate and 70% alcohol. B, Chloraprep Frepp, which contains 1.5 mL. (Courtesy and © Becton, Dickenson and Company.)
Troubleshooting Tips

Common reasons for failure of venipuncture include:

- Failure to release the tourniquet promptly when the vein is sufficiently cannulated
- Use of a “stop and start” technique by beginners who may lack confidence; this tentative approach can injure the vein, causing bruising.
• Inadequate vein stabilization. Not using traction to hold the vein causes the stylet to push the vein aside.
• Failure to recognize that the catheter has gone through the opposite vein wall
• Stopping too soon after insertion so that only the stylet, not the catheter, enters the lumen (intima) of the vein. Blood return disappears when the stylet is removed because the catheter is not in the lumen.
• Inserting the cannula too deeply, below the vein. This is evident when the catheter will not move freely because it is imbedded in fascia or muscle. The patient also complains of severe discomfort.
• Failure to penetrate the vein wall because of improper insertion angle (too steep or not steep enough), causing the catheter to ride on top of or below the vein

**NURSING FAST FACT!**

A single nurse should attempt PIV placement no more than two times with total attempts by any clinician limited to no more than four. The consequences of multiple attempts at placement include pain, delayed treatment, limiting future vascular access, cost, and increased risk for complications. Patients with difficult vascular access require a careful assessment of VAD needs and collaboration with the health-care team to discuss appropriate options (Gorski et al., 2016a, p. S64).

**NURSING FAST FACT!**

When aseptic technique is compromised (e.g., in an emergency situation), the cannula is also considered compromised, and a new catheter should be placed as soon as possible and within 24–48 hours (Gorski et al., 2016a, p. S91).

Safety features on all active safety catheters must be activated according to the manufacturer’s recommendations (Fig. 6-13). Recall that passive safety catheters do not require any activation because the safety features are automatic.

**Step 11: Catheter Stabilization and Dressing Management**

**CATHETER STABILIZATION**

Stabilization of movement at the catheter hub is recognized as an important intervention in increasing the dwell time for PIV catheters and in reducing the risk for phlebitis, infection, catheter migration, and catheter dislodgement. Many nurses equate stabilization with application of a dressing and tape; however, use of a stabilization device is the preferred method (Gorski et al., 2016a, p. S72). Some devices consist of an adhesive pad and a mechanism for holding the catheter to the pad, thus controlling movement at the insertion site (Fig. 6-14).
As for the future of catheter stabilization, preliminary evidence supports the use of tissue adhesives, essentially a drop of “glue” to seal the catheter at the insertion site (Bugden et al., 2016; Marsh et al., 2015).

A stabilization device used with a PIV catheter is attached at the time of catheter placement and removed when the catheter is discontinued. It is important
that the PIV catheter is stabilized in a manner that does not interfere with visualization and evaluation of the site.

**Add-on Devices**

With PIV catheters, typical add-on devices include extension sets, T ports, and J loops. In general, the use of add-on devices should be minimized because their use may increase the risk for accidental disconnections or misconnections (Gorski et al., 2016a, p. S72). However, advantages to their use include an easier transition from a continuous to an intermittent infusion because a needleless connector can be easily attached to the extension with less movement at the catheter site. All add-on devices should be of Luer-lock design to ensure a secure junction. Of note, the use of PIV catheters with an integrated extension tubing avoids the need for add-on devices.

**Joint Stabilization and Site Protection**

As addressed previously, areas of joint flexion should be avoided with PIV placement. However, there are times when this is not possible. In such cases, the joint should be stabilized with an arm board or splint (Gorski et al., 2016a, p. S75). Any joint stabilization device should be applied in a manner that allows ongoing visual assessment of the catheter and vein path. Arm boards may be flat or contoured to fit the extremity and should be padded for comfort. They should support the area of flexion to assist in maintaining a functional position. If tape is used, it should not obstruct the view of the catheter insertion site or impair circulation. When an arm board is used, additional assessment should address skin inspection for any signs of breakdown.

Site protection refers to the methods used to prevent accidental catheter dislodgement. Site protection methods are recommended particularly for pediatric patients or for those with cognitive limitations who may be more likely to touch or manipulate the catheter or dressing. Hiding or disguising the site may decrease the risk of catheter loss. Figure 6-15 shows an example of a site-protection product.

**NOTE:** If an arm board is used for the purpose of stabilizing an area of flexion, it is not considered a restraint.

**Dressing Management**

There are two options for dressings: (1) a gauze dressing secured with tape and (2) a transparent semipermeable membrane (TSM) dressing. Use of a TSM dressing is preferred and is the more prevalent practice, as it allows for continuous inspection of the site. To apply a TSM dressing:

1. Center the transparent dressing over the cannula site and partially over the hub.
2. Press down on the dressing, sealing the catheter site.
3. A piece of tape can be added to loop the administration set tubing, securing it to the skin outside of the dressing (Fig. 6-16).
Dressings on short PIVs are changed if the dressing becomes damp, loosened, and/or visibly soiled and at least every 5 to 7 days, should the peripheral site last that long (Gorski et al., 2016a, p. S82). Figure 6-17 shows a PIV site being dressed with a TSM dressing with an integrated chlorhexidine gel pad. (Courtesy of I.V. House, Inc., Chesterfield, MO.)

**NURSING FAST FACT!**

Do not put tape over the TSM dressing because it will be difficult to remove the dressing if it needs to be changed because of a break in the integrity of the dressing.

Dressings on short PIVs are changed if the dressing becomes damp, loosened, and/or visibly soiled and at least every 5 to 7 days, should the peripheral site last that long (Gorski et al., 2016a, p. S82). Figure 6-17 shows a PIV site being dressed with a TSM dressing with an integrated chlorhexidine gel pad.

**Postcannulation**

**Step 12: Labeling**

Three areas should be labeled: the dressing over the insertion site, the tubing, and the solution container, which can be time-stripped.

1. Label the dressing on the side of the transparent dressing or across the hub. Do not place the label over the site because this obstructs visualization of the site. Include the date performed or the date to be changed (based on organizational procedures) (Gorski et al., 2016b):
2. Label the administration set with date and time according to organizational policy and procedure so that nurses on subsequent shifts will be aware of when the tubing must be changed.
3. Labeling the solution container with a strip of tape or a preprinted strip is still practiced in some organizations. The time strip should be labeled with the time the solution was started.

**Figure 6-16** A and B, Steps in applying transparent semipermeable dressing directly over the I.V. catheter hub and insertion site. C, Label site below transparent semipermeable membrane dressing.

**NURSING FAST FACT!**

Time strips are helpful as a quick method to visually assess whether the solution is on schedule. They are not used in all institutions.
Step 13: Equipment Disposal

All blood-contaminated items and sharps must be discarded in nonpermeable, puncture-resistant, tamperproof biohazard containers (U.S. Department of Labor, n.d.). All devices should have engineered sharps injury protection mechanisms, and these mechanisms should be activated before disposal. Figure 6-18 shows examples of tamperproof biohazard containers.

Figure 6-17 Applying a Tegaderm CHG dressing over a peripheral I.V. catheter. (Courtesy 3M Medical Division, St. Paul, MN.)

Figure 6-18 Tamperproof biohazard containers. (Courtesy and © Becton, Dickenson and Company.)
Step 14: Patient Education

Patient education begins before initiation of infusion therapy with a discussion of the potential complications and the risks and benefits of therapy. After PIV placement, teaching should address:

- Limitations on movement or mobility and protection of the site
- Signs and symptoms to report, including those that may occur after the PIV is removed (e.g., postinfusion phlebitis) and how/where to report them
- Alarms if an electronic infusion device (EID) will be used
- Infection prevention precautions, including hand hygiene by all healthcare providers who provide care

**INS Standard** The nurse shall educate the patient, caregiver, or legally authorized representative about the prescribed infusion therapy and plan of care, including, but not limited to, the purpose and expected outcomes and/or goals of treatment, infusion therapy administration, infusion device-related care, potential complications or adverse effects associated with treatment or therapy, and risks and benefits (Gorski et al., 2016a, p. S25).

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**NURSING FAST FACT!**

Attention should be given to age, developmental (psychosocial as well as psychomotor) and cognitive levels, and cultural and linguistic sensitivity.

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**NURSING FAST FACT!**

It is important to validate the patient’s understanding of and ability to perform infusion-related self-care procedures. Use “teach-back” technique. Ask patients to repeat instructions in their own words, to demonstrate skills back to the nurse. Clarify and correct information if patient is unable to “teach-back” correctly. Repeat and rephrase information as necessary to increase understanding. This may take several times (Agency for Healthcare Research and Quality, 2015).

---

Step 15: Rate Calculations

Infusions are delivered over a specific period of time. Calculating the proper infusion rate for medication and solution delivery is critical. Whereas most infusions are delivered via an EID, others may be delivered via a gravity infusion. All infusions should be monitored frequently for accurate flow rates and complications associated with infusion therapy.

**NOTE:** Practice problems are included in the chapter along with extra practice problems on DavisPlus.
When administering a gravity infusion, calculate the rate of infusion in drops per minute. Factors required to calculate the drop rate are:

1. **Drop factor** of tubing
2. The hourly infusion rate

**Drop Factor of Tubing**

For **macrodrop** sets:

The drop factor of the administration set is usually found printed on the side, front, or back of the administration package. Drop factors provided by the administration set for macrodrop tubing are as follows:

- Primary (macrodrop) sets:
  - 10 drops = 1 mL
  - 15 drops = 1 mL
  - 20 drops = 1 mL

Use macrodrop sets whenever (1) a large amount of fluid is ordered to be infused over a short period of time or (2) the microdrips per minute are too many, making counting too difficult.

**Formula for I.V. Flow Rates Using Drops Per Minute**

After the drop factor of the tubing and the amount of solution to be infused are known, the following formula can be used to calculate the drop rate per minute:

\[
\text{drops per minute} = \frac{\text{mL per hour} \times \text{drops per mL (drop factor [DF])}}{\text{time (minutes)}}
\]

**Macrodrop Infusion.** Example: Orders are for 125 mL/hr, and the primary tubing selected has a drop factor of 15. Two steps are needed.

**Step 1:**

\[
\frac{125 \times 15}{60} = gtt/min
\]

**Step 2:**

= 31 gtt/min

**Microdrop Sets.** All manufacturers of microdrip sets are consistent in having 60 drops = 1 mL.

Pediatric (microdrop) sets:

- 60 drops = 1 mL

Use microdrop sets whenever (1) the I.V. is to be administered over a long period of time, (2) a small amount of fluid is to be administered, or (3) the macrodrops per minute are too few.

**Microdrop Infusion.** When using a microdrip (pediatric tubing) that is 60 drops/mL, the drops per minute equal the milliliters per hour, so only one step is needed.
Example: The LIP orders 35 mL of 0.45% sodium chloride solution per hour for a 2-year-old girl. You would set up your rate calculation as follows, using only one step.

\[
\text{Formula: } \frac{\text{mL/hr} \times \text{DF}}{\text{minutes}} = \text{gtt/min}
\]

\[
\text{Step 1: } \frac{35 \times 60}{60} = \text{gtt/min} = 35 \text{ gtt/min}
\]

**NOTE:** Table 6-8 provides a conversion chart for rate calculation.

### Step 16: Documentation

After implementation of infusion therapy, the procedure should be documented in the medical records. With electronic health records, there are often standardized formats with drop-down options for choices. It is essential to be familiar

<table>
<thead>
<tr>
<th>Table 6-8</th>
<th>Conversion Chart: Rate Calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Drop Factors</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Order (mL/hr)</strong></td>
<td><strong>10 Drops/mL</strong></td>
</tr>
<tr>
<td>10</td>
<td>2</td>
</tr>
<tr>
<td>15</td>
<td>3</td>
</tr>
<tr>
<td>20</td>
<td>3</td>
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<td>250</td>
<td>42</td>
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<tr>
<td>300</td>
<td>50</td>
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</tbody>
</table>

Microdrip tubing is not appropriate for rates greater than 50 mL/hr.
with the organizational guidelines for infusion-related documentation. In accordance with INS Standards, documentation of peripheral and midline catheter placement and infusion therapy procedure includes:

- Date and time of insertion, number and location of attempts (e.g., anatomic descriptors, landmarks, appropriately marked drawings)
- Site preparation (e.g., skin antiseptic agent, other precautions such as sterile barriers used with midline catheter placement)
- Use of visualization technology, pain management interventions
- Gauge and length of device
- Infusate, dose, rate, time, route and method of administration (e.g., gravity, EID)
- Patient’s specific comments related to the procedure; patient education and response
- Patient response (e.g., excessive anxiety, patient movement, or untoward response)
- Ongoing assessment, care, and management: Site/patency assessment, site care and dressing changes, daily assessment of need for the PIV catheter

Table 6-9 summarizes the steps in initiating peripheral infusion.

**NOTE:** Refer to Procedures Display 6-1 at the end of this chapter for “Steps for Inserting a Peripheral-Short Over-the-Needle Catheter by Direct and Indirect Methods.”

### Postinsertion Care and Management

#### Assessment and Monitoring

Assessment includes an inspection of the infusion system, from the solution container down to the catheter insertion site (Gorski et al., 2016a, p. S81). Assessment parameters include the infusate (e.g., clarity), the integrity of the system (e.g., secure connections), accurate flow rate, and nonexpired infusates/administration set. At the level of the insertion site, assessment includes the PIV site, intactness of the dressing, and the surrounding area. The INS (Gorski et al., 2016a, p. S82) provides guidance for the frequency of assessing the short PIV catheter as follows:

- At least every 4 hours for alert and oriented adult patients who are receiving nonirritant/nonvesicant infusions for any signs of problems such as pain, swelling, or redness at the site tissue.
- Every 1 to 2 hours for critically ill patients, for adult patients who have cognitive/sensory deficits or who are receiving sedative-type medications and are unable to notify the nurse of any symptoms, and for patients in whom PIVs are placed in a high-risk location (e.g., external jugular, area of flexion).
- Every hour for pediatric and neonatal patients.
Information that is obtained by monitoring is communicated to other health-care professionals responsible for the patient's care by documentation. Observation of the patient and the delivery of infusion therapy provide data for nursing interventions. Assessment and key nursing interventions are presented under *Nursing Points of Care: Older Adult Peripheral Infusion*.

### Intermittent Infusions and Needleless Connectors

A needleless connector is placed on the end of the short PIV or midline catheter when a continuous infusion is converted to an intermittent access. This method
of intermittent access is sometimes called a saline lock. The needleless connector is designed to accommodate the tip of a syringe or I.V. tubing for catheter flushing or intermittent administration of solutions into the vascular system.

**ADVANTAGES TO INTERMITTENT INFUSIONS**

- Provide access to the vascular system without the patient being attached to a continuous infusion, allowing greater patient mobility
- Allow for reduced volume of fluid administered, important for patients at risk (e.g., those with heart failure)
- Provide access for delivery of emergency medications

**DISADVANTAGES**

- May increase risk for BSI due to more manipulation at the catheter hub and thus opportunity for intraluminal entry of microbes; aseptic technique is essential with every catheter access
- May increase risk for thrombotic catheter occlusion

**NEEDLELESS CONNECTORS**

Important issues related to needleless connectors include frequency of device change and maintenance of aseptic technique when accessing the needleless connector for infusion, flushing, and locking. The needleless connector is changed on a regular basis as follows: no more often than every 96 hours; or when the I.V. tubing is changed, residual blood is present in the device; and whenever the integrity is compromised or contamination is suspected (Gorski et al., 2016a, p. S69). Manufacturer’s guidelines and organizational policies will provide further guidance on frequency of change, including whether the device should be changed after blood withdrawal for laboratory tests. All needleless connectors should be of Luer-lock design to reduce the risk of accidental disconnection.

Failure to disinfect the needleless connectors for flushing or medication administration is a significant problem. Based upon a systematic literature review, the needleless connector was identified as the greatest source for contamination after insertion of the VAD, with 33% to 45% of needleless connectors identified as contaminated; adherence to disinfection was reported to be as low as 10% (Moureau & Flynn, 2015). The Joint Commission includes the following in its 2017 National Patient Safety Goals: “use a standardized protocol to disinfect catheter hubs and injection ports prior to accessing the port.”

The INS recommends 70% alcohol (i.e., typical alcohol “wipes”), alcoholic chlorhexidine solution, and iodophors as acceptable antisepsics for needleless connector disinfection. Many nurses are familiar with the “scrub the hub” mantra, emphasizing the importance of cleansing with friction and not just a quick “wipe.” While the optimal disinfection time has not been established in research, 15 seconds is a common time frame. Of note, there is a chlorhexidine/alcohol disinfectant wipe that is available for NC disinfection with a recommended 5 second scrub followed by a 5 second dry time. There are also technology solutions to infection concerns. There are needleless connectors designed
with silver and chlorhexidine microbial barriers built into the device. There are also “disinfection caps” that are attached to the needleless connector (Chapter 5). The needleless connector is continually protected until the cap is removed, and the step of scrubbing the needleless connector is not necessary for the initial access. For repeated access (e.g., multiple medications/flushes), the INS Standards suggest a vigorous 5- to 15-second scrub prior to each subsequent entry (Gorski et al., 2016a, p. S69).

Follow these steps every time the needleless connector is accessed:

1. Perform proper hand hygiene.
2. Disinfect needleless connector with each access using 70% alcohol or alcoholic chlorhexidine for 15 seconds (or in accordance with product recommendations) using friction (twisting motion).
3. Allow the disinfectant to fully dry.

Figure 6-19 shows an example of a needleless connector connected to the extension tubing of the PIV catheter, which makes it an intermittent infusion device.

Maintaining Catheter Patency: Flushing and Locking

The terms flushing and locking are commonly used yet sometimes misunderstood. Catheters are flushed after each intermittent infusion to clear any medication from the catheter and to prevent contact between incompatible medications or I.V. solutions. When a catheter is not properly flushed, a precipitate may form or blood may reflux into the catheter, resulting in occlusion.

**Figure 6-19** Intermittent infusion device. (Courtesy of Baxter Healthcare Corp., Round Lake, IL.)
Catheters are flushed with preservative-free 0.9% sodium chloride. Catheter flushing is performed with medications administered via a port into a continuous infusion and with intermittent infusions (i.e., saline lock). Catheter locking is used with intermittently accessed peripheral catheters and refers to the solution left instilled in the catheter to prevent occlusion in between intermittent infusions.

- Flush PIVs with 0.9% preservative-free sodium chloride before and after administration of medication and lock SPCs also with 0.9% preservative-free sodium chloride at least every 24 hours if the catheter is not in use. The INS recommends a minimum volume for flushing equal to twice the internal volume of the catheter plus any add-on device and a locking volume equal to the internal catheter volume plus 20%. The internal volumes of peripheral and midline catheters are fractions of 1 mL. Organizations typically will use the smallest available prefilled flush syringe (e.g., 3 mL) for both flushing and locking.
- Lock midline peripheral catheters with either a low-concentration heparin (10 units per mL) or 0.9% preservative-free sodium chloride, as there are no clear evidence-based recommendations.

**NURSING FAST FACT!**

Some medications are incompatible with 0.9% sodium chloride. In this case, 5% dextrose in water is used for flushing, followed by normal saline and/or a heparin solution. Dextrose should not be left in the catheter lumen because it provides nutrients for growth of bacteria (Gorski et al., 2016a, p. S77).

**NURSING FAST FACT!**

**Pulsatile versus a consistent smooth flushing technique:** Based on in vitro studies, the INS suggests consideration for use of a pulsatile (e.g., push–pause–push–pause) flushing technique to better clear the catheter of solid deposits (e.g., fibrin, drug precipitate) (Gorski et al., 2016a, p. S78). Theoretically, this re-creates a turbulence within the catheter lumen that causes a swirling effect to move any debris (residues of fibrin or medication) attached to the catheter lumen. It has also been suggested that pulsatile flushing of PIVs may cause damage to the tunica intima. The issue of flushing technique remains an area of controversy, and continued research aims to establish the most effective flushing procedure.

**NOTE:** Refer to Procedures Display 6-2 at the end of this chapter for “Flushing and Locking a Short PIV or Midline Catheter After an Intermittent Infusion.”
Catheter Removal

All VADs, including PIV catheters and midline catheters, should be removed when there is evidence of a complication (e.g., signs of phlebitis or infiltration), when therapy is discontinued, and when the device is no longer necessary. Short PIVs and midline catheters should be removed if the catheter is no longer included in the plan of care or it has not been used for 24 hours or more (Gorski et al., 2016a, p. S91).

**INS Standard** When a catheter has been placed in suboptimal aseptic conditions (e.g., emergent care), remove and insert a new catheter as soon as possible and no later than 48 hours (Gorski et al., 2016a, p. S91).

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**NURSING PLAN OF CARE**

**ADULT PERIPHERAL INFUSION**

**Nursing Assessment**

- Interview the patient regarding previous experiences with venipunctures, including pain issues and preferences for pain management strategies.
- Review the purpose of the infusion and patient diagnosis.
- Assess potential venipuncture sites, taking into consideration the physical condition of veins, patient activity level, type of prescribed infusion therapy (e.g., irritants), patient preferences regarding site location, possible need for visualization technology, and cultural issues.
- Review laboratory test results, vital signs, and continued need for PIV catheter.
- Check solution container and administration set for solution clarity, system integrity, and proper labeling.
- Be alert for signs/symptoms of complications/adverse reactions.

**Key Nursing Interventions**

1. Verify the authorized prescriber’s orders for infusion therapy.
2. Determine compatibility of all infusion fluids and additives by consulting the appropriate literature/pharmacist.
3. Select and prepare the EID as indicated.
4. Provide patient education.
5. Choose an appropriate-size catheter for delivery of infusion.
6. Maintain standard precautions and adhere to hand hygiene.
7. Employ aseptic technique during insertion and maintenance of the catheter.
8. Apply stabilization device and dressing after catheter placement.
9. Initiate infusion.
10. Document the procedure and observations of the site.
AGE-RELATED CONSIDERATIONS

Pediatric Infusion Therapy

Physiological Characteristics
A neonate is a child in the period of extrauterine life up to the first 28 days after birth. Low-birth-weight and premature infants have decreased energy stores and increased metabolic needs compared with full-term, average-weight newborns.

Whereas the adult body consists of approximately 60% water, the infant body consists of 70% to 80% water, and infants have proportionately more water in the extracellular compartment than do adults (Doellman, 2014). Therefore, any depletion in these water stores may lead to dehydration. As an infant becomes older, the ratio of extracellular to intracellular fluid volume decreases.

Although infants have relatively greater circulating blood volume per unit of body weight compared with adults, the absolute blood volume is small, which makes infants more vulnerable to hypovolemia. Immature and inefficient kidneys lead to excretion of more water than is found in older pediatric patients, and renal function does not reach maturity until the end of the second year (Doellman, 2014). Any condition that interferes with normal water and electrolyte intake or that produces excessive water and electrolyte losses will result in more rapid depletion of water and electrolyte stores in an infant than it will in an adult.

Young children have immature homeostatic regulating mechanisms that need to be considered when water and electrolyte replacement is needed. Renal function, acid–base balance, body surface area differences, and electrolyte concentrations all must be taken into consideration when planning fluid needs.

The buffering capacity to regulate acid–base balance is lower in newborns than in older children. Neonates, with an average pH of 7.30 to 7.35, are slightly more acidotic than adults (Doellman, 2014). The base bicarbonate deficit is thought to be related to high metabolic acid production and renal immaturity.

The integumentary system in neonates is an important route of fluid loss, especially in illness. This must be considered when determining fluid balance in infants and young children because their body surface area in relation to weight is greater than those of older children and adults. Any condition that produces a decrease in intake or output of water and electrolytes affects the body fluid stores of the infant. Because the gastrointestinal (GI) membranes are an extension of the body surface area, relatively greater losses occur from the GI tract in sick infants.

Plasma electrolyte concentrations do not vary strikingly among infants, small children, and adults. The plasma sodium concentration changes little from birth to adulthood. Potassium and chloride concentrations are higher in the first few months of life than at any other time. Magnesium and calcium levels both are low in the first 24 hours after birth. The serum phosphate level is elevated in the early months of infancy, which contributes to a low calcium level. Newborn infants are vulnerable to disrupted calcium homeostasis when they are stressed by illness or by an excess phosphate load and are at risk for hypocalcemia (Doellman, 2014).

Physical Assessment
A physical assessment of pediatric patients should be performed before I.V. therapy is initiated. Table 6-10 lists the components of a pediatric assessment. Risk factors that must be considered during the assessment phase include prematurity, catabolic disease state, hypothermia, hyperthermia, metabolic or respiratory alkalosis or acidosis, and other metabolic abnormalities.
The I.V. catheter must be placed in the direction of blood flow to ensure that the I.V. fluid will flow in the same direction as the blood returning to the heart. In the scalp, venous blood generally flows from the top of the head down.

<table>
<thead>
<tr>
<th>Table 6-10</th>
<th>Components of the Pediatric Physical Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measurement of head circumference (up to 1 year)</td>
<td></td>
</tr>
<tr>
<td>Height or length</td>
<td></td>
</tr>
<tr>
<td>Weight</td>
<td></td>
</tr>
<tr>
<td>Vital signs</td>
<td></td>
</tr>
<tr>
<td>Skin turgor</td>
<td></td>
</tr>
<tr>
<td>Presence of tears</td>
<td></td>
</tr>
<tr>
<td>Moistness and color of mucous membranes</td>
<td></td>
</tr>
<tr>
<td>Intake and urinary output</td>
<td></td>
</tr>
<tr>
<td>Characteristics of fontanelles</td>
<td></td>
</tr>
<tr>
<td>Level of child’s activity related to growth and development</td>
<td></td>
</tr>
</tbody>
</table>

Site Selection
When selecting the venipuncture site, keep in mind that the main goal of infusion therapy is to provide the treatment with safety and efficiency while meeting the child’s emotional and developmental needs.

Consider the following factors before selecting a site for venipuncture:

- Age of the child
- Size of the child
- Condition of veins
- Objective of the infusion therapy (hydration, administration of medication, etc.)
- General patient condition
- Mobility and level of activity of child
- Gross and fine motor skills (e.g., sucks fingers, plays with hands, holds bottle, draws)
- Sense of body image
- Cognitive ability of the child (i.e., can understand and follow directions)

Peripheral Sites
Peripheral routes for pediatric I.V. therapy include scalp veins and the veins in the dorsum of the hand, forearm, and foot. Advantages and disadvantages of these sites are found in Table 6-11.

Scalp Veins
The major superficial veins of the scalp can be used. Scalp veins can be used in children up to age 18 months; after that age, the hair follicles mature and the epidermis toughens. Four scalp veins are used most commonly for I.V. access: temporal, frontal, posterior auricular, and occipital (Fig. 6-20). Of note, scalp veins do not contain valves (Doellman, 2014).

NURSING FAST FACT!
The choice of a scalp vein for placement of I.V. therapy is often traumatic for the parents because removal of hair may have cultural and religious significance. In addition, maintaining patency of this site can be difficult at times.

The I.V. catheter must be placed in the direction of blood flow to ensure that the I.V. fluid will flow in the same direction as the blood returning to the heart. In the scalp, venous blood generally flows from the top of the head down.
## Table 6-11  Pediatric Infusion Sites

<table>
<thead>
<tr>
<th>Veins and Site</th>
<th>Age Appropriate</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Scalp</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Superficial temporal</td>
<td>Infant &lt;18 months of age</td>
<td>Highly visible</td>
<td>Hair must be trimmed or clipped</td>
</tr>
<tr>
<td>(front of ear)</td>
<td></td>
<td>Easily accessed and monitored</td>
<td>Infiltrates easily</td>
</tr>
<tr>
<td>Frontal (middle of</td>
<td></td>
<td>Veins readily dilate</td>
<td>Difficult to stabilize</td>
</tr>
<tr>
<td>forehead)</td>
<td></td>
<td>Keeps feet and hands free</td>
<td>Increase familial anxiety</td>
</tr>
<tr>
<td>Occipital</td>
<td></td>
<td>No valves</td>
<td>May have cultural issues</td>
</tr>
<tr>
<td>Posterior auricular</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| **Lower Extremities**    |                            |                                                              |                                                                              |
| Leg: Saphenous           | Infant: Used before       | Large vessels                                               | Decreased mobility                                                          |
| Foot: Metatarsal         | crawling and walking      | Readily dilate                                              | Located near arterial structures                                            |
|                          |                            | Hands kept free                                             | Difficult to observe/palpate in chubby infants                              |
|                          |                            | Easily restrained/splinted                                   | Risk of phlebitis is increased                                              |

| **Hand**                 |                            |                                                              |                                                                              |
| Metacarpal               | All ages                   | Easily accessible/visible in older children                 | Uncomfortable                                                                |
|                          |                            | Distal location                                             | Difficult to anchor/stabilize                                               |
|                          |                            | May not require splinting                                   | May impede child’s activities (thumb-sucking, schoolwork)                   |

| **Forearm**              |                            |                                                              |                                                                              |
| Cephalic                 | All ages                   | Same as for hand                                            | Difficult to observe/palpate in chubby infants/toddlers                     |
| Basilic                  |                            | Keeps hands free                                            |                                                                              |
| Median antebrachial      |                            |                                                              |                                                                              |

**NOTE:** Shaving is never recommended; if necessary, clip the hair on infants.

**DORSUM OF THE HAND AND FOREARM**

Because the veins over the metacarpal area are mobile and not well supported by surrounding tissue, the limb should be immobilized with a splint and taped before cannulation. This site can be used in children of all ages.

The antecubital fossa should not be used routinely for peripheral I.V. access, as it is an area of flexion with an increased risk for infiltration. It should be reserved for blood drawing and may be used in emergency situations for vascular access.

**LOWER EXTREMITIES**

Lower-extremity sites are used as venipuncture sites for infants before they can crawl and walk. The curve of the foot, especially around the ankle, makes entry and cannula...
advancement difficult. The veins used are the metatarsal, saphenous, median, and marginal dorsal arch.

Selecting the Equipment
The nurse must be aware of the special needs of pediatric patients when selecting appropriate equipment for administering fluids and medication. When choosing administration equipment, the safety of the child requires that the activity level, age, and size of the patient be considered. For safe delivery of I.V. therapy in pediatric patients, use:

- An EID for administration of therapy; tamperproof features as well as variable pressure limits and alarms should be present (Doellman, 2014)
- A solution container with a volume based on the age, height, and weight of the patient and containing no more than 24-hour volume requirements
- Controlled-volume sets (50-, 100-, 150-mL) for pediatric patients with infusion rates less than 100 mL per hour unless an EID will be used
- Microdrip tubing (60 gtt/min)
- Non-DEHP (di[2-ethylhexyl] phthalate) I.V. containers and administration sets

**NURSING FAST FACT!**
The foot should be secured on a padded board with a normal joint position.
• Filtration, especially in critically ill children; some studies have shown a reduction in overall complications including systemic inflammatory response syndrome for patients in pediatric intensive care units (Gorski et al., 2016a, p. S71) (Fig. 6-21)

Catheter Selection
Catheter choice depends on the site selected. In children, peripheral over-the-needle-type catheters are preferred (22- to 24-gauge). A 19- to 27-gauge scalp vein (buterfly) needle is easy to insert and can be used, but it has the risk of infiltrating easily and can be used only with single, one-time short infusions.

Venipuncture Tips
1. Venipuncture should be performed in a room separate from the child’s room. The child’s room is his or her “safe space.” Always have extra help.
2. For the scalp vein position, the head is in a dependent position.
3. Use developmentally supportive measures to minimize stress, such as offering a pacifier, talking softly, swaddling, or avoiding sudden moves (Doellman, 2014).
4. A smaller tourniquet is preferred for neonates and pediatric patients.
5. Infants should be covered with a blanket to minimize cold stress.
6. A flashlight or transilluminator device placed beneath the extremity helps to illuminate tissue surrounding the vein; the veins are then outlined for better visualization. Only cold light sources should be used due to the risk of thermal burns (Gorski et al., 2016a).
7. Warm hands by washing them in warm water before gloving.

Figure 6-21 Neonatal filter. Posidyne® NEO 0.2-micron filter with 96-hour bacterial and endotoxin retention. (Illustration courtesy of PALL CORPORATION. Copyright PALL CORPORATION, 2015.)
8. Minimizing pain during venipuncture is a goal of nursing care. Use anesthetics and behavioral interventions as addressed in Step 6.

**NOTE:** Use colored stickers or drawings on the I.V. site as a reward. *Always have extra help.*

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**NURSING FAST FACT!**

When securing a child’s extremity to an arm board, use clear tape for visualization of the I.V. site and digits or skin immediately adjacent to the site.

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Stabilizing and maintaining the patency of I.V. cannula sites can be a challenge. Poorly secured I.V. access sites may result in dislodgements or infiltrations requiring I.V. restarts. Products are available to protect pediatric I.V.s while maintaining visualization, such as a clear, one-piece unit (Fig. 6-22).

Children’s understanding of, reaction to, and methods of coping with illness or hospitalization are influenced by the significance of individual stressors during each developmental phase. Major stressors include separation, loss of control, and bodily injury.

**Site Care and Maintenance**

Inspect and monitor the VAD, connections, infusate prescribed, and pump functions including flow rate. Perform site checks minimally every hour (Gorski et al., 2012). Assess the range of motion of the cannulated extremity, taking into consideration the child’s developmental age. Monitor the patient’s overall response to therapy. Remove and replace peripheral-short catheters based on clinical condition of the site.

---

*Figure 6-22* I.V. House Ultradressing Pediatric. (Courtesy of I.V. House, Inc., Chesterfield, MO.)
Peripheral Infusion Therapy in the Older Adult

As with the pediatric patient, care of the older adult has become an area of specialty nursing that requires special approaches to infusion-related care. Consider the following statistics (Department of Health & Human Services, Administration on Aging, 2016):

- In the United States, there were 46.2 million persons 65 years or older in 2014 (the latest year for which data are available), representing 14.5% of the U.S. population (about one in every seven Americans).
- Persons older than 65 years of age are expected to represent 19% of the population by 2040.
- By 2060, there will be about 98 million older persons, more than twice their number in 2014.

Nursing Points of Care

PEDIATRIC PERIPHERAL INFUSION

Nursing Assessment

- Interview the parents/caregiver (and older child) for history and current health status.
- Measure height and weight for calculation of body surface area and drug dosages.
- Assess potential venipuncture sites, taking into consideration infant/child activity/development level, possible need for visualization technology, and cultural issues.

Key Nursing Interventions

1. Explain the procedure and equipment and the rationale for treatment to the parents and child, if appropriate.
2. Address pain management during PIV placement: For infants, provide opportunities for non-nutritive sucking (i.e., sucrose); for older children, consider both pharmacological and nonpharmacological management, including cognitive and behavioral strategies such as distracting and positioning.
3. Encourage parents to provide daily care of the child.
4. Maintain the daily routine during hospitalization.
5. Provide a quiet, uninterrupted environment during naptime and nighttime as appropriate.
6. Use appropriate equipment for delivery of safe infusions (e.g., metered volume chamber, EID, syringe pump for small volumes) (Chapters 5, 10).
7. Double-check dosage calculations with another health-care provider (e.g., nurse, pharmacist) before administration.
Physiological Changes

The skin is one of the first systems to show signs of the aging process. The epidermis and dermis are visible markers of aging and greatly affect the placement of peripheral catheters. The most striking change is an approximately 20% loss in thickness of the dermal layer, which results in the paper-thin appearance of aging skin (Baranoski et al., 2012). This results also in decreased pain perception, which potentially makes older patients less likely to feel and report pain with infiltration or phlebitis. Purpura and ecchymoses may appear as a result of the greater fragility of the dermal and subcutaneous vessels and the loss of support for the skin capillaries. Minor trauma can easily cause bruising.

A common symptom in older people is pruritus or “itchiness.” Dryer skin may result from atrophy of sweat glands in the dermal layer as well as from medications and should be considered when preparing the patient for parenteral therapy.

**NURSING FAST FACT!**

Alcohol, when used in skin antisepsis, will add to the drying effect on the skin.

The dermis becomes relatively dehydrated and loses strength and elasticity. This layer has underlying papillae that hold the epidermis and dermis together; thus, as a person ages, the older skin loosens. Older skin has decreased flexibility of collagen fibers, increased fragility of the capillaries, and fewer capillaries (Fig. 6-23).

*Figure 6-23* Fragile veins.
Websites
Hartford Institute for Geriatric Nursing: https://consultgeri.org/
American Geriatrics Society: www.americangeriatrics.org

Venipuncture Techniques
Special venipuncture techniques are required to successfully place and maintain infusion therapy in older patients. The tunica intima and the tunica media become thicker, making vein entry more difficult, and the valves also become more rigid and sclerotic (Coulter, 2016). Veins are more fragile and may be more likely to rupture. The potential complications associated with trauma, surgery, and illness in the older adult, along with the physiological changes previously addressed, require that nurses be knowledgeable about aging changes and their implications for nursing practice. Because the older adult patient may be at greater risk for potential complications related to infusion therapy, frequent monitoring is required. For example, even small infiltrations can lead to significant complications.

Selecting a Vein
Selecting a vein can be a challenge for nurses caring for the older adult. Moderate-size veins in the forearm are usually a good choice (Coulter, 2016). Areas for PIV access should have adequate tissue and skeletal support. Avoid flexion areas and areas with bruising.

Use a tourniquet to help distend and locate appropriate veins, but avoid applying it too tightly because it can cause vein damage when the vein is punctured. Alternatively, a blood pressure cuff may be used, and, in some cases, a tourniquet may not be needed for venous access. During venous distention, palpate the vein to determine its condition. Veins that feel ribbed or rippled may distend readily when a tourniquet is applied, but these sites are often impossible to access and cause pain to the patient. Table 6-12 summarizes tips for use with fragile veins.
Valves become stiff and less effective with age. Bumps along the vein path (i.e., valves) may cause problems during attempts at vein access. Venous circulation may be sluggish, resulting in slow venous return, distention, venous stasis, and dependent edema. A catheter may not thread into a vein with stiff valves.

**Cannulation Techniques**

In elderly patients, stabilization of the vein is critical. The vessels may lack stability as a result of the loss of tissue mass and may tend to roll. Techniques to perform a venipuncture in elderly patients include:

1. Use of traction by placing the thumb directly along the vein axis about 2 to 3 inches below the intended venipuncture site. The palm and fingers of the traction hand serve to hold and stabilize the extremity. Using the index finger of the hand, provide traction to further stretch the skin above the intended venipuncture site. Maintain traction throughout venipuncture.

2. Insert the catheter, using either the direct or indirect technique. When the direct technique is used, insert the catheter at a 5- to 15-degree angle in a single motion, penetrating the skin and vein simultaneously. A low angle is best to avoid nicking or going through the underside of the vein wall (Coulter, 2016). Do not stab or thrust the catheter into the skin, which could cause the catheter to advance too deeply and accidentally damage the vein. Use the indirect method (two-step) for patients with small, delicate veins. An alternative method is to have another nurse apply digital pressure with the hand above the site of venipuncture and then release it after the vein has been entered.

**Table 6-12  Tips for the Older Adult With Fragile Veins**

<table>
<thead>
<tr>
<th>The following tips are for patients with fragile veins (age or disease process related):</th>
</tr>
</thead>
<tbody>
<tr>
<td>• To prevent hematoma, avoid overdistention of the vein with tourniquet or blood pressure cuff; may not need to use tourniquet.</td>
</tr>
<tr>
<td>• Avoid multiple tapping of the vein.</td>
</tr>
<tr>
<td>• Use the smallest-gauge catheter for the therapy prescribed.</td>
</tr>
<tr>
<td>• Lower the angle of approach into the vein.</td>
</tr>
<tr>
<td>• Pull the skin taut and stabilize the vein throughout venipuncture.</td>
</tr>
<tr>
<td>• Use the one-handed technique: Advance the catheter off the stylet into the vein.</td>
</tr>
<tr>
<td>• Use warm compress to dilate vein if needed. Be aware that the older adult is more sensitive to heat.</td>
</tr>
</tbody>
</table>

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**NURSING FAST FACT!**

Place a tourniquet over a gown or sleeve to decrease the shearing force on fragile skin.
NURSING POINTS OF CARE
OLDER ADULT PERIPHERAL INFUSION

Nursing Assessment
- Ask the patient about previous experiences with venipuncture.
- Review the purpose of the infusion and patient diagnosis, history, comorbidities, and medications.
- Assess venipuncture sites, taking into consideration the physical condition of the skin, any disease processes, and cultural issues.

Key Nursing Interventions
1. Use small gauge catheters (22-24 gauge).
2. Avoid tight tourniquet use; avoid use or consider use of blood pressure cuff.
3. Stabilize vein and insert the PIV at a low angle (5-15 degrees).
4. Explain procedures, keeping in mind possible sensory or auditory deficits.

Home Care Issues
The SPC is generally indicated for short-term (e.g., 7 days) or infrequent intermittent infusions (e.g., monthly infusion) of nonirritating drugs and fluids. The use of midline catheters is becoming very common in home care, especially for 1-2 week courses of I.V. antibiotic therapy. Home-care issues related to the initiation and maintenance of PIV administration include technical procedures, such as infusion administration and site rotation, as well as monitoring for expected effects and potential adverse reactions.

- The patient who is receiving infusions via any type of PIV catheter in the home setting presents a unique situation because the nurse is in the home only intermittently. Patient safety is an important aspect of home care. The patient and caregiver must be motivated, willing, and able to participate in the care and monitoring of the PIV catheter and the infusion (Gorski, 2017). With every home visit, the nurse assesses the I.V. site, but this becomes the patient's/caregiver's responsibility between the nurse's home visits. Patient education is critical. Information must include (Gorski et al., 2012):
  - What to look for: Redness, tenderness, swelling, site drainage
  - Check site at least every 4 hours (SPC) during waking hours or daily for midline catheters.
  - Ways to protect site during sleep and activity.

Continued
Home Care Issues—cont’d

- How to stop infusion if signs and symptoms are present
- To promptly report to the home-care organization’s 24-hour contact numbers

The degree to which the patient is expected to learn and perform technical procedures depends on his or her cognitive ability, willingness to learn, and the specific technique being taught. In some cases, the patient/caregiver may actually self-administer the infusions; in other cases, the nurse administers each dose. For a patient/caregiver who self-administers PIV infusions, teaching will address administration sets, setting up and monitoring infusion pumps, and adhering to aseptic technique with all procedures. Challenges in the home setting include:

- The nurse may have to adapt to poor lighting, homes that are not clean, disorganized environments, and pets. It is important to establish a safe place for storage of supplies and a safe and efficient space for infusion administration. Many times the kitchen table is a good place because it has a cleanable surface and good lighting.
- Territoriality (i.e., the need for space) serves four functions: security, privacy, autonomy, and self-identification. People tend to feel safer in their own territory because it is arranged and equipped in a familiar manner. Most people believe that there is a degree of predictability associated with being in one’s own personal space and that this degree of predictability is hard to achieve elsewhere (Giger, 2017).

Pediatric Patients in the Home

The home-care environment must be assessed to be sure that infusion therapy can be carried out safely. In the home, children are more mobile and active. The parents must be educated about the use and care of therapy and accept involvement in and responsibility for the treatment regimen. Depending on the age, the child may want to participate in infusion therapy.

- Focus on the psychosocial and developmental needs of the child and family in planning home infusion therapy.
- The best infusion device is one that is portable and easy for the child and family to operate. A syringe pump and disposable elastomeric infusion devices are examples of easy-to-use equipment (See Chapter 5).
- Identify alternate caregivers.

Older Adult Patients in the Home

Educating older adults on the administration of home infusion therapy can present challenges. Sensory changes (e.g., vision, hearing, manual dexterity)
Home Care Issues—cont’d

occur as part of the normal aging process and may impact the teaching-learning process. Suggestions include:

• Foster an unhurried and relaxed atmosphere.
• Use a slower pace of teaching if needed, especially when working with older adults.
• Make direct eye contact. Be alert to facial expressions that indicate a lack of understanding.
• Consider ways to simplify the procedure if the patient has functional limitations (e.g., arthritis in the hands) (Gorski, 2017).

NURSING FAST FACT!

The home-care nursing staff is responsible for routine restarts of PIV or blood draws. (In some areas, home laboratory services are also available for routine phlebotomy for needed laboratory studies.)

Nursing Process

The nursing process is a six-step process for problem-solving to guide nursing action (see Chapter 1 for details on the steps of the nursing process related to vascular access). The following table focuses on nursing diagnoses, nursing outcomes classification (NOC), and nursing interventions classification (NIC) for peripheral infusion therapy in adults and pediatric patients. Nursing diagnoses should be patient specific and outcomes and interventions individualized. The NOC and NIC presented here are suggested directions for development of specific outcomes and interventions.

<table>
<thead>
<tr>
<th>Nursing Diagnoses Related to Peripheral Infusion Therapy in Adults and Children</th>
<th>Nursing Outcomes Classification (NOC)</th>
<th>Nursing Interventions Classification (NIC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infection risk of related to: Environmental exposure to pathogens; immunosuppression, invasive procedures</td>
<td>Infection control, risk control and detection</td>
<td>Infection control; infection protection</td>
</tr>
<tr>
<td>Deficient knowledge related to: Alteration in cognitive functioning; information misinterpretation; lack of exposure; lack of interest in learning; unfamiliar with information resources regarding peripheral infusion therapy</td>
<td>Knowledge: disease process, medication; personal safety; prescribed activity; treatment procedures</td>
<td>Teaching: Disease process (reasons for infusion therapy, treatment)</td>
</tr>
</tbody>
</table>

Continued
Chapter Highlights

- The epidermis and the dermis overlay the subcutaneous tissue. The three layers of veins are the tunica adventitia, tunica media, and tunica intima.
- The primary veins of the hands and arms pertinent to peripheral catheter placement include the metacarpal, cephalic, and basilic veins. Scalp and lower-extremity veins may be used in infants.
- The Phillips’ 16-step venipuncture method is an easy-to-remember step approach for beginning practitioners.
- A goal in VAD selection is that the least invasive VAD that meets the patient’s needs with the fewest number of replacements should be selected. Short PIV and midline catheters are not used for high-osmolarity (>900 mOsm/L), or continuous vesicant solutions. For more irritating solutions, the midline catheter may provide advantages due to tip placement in the larger veins in the upper arm, allowing better hemodilution of the infusate.
- The forearm is a preferential site for the short PIV, as it is associated with greater dwell time.
Visualization technologies including transillumination, nIR, and ultrasound are increasingly used to improve cannulation success, especially in patients with difficult venous access.

Attention to pain management strategies during catheter insertion is associated with improving the patient experience and reducing fear and anxiety associated with venipuncture.

Attention to skin preparation includes skin cleansing and skin antisepsis, which are critical steps in reducing the risk of infection.

Attention to needleless connector disinfection is another critical step in infection prevention; failure to disinfect the connectors is a significant problem among nurses.

Catheters should be removed as soon as they are no longer needed, as any existing invasive device is a source for infection.

There are anatomic and physiological differences/changes in the neonatal/pediatric and older adult populations that impact site selection, catheter placement, infusion administration, and monitoring.

**Thinking Critically: Case Study**

A 20-year-old obese African American man is readmitted to the hospital with a diagnosis of osteomyelitis. The patient is to be medically managed with I.V. antibiotics for 4 to 6 weeks and is to receive a diet high in protein and hydration.

**Case Study Questions**

1. Decide which access devices should be used to initiate therapy, and give the rationale.
2. What should be taken into consideration during assessment of venous access sites?
3. What equipment might help you with a successful venipuncture?

**References**


Bugden, S., Shean, K., Scott, M., Mihala, G., Clark, S., Johnstone, C., ... Rickard, C. M. (2016). Skin glue reduces the failure rate of emergency department inserted peripheral intravenous catheters: a randomized controlled trial. *Annals of Emergency Medicine, 68*(2), 196-201.


CHAPTER 6  Peripheral I.V. Catheters


Equipment Needed
I.V. start kit (preferred) containing the following:
• Gloves
• Tourniquet
• Antiseptic solution (chlorhexidine gluconate/alcohol recommended)
• Transparent and gauze dressing
• Label
I.V. catheter (22- to 24-gauge catheter most common)
Stabilization device
Needleless connector (for intermittent infusions)
Extension set (optional)
Primary administration set
Prescribed infusate

Delegation
This procedure can be delegated to the licensed practical or vocational nurse (LVN/LPN) depending on the state nurse practice act for initiation of infusion therapy and agency policy.

Procedure
1. Verify order.
2. Introduce yourself to the patient.
3. Verify the patient’s identity using two forms of ID.
4. Perform hand hygiene.
5. Assess patient (verify allergy status) and evaluate for psychological preparedness. Instruct patient on purpose of infusion or locking device. Apply tourniquet and evaluate both arms for best access site. Release tourniquet. Perform hand hygiene again before beginning procedure and don gloves.

Rationale
1. A written order is a legal requirement.
2. Establishes nurse–patient relationship
3. Patient safety.
4. Single most important means of infection prevention
Standard precautions

PROCEDURES DISPLAY 6-1
Steps for Inserting a Peripheral-Short Over-the-Needle Catheter by Direct and Indirect Methods
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PROCEDURES DISPLAY 6-1

Steps for Inserting a Peripheral-Short Over-the-Needle Catheter by Direct and Indirect Methods—cont’d

Procedure

6. Help patient get into a comfortable position. Place linen saver pad under arm or hand.

7. Select the site and dilate the vein.

8. Select the appropriate catheter for therapy.

9. Don clean gloves. Gloves must be left on throughout the entire procedure.

10. Prepare the site:
    * Cleanse skin with soap and water if visibly soiled.
    * Remove excess hair if necessary using scissors or surgical clippers.
    * Skin antisepsis, preferentially with alcoholic chlorhexidine. Use back-and-forth motion for at least 30 seconds and allow to fully dry.

11. Reapply the tourniquet.

12. Insert the catheter by a direct or indirect method at about a 30 degree angle with a steady motion using traction to maintain an anchor on the vein.

Rationale

6. Promotes cooperation with the procedure and facilitates your ability to perform the procedure. Protects bed linens.

7. Select the site most likely to last the full length of the prescribed therapy, preferentially using the forearm to increase dwell time. Ensures preservation of veins.

8. Choose the best needle gauge for the therapy and age of patient, most often a 22- to 24-gauge catheter.

9. Standard precautions

10. Prevents infection

11. Distends veins.

12. Anchoring the vein properly is the key to successful catheter insertion. Quickly passes through layers of epidermis and dermis, decreasing pain, and allows for adjustment to technique based on skin thickness.
PROCEDURES DISPLAY 6-1

Steps for Inserting a Peripheral-Short Over-the-Needle Catheter by Direct and Indirect Methods—cont’d

Procedure
For the Direct (One-Step) Method
A. Insert the catheter directly over the vein.
B. Penetrate all layers of the vein with one motion.

For the Indirect (Two-Step) Method
A. Insert the catheter alongside the vein; gently insert the catheter distal to the point at which the needle will enter the vein.
B. Maintain parallel alignment and advance through the subcutaneous tissue.
C. Relocate the vein and decrease the angle as the catheter enters the vein.

Note: Jabbing, stabbing, or quick thrusting should be avoided because such actions may cause rupture of delicate veins. For performing a venipuncture on difficult veins, follow these guidelines:
- For paper-thin transparent skin or delicate veins: Use a small catheter (e.g., 24-gauge); use direct entry; consider not using a tourniquet (blood pressure cuff); decrease the angle of entry to 10–15 degrees; apply minimal tourniquet pressure.
- For an obese patient or if you are unable to palpate or see veins, consider ultrasound guidance.

Rationale
Flashback of blood indicates that the vein has been cannulated. Releasing the tourniquet restores full circulation to the patient’s extremity.
CHAPTER 6  Peripheral I.V. Catheters

**PROCEDURES DISPLAY 6-1**

**Steps for Inserting a Peripheral-Short Over-the-Needle Catheter by Direct and Indirect Methods—cont’d**

**Procedure**
- For veins that roll when venipuncture is attempted:
  Apply traction to the vein with the thumb during venipuncture, keeping skin taut; leave tourniquet on to promote venous distention; use a blood pressure cuff for better filling of vein; use 18-gauge catheter.

After the bevel enters the vein and blood flashback occurs, lower the angle of the catheter and stylet (needle) as one unit and advance into the vein. After the catheter tip and bevel are in the vein, advance the catheter forward off the stylet and into the vein.

After the vein is entered, cautiously advance the catheter into the vein lumen. Hold the catheter hub with your thumb and middle finger and use your index finger to advance the catheter, maintaining skin traction. A one-handed technique is recommended to advance the catheter off the stylet so that the opposite hand can maintain proper traction on the skin and maintain vein alignment. (A two-handed technique can be used, but this increases the risk of vessel rupture during threading of a rigid catheter in a nonstabilized vein.) While the stylet is still partially inside the catheter, release the tourniquet.

*Continued*
PROCEDURES DISPLAY 6-1
Steps for Inserting a Peripheral-Short Over-the-Needle Catheter by Direct and Indirect Methods—cont’d

Procedure
Remove the stylet and activate the safety feature of the catheter. If using a passive safety device, the safety mechanism is automatic.

13. Connect the administration set or needleless connector with a twisting motion.
14. Stabilize the catheter with a stabilization device or apply transparent semipermeable membrane (TSM) dressing directly over the catheter and hub.
15. Label the site with date and time, type and length of catheter, nurse’s initials.
16. Dispose of all equipment in appropriate receptacle.
17. Instruct the patient on use of an electronic infusion device (EID), what to report regarding site, and how often to expect the nurses to check the infusion site.
18. Calculate the infusion rate or dial appropriate rate into EID.
19. Document in the medical records: Date and time of insertion; type of device; gauge and length of catheter; solution infusing and rate of flow; any additional equipment (EID); number of attempts; condition of extremity before access; patient education, patient’s response; signature.

Rationale
13. Secures the Luer-lock and prevents leakage and contamination.
14. To reduce micromovement of catheter in the vein. Prevents microorganisms from entering the catheter–skin junction.
15. Legal protection of the patient and nurse.
16. Reduces risk of exposure to blood.
17. Knowledge of infusion therapy treatment assists in providing a positive outcome.
18. Ensure correct delivery of prescribed solution or medications.
19. Maintains a legal record and communication with the health-care team.
### Equipment Needed
- Prefilled syringe of 0.9% sodium chloride
- Antiseptic solution: 70% alcohol

### Delegation
This procedure can be delegated to an LPN/LVN who is specially trained in I.V. therapy, depending on the state nurse practice act for initiation of infusion therapy and agency policy and procedure. This cannot be delegated to nursing assistive personnel.

### Procedure Rationale
1. Follow standardized protocol for the agency or confirm order.
2. Establishes the nurse–patient relationship.
3. Single most important means of infection prevention.
4. Patient safety
5. Locking technique varies based on category.
6. Whether or not gloves are worn, the critical steps in aseptic technique are *not touching* the needleless connector after disinfection and *not touching* the tip of the flush syringe after the protective cover is removed.

### Procedure

<table>
<thead>
<tr>
<th>Step</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Follow standardized protocol for the agency or confirm order.</td>
<td>1. A standard protocol or order is required.</td>
</tr>
<tr>
<td>2. Introduce yourself to the patient.</td>
<td>2. Establishes the nurse–patient relationship.</td>
</tr>
<tr>
<td>3. Perform hand hygiene.</td>
<td>3. Single most important means of infection prevention.</td>
</tr>
<tr>
<td>4. Verify the patient’s identity using two forms of ID.</td>
<td>4. Patient safety</td>
</tr>
<tr>
<td>5. Identify whether the needleless connector is a negative-displacement device, a positive-displacement device, or a neutral-displacement device (see below).</td>
<td>5. Locking technique varies based on category.</td>
</tr>
<tr>
<td>6. Don gloves if required by organizational procedures.</td>
<td></td>
</tr>
<tr>
<td>7. Stop intermittent infusion, disconnecting I.V. administration set.</td>
<td></td>
</tr>
</tbody>
</table>

*Continued*
8. Disinfect the needleless connector with 70% isopropyl alcohol using a scrubbing motion and allow to dry. Most organizations require at least a 15-second scrub.

9. Attach prefilled syringe of 0.9% sodium chloride to the needleless connector.

10. Begin to flush and then slowly aspirate until blood is aspirated.

11. Flush and lock catheter with 0.9% sodium chloride.

12a. For negative-displacement devices:
Flush all solution into the catheter lumen, maintain force on the syringe plunger as a clamp on the catheter or extension set is closed, and then disconnect the syringe.

12b. For positive-displacement device:
Flush all solution into the catheter lumen, disconnect the syringe, and then close the catheter clamp.

12c. For neutral-displacement device:
Flush all solution into the catheter lumen.


Rationale


9. Confirms catheter patency.

10. Maintains patency of catheter and prevents occlusion.

10a. A “positive pressure” flushing technique to prevent reflux of blood.

10b. Catheter is clamped after disconnection of the syringe.

10c. It does not matter whether the catheter clamp is closed before or after the flush procedure.

11. Maintains a legal record.

Sources: Gorski et al., 2016b.
Chapter 7
Phlebotomy Techniques

LEARNING OBJECTIVES
After completing this chapter, the reader will be able to:

1. Define terminology related to phlebotomy.
2. Identify three methods used for blood collection.
3. Describe components of the evacuated tube system.
4. Describe differences between the evacuated tube system method and the syringe system.
5. List indications for testing via capillary puncture.
6. List the various types of anticoagulants used in blood collection.
7. Recognize the importance of the order of the draw for patients requiring multiple tube collections.
8. Identify appropriate veins used for phlebotomy.
9. Describe risks and benefits to blood sampling via a vascular access device (VAD).
10. Differentiate between the discard and the mixing methods used in VAD blood sampling.
12. Summarize pediatric and older adult implications related to phlebotomy.

Glossary

Anticoagulant  Substance introduced into the blood or a blood specimen to keep it from clotting
Capillary puncture  The collection of blood via a skin puncture with a lancet
Citrate–phosphate–dextrose (CPD)  Anticoagulant typically used for blood donations
Clinical and Laboratory Standards Institute (CLSI)  A global, nonprofit, standards-developing organization comprising representatives from the profession, industry, and government.
Ethylenediaminetetraacetic acid (EDTA)  Anticoagulant additive used to prevent the blood clotting sequence by removing calcium and forming calcium slats. EDTA prevents platelet aggregation and is useful for platelet counts and platelet function tests.
Evacuated Tube System (ETS)  A closed system in which the patient’s blood flows directly into a collection tube through a needle inserted into a vein.

Hemoconcentration  A decrease in the fluid content of the blood, with a subsequent increase in nonfilterable large-molecule or protein-based blood components such as red blood cells.

Hemolysis  The destruction of the membrane of the red blood cells.

Multisample needle  Used with the evacuated tube method of blood collection. These needles are attached to a tube holder and allow for multiple-specimen tube fills.

Oxalates  Anticoagulants that prevent blood clotting sequence by removing calcium and forming calcium salts.

Phlebotomist  Individual who practices phlebotomy.

Phlebotomy  Withdrawal of blood from a vein.

Point-of-care testing (POCT)  Testing—ancillary, bedside, or near patient—performed using portable or handheld instruments.

Preanalytical phase  Refers to the time of laboratory sampling before the sample reaches the laboratory; includes the phlebotomy procedures.

Syringe method  A sterile safety needle, a disposable plastic syringe, and a syringe transfer device.

Introduction

Blood and other specimen collections are important to the health assessment of the patient. The term phlebotomy is derived from the Greek words “phlebos,” meaning vein, and “tome,” meaning incision. Phlebotomy is accomplished through venipuncture and also via capillary puncture, which is the collection of blood through a skin puncture with a lancet (McCall & Tankersley, 2016). Blood may also be withdrawn from a vascular access device (VAD), most often by the registered nurse.

Advances in laboratory technology have resulted in making point-of-care testing (POCT) (e.g., blood glucose, international normalized ratio [INR]) more common, with advantages including rapid results and blood conservation, although procedures for quality control must be in place to ensure testing accuracy. Blood collection is used for three important purposes:

1. Diagnostic testing and monitoring of prescribed treatment
2. Blood donation for transfusion
3. Therapeutic reasons such as treatment for polycythemia (McCall & Tankersley, 2016)

Professional Competency

The term phlebotomist is applied to a person who has been trained to collect blood. The role of the nurse may include phlebotomy; the nurse also has the responsibility of preserving veins for infusion therapy. The nurse has
the unique ability to perform a single venipuncture, permitting both the withdrawal of blood for testing and the initiation of an infusion, thereby preserving veins. In a multiyear study sponsored by a medical device company, nurses who were surveyed believed that standardization and innovation are essential to blood collection practices. Some specific survey findings included:

- Nurses estimate that 25% of patients receive “fishing” or probing during venipuncture and that an equal amount of patients get re-sticks with approximately 45% experiencing more than two attempts at venipuncture.
- 33% of all patients have difficult venous access, requiring multiple sticks, bruising, and insufficient samples. Due to the aging and chronically ill population, this number is expected to escalate.
- 82% have some level of concern about accidental needlesticks or occupational health hazards during blood draws.
- Nearly 90% of respondents indicated they would frequently or almost always use a needle-free device for blood collection (Velano Vascular, 2016).

As many health professionals are cross-trained to perform phlebotomy, the term phlebotomist may be applied to anyone who has been trained to collect blood specimens. Table 7-1 lists the duties and responsibilities of the phlebotomist. The nurse performing phlebotomy procedures or the dedicated phlebotomist must be competent. It is important to recognize that most errors in the laboratory testing process occur in the “preanalytical” phase before the sample reaches the laboratory and include phlebotomy procedures (Cornes et al., 2017). As addressed in Chapter 1, competence includes knowledge, skill, ability, and judgment. Some areas of competency assessment relevant to safe phlebotomy include:

- Knowledge of basic anatomy and physiology, medical terminology, potential sources for laboratory error/inconsistencies, infection prevention practices including standard and transmission-based precautions (Chapter 2)

<table>
<thead>
<tr>
<th>Table 7-1 Phlebotomist: Functions and Responsibilities</th>
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<tbody>
<tr>
<td>1. Prepare patients for blood collection procedures.</td>
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<tr>
<td>3. Comply with all procedures instituted in the organizational procedures manual.</td>
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<tr>
<td>4. Adhere to standard and transmission-based precautions.</td>
</tr>
<tr>
<td>5. Perform venipuncture and collect venous specimens for testing.</td>
</tr>
<tr>
<td>6. Perform point-of-care testing.</td>
</tr>
<tr>
<td>7. Prepare specimens for transport.</td>
</tr>
<tr>
<td>8. Perform quality control checks while performing clerical, clinical, and technical duties.</td>
</tr>
<tr>
<td>9. Transport specimens to the laboratory.</td>
</tr>
<tr>
<td>10. Perform laboratory computer operations.</td>
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</tbody>
</table>
• Demonstration of skills such as preparing the patient, selecting the best venipuncture site, conducting the venipuncture, and obtaining an accurate specimen collection based on organizational policies and procedures.

Certification is evidence that an individual has mastered fundamental competencies of a technical area. Usually a phlebotomist must complete a phlebotomy program. Examples of national agencies that certify phlebotomists, along with the title and corresponding initials awarded, are listed as follows:

• American Medical Technologists (AMT)—Registered Phlebotomy Technician (RPT)
• American Certification Agency—Certified Phlebotomy Technician (CPT)
• American Society for Clinical Pathology—Phlebotomy Technician (PBT)
• National Center for Competency Testing (NCCT)—National Certified Phlebotomy Technician (NCPT)

NURSING FAST FACT!
The National Patient Safety Goals (NPSGs) for laboratory services include the following:
1. Improve the accuracy of patient identification. Use at least two patient identifiers when obtaining laboratory specimens.
2. Improve the effectiveness of staff communication. Report critical results of tests and diagnostic procedures on a timely basis.
3. Prevent infection. Comply with either the current Centers for Disease Control and Prevention (CDC) hand hygiene guidelines or the current World Health Organization (WHO) hand hygiene guidelines (The Joint Commission, 2017).

Phlebotomy Methods and Supplies
Before performing any type of specimen collection, the nurse or phlebotomist gathers the necessary equipment including phlebotomy supplies and test requisitions. Supplies for venipuncture differ according to the method used (i.e., evacuated tube system [ETS], syringe method, capillary puncture, or withdrawal from the VAD). Table 7-2 provides a list of supplies that should be included on a blood collection tray.

Phlebotomy: Using the Evacuated Tube System
Venipuncture with an ETS is the most direct and efficient method for obtaining a blood specimen. It is a closed system in which the patient's blood flows through a needle inserted into a vein and directly into a collection tube without being exposed to the air or outside contaminants. The system allows for multiple tubes to be collected with a single venipuncture. The ETS requires three components: tube holders, multisample needles, and evacuated tubes (Fig. 7-1).
CHAPTER 7  Phlebotomy Techniques

NURSING FAST FACT!

According to Occupational Safety and Health Administration (OSHA) regulations, if the needle does not have a safety feature, the equipment it will be used with (e.g., tube holder, syringe) must have a safety feature to minimize the chance of an accidental needlestick (OSHA, 2015).

Tube Holders

The tube holder is a clear plastic disposable cylinder with a small threaded opening at the end where the needle is screwed in and a large opening at the other end where the collection tube is inserted. Holders typically are available in several sizes (McCall & Tankersley, 2016). There are preassembled tube holders that have the needle permanently attached, and there are also tube holders that Luer-lock directly onto the catheter hub or needleless connector of a VAD. The tube holder that requires attachment with the needle is always disposed of as a unit after use and never removed from the needle and reused (OSHA, 2015).

Multisample Needles

Multisample needles are used as part of the ETS system. These needles allow multiple tubes of blood to be collected during a single venipuncture. They are threaded in the middle and have a beveled point on each end. The threaded portion screws into a tube holder. The end of the needle that pierces the vein is longer and has a longer bevel. The shorter end penetrates the tube stopper during specimen collection. It is covered by a sleeve that retracts as the needle...

Table 7-2  Blood Collection Equipment and Supplies

| Equipment carriers: Handheld carriers or phlebotomy carts |
| Gloves: Nonsterile, powder free (e.g., nitrile, neoprene, polyethylene, or vinyl examination gloves) Note: A good fit is essential. |
| Antiseptics: Most often 70% isopropyl alcohol; chlorhexidine gluconate or povidone-iodine is used for a higher degree of skin antisepsis (e.g., blood culture collection) |
| Alcohol-based hand sanitizer |
| Gauze pads/cotton balls (2 × 2 gauze pads) |
| Bandages (latex free): cover site after bleeding has stopped |
| Paper, cloth, or knitted tape for use over cotton balls |
| Vacuum tubes/tube holders |
| Needles: multisample and hypodermic/winged infusion sets (for syringe draws) |
| Tourniquets (nonlatex, single-use) |
| Safety lancets |
| Microcollection blood serum separator tubes |
| Vein locating device (optional) |
| Marking pen (to label tubes) |
| Watch (to time tests) |
| Biohazard disposal containers |
| Biohazard bags (transport specimen from collection site to laboratory) |

goes through the tube stopper so that blood can flow into the tube (McCall & Tankersley, 2016). The needle includes a safety device that is activated by the phlebotomist after withdrawal from the patient’s vein; this is called an “active” safety device. Alternatively, some needles may utilize “passive” safety features, meaning that the safety device automatically deploys upon withdrawal from the vein. Figure 7-2 shows an example of an active safety feature.

**Figure 7-2** BD Vacutainer Eclipse™ blood collection safety needle. (Courtesy and © Becton, Dickenson and Company.)
Phlebotomy: Using a Syringe System

Although the ETS is preferred for blood collection, a syringe system is sometimes used for patients with small or difficult veins. This means that a traditional syringe (most often a 5- to 20-mL syringe) with a safety hypodermic needle (most often 1–1.5 inches, gauge 21–23) is used to perform the venipuncture. After the venipuncture, the needle safety device is activated and the needle discarded into the biohazard container. A syringe transfer device is attached to the hub of the syringe. The syringe transfer device is similar to an ETS tube holder but with a permanently attached needle. The tube is inserted into the device, allowing the blood to flow into the tube (Fig. 7-3).

Winged Infusion Set

The winged infusion set or butterfly needle is commonly used in blood collection when the patient has small or difficult veins. Butterfly needles are typically ½ to ¾ inch long and are permanently connected to a 5- to 12-inch length of tubing with either a Luer attachment for syringe use or a multisample Luer adapter for use with the ETS (Fig. 7-4). A 23-gauge needle size is commonly used. Larger-gauge needles (e.g., 18-gauge) are used for collecting donor units of blood and for therapeutic phlebotomy.

NURSING FAST FACT!

The first tube collected with a winged infusion set will underfill because of the air in the tubing.
Evacuated Tubes

Tubes have premeasured amounts of vacuum, which allows for automatic filling with blood. The tubes are available in different sizes (1.8–15 mL). Tube size selection is based upon the patient’s age, the amount of blood required for testing, and vein condition (McCall & Tankersley, 2016). Most tubes are made of unbreakable plastic and are color coded and referred to as red tops, green tops, and so forth. For most tubes, the stopper color identifies a type of additive placed in the tube by the manufacturer. It is imperative to check the expiration date before using any blood collection tube. Manufacturers guarantee reliability of the additive and the tube vacuum until the expiration date printed on the label, providing the tubes are handled properly and stored between 4°C and 25°C.

Most ETS tubes contain some type of additive placed within the tube. Additives have one or more specific functions, such as preventing clotting or preserving certain blood components. Additive free tubes are often used for discarding an initial blood sample. Pictures of ETS tubes can be found in Figure 7-5.

![Figure 7-4 BD Vacutainer push button blood collection set. (Courtesy and © Becton, Dickenson and Company.)](image)

**NURSING FAST FACT!**
Use of closed systems minimizes laboratory personnel’s risk of exposure to blood. The expiration dates of tubes must be monitored carefully.
Anticoagulant Tube Additives

The most common reason for using an additive is to prevent blood clotting. Many coagulation factors are involved in blood clotting, and coagulation can be prevented by the addition of an anticoagulant. These anticoagulants often contain preservatives that can extend the metabolism and life span of the red blood cell.

The most common anticoagulants are oxalates, citrates, ethylenediaminetetraacetic acid (EDTA), or heparin. Oxalates, citrates, and EDTA prevent coagulation of blood by removing calcium and forming insoluble calcium salts. They cannot be used in calcium determinations; however, citrates are frequently used in coagulation blood studies. EDTA prevents platelet aggregation and is used for hematology tests (e.g., complete blood counts). Heparin prevents blood clotting by inhibiting the conversion of prothrombin to thrombin and fibrinogen to fibrin.

NURSING FAST FACT!

Vigorous mixing or an excessive number of inversions can activate platelets and shorten clotting times.

NURSING FAST FACT!

Clotted specimens should not be shaken.
Phlebotomy: Via Capillary Puncture

Drops of blood for testing may be obtained by use of a lancet. Lancets are sterile, disposable instruments used to puncture or make an incision in the skin. Lancets are available in a variety of sizes and are specifically designed for either a finger or heel puncture. Lancets are safety devices; the blades retract after activation to prevent health-care worker needlesticks. Figure 7-6 shows an example of a microcollection lancet. Common terms used to describe this technique of blood collection are **capillary specimens** and **capillary punctures** (McCall & Tankersley, 2016).

Capillary punctures may be used in the following circumstances, as long as the prescribed test allows for testing with a small quantity of blood:

- Infants/very young children (preferred method)
- Patients who have fragile veins/no accessible veins
- Unsuccessful venipunctures
- Patients with thrombotic tendencies
- Patients with severe needle phobias
- POCT procedures (e.g., blood glucose, international normalized ratio [INR])
  (McCall & Tankersley, 2016)

**NURSING FAST FACT!**

The recommended penetration depth of the lancet is no more than 2.0 mm on the heel, as deeper punctures may cause bone injury (McCall & Tankersley, 2016). Refer to Age-Related Considerations for more guidance related to pediatric blood collection.

**Figure 7-6** BD Quikheel™ microcollection lancet. (Courtesy and © Becton, Dickenson and Company.)
**Blood Collection Procedures**

When preparing for blood collection, the phlebotomist carries out essential steps to ensure a successful blood specimen collection. The CLSI has recommendations for safe blood collection. These steps may vary in individual facilities depending on the characteristics of their patient populations. Some steps may be carried out simultaneously. The recommended steps include:

1. Review the test requisition.
2. Approach the patient
3. Assess the patient and identify the patient using two identifiers.
4. Select and prepare equipment and supplies.
5. Select a puncture site.
6. Choose a venipuncture method.
7. Prepare the puncture site and perform venipuncture.
8. Collect the samples in the appropriate tubes and in the correct order.
9. Label the samples.
10. Assess the patient after withdrawal of the blood specimen.
11. Consider any special circumstances that occurred during the phlebotomy procedure.
12. Assess criteria for sample re-collection or rejection.
13. Dispose of needles/blood saturated items in biohazard containers.
14. Transport the specimen to the laboratory.

**Test Requisition**

Laboratory tests are ordered by a licensed independent practitioner (LIP). Both the manual and computer requisitions often contain a barcode. Labels to be placed on the specimen tubes immediately after collection are usually computer generated. The phlebotomist typically is required to write the time of collection and his or her initials on the label after collection. The requisition should contain the following information (McCall & Tankersley, 2016).

- Patient’s first and last names/ birth date
- Physician or authorized prescriber’s name
- Patient’s identification or medical record number
- Room number and bed (if inpatient)
- Types of tests to be performed
- Date of tests
- Billing information and International Classification of Diseases (ICD)-10 codes (if outpatient)
- Test status (timed, priority, fasting, etc.)
- Special precautions (on anticoagulant, faints easily, etc.)

**Drawing Station**

A blood drawing station is a dedicated area of a medical laboratory or clinic equipped for performing phlebotomy. A phlebotomy chair should be used for the patient to sit in during the blood collection procedure. Most have
adjustable armrests that lock in place to prevent the patient from falling should he or she faint (Fig. 7-7). In the acute care setting, blood is drawn at the bedside. In the home-care setting, the patient may be seated in a comfortable chair or in bed.

**Patient Assessment and Identification**

The nurse or phlebotomist must be aware of the physical or emotional disposition of the patient, which can have an impact on the blood collection process. Relevant assessment data focus on the following (McCall & Tankersley, 2016):

- **Diet:** It is important to note whether or not the patient has been fasting, which may be required for some laboratory tests.
- **Stress:** A patient who is excessively anxious or emotional may need extra time.
- **Age:** The elderly may have more difficult or frail veins from which to choose for the venipuncture site. A pediatric patient usually needs additional support for venipuncture.
- **Weight:** An obese patient may require special equipment, such as a large blood pressure cuff for the tourniquet or a longer needle to penetrate the vein.

**Figure 7-7** Blood drawing chair.
Patient Identification Process

Before any specimen collection procedure, the patient must be correctly identified by using a two-step process:

1. Ask the patient to state his or her first and last names.
2. Confirm a match between the patient’s response, the test requisition, and some form of identification, such as hospital identification bracelet, driver’s license, or another identification card.
3. The use of an electronic system (e.g., barcoding) for patient identification as well as sample container labeling is associated with reduced risk for errors (Gorski et al., 2016a, p. S86).

NURSING FAST FACT!

Technology has advanced such that most hospitals have one- and two-dimensional barcode technologies that enable more information to be encoded. Barcodes tend to be very accurate and cost-effective for larger organizations. Specimen labels are now barcoded (Fig. 7-8).

Blood specimen collection for blood banking, such as typing and cross-matching, requires special patient identification procedures and armband application (Chapter 11).

Care must be taken in identification of emergency room patients. Often when patients come to the emergency room, they are unconscious and/or
unidentified. Each hospital has policies and procedures for dealing with these cases; they usually include assigning the patient an identification tag with a hospital or medical record number.

**NOTE:** Never attempt to collect a blood specimen from a sleeping patient. Such an attempt may startle the patient and cause injury to the patient or the phlebotomist.

### Hand Hygiene/Gloving

Follow standard precautions by using alcohol-based hand sanitizer before donning gloves for the procedure.

### Venipuncture Site Selection

Position the patient with his or her arm extended downward in a straight line from the shoulder to the wrist and not bent at the elbow. In the outpatient setting, blood is drawn with the patient sitting up in a phlebotomy chair.

The tourniquet is applied 3 to 4 inches above the intended venipuncture site. The tourniquet should be tight enough to slow venous flow without affecting arterial flow. If a patient has prominent visible veins, tourniquet application can wait until after the site is cleansed and before insertion of the needle. In some situations, a tourniquet may not be needed. The venipuncture site may be warmed to promote vasodilation.

The preferred site for venipuncture is the antecubital area of the arm (Fig. 7-9). The health-care practitioner should palpate the veins to determine the size, angle, and depth of the vein. For most patients, prominent veins include the cephalic vein, which communicates with the basilic vein via the median cubital vein. Venipuncture preferences are as follows:

- The median cubital vein is preferred as it is larger, closer to the skin surface, and more stationary. It is easy to access and causes less pain with venipuncture.
- The cephalic vein is the second choice and may be the only palpable vein in patients who are obese.
- The basilic vein is the last choice as it is not as well anchored, tends to roll, and is associated with increased risk for median or anterior interosseous nerve injury.

In some patients, the median cubital vein may have variations, including two branches coming from the median vein (also called the intermediate antebrachial): the median basilic vein and the median cephalic vein. In this anatomic situation:

- The median vein is preferred. It is well anchored, less painful to access, and not as close to major nerves or arteries.
- The median cephalic vein is the second choice.
- The median basilic vein is the last choice for the same reasons listed above regarding the basilic vein (Gorski et al., 2016a, S102; McCall & Tankersley, 2016).
Veins on the dorsal side of the hand are used if arm veins are unsuitable. The cephalic vein above the thumb should not be used due to risk for nerve injury. Foot or ankle veins are avoided due to coagulation and vascular complications. Additional venipuncture guidance from the *Infusion Therapy Standards of Practice* includes:

- Perform the venipuncture on the opposite extremity of an infusion; if the blood must be drawn on the extremity with the infusion, use a vein below (distal to) the I.V. catheter site.
- Avoid venipuncture on upper extremities with lymphedema, compromised circulation with radiation treatment, or paralysis or hemiparesis from a cerebrovascular accident.
- In patients with an actual or planned dialysis fistula or graft, restrict venipuncture to the hand (Gorski et al., 2016a, p. S86).
Preparation of the Venipuncture Site: Skin Antisepsis

Once the site is selected, the site should be prepped with an appropriate skin antiseptic agent. These include: 70% isopropyl alcohol (most common), >0.5% chlorhexidine in alcohol solution, tincture of iodine, or povidone-iodine (Gorski et al., 2016a, p. S86). The area should be allowed to dry naturally for 30 to 60 seconds prior to venipuncture.

NOTE: According to CLSI Standard H3-A5, an attempt must have been made to locate the median cubital on both arms before considering an alternate vein. Also, because of the possibility of nerve injury and damage to the brachial artery, the basilic vein should not be chosen unless no other vein is prominent (CLSI, 2007a).

Equipment Preparation and Venipuncture Technique

Place all collection equipment and supplies within easy reach, typically on the same side of the patient's arm as your free hand during venipuncture. Select the appropriate ETS tubes based on requisition. Check the expiration date on each of the tubes. Inspect the seal of the needle and discard if broken. Twist the needle cover apart to expose the short or back end of the needle that is covered by a retractable sleeve. Screw this end of the needle into the threaded hub of an ETS tube holder. Place the first tube in the holder and use a slight clockwise

NURSING FAST FACT!

- Never draw above an infusing I.V.; this can alter the test results.
- Use caution during venipuncture. Although nerve damage during venipuncture is rare, it has been known to occur as a result of excessive needle probing and sudden movement of the patient.

NURSING FAST FACT!

If the patient has sensitive skin or dermatitis, apply the tourniquet over a dry washcloth or gauze wrapped around the arm or over a hospital gown sleeve.

NURSING FAST FACT!

Do not touch the prepared venipuncture site after prepping. The alcohol should be allowed to dry (30–60 seconds). Never fan the site with your hand or blow on it to hasten drying time.
twist to push it onto the needle just far enough to secure it from falling out but not far enough to release the tube vacuum.

**NURSING FAST FACT!**

Do not place the phlebotomy tray on the patient’s bed or any other place that could be considered contaminated.

Once the venipuncture site is prepped and the tourniquet reapplied, the health-care worker may hold the patient’s arm below the site, pulling the skin tightly with the thumb (traction) to anchor the vein.

**NURSING FAST FACT!**

For safety do not use a two-finger technique (also called “C”) in which the entry point of the vein is straddled by the index finger above and the thumb below. If the patient pulls the arm back when the needle is inserted, there is a possibility that the needle may recoil as it comes out of the arm and spring back into the phlebotomist’s index finger.

Line up the needle with the vein and insert smoothly and quickly at approximately a 15- to 30-degree angle with the skin. The needle should be inserted with the bevel side upward and directly above a prominent vein or slightly below the palpable vein. Sometimes a slight “pop” can be felt when the needle enters the vein. The tourniquet should be released immediately after blood begins to flow. The tourniquet should not be left on more than 1 minute to reduce the risk for hemolysis and inaccurate chemistry values caused by changes in the vascular endothelium from increased pressure and hypoxia (Gorski et al., 2016a, p. S87).

**Evacuated Tube System Technique**

**NURSING FAST FACT!**

- For beginners it is easier not to try to balance the tube in the holder before venipuncture. Access the vein and then pick up the tube and push it onto the inner needle.
- Vigorous handling of the blood tubes and sluggish propulsion of blood into the tube can cause hemolysis and separation of cells from liquid, which can affect the test results.
- Some clinicians use the dominant hand to change tubes while using the other hand to keep the needle apparatus steady.
See Procedures Display 7-1 at the end of this chapter for steps in performing the evacuated tube blood collection method.

When multiple sample tubes are to be collected, each tube should be gently removed from the tube holder and replaced with the next tube. See Figure 7-10 for proper insertion of the tube into the tube holder. Experienced clinicians are able to mix a full tube in one hand while holding the needle apparatus with the other hand. Multiple tubes can be filled in less than 1 minute if the needle remains stable in the vein and the vein does not collapse. The holder must be securely held while the tubes are being changed so that the needle is not pushed farther into or removed from the vein. After collection of the blood and removal of the last tube, the entire needle assembly should be withdrawn quickly. Safety devices should be activated immediately, depending on the manufacturer’s directions.

Figure 7-10 Proper insertion of needle into Vacutainer holder. (Courtesy and © Becton, Dickenson and Company.)
Winged Infusion Set Equipment Preparation and Venipuncture Technique

A winged infusion system is often used for difficult venipunctures. Figure 7-11 shows insertion of a winged needle into the ETS holder. Figure 7-12 shows the steps for push-button winged needle blood collection. This method is sometimes useful for:

- Patients with small veins, such as in the hand
- Pediatric or older adult patients
- Patients in restrictive positions (i.e., those in traction or with severe arthritis)
- Patients with numerous needlesticks
- Patients with fragile skin and veins
- Patients who are severely burned

Syringe Equipment Preparation and Venipuncture Technique

Select a syringe and needle size compatible with the size and condition of the patient's vein and the amount of blood to be collected. Open the needle package aseptically and then attach the syringe. A blood specimen collected in a syringe will have to be transferred to ETS tubes (Fig. 7-12).

When using the syringe method, follow the same approach to needle insertion as the one used for the evacuated tube method. Once the needle is in the vein, the syringe plunger can be drawn back gently to avoid hemolysis of the specimen until the required volume of blood has been withdrawn. The health-care worker must be careful not to withdraw the needle from the vein while pulling back on the plunger.

Figure 7-11 Insertion of winged needle into ETS holder. (Courtesy and © Becton, Dickenson and Company.)
Figure 7-12 Vacutainer push-button winged needle blood collection set steps. (Courtesy and © Becton, Dickenson and Company.)
**Nursing Fast Fact!**

- Turn the syringe so that the graduated markings are visible.
- See Procedures Display 7-2 at the end of this chapter for steps on the syringe method of blood collection.

**Order of Tube Collection**

As stated earlier, most errors in the laboratory testing process occur in the preanalytical phase outside of the laboratory. Based upon a review of the evidence, one important area for sample contamination occurs when the order of draw is not followed (Cornes et al., 2017). Although there may be some small variations among organizations, it is important to fill the tubes in the correct order. The following order should be followed when collecting multiple tubes of blood:

1. Blood culture tubes, vials, or bottles
2. Coagulation tubes (light blue top)
3. Serum tube with or without clot activator, with or without gel (red, red/gray-mottled, gold top)
4. Heparin tube with or without gel separator (green)
5. EDTA tube with or without gel separator (lavender, purple, white/pearl)

Table 7-3 gives the order of draw for multiple tube collections. Also see insert at front of book for a “Tube Guide.”

<table>
<thead>
<tr>
<th>Collection Tube</th>
<th>Mix by Inverting</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blood cultures—Sodium polyanethol sulfonate (SPS)</td>
<td>8–10 times</td>
<td>Yellow</td>
</tr>
<tr>
<td>Coagulation citrate tubes</td>
<td>3–4 times</td>
<td>Light blue</td>
</tr>
<tr>
<td>Serum tube (glass)</td>
<td>None for glass</td>
<td>Red</td>
</tr>
<tr>
<td>Plastic clot activator tubes</td>
<td>5 times for plastic</td>
<td>Red or red/gray rubber Gold plastic</td>
</tr>
<tr>
<td>Plasma separator tubes (PSTs) with gel separator/heparin</td>
<td>8–10 times</td>
<td>Green/gray Light-green plastic</td>
</tr>
<tr>
<td>Heparin tube</td>
<td>8–10 times</td>
<td>Green</td>
</tr>
<tr>
<td>EDTA tube</td>
<td>8–10 times</td>
<td>Lavender or pink</td>
</tr>
<tr>
<td>Oxalate/fluoride tubes</td>
<td>8–10 times</td>
<td>Gray</td>
</tr>
</tbody>
</table>

*Note: Always follow your facility’s protocol for order of draw.*
Yellow, Light Blue, Red, Green, Lavender/Pink, and Gray Tops

- Be meticulous about time, type of test, and volume of blood required.
- Always draw blood cultures first to decrease the possibility of bacterial contamination; use of a dedicated phlebotomy team is recommended to reduce blood culture contamination (Gorski et al., 2016a, S87).
- When drawing just coagulation studies for diagnostic purposes, it is preferable that at least one other tube of blood be drawn before the coagulation test specimen. This diminishes contamination with tissue fluids, which may initiate the clotting sequence. This is an example of when a nonadditive tube may be used, and this sample would be discarded.
- Coagulation tubes should be mixed as soon as possible after collection.
- When a large volume (more than 20 mL) of blood has been drawn using a syringe, there is a possibility that some of the blood may be clotted.
- Watch the “fill” rate and volume in each tube; evacuated tubes with anticoagulants must be filled to the designated level for the proper mix of blood with the anticoagulant.

**NOTE:** Partial fill tubes are available when it is suspected that the blood specimen will not be adequate.

**Fill and Mix of Tubes**

If the tube contains an additive, mix it by gently inverting it three to eight times, depending on the type of additive and the manufacturer’s recommendations, as soon as it is removed from the tube holder. Nonadditive tubes do not require mixing.

**NOTE:** Do not shake or vigorously mix blood specimens because this can cause hemolysis.

Remove the last specimen tube from the holder before removing the needle from the vein. Gently but quickly remove the needle. After collection of the blood, the entire blood collection assembly should be withdrawn quickly. Safety devices should be activated immediately, depending on the manufacturer’s specifications.

A dry sterile gauze or cotton ball should be applied with pressure to the puncture site until bleeding has stopped. A bandage should be applied and the patient instructed to leave it on for at least 15 minutes.

**NURSING FAST FACT!**

Failing to apply pressure or applying inadequate pressure can result in leakage of blood and hematoma formation.

It is acceptable to have the patient apply pressure while you label the tubes, providing the patient is fully cooperative.
Disposal of Equipment
All contaminated equipment should be discarded into appropriate containers. Needles, lancets, and any blood saturated items, such as a gauze, should be placed into a biohazard container.

Specimen Identification and Labeling
Specimens should be labeled immediately at the patient's bedside or ambulatory setting. Some laboratories require labels to be placed such that the label does not obscure the entire specimen. If using preprinted computer or barcode label, write the date, time, and your initials on the label immediately after withdrawal from the tube. Any handwritten labeling must be done with permanent ink pen and provide the following information:

- Patient's full name
- Patient's identification numbers
- Date and time of collection
- Health-care worker's initials
- Patient's room number, bed assignment, and outpatient status are optional information.

Transport of the Specimen to the Laboratory
All specimens should be transported to the laboratory or designated pickup site in a timely fashion. The phlebotomist typically is responsible for verifying and documenting collection by computer entry (McCall & Tankersley, 2016).

NURSING FAST FACT!
If the specimen cannot be transported to the laboratory within a reasonable period of time, or if analysis is delayed, arrange for proper storage to prevent deterioration or contamination that can cause inaccurate results (Van Leeuwen, Poelhuis-Leth, & Bladh, 2012).

Blood Sampling From a Vascular Access Device
Use of the VAD for blood sampling provides patient benefits such as eliminating anxiety and pain from venipuncture and decreasing patient dissatisfaction with repeatedly being “stuck,” as well as avoiding the complications associated with venipuncture. However, there are potential risks, including:

- Increased risk for occlusion, especially that associated with inadequate technique and flushing
- Increased risk for catheter-related bloodstream infection as a result of manipulation at the catheter hub
- Potential for inaccurate laboratory test results associated with adsorption of medications infused via the VAD (Gorski et al., 2016a).
The INS Standards recommend a careful analysis of risks versus benefits when making the decision to use the catheter for blood sampling. Organizations should have procedures in place that address safe blood sampling via the VAD. From the INS Standards, the following issues should be considered in relation to blood draws from a VAD (Gorski et al., 2017, p. S87):

- Stop infusions for at least 2 minutes and waste 1 to 2 mL of blood before obtaining a blood sample from a peripheral catheter.
- Use the largest central VAD (CVAD) lumen or, for CVADs with staggered lumens, draw from the lumen exiting at the point farthest from the heart (Chapter 8).
- Avoid using CVADs for blood sampling in the patient receiving parenteral nutrition as this practice has been associated with increased risk for bloodstream infection (Chapter 12).
- Use caution when interpreting drug levels. When a questionable result is obtained (e.g., unexpected high level that would require a medication dose change), consider the need to retest via a direct venipuncture. The risk of erroneous drug levels is increased when blood is not drawn from a dedicated CVAD lumen.
- Carefully assess coagulation levels from a heparinized CVAD because this practice may provide questionable results.

There are two recommended methods for blood sampling from a CVAD. The most common method is what is commonly called the “discard” method. The first aspirate of blood is discarded to reduce the risk of any drug, normal saline, or heparin interfering with the laboratory test results. Refer to Procedures Display 7-3 at the end of this chapter for steps on drawing a blood sample from a CVAD using the discard method.

Another method endorsed by INS (Gorski et al., 2016a) is the push–pull or mixing method. The advantage to this method is less blood loss because there is no discarded blood. Key steps to this procedure include:

- Flush the CVAD with 5 mL of 0.9% sodium chloride for injection using a 10-mL syringe.
- Aspirate 6 mL of blood (without detaching the syringe).
- Push blood back into the catheter and repeat process 3 to 5 times.
- Remove empty syringe; attach a new syringe or Vacutainer to obtain laboratory sample.
- Flush catheter with saline and heparinize per orders or resume infusion.

**NURSING FAST FACT!**

Be aware that withdrawal of blood through the CVAD can contribute to thrombotic catheter occlusion if the catheter is not flushed adequately after blood withdrawal.
Complications

Hematoma

Hematoma formation is the most common complication of venipuncture. It is caused by blood leaking into the tissues during or after venipuncture and is identified by rapid swelling at or near the venipuncture site. Presence of a hematoma makes the site unacceptable for subsequent venipunctures.

If a hematoma forms during blood collection, the draw should be discontinued, and pressure must be held over the site for 2 minutes. Cold compresses can be used for large hematomas to reduce swelling. Figure 7-13 shows an example of hematoma formation after venipuncture.

Situations that can trigger hematoma formation:

- Use of excessive or blind probing to locate a vein
- Inadvertent arterial puncture
The vein is fragile or too small for the needle size.
The needle penetrates all the way through the vein.
The needle is only partly inserted into the vein.
The needle is removed while the tourniquet is still on.
Pressure is not adequately applied following venipuncture.

**Iatrogenic Anemia**
Blood loss as a result of blood removal for testing is called iatrogenic blood loss. Removing blood on a regular basis or in large quantities can lead to iatrogenic anemia in some patients, especially neonates and critically ill patients. This topic is addressed in Chapter 11 as it relates to reducing the need for blood transfusions. Blood conservation methods include eliminating unnecessary tests, consolidating all laboratory tests with a daily blood draw, recording the volume of blood obtained, using low-volume blood collection tubes, and considering the use of POCT methods (Gorski et al., 2016a, S86).

**Infection**
Although rare, infection at the site of venipuncture can occur. The risk of infection is minimized by use of proper aseptic technique, hand hygiene, and gloves.
Nerve Injury

Nerves and veins in the arms lie close to each other. Improper vein selection can lead to nerve injury if the needle is inserted too deeply or quickly. Movement by the patient as the needle is inserted can also cause nerve injury. Blind probing while attempting venipuncture can lead to injury of a main nerve. The consequences of nerve injury may be minor or major. Nerve injury can result in the formation of a traumatic neuroma (an unorganized mass of nerve fibers) at the point of needle contact that requires surgical removal (Gorski et al., 2016a, p. S102). Complex regional pain syndrome (CRPS), a chronic debilitating condition, may result from venipuncture.

Vein Damage

Numerous venipunctures in the same area over an extended period of time can cause a buildup of scar tissue and increase the difficulty of performing subsequent venipunctures. Blind probing and improper technique when redirecting the needle can also damage veins and impair patency (McCall & Tankersley, 2016). Avoid venipuncture from damaged veins.

AGE-RELATED CONSIDERATIONS

The Pediatric Client

- Heel stick: Capillary collection is preferable and normally recommended for pediatric patients, especially newborns and infants up to 12 months. Venipuncture is done in the area of the heel where there is little risk of puncturing the bone. According to CLSI, the only safe area of the heel is the plantar surface of the heel, medial to an imaginary line extending from the middle of the great toe to the heel, or lateral to an imaginary line extending from between the fourth and fifth toes to the heel (Fig. 7-14).
- When capillary puncture is not appropriate based upon the type of test or volume of blood required, blood is obtained by venipuncture. In children younger than 2 years old, venipuncture should be limited to superficial veins. The accessible veins of infants and toddlers are veins of the antecubital fossa and forearm.
- Removal of large quantities of blood at once, or even small quantities on a regular basis, can lead to anemia. Removing more than 10% of an infant’s blood volume at one time can lead to shock and cardiac arrest. Most facilities have limits on the amount of blood that can be removed per draw. Many facilities do not allow more
than 3% of a child’s blood volume to be collected at one time and allow no more than 10% in 1 month (McCall & Tankersley, 2016).

- The most effective intervention to ease pain is oral sucrose (see EBP box below).
- Selecting the method of restraint when dealing with infants and children is important to ensure their safety. A newborn or young infant can be wrapped in a blanket, but physical restraint is often required for older infants, toddlers, and younger children. Older children can sit by themselves in the blood drawing chair, but a parent or another phlebotomist should help steady the arm.

**NOTE:** Never tell a child that it won’t hurt. Instead, say that it may hurt just a little bit, but it will be over quickly.

**EBP**
- In a Cochrane review that included 74 randomized controlled trials and 7049 neonates, there was high-quality evidence supporting the use of 2 mL of 24% sucrose prior to venipuncture. The researchers concluded that sucrose is effective for reducing procedural pain from single events such as heel lance, venipuncture, and intramuscular injection in both preterm and term infants without evidence of serious side effects or harm (Stevens, Yamada, Ohlsson, Haliburton, & Shorkey, 2016).
- In a review of 15 studies that met inclusion criteria for evaluation of pain in neonates who underwent heel punctures or venipunctures, the moderate to severe level of pain associated with these procedures was asserted. The use of topical anesthetic creams, systemic analgesics, posturing, and 10% oral glucose had “scarc” effectiveness. The most effective procedures included sucrose/glucose at a greater than 20% concentration, multisensory stimulation, and non-nutritive sucking (pacifier dipped in sucrose) used along with 10% glucose (Bellieni et al., 2016).
The Older Adult

Due to the physical effects of aging, such as skin changes, hearing and vision problems, and mobility issues often related to a disease process, expert skills from a phlebotomist are required.

- Veins thicken and fibrose with aging, which can make the vein wall more difficult to enter. Vein distention may take longer. Blood vessels become more fragile and can rupture with venipuncture, especially if a tourniquet is applied too tightly.
- Hearing-impaired patients may strain to hear and have difficulty answering questions and understanding instructions.
- Due to mobility issues or visual impairment with some older adults, assistance to the drawing chair or escort to the restroom for a specimen collection may be required. The phlebotomy area should have adequate lighting without glare. Provide instructions in large print.
- If the patient is in a wheelchair and cannot be transported to the laboratory drawing chair, it is safest and easiest to draw blood from the patient in the wheelchair by supporting the arm on a pillow or on a special padded board placed across the arms of the chair.
- Slower nerve conduction may lead to slower learning, slower reaction times, and diminished perception of pain, which could lead to an increase in injuries. Especially for patients with dementia or other cognitive decline, approach the patient in a calm, professional manner.
- Effects of the disease process may impact blood collection. Patients who have coagulation disorders and who take blood thinning medications are at risk for hematoma formation or uncontrolled bleeding at the blood collection site. Patients with Parkinson’s disease may have difficulty with tremors and movement of the hands, which can make blood collection difficult (Coulter, 2016; McCall & Tankersley, 2016).

**NOTE:** Never use force to extend a patient’s arm or open a hand because this can cause pain and injury.

**NURSING FAST FACT!**

The safest and easiest way to draw blood from a patient in a wheelchair is by supporting the arm on a pillow or on a special padded board placed across the arms of the chair.

**Home Care Issues**

A home-care phlebotomist must have exceptional phlebotomy, interpersonal, and organizational skills; be able to function independently; and be comfortable working in varied situations. The physical setting can affect
Patient Education

The first and last steps of phlebotomy procedures are to prepare the patient for the procedure. Pretesting explanation to the patient or caregiver follows essentially the same pattern for all sites and types of studies and includes:

- Explain the purpose of the test.
- Describe the procedure, including site and method.
- Describe any sensations, including discomfort and pain that the patient may experience during the specimen collection procedure.

**NOTE:** Cultural and social issues, as well as concern for modesty, are important in providing psychological support.

- Instruct regarding pretesting preparations related to diet, liquids, medications, and activity as well as any restrictions.
- Identify any anxiety related to test results. Encourage the patient to ask questions and verbalize his or her concerns.
- Educate regarding any limitations of movement.
- Instruct the patient to notify the nurse if the puncture site begins to bleed after the pressure dressing is applied.

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Home Care Issues—cont’d

the collection of blood in the home-care setting. For specimens collected in homes, the procedures are similar, and key points are listed.

- Obtain necessary supplies, including venipuncture supplies, blood collection tubes, a biohazard container for disposal, and a specimen transport container, and bring to the home.
- Identify the patient: While patient identification in the home is less prone to error as compared with other health-care settings, it remains important to ensure accurate patient identification. For the first encounter, confirmation of the patient’s address is acceptable when used with another specific identifier (e.g., name/birth date). For ongoing encounters when the patient is known to the phlebotomist, facial recognition can be an identifier in conjunction with another identifier.
- Carefully inspect the area after the procedure to ensure that all trash and used supplies have been properly discarded before leaving the home environment.
- Label specimens and place in leakproof containers.
- Ensure that specimens are transported at appropriate temperatures.
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Nursing Process

The nursing process is a five- or six-step process for problem-solving to guide nursing action (see Chapter 1 for details on the steps of the nursing process related to vascular access). The following table focuses on nursing diagnoses, nursing outcomes classification (NOC), and nursing interventions classification (NIC) for patients requiring laboratory analysis. Nursing diagnoses should be patient specific and outcomes and interventions individualized. The NOC and NIC presented here are suggested directions for development of specific outcomes and interventions.

### Patient Education—cont’d

- Instruct the patient to notify the nurse if the puncture site becomes red or warm to the touch, or if pain develops (Van Leeuwen, Poelhuis-Leth, & Bladh, 2012).

### Nursing Diagnoses Related to Management of Venipuncture for Laboratory Analysis

<table>
<thead>
<tr>
<th>Nursing Diagnoses Related to Management of Venipuncture for Laboratory Analysis</th>
<th>Nursing Outcomes Classification (NOC)</th>
<th>Nursing Interventions Classification (NIC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infection, risk for related to: Invasive procedure</td>
<td>Risk control: infectious process</td>
<td>Infection control, infection protection</td>
</tr>
<tr>
<td>Deficient knowledge: Information misinterpretation; unfamiliarity with phlebotomy laboratory procedures/analysis</td>
<td>Knowledge: treatment procedures; treatment regimen</td>
<td>Teaching: Purpose of phlebotomy and laboratory tests</td>
</tr>
<tr>
<td>Skin integrity impaired related to: External: interruption in barrier protection—venipuncture</td>
<td>Tissue integrity: skin, primary intention</td>
<td>Skin care, skin surveillance, incisional (venipuncture) site care</td>
</tr>
</tbody>
</table>

Sources: Ackley, Ladwig, & Makic, 2017.

### Chapter Highlights

- Specimens incorrectly acquired, labeled, or transported by the nurse can result in inaccurate laboratory tests.
- The nurse performing phlebotomy procedures must have the following knowledge base to perform blood withdrawal procedures safely: knowledge of basic anatomy and physiology, medical terminology, sources of error, safety measures and infection control practices, quality control procedures, equipment and methods, and sites for blood collection.
- Two identifiers are always used to verify patient identity.
- Most blood collection tubes contain additives to prevent blood clotting.
- Four methods of phlebotomy include the ETS system, the syringe method, capillary puncture, and withdrawal of blood from a VAD. The winged infusion...
needle set may be beneficial for phlebotomy in some patients with difficult veins.
- The antecubital area is the most frequently used area for blood collection. The median or median cubital veins are preferred for venipuncture. The dorsal side of hand or wrist should be used only if the arm veins are unsuitable.
- The tourniquet should be released once blood begins to flow into the tube (no longer than 1 minute) to avoid hemolysis and inaccurate test results.
- Capillary puncture is often used for neonates/infants and for POCT methods.
- While benefits of VAD blood sampling include avoidance of venipuncture complications and patient anxiety, potential risks include increased risk for VAD occlusion, increased risk for catheter-related bloodstream infection as a result of manipulation at the catheter hub, and the potential for inaccurate laboratory test results associated with adsorption of medications infused via the VAD.
- It is important that the order of tube draw be done correctly to avoid inaccurate test results.
- Safety needles and products are always used to prevent health-care worker injury, regardless of the phlebotomy method used.
- Complications associated with phlebotomy include hematoma, iatrogenic anemia, infection, nerve injury, and vein damage.

**Thinking Critically: Case Study**

A 70-year-old Hmong, non-English-speaking woman was admitted to an acute care hospital accompanied by her husband, who had limited English language ability. On admission her physician had ordered a series of blood tests. When the health-care worker arrived to collect blood for laboratory tests, she introduced herself and asked the patient her name. The patient did not respond and looked perplexed.

**Case Study Questions**

1. What should the health-care worker do next?
2. What do TJC National Patient Safety Goals state regarding patient identification?
3. What other factors need to be considered in this scenario (i.e., safety, ethics, legal)?

**References**

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**Equipment Needed**

- Gloves, nonsterile
- Tourniquet—disposable
- Biohazard container
- Waste receptacle
- Evacuated tubes for specific laboratory studies
- Tube holder
- Multisample needle
- Labels (barcoded) for tubes
- Transport container
- Skin antiseptic agent (70% alcohol, chlorhexidine gluconate, or povidone-iodine)
- Gauze pads or cotton ball
- Tape

**PROCEDURES DISPLAY 7-1**  
**Collection of Blood in Evacuated Tube System**

Continued
### Delegation
This procedure can be delegated to a phlebotomist.

#### Procedure
1. Confirm test orders from the authorized prescriber.
2. Approach, identify, and prepare the patient. Place the patient in a position of comfort and safety, arm extended and in a dependent position if possible if in a hospital bed. Use a phlebotomy chair in the outpatient setting. Explain the procedure to the patient and verify fasting, if required for ordered laboratory test.
3. Gather and organize needed supplies; verify the correct blood collection tubes and line them up in appropriate sequence for obtaining blood.
4. Perform hand hygiene procedure and don gloves.
5. Apply tourniquet 3–4 inches above intended site; locate the vein, preferably median cubital or median vein in the antecubital fossa; and then release the tourniquet.
6. Provide skin antisepsis, usually 70% alcohol, and allow the skin to air-dry.
7. Select the appropriate equipment for the size, condition, and location of the vein. Prepare while the site is drying. Attach a multisample needle to a tube holder. Put the first tube in the holder at step 7 or wait until after needle entry (step 10).

#### Rationale
1. A written order is a legal requirement.
2. Establishes the nurse–patient relationship, ensures safety, reduces patient anxiety, and ensures accuracy of test results.
3. Saves time and prevents interruption during the blood draw and reduces risk for errors.
4. Single most important aspect of infection prevention.
5. Distends veins. The median cubital or median vein is preferred to promote successful venipuncture and reduce risk for nerve injury.
6. Reduces risk for infection. Letting the site dry naturally permits maximum antiseptic action.
7. Ensures successful blood draw and accuracy of test results.

### PROCEDURES DISPLAY 7-1

**Collection of Blood in Evacuated Tube System—cont’d**
8. Reapply the tourniquet.
9. Apply traction to the skin of the forearm, below the intended venipuncture site, to stabilize the vein. Hold the tube holder/tube assembly between the thumb and last three fingers of your dominant hand. Rest the backs of these fingers on the patient’s arm. The free index finger rests against the hub of the needle and serves as a guide. With the needle held at an angle of 15–30 degrees to the arm and in line with the vein, insert the needle into the vein, with the bevel up.
10. Once you feel that you are in the vein, change your grip: The hand that was stabilizing the vein in place should now hold the hub firmly, while the index and third finger of the dominant hand grip the tube. This will prevent movement of the needle. Now use your thumb to gently but firmly push the tube onto the needle.
11. Fill the tubes until the vacuum is exhausted and mix them immediately on removal from the holder using 3–10 gentle inversions (depending on the type and manufacturer). Follow the order of draw. If more than one tube is to be drawn, pull the filled tube out of the hub very gently with the hand that pushed it in.

**Rationale**
8. Distends veins.
9. Anchors the skin so that the needle enters easily and with less pain; keeps vein from rolling.
10. Allows the vacuum to pull blood into the tube; blood will not flow until the needle pierces the tube stopper.
11. Ensures correct blood-to-additive ratio.
**PROCEDURES DISPLAY 7-1**

**Collection of Blood in Evacuated Tube System—cont’d**

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>12. When the last tube of blood is drawn, remove it from the hub. Release the tourniquet during filling of the last tube, then gently remove the needle from the arm and place a cotton ball or small gauze pad over the puncture site. Ask the patient to put pressure on the area if appropriate.</td>
<td>12. Prevents hematoma formation.</td>
</tr>
<tr>
<td>15. Examine the patient’s arm to verify that bleeding has stopped on the skin surface. If bleeding has stopped, apply bandage and advise patient to keep it in place for a minimum of 15 minutes.</td>
<td>15. Prevents hematoma formation and bleeding.</td>
</tr>
<tr>
<td>16. Remove gloves and dispose of used and contaminated materials in biohazard container (e.g., tube holder/needle) and in other appropriate receptacles (e.g., used gloves/tourniquet).</td>
<td>16. Reduces risk of blood exposure.</td>
</tr>
<tr>
<td>17. Perform hand hygiene.</td>
<td></td>
</tr>
<tr>
<td>18. Transport specimen to the laboratory.</td>
<td>18. Prompt delivery to the laboratory protects specimen integrity.</td>
</tr>
</tbody>
</table>

Sources: McCall & Tankersley, 2016.
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Equipment Needed
Gloves, nonsterile
Tourniquet—disposable
Biohazard container
Waste receptacle
Syringe/needle
Syringe transfer device
Evacuated tubes for specific laboratory studies
Labels (barcoded) for tubes
Transport container
Skin antiseptic agent (70% alcohol, chlorhexidine gluconate, or povidone-iodine)
Gauze pads
Tape

Delegation
This procedure can be delegated to a phlebotomist.

Procedure
1. Confirm test orders from the authorized prescriber.
2. Approach, identify, and prepare the patient.
   Place the patient in a position of comfort and safety, arm extended and in a dependent position if possible if in a hospital bed. Use a drawing chair in outpatient setting.
   Explain the procedure to the patient and verify fasting, if required for ordered laboratory test.
3. Gather and organize needed supplies; verify the correct blood collection tubes and line them up in appropriate sequence for obtaining blood.
4. Perform hand hygiene procedure and don gloves.

Rationale
1. A written order is a legal requirement.
2. Establishes the nurse–patient relationship, ensures safety, reduces patient anxiety, and ensures accuracy of test results.
3. Saves time and prevents interruption during the blood draw and reduces risk for errors.
4. Single most important aspect of infection prevention.

Continued
PHLEBOTOMY TECHNIQUES

PROCEDURE DISPLAY 7-2
Phlebotomy Using the Syringe System and a Syringe Transfer Device—cont’d

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>5. Apply tourniquet 3–4 inches above intended site; locate the vein, preferably median cubital or median vein in the antecubital fossa; and then release the tourniquet.</td>
<td>5. Distends veins. The median cubital or median vein is preferred to promote successful venipuncture and reduce risk for nerve injury.</td>
</tr>
<tr>
<td>6. Provide skin antisepsis, usually 70% alcohol, and allow the skin to air-dry.</td>
<td>6. Reduces risk for infection. Letting the site dry naturally permits maximum antiseptic action.</td>
</tr>
<tr>
<td>7. Reapply the tourniquet.</td>
<td>7. Distends veins.</td>
</tr>
<tr>
<td>8. Apply traction to the skin of the forearm, below the intended venipuncture site, to stabilize the vein. Hold the syringe in your dominant hand. Place your thumb on top near the needle and fingers underneath. With the needle held at an angle of 15–30 degrees to the arm and in line with the vein, insert the needle into the vein, with the bevel up.</td>
<td>8. Anchors the skin so that the needle enters easily and with less pain; keeps vein from rolling.</td>
</tr>
<tr>
<td>9. Once you feel that you are in the vein, as indicated by blood in the syringe hub, release the tourniquet and slowly pull back on the syringe plunger to fill with blood.</td>
<td>9. Unlike the ETS system, blood does not automatically flow into the syringe.</td>
</tr>
<tr>
<td>10. Remove needle and immediately place a cotton ball or small gauze pad over the puncture site. Ask the patient to put pressure on the area if appropriate.</td>
<td>10. Prevents hematoma formation.</td>
</tr>
<tr>
<td>12. Attach the syringe hub to the hub of the syringe transfer device.</td>
<td></td>
</tr>
</tbody>
</table>
**Chapter 7  Phlebotomy Techniques**

**PROCEDURES DISPLAY 7-2**

**Phlebotomy Using the Syringe System and a Syringe Transfer Device—cont’d**

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>13. Hold syringe vertically with the tip down and transfer device at the bottom and place the tube in the barrel of the transfer device, allowing the tube vacuum to pull blood into the tube.</td>
<td>15. Prevents mislabeling errors.</td>
</tr>
<tr>
<td>14. Fill the additive tube(s) until the vacuum is exhausted and mix them immediately on removal from the holder using 3–10 gentle inversions (depending on the type and manufacturer). Follow the order of draw.</td>
<td>16. Prevents hematoma formation and bleeding.</td>
</tr>
<tr>
<td>15. Label all samples at the bedside.</td>
<td>17. Reduces risk of blood exposure.</td>
</tr>
<tr>
<td>16. Examine the patient’s arm to verify that bleeding has stopped on the skin surface. If bleeding has stopped, apply bandage and advise patient to keep it in place for a minimum of 15 minutes.</td>
<td>18. Prompt delivery to the laboratory protects specimen integrity.</td>
</tr>
<tr>
<td>17. Remove gloves and dispose of used and contaminated materials in biohazard container (e.g., tube holder/needle) and in other appropriate receptacles (e.g., used gloves/tourniquet).</td>
<td></td>
</tr>
<tr>
<td>18. Perform hand hygiene.</td>
<td></td>
</tr>
<tr>
<td>19. Transport specimen to the laboratory.</td>
<td></td>
</tr>
</tbody>
</table>

Sources: McCall & Tankersley, 2016.
PROCEDURES DISPLAY 7-3

**Blood Sampling from a Central Vascular Access Device (CVAD): Discard Method**

**Equipment Needed**
- Clean gloves
- Evacuated tubes for specific laboratory studies
- Tube holder with Luer adapter device
- Alcohol wipes or other disinfectant used by organization
- Appropriate number of empty 10-mL syringes (if vacuum system is not used)
- Prefilled syringes of 10 mL preservative-free 0.9% sodium chloride
- Heparin syringe, if ordered
- Labels (barcoded) for tubes
- Transport container
- Biohazard container
- Needleless connector (if organizational policy requires replacement after blood withdrawal)

**Delegation**
Most institutions do not have phlebotomists draw blood from a central line. This procedure is not delegated to a licensed practical nurse/licensed vocational nurse (LPN/LVN) or unlicensed assistive personnel (UAP).

**Procedure**
1. Confirm test orders from the authorized prescriber.
2. Approach, identify, and prepare the patient.
   - Place the patient in a position of comfort and safety, arm extended and in a dependent position if possible if in a hospital bed. Use a drawing chair in outpatient setting.
   - Explain the procedure to the patient and verify fasting, if required for ordered laboratory test.
3. Gather and organize needed supplies; verify the correct blood collection tubes and line them up in appropriate sequence for obtaining blood.

**Rationale**
1. A written order is a legal requirement.
2. Establishes the nurse–patient relationship, ensures safety, reduces patient anxiety, and ensures accuracy of test results.
3. Saves time and prevents interruption during the blood draw and reduces risk for errors.
Chapter 7  Phlebotomy Techniques

PROCEDURES DISPLAY 7-3
Blood Sampling from a Central Vascular Access Device (CVAD): Discard Method—cont’d

Procedure
4. Perform hand hygiene procedure and don gloves.

7. If CVAD is locked (i.e., no active infusion): Disinfect needleless connector with alcohol for 15 seconds using a twisting motion and allow to dry. (Note: If drawing blood for blood cultures, the needleless connector is changed prior to blood draw.)

8. If CVAD is in use (i.e., active infusion)
   a. Single-lumen:
      i. Stop infusion.
      ii. Close catheter clamp.
      iii. Disconnect administration set tubing from catheter hub/needleless connector.
      iv. Place sterile cap on the end of the administration set.
      v. Disinfect needleless connector with alcohol for 15 seconds using a twisting motion and allow to dry.
   b. Multilumen:
      i. Stop all infusions.
      ii. Use the proximal lumen for blood withdrawal; if infusion running through lumen, follow steps i–v above.

9. Attach the 10-mL syringe of 0.9% sodium chloride, unclamp CVAD, flush CVAD, withdraw 4–5 mL of blood, and discard into biohazard container.

Rationale
4. Single most important aspect of infection prevention.

7. Reduces risk for introduction of microorganisms into the system.

8. Prevents air entry into the circulation and thus risk for air embolism; prevents introduction of microorganisms into the system.

9. Establishes catheter patency; reduces risk of inaccurate laboratory test results (e.g., elevated drug levels).

Continued
PROCEDURES DISPLAY 7-3

Blood Sampling from a Central Vascular Access Device (CVAD): Discard Method—cont’d

Procedure

10. Disinfect needleless connector with alcohol for 15 seconds using a twisting motion and allow to dry.

11. Attach the Luer-lock tube holder to the needleless connector.
(Alternatively, all blood may be withdrawn using a syringe, then placing blood from syringe into the tubes using a syringe transfer device as described in Procedure Display 7-2.)

12. Insert each blood tube into the Vacutainer and allow to fill with blood in the correct sequence.

13. Remove tube holder and discard into biohazard container.

14. Disinfect needleless connector with alcohol for 15 seconds using a twisting motion and allow to dry.

15. Attach the 10-mL syringe of 0.9% sodium chloride and flush CVAD.

16. Replace needleless connector if required by organizational policy; resume infusion as ordered or lock CVAD with prescribed heparin.

17. Label all samples at the bedside.

18. Remove gloves and dispose of used and contaminated materials in biohazard container (e.g., tube holder/needle) and in other appropriate receptacles (e.g., used gloves/tourniquet).

19. Perform hand hygiene.

20. Transport specimen to the laboratory.

Rationale

10. Prevents introduction of microorganisms into the system.

12. Obtains all required specimens.

14. Prevents introduction of microorganisms into the system.

15. Clears the CVAD of blood and reduces risk for thrombotic occlusion.

17. Prevents mislabeling errors.

18. Reduces risk of blood exposure.

19. Prevents introduction of microorganisms into the system.

20. Prompt delivery to the laboratory protects specimen integrity.

Sources: Gorski et al., 2016a; Gorski et al., 2016b.
LEARNING OBJECTIVES

After completing this chapter, the reader will be able to:

1. Define terms related to central vascular access devices (CVAD).
2. Identify common indications for CVAD placement.
3. Differentiate between the four different categories of CVADs.
4. Describe pertinent anatomy and physiology related to central vascular access.
5. Identify tip location for a properly placed CVAD.
6. Discuss issues related to device selection.
7. Recognize the value of infusion/vascular access teams.
8. List the elements of the central line insertion bundle.
9. Discuss evidence-based practices related to care and maintenance of CVADs.
10. Summarize anatomic and physiological characteristics in neonates and children and their impact on catheter placement and infusion therapy.

Glossary

**Anthropometric measurement**  Measurement of the size, weight, and proportions of the human body

**Biocompatibility**  The quality of not having a toxic or injurious effect on biological systems

**Central vascular access device (CVAD)**  Catheter inserted into the central circulation for infusion therapy, the tip located in the lower one-third of the superior vena cava. CVADs are commonly referred to as “central lines.”

**Distal**  Farthest from the heart; farthest from the point of attachment; below previous site of cannulation

**External jugular**  Peripheral vein located on the exterior aspect of the neck

**Implanted vascular access port**  A type of CVAD; surgically placed and consisting of a catheter attached to a reservoir (port) and placed completely underneath the skin and accessed using a noncoring needle

**Lymphedema**  Swelling of an extremity caused by obstruction of lymphatic vessels
**Nontunneled central vascular access device** A short-term type of CVAD that is inserted directly through the skin, usually via the subclavian, femoral or internal jugular vein

**Peripherally inserted central catheter (PICC)** A type of CVAD; catheter inserted above the antecubital fossa and threaded into the superior vena cava via the cephalic, basilic, or median veins

**Polyurethane** Medical-grade resins, widely varying in flexibility, used in chemical-resistant coatings and adhesives for making catheters for venous access

**Port, distal** Catheter lumen opening located farther from the catheter tip

**Port, proximal** Lumen opening closest to catheter tip

**Silicone elastomer** A polymer of organic silicone oxides, which may be a liquid, gel, or solid depending on the extent of polymerization; some CVADs are made of silicone elastomer

**Trendelenburg position** Position in which the head is lower than the feet; used to increase venous distention

**Subcutaneously tunneled, cuffed catheter** A CVAD that is surgically placed and tunneled in the subcutaneous tissue between the entrance and exit sites. A synthetic cuff attached to the catheter lies in the subcutaneous tissue within the tunnel tract.

**Valsalva maneuver** The process of making a forceful attempt at expiration with the mouth, nostrils, and glottis closed

**Vascular access device (VAD)** Access device inserted into a main vein or artery, or bone marrow; used primarily to administer fluids and medication, monitor pressure, and collect blood

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**Introduction**

The first steps in provision of infusion therapy are selection and placement of the best type of vascular access device (VAD) to meet the patient's needs. A variety of factors guide the decision-making process, such as the characteristics of the prescribed infusate, expected duration of treatment/dwell time of the device, integrity of the patient's veins, and patient preference. As discussed in Chapter 6, the peripheral I.V. catheter is often the first choice for short-term (i.e., usually less than 1 week) infusion needs. A midline peripheral I.V. catheter might be best if therapy is anticipated to last approximately 2 weeks. While a peripheral I.V. catheter is associated with fewer risks and complications compared with a central vascular access device (CVAD), characteristics of the infusate (e.g., irritating/vesicant infusate, high-osmolarity solution) or other patient factors may make a peripheral catheter an inappropriate choice, even if short-term infusion therapy is planned. A CVAD then becomes the necessary choice. Some guidelines indicating need for a CVAD rather than peripheral I.V. catheters include:

- Medications or solutions with osmolarity greater than 900 mOsm/L
- Continuous infusion therapy (e.g., parenteral nutrition [PN], fluid and electrolytes, blood or blood products)
• History of failed or difficult peripheral venous access, if use of ultrasound guidance has failed
• Long-term intermittent infusion therapy (e.g., any medication including anti-infectives in patients with a known or suspected infection)
• Episodic chemotherapy treatment
• Clinical instability of the patient and/or complexity of infusion regimen (multiple infusates) (Gorski et al., 2016a).

In this chapter, anatomy related to CVAD placement, appropriate device selection, catheter insertion, and care and maintenance are explored. Complications associated with CVADs are addressed in Chapter 9.

Definition and Categories of CVADs

A CVAD is defined by placement of the catheter tip in the central vasculature, specifically located in the lower superior vena cava (SVC), near its junction with the right atrium (Gorski et al., 2016a). For CVADs placed in a femoral vein, the CVAD tip is located in the inferior vena cava above the level of the diaphragm. Of note, CVADs are commonly called “central lines” or “central venous catheters.”

When selecting a CVAD, the goal is to deliver safe, efficient infusion therapy that maximizes the patient’s quality of life, with minimal risk of complications. There are four main categories of a CVAD:

1. The **nontunneled CVAD** is a percutaneously placed catheter, usually by way of the subclavian or internal jugular vein. Less desirable is placement via the femoral vein due to increased risk of infection in adults associated with this site. This type of CVAD is indicated for short-term needs and is used primarily in the acute care setting.

2. The **peripherally inserted central catheter (PICC)** is the most common type of CVAD used in all settings, including acute care, long-term care, outpatient, and home care. The PICC may be placed for short-term or longer-term (e.g., anticipated therapy generally less than 1 year) infusion therapy needs.

3. The **subcutaneously tunneled cuffed catheter** is a surgically placed CVAD that is indicated for long-term infusion needs, such as chemotherapy administration or PN.

4. The **implanted vascular access port** is also a surgically placed CVAD consisting of a catheter attached to a reservoir (“port”). It is placed completely underneath the skin. The port is also indicated for long-term infusion needs.

Anatomy of the Vascular System

The anatomy of the venous system of the arm, shoulder, and chest is important for the nurse to understand before placement and during the care of a CVAD. Important veins to central vascular access include the basilic, cephalic, axillary, subclavian, internal, brachiocephalic (formerly called innominate), internal jugular veins, and the SVC.
Venous Structures of the Arm and Shoulder

The superficial veins of the upper extremities lie in the superficial fascia; they are visible and palpable. Superficial veins include the cephalic and the basilic veins, which originate from the dorsal venous network on the back of the hand. In the antecubital fossa, the cephalic and basilic veins are connected by the median cubital vein (Drake, Vogl, & Mitchell, 2015). In some patients, the median cubital vein may have variations including two branches coming from the median vein (also called the intermediate antebrachial): the median basilic vein and the median cephalic vein (McCall & Tankersley, 2012).

The cephalic vein ascends along the outer border of the biceps muscle to the upper third of the arm. It passes in the space between the pectoralis major and deltoid muscles and the clavicle. In this area of depression, the vein passes into the axilla by penetrating the deep fascia inferior to the clavicle. Normally, the cephalic vein turns sharply (90 degrees) as it pierces the clavipectoral fascia and passes beneath the clavicle (Drake, Vogl, & Mitchell, 2015).

The basilic vein is usually larger than the cephalic vein. From the posterior–medial aspect of the forearm, it passes upward in a smooth path along the inner side of the biceps muscle and then becomes the axillary vein. The brachial veins are deep veins that are tributaries of the axillary veins (Drake, Vogl, & Mitchell, 2015) (Fig. 8-1).

Above the antecubital fossa, the median cubital, cephalic, basilic, and brachial veins are considered appropriate for the placement of PICCs (Gorski et al., 2016a) and peripherally implanted ports as well as midline peripheral catheters, as discussed in Chapter 6.

Valves are present in the venous system until approximately 1 inch before the formation of the brachiocephalic vein. The presence of valves within veins helps to prevent the reflux of blood and is especially important in the lower extremities, where venous return is working against gravity.

Venous Structures of the Chest

The main venous structures of the chest include the subclavian, internal and external jugular, and right and left brachiocephalic veins, and the SVC. Large veins in the head, neck, and chest do not have valves. Gravity helps blood to flow properly from the head and neck, and negative intrathoracic pressure promotes flow from the head, neck, and inferior vena cava (Fig. 8-2).

The subclavian vein is a continuation of the axillary vein and extends from the outer border of the first rib to the sternal end of the clavicle and measures about 4 to 5 cm in length. The external jugular lies on the side of the neck and follows a descending inward path to join the subclavian vein along the middle of the clavicle. The internal jugular vein descends first behind and then to the outer side of the internal and common carotid arteries; it joins the subclavian vein at the root of the neck. The internal jugular and subclavian veins join in creation of the brachiocephalic veins.
The right brachiocephalic vein is about 2.5 cm long and passes almost vertically downward to join the left brachiocephalic vein just below the cartilage of the first rib. The left brachiocephalic vein is about 6 cm long (Standring, 2008). It passes from left to right in a downward slant across the upper front of the chest. It joins the right brachiocephalic vein to form the SVC. The SVC receives all blood from the upper half of the body. It is composed of a short trunk approximately 7 cm long in an average adult. It begins below the first rib close to the sternum on the right side, descends vertically slightly to the right, and emptied into the right atrium of the heart. The right atrium receives blood from the upper body via the SVC and from the lower body via the inferior vena cava. Table 8-1 summarizes the anthropometric measurements of the upper-extremity veins.
**Figure 8-2** Central venous anatomy.

**Table 8-1** Measurements of Veins (Adult)

<table>
<thead>
<tr>
<th>Vein</th>
<th>Length (cm)</th>
<th>Vein Diameter (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brachial</td>
<td>—</td>
<td>0.60–7.10*</td>
</tr>
<tr>
<td>Cephalic</td>
<td>35–38</td>
<td>0.15–6.10*</td>
</tr>
<tr>
<td>Basilic</td>
<td>24</td>
<td>0.70–7.30*</td>
</tr>
<tr>
<td>Axillary</td>
<td>11–13</td>
<td></td>
</tr>
<tr>
<td>Subclavian</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Left brachiocephalic</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Right brachiocephalic</td>
<td>2.5</td>
<td></td>
</tr>
<tr>
<td>Superior vena cava</td>
<td>7–9</td>
<td></td>
</tr>
</tbody>
</table>

Sources: Bullock-Corkhill, 2010; Sharp et al., 2015; Standring, 2008.*

*Based on an observational study of adults requiring a PICC or midline catheter placement.
Assessment and Device Selection

A CVAD with the least number of lumens should be selected for the patient’s infusion therapy. There is more manipulation and catheter access with multilumen catheters, which increases the risk for catheter-related bloodstream infection (CR-BSI). However, patients who require multiple medications and fluids, such as the critically ill, will likely need a multilumen catheter. Patients who require ongoing testing involving contrast media (i.e., computed tomographic [CT] scans) may benefit from a power-injectable CVAD, which can tolerate the high pressures required for rapid injection of contrast material. Antimicrobial-impregnated CVADs are used routinely by some organizations as an infection prevention measure.

Physical factors considered during assessment include the suitability of intended vein in terms of size and patency, presence of other devices (e.g., pacemaker), and breaks in skin integrity. The vein must be large enough to accommodate the selected VAD to minimize the risk of phlebitis and thrombosis. For PICCs, the catheter-to-vein ratio should be 45% or less (Gorski et al., 2016a, p. S52). Vein size is assessed by the catheter inserter using ultrasound. The smallest device in the largest vein allows for better hemodilution of the infusate and better blood flow around the catheter. The presence of a pacemaker requires special consideration. Pacemakers are usually placed on the left side of the chest or abdomen, so when present, the opposite side is preferred for CVAD placement. If a CVAD must be placed on the same side as the pacemaker, a PICC is a better and safer choice (Gorski et al., 2016a, p. S65).

Patient preference and lifestyle should be evaluated. This is especially important when the intended infusion therapy will extend beyond the acute care setting and the patient will be sent home with the CVAD in place. For PICCs, placement in the nondominant arm should be considered. The patient’s lifestyle is an important consideration in choosing an implanted versus an external device. Take into consideration activity restrictions, maintenance requirements, body image distortion, and ease of use. The patient’s usual occupational and recreational activities need to be included in the assessment process.

### NURSING FAST FACT!

Blood flow in the SVC in the average adult is approximately 1.5 to 2.5 L/min. Poiseuille’s law (fourth power law) states that flow through a single vessel is affected by the vessel diameter, and as vessel diameter increases, the flow rate increases by a factor of 4. For example, when the diameter doubles, flow rate increases 16 times; when the diameter increases by 4, the flow rate increases 256 times. The rates of blood flow in major veins are as follows:

- Cephalic and basilic veins: 45–95 mL/min
- Subclavian veins: 150–300 mL/min
- SVC: 2000 mL/min

---

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Physical factors considered during assessment include the suitability of intended vein in terms of size and patency, presence of other devices (e.g., pacemaker), and breaks in skin integrity. The vein must be large enough to accommodate the selected VAD to minimize the risk of phlebitis and thrombosis. For PICCs, the catheter-to-vein ratio should be 45% or less (Gorski et al., 2016a, p. S52). Vein size is assessed by the catheter inserter using ultrasound. The smallest device in the largest vein allows for better hemodilution of the infusate and better blood flow around the catheter. The presence of a pacemaker requires special consideration. Pacemakers are usually placed on the left side of the chest or abdomen, so when present, the opposite side is preferred for CVAD placement. If a CVAD must be placed on the same side as the pacemaker, a PICC is a better and safer choice (Gorski et al., 2016a, p. S65).

Patient preference and lifestyle should be evaluated. This is especially important when the intended infusion therapy will extend beyond the acute care setting and the patient will be sent home with the CVAD in place. For PICCs, placement in the nondominant arm should be considered. The patient’s lifestyle is an important consideration in choosing an implanted versus an external device. Take into consideration activity restrictions, maintenance requirements, body image distortion, and ease of use. The patient’s usual occupational and recreational activities need to be included in the assessment process.
The ability of the patient or designated caregiver to manage day-to-day CVAD care and infusions should be assessed before device selection and placement. Important considerations include the ability to see, hear, perform fine motor tasks, read and understand written instructions, and emotionally cope with the demands of site care and therapy. In addition, the home environment and caregiver support for patients who will transition from acute care to home care should be evaluated.

Expert Recommendations for CVAD Placement

The Michigan Appropriateness Guide for Intravenous Catheters (MAGIC) study provides specific recommendations for placement of CVADs based upon a sophisticated expert consensus research methodology (Chopra et al., 2015). The recommendations include:

• For peripherally compatible infusates (e.g., nonirritant, nonvesicant), a central line is selected based upon extended duration of infusion therapy.
• A PICC is recommended for infusions anticipated to last 15 or more days.
• A nontunneled catheter is preferred for critically ill patients and for those who need hemodynamic monitoring for 6 to 14 days.
• Tunneled catheters and implanted vascular access ports are considered for infusion therapy needs lasting beyond a month.

For non–peripherally compatible infusates (e.g., irritant, vesicant), a CVAD of any type is appropriate, with a PICC rated as appropriate at all proposed durations of infusion.

A condensed summary of the nursing process related to assessment for CVAD placement, communication of the plan, and ongoing monitoring and evaluation is summarized as follows:

• Assessment
  • Patient health problems/medical history
  • Previous I.V. complications/vascular integrity
  • Patient needs/preferences
• Planning
  • Purpose, infusate characteristics, and anticipated duration of I.V. therapy
  • Presentation of vascular access options/recommendations
  • Interprofessional plan/involvement of patient/family
• Implementation
  • CVAD placement
  • Intravenous fluid administration
  • Administration of blood products
  • Administration of medications
  • Monitoring of central venous pressure (CVP)
• Evaluation
  • Ongoing assessment of the CVAD site, patency, and need for catheter
  • Potential complications and assessment of response to the infusion therapy, including evidence of side effects/adverse reactions and actions taken
Conditions That Limit Central Vascular Access Device Placement

Clinical conditions such as coagulopathy, venous stenosis, acute thrombosis, and local skin infection at the insertion site are factors that may affect the decision-making process as to the best CVAD option (Yeager, 2017). For example, a PICC may be the best choice for patients with bleeding disorders. Any abnormalities should be considered as part of the risk-to-benefit ratio prior to CVAD placement. Conditions that may limit VAD site placement are listed in Table 8-2.

Catheter Material

All catheters, whether they are used for short- or long-term access, should be radiopaque, which allows for location of the catheter/fragment in the event of a catheter fracture or embolus. Most CVADs are made of thermoplastic urethane (polyurethane) or silicone elastomers. There is also the emergence of newer catheter materials, which may reduce the risk of thrombus formation. Polyurethane catheters are the most commonly used catheters because of the material’s versatility, strength, and biocompatibility. Catheters made of polyurethane are made with thinner walls and larger internal catheter lumen diameters, which allow for greater blood flow. Polyurethane is stiffer than silicone, which makes threading of the catheter easier, yet once inside the body, it becomes softer and more

<table>
<thead>
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<th>Table 8-2</th>
<th>Conditions Affecting Vascular Access Device Site Placement</th>
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| **Previous Surgical Interventions** | Lymph node dissections  
Presence of vena cava filter  
Myocutaneous flap reconstruction  
Skin grafts  
Previous vein harvesting  
Presence of arteriovenous (A-V) grafts and hemodialysis fistulas  
Presence of intravascular stents |
| **Cutaneous Lesions in Proximity to VAD Exit or Puncture Site** | Herpes zoster and skin tears  
Malignant cutaneous lesions  
Bacterial or fungal lesions and nonintact skin  
Burns  
Extensive scarring or keloids |
| **Disease Process or Conditions** | Severe thrombocytopenia  
Other coagulopathy (e.g., hemophilia, idiopathic thrombocytopenia purpura)  
Concurrent anticoagulation therapy  
Lymphedema  
Allergies  
Extremity paraplegia  
Preexisting vessel thrombosis or stenosis |
| **Other Considerations** | Devices near exit site (e.g., tracheostomy)  
Morbid obesity  
Patient inability to position desired site for placement  
Patient inability to tolerate insertion procedure |
flexible, which reduces irritation to the intimal layer of the vein. Silicone catheters are soft and pliable and considered very biocompatible. The catheter walls must be thicker to achieve adequate strength as a CVAD. Subcutaneously tunneled catheters, implanted ports, and some PICCs are made of silicone. In a systematic review that included 19 clinical articles, postinsertion complication rates of silicone and polyurethane PICCs were compared (Seckold, Walker, & Dwyer, 2015). Although the overall rates were almost identical, there were fewer infections, catheter dislodgements, thrombi, and catheter ruptures reported with polyurethane catheters, but the occlusion rates were slightly higher. For oncology patients, there were higher phlebitis rates with polyurethane catheters.

Antimicrobial Catheters
CVADs are available that have been impregnated with antimicrobial or antiseptic agents, including minocycline/rifampin, chlorhexidine/silver sulfadiazine, and platinum/silver. One review found that minocycline/rifampin catheters were most effective (Lai et al., 2016), whereas a study looking specifically at antimicrobial-impregnated PICCs found no significant difference between the minocycline/rifampin and the chlorhexidine/silver catheters (Kramer et al., 2017). Overall, research evidence suggests that antimicrobial catheters, including impregnated PICCs, are associated with central line–associated bloodstream infection (CLABSI) reduction and that they may be most effective in high-risk patient groups such as intensive care unit patients, those with burns, and those who are neutropenic (Kramer et al., 2017; Lai et al., 2016). As translated into current evidence-based guidelines, antiseptic/antimicrobial catheters are recommended as follows:

- Use when the CVAD is expected to remain in place for more than 5 days if CR-BSI rates remain above the locally agreed benchmark, despite implementation of a comprehensive strategy to reduce CR-BSIs (Loveday et al., 2014).
- Use as a “special approach” when CLABSI rates are unacceptably high despite implementation of basic CLABSI prevention measures, when patients have a history of recurrent CLABSI and limited venous access, and when patients are at a heightened risk of severe sequelae from a CLABSI (e.g., patients with a prosthetic heart valve) (Marschall et al., 2014).

**NOTE:** Potential development of resistant organisms is a concern with these catheters.

Catheter Valves
Some CVADs have built-in catheter valves that reduce the risk for blood reflux into the catheter and thus reduce the risk for catheter occlusion. The first valved catheter, which was developed in the 1980s, has a valve located on the catheter wall near the catheter tip. The catheter tip is closed while the valve opens during
infusion and during aspiration. There are also catheters with valves located inside the catheter hub (Fig. 8-3). In terms of catheter care, manufacturer recommendations for valved catheters include catheter locking with 0.9% sodium chloride rather than heparin.

**Multilumen Central Vascular Access Devices**

Catheters are available with single as well as multiple lumens. The lumens are available in several sizes. The lumens of the catheter may have staggered locations near the catheter tip, or they may exit at the same place at the end of the catheter tip (Figs. 8-4a, 8-4b). With staggered locations, the lumens will be labeled, for example, proximal, distal, and medial lumen (see Fig. 8-4a). Because blood flow in the SVC is great (about 2000 mL/min), the likelihood of incompatible fluids administered simultaneously via a multilumen catheter mixing and precipitating is not likely. It is important to refer to each particular manufacturer’s information to ascertain which of its lumens is the largest if rapid administration is needed. Multiple-lumen CVADs allow for a dedicated port for

![Image of Power PICC Solo*2 catheters, single, double, and triple lumen; valve is located in catheter hub. (©2013 C. R. Bard, Inc. Used with permission.)](image)
blood sampling. Examples of lumen sizes and indications for a four-lumen non-tunneled CVAD are as follows:

- **Distal port 16 gauge:** CVP monitoring and high-volume or viscous fluids, colloids, medications (distal port is the largest lumen), administration of blood or CVP monitor.

![Figure 8-4](image-url)

*Figure 8-4*  
*A,* Injection ports of the triple-lumen catheter include the proximal lumen port, distal lumen port, and medial lumen port. The distal port (middle line) is usually the largest of the three lines. *B,* Cross section of a triple-lumen catheter without staggered openings. (©2013 C. R. Bard, Inc. Used with permission.)
Medial port 18 gauge: Used for PN or medications if PN not ordered
Proximal port 18 gauge: Blood sampling, medications, or blood component administration
Fourth port 18 gauge: Infusion of fluids or medications

Catheter Gauge

The outer diameter of a catheter is usually used to indicate catheter size. French size is calculated by multiplying the outer diameter in millimeters times three. Gauge size is most often used for short peripheral catheters, lumen sizes for multilumen catheters and introducers. Gauge and French sizes do not evenly convert. The gauge of a catheter influences flow rate. Silicone catheters tend to be smaller gauge than those made of polyurethane and have slower flow rates. Gauge depends in part on the type of material from which the catheter is made. The sizes of PICCs range from 1.9 French (neonate) to 6 French.

It is very important to consider catheter size in relation to the blood vessel that will be cannulated. The catheter selected should be of the smallest outer diameter needed to accommodate the prescribed therapy (Gorski et al., 2016a, p. S51). Large-gauge catheters take up more space in the vein. Presence of the catheter in the vein decreases blood flow and potentially can create venous stasis and lead to catheter-associated venous thrombosis, a complication more common than infections (Chapter 9). In an experimental study, researchers demonstrated that fluid flow is dramatically decreased by insertion of a centrally located obstruction (i.e., a catheter). Assuming that blood flow behaves in a way similar to that shown in experimental models, PICCs in particular may substantially decrease venous flow rates by as much as 93% (Nifong & McDevitt, 2011)! The researchers state that choosing the smallest catheter size is a controllable risk factor for catheter-associated venous thrombosis.

NURSING FAST FACT!

Equivalent gauge and French sizes of common central venous catheters are as follows:

- 23 ga = 1.7 Fr
- 20 ga = 2.7 Fr
- 18 ga = 3.8 Fr
- 16 ga = 5.0 Fr
- 14 ga = 6.3 Fr (Cornell University, 2010)

Information about the flow rates for catheters can be found in the manufacturer’s specifications.

Power-Injectable Central Vascular Access Devices

Power-injectable catheters can tolerate the high pressures required for rapid injections of contrast materials used in radiological studies such as CT scans. There are power-injectable catheters for all categories of CVADs, including
implanted vascular access ports. From a general care and management standpoint, care of a power-injectable CVAD is the same as for a nonpower catheter. However, there may be potential confusion and risk if a non–power-injectable catheter is used for that purpose, thus increasing the risk of catheter rupture. When planning to use a CVAD for power injection, power injection capability should be identified at the time of access and immediately prior to power injection. This is particularly important with implanted ports because there is no reliable external method to determine the type of port. Some power injection–capable ports have unique characteristics that can be identified by palpation, but palpation should not be the only identification method used. It is recommended that at least two identification methods be used, including verifying identification cards, wristbands, or keychains provided by the manufacturer, reviewing operative procedure documentation, and palpating the port (Gorski et al., 2016a, p. S58).

**Infusion and Vascular Access Teams**

The Infusion Nurses Society (INS) recommends that VAD insertion, management, and surveillance be performed only by clinicians and/or teams with infusion therapy education, training, and validated competency (Gorski et al., 2016a, p. S17). In a white paper, the INS (Hadaway, Dalton, & Mercanti-Erieg, 2013) defines an infusion team as a group of nursing personnel centrally structured within an acute health facility and charged with the shared mission of outcome accountability for the delivery of infusion therapy. The use of designated infusion teams is associated with first-attempt cannulation success with short peripheral catheters, decreased VAD-related infections, decreased incidence of phlebitis/infiltration, and increased patient satisfaction (Gorski et al., 2016a, p. S16).

Early vascular access is an important component of many teams’ responsibilities and involves assessing the patient’s needs for vascular access when he or she is admitted to the hospital. Some teams perform all PICC insertions, conduct daily surveillance of each catheter and dressing, perform dressing changes, troubleshoot catheter problems, provide formal and informal staff education, and conduct outcome monitoring. As noted in the following section, nurses with specialty training and education are also placing nontunneled CVADs. Some infusion teams may limit interventions to CVAD placement only, while the general nursing staff performs care and management of the catheter.

**EBP** In a study of nurse-led CVAD placement in three Australian hospitals, CVADs placed included PICCs, nontunneled CVADs, and dialysis catheters. There were minimal complications among the 760 catheters placed by the nurse teams. Insertion-related complications included one pneumothorax and one arterial puncture (Alexandrou et al., 2012).
Nontunneled Central Vascular Access Devices and Peripherally Inserted Central Catheters

Nontunneled Catheters

The nontunneled CVAD is a short-term device intended to be used for several days and is placed and used primarily in an acute care setting. These devices are available as single- or multiple-lumen catheters and are most often made of polyurethane.

The nontunneled catheter is usually placed at the bedside. It is inserted via the subclavian, internal jugular, or femoral veins. In fact, the catheters are often referred to by their insertion site rather than the term nontunneled, for example, “subclavian line” or “jugular” or “IJ” (internal jugular). Site selection for nontunneled catheter placement is an important issue related to the risk for catheter-associated bloodstream infection. The density of skin flora at the catheter insertion site is a risk factor for infection (Marschall et al., 2014). The femoral site is generally avoided because of its higher skin colonization rates. Furthermore, the risk for infection related to femoral placement is increased in obese patients. Guidelines from the Society for Healthcare Epidemiology of America and the Infectious Diseases Society of America (SHEA/IDSA) state to avoid using the femoral vein for CVAD access in obese adult patients when the catheter is placed under planned and controlled conditions (Marschall et al., 2014).

Patients with renal disease present with special issues. Because these patients may ultimately require long-term venous access for hemodialysis, vein preservation is critical. The preference for vascular access in this population is an arteriovenous fistula (American Nephrology Nurses’ Association, 2013). In contrast to the situation in the majority of patients, subclavian vein catheterization should be avoided in patients with renal disease, and the internal jugular vein is a first choice (Association for Vascular Access, 2011; Gorski et al., 2016a). Subclavian vein catheterization is associated with central venous stenosis, which may preclude the use of the entire ipsilateral arm for vascular access.

Insertion Issues

CVADs may be inserted by a physician, but increasingly nurses with specialty training and education are placing nontunneled CVADs (Plohal et al., 2017). Strict technique is maintained during the procedure. The central line insertion bundle (discussed in Chapter 2) is the standard of care for CVAD placement. It includes adherence to the following evidence-based actions during placement: hand hygiene, maximal sterile barrier precautions during insertion, chlorhexidine skin antisepsis, and avoidance of the femoral site. Adherence to the central line insertion bundle, along with the presence of an observer to ensure adherence to critical actions via a checklist during each insertion, is one of the top 10 patient safety strategies strongly encouraged by the Agency for Healthcare Research and Quality (AHRQ, 2013). The CVAD placement procedure is stopped for any breaches in technique that occur (Gorski et al., 2016, p. S65).
Use of Ultrasound Guidance

Ultrasound should be used during placement to identify blood vessels, increase success rates, and decrease insertion-related complications such as inadvertent puncture of an artery. Use of real-time ultrasound with CVAD placement is also one of the top 10 patient safety strategies (AHRQ, 2013).

Improvements in ultrasound portability and transducer ability have greatly enhanced ultrasound's viability for VAD placement. Ultrasound guidance for CVAD insertion is being implemented at all levels of practice for both nurses and physicians and is now a standard of practice for all CVAD placements, including PICCs (Fig. 8-5).

CVAD Placement Procedures

The patient is placed in the supine or Trendelenburg position with a rolled bath blanket or towel between his or her shoulders; such positioning reduces the risk of air embolism during the procedure. The patient may be instructed to perform a Valsalva maneuver during the venipuncture procedure to reduce the risk for air embolism. The nontunneled catheter is inserted via the following methods:

- Modified Seldinger technique (MST): While ultrasound is used to locate the vein, venipuncture is made using a micropuncture needle; a guidewire is inserted several inches into the vein through the needle; the guidewire is secured to prevent embolism, and the needle is removed; a dilator and introducer sheath are threaded over the guidewire and advanced into the

![SiteRite ultrasound system](https://example.com/siterite.jpg)

**Figure 8-5** SiteRite ultrasound system. (©2013 C. R. Bard, Inc. Used with permission.)
skin (the opening of the skin may be slightly enlarged with a scalpel to accommodate the dilator) and into the vein; the guidewire and dilator are removed; and the catheter is threaded into the introducer and advanced to the SVC. The sheath is then withdrawn, broken, and peeled apart (Gorski et al., 2016b).

- Seldinger technique: Similar to the MST in that a needle and guidewire are used; however, the catheter is advanced over the guidewire and into the vein, and the guidewire is then removed from the catheter hub. A larger guidewire is required (completely different from one used for MST; guidewires are not interchangeable), and control of the guidewire must be maintained at all times to prevent embolization of the guidewire. An advantage of Seldinger technique is success may be increased in the situation of tortuous vessels (Gorski et al., 2016b).

- Accelerated Seldinger technique: A newer insertion technique that has the needle, dilator, guidewire, and catheter in an all-in-one device. The needle is placed in the vein, the guidewire is advanced, and the dilator/catheter is inserted over the needle and guidewire. Advantages include a decreased risk of contamination (Caparas, Hu, & Hung, 2014). Following placement, the catheter is secured, preferably using a stabilization device rather than sutures, and a sterile transparent dressing is placed over the site.

**Peripherally Inserted Central Catheters**

The PICC is the most commonly placed CVAD. However, the increasing use of PICCs has been challenged in the literature, especially when used in hospitalized patients with difficult venous access (Chopra, Flanders, & Saint, 2012; Chopra et al., 2015). PICCs are also associated with a higher risk of catheter-associated venous thrombosis compared with other types of CVADs (Chopra et al., 2013) (catheter-associated venous thrombosis is addressed in Chapter 9). As with any CVAD, there are risks and complications, and the decision for placement should be based on clear need for the catheter.

PICCs are made of silicone elastomers or polyurethane, and they may have one, two, or three lumens. Multilumen PICCs may be inserted when administration of multiple medications is required. As with nontunneled catheters, PICCs are often placed at the bedside. The PICC is placed in an insertion site above the antecubital fossa and threaded to the central location in the SVC (Fig. 8-6). Veins considered for cannulation via a PICC include the basilic, median cubital, cephalic, and brachial veins (see Fig. 8-1). The basilic vein is generally most desirable because it is often the largest vein and because the pathway in the upper arm to the thorax is a direct route with less obstructions. In a study involving adults who were having either a PICC or midline catheter placed, the basilic, cephalic, and brachial vein diameters were measured using ultrasound. The diameter of the basilic vein was on average 0.46 mm greater than that of the brachial vein and 0.89 mm greater than that
of the cephalic vein. However, when researchers were able to measure all three veins in both arms, the basilic vein was the largest in 55% of the subjects. Hand dominance and arm side for placement were not associated with the average vein diameter (Sharp et al., 2015). Although left-sided insertion is often avoided because of increased risk for thrombosis due to longer catheter length, the researchers suggest that most studies do not demonstrate that association and that both arms should be assessed as part of the insertion site procedure.

When assessing potential sites, areas to avoid include those with pain on palpation, wounds, and veins that are compromised (e.g., bruised, infiltrated, phlebotic, sclerosed, corded, or engorged) (Gorski et al., 2016a, p. S55). Also, avoid placement in the upper extremity on the side of previous axillary node dissection or radiation therapy, in a region where lymphedema is present, or on the side affected by a stroke. The risk for infection is increased when lymph nodes are removed. Recall from Chapter 2 that lymph fluid is filtered at the lymph nodes, which remove foreign material such as bacteria. Patients who have paralysis from strokes have increased risk for venous thrombosis because of venous stasis from lack of skeletal muscle compression (Nifong & McDevitt, 2011).

As with nontunneled CVADs placed via the subclavian vein, PICCs are not recommended for use in patients with chronic renal disease because of a high incidence of upper-extremity thrombosis (Association for Vascular Access, 2011).
**Insertion Issues**

PICCs are frequently placed by specialized teams of nurses who have completed education and demonstrated competency. Alternatively, in some organizations, PICCs are placed in the interventional radiology suite by radiologists. The central line insertion bundle, as discussed earlier, is also followed with PICC placement. PICCs should be inserted with ultrasound guidance, which allows visual inspection of the vasculature and assessment of the size and location of the vessel.

**INS Standard:** Use ultrasound (US) when placing CVADs in both adults and children to improve insertion success rates, reduce number of needle punctures, and decrease insertion complication rates (Gorski et al., 2016a, p. S45).

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**NURSING FAST FACT!**

After insertion of the catheter, final verification must be performed before any infusion. Chest x-ray confirmation remains a common method for verification and should occur before CVAD use and whenever tip location is questioned. Electrocardiogram (ECG) methods are now increasingly used as a "real time" method of tip verification. In simple terms, the ECG is monitored during insertion and when the P wave is at its maximum height, indicating that the catheter tip is in the lower 1/3 of the SVC above the right atrium. Catheter tip location should be documented in the medical record by way of a chest radiograph report or a copy of the ECG tracing (Gorski et al., 2016a, p. S47).

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**PICC ADVANTAGES**

1. Reduced risk of insertion-related complications including pneumothorax or hemothorax.
2. Decreased risk of air embolism as the insertion site is below the heart.
3. Decreased pain and discomfort associated with frequent venipunctures with peripheral I.V. catheter placement.
4. Is cost-effective and time-efficient.
5. Is appropriate for home infusion therapy.
6. Appropriate for individuals of all ages.
7. May be used for laboratory draws.
8. Can be removed by a registered nurse (RN) who is competent in performing the procedure.

**PICC DISADVANTAGES/RISKS**

1. Daily or weekly care is required.
2. Consistent flushing after infusions and blood draws is necessary to prevent thrombotic catheter occlusion.
3. Difficulty in obtaining blood samples with small-lumen PICCs.
4. Contraindicated in patients whose lifestyles or occupations involve being in water; those with preexisting skin infections in the arm; those with anatomic distortions related to injury, surgical dissection, or trauma; and those with coagulopathies.

5. Potential for CVAD-related complications such as catheter-associated venous thrombosis and catheter occlusion (see Chapter 9).

**Catheter Placement**

The patient is placed in the supine position for PICC placement. A baseline measurement of the arm is taken, which is recommended to be measured at 10 cm above the antecubital space (Gorski et al., 2016a, p. S29). The reason for this measurement is comparison later on. If there is suspected swelling in the extremity, the circumference can be remeasured, providing objective data. Increased arm circumference is often a sign of catheter-associated venous thrombosis. Anthropometric measurements are used to calculate catheter length needed to reach the SVC from the insertion site. A close estimation is achieved by measuring from the insertion site to the clavicular head on the right side and then to the third intercostal space; this correlates with the distance from the insertion site to the SVC (Gorski et al., 2016b). In some cases, the PICC is cut to length to reduce the amount of catheter length at the exit site. This is a controversial area as this practice may be associated with an increased risk of catheter-associated venous thrombosis (Camp-Sorrell & Matey, 2017; Steele & Norris, 2014). The manufacturer's instructions for use are always reviewed before placement. The most common insertion method used for PICC insertion is the MST, described earlier. And, as highlighted in the box above, ECG monitoring systems increasingly are used during the placement procedure to ensure proper catheter tip position.

**INS Standard:** Tip location of a CVAD is determined radiographically or by other imaging technologies prior to initiation of infusion therapy or when clinical signs and symptoms suggest tip malposition (Gorski et al., 2016a, p. S46).

**Catheter Removal**

The CVAD should be removed when it is no longer needed. Because the very existence of the CVAD is a risk factor for catheter-associated bloodstream infection, daily review of catheter necessity and prompt removal when it is no longer needed are components of the central line insertion bundle. The risk of bloodstream infection is increased as catheter duration is extended. Catheter removal when it is no longer needed is applicable in all health care settings.

Nurses can remove nontunneled catheters and PICCs as long as there are organizational procedures in place. An order is always obtained. Potential complications associated with CVAD removal include air embolism, catheter embolism, and excessive bleeding. Minimize the risk of air embolism by positioning the
patient in a supine position and instructing the patient to perform the Valsalva maneuver while the catheter is being withdrawn. Digital pressure should be applied to the puncture site until hemostasis is achieved, and an occlusive dressing is always placed over the insertion site after removal. The recommended procedure is presented in Procedures Display 8-1 at the end of this chapter.

Particularly with PICCs, resistance during removal is also possible. When the PICC is pulled through the vein during removal, an irritation can cause a venospasm, often the cause of resistance during removal. A blood clot around the catheter and within the vein is a rare cause of removal resistance. Patient anxiety may contribute to the problem (Gorski et al., 2016b). It is important never to pull against resistance because catheter breakage and catheter embolism, or vein wall damage, can occur. If resistance is present, the following interventions may be helpful:

- Use of a warm compress to dilate the vein proximal to the exit site
- Use of relaxation techniques
- Hand and arm exercises
- Reattempt of removal after a short or intermediate time period

Figure 8-7 shows an algorithm for a “stuck” PICC catheter. If such interventions do not work, the patient should be sent to the interventional radiology suite for evaluation and catheter removal. The following should be documented in relation to catheter removal:

- Catheter length and integrity
- Site appearance
- Application of dressing
- Patient response to the procedure.

After catheter removal, the site should be assessed every 24 hours until the site is epithelialized.

**Figure 8-7** Algorithm for a “stuck” peripherally inserted central catheter.
NURSING POINTS OF CARE

NONTUNNELED CVADS AND PICCS:
INSERTION AND PLACEMENT

Nursing Assessment
- Identify prescribed therapy and expected duration of therapy.
- Obtain medical/health history including history of previous VAD placements.
- Identify patient preferences.
- Assess for skin lesions, presence of a pacemaker, or other implanted device.
- Take baseline arm circumference (10 cm above antecubital fossa) for PICC insertion.
- Obtain baseline vital signs.

Key Nursing Interventions
1. Select appropriate type of CVAD and insertion site.
2. Have all supplies needed for catheter insertion at the bedside before starting insertion.
3. Use of ultrasound (by inserter) to identify appropriate vein and to facilitate catheter placement.
4. Adhere to central line insertion bundle during insertion.
   a. Hand hygiene
   b. Maximum sterile barrier precautions
   c. Skin antisepsis using chlorhexidine/alcohol
   d. Avoidance of femoral site
   e. Time-out called if proper procedures are not followed (then start again)
5. Verify appropriate catheter tip placement prior to infusion.
6. Document the following:
   a. Patient education and response to teaching
   b. Performance of procedure
   c. Patient response to insertion
   d. Type of CVAD/insertion site location
   e. Description of the insertion site
   f. Insertion methodology and visualization technology used
   g. External catheter length and length of catheter inserted
   h. Patient response to catheter and patient education
   i. Type of I.V. site dressing
   j. PICCs: Arm circumference
Long-Term Central Vascular Access Devices

Subcutaneously Tunneled Cuffed Catheters

The need for prolonged central venous access and a method to decrease potential infection from the skin exit site resulted in the development of the subcutaneously tunneled CVAD. It was originally developed by Dr. Broviac in 1973 for patients requiring long-term PN and was later modified by Dr. Hickman to meet the needs of patients undergoing bone marrow transplant. These long-term catheters can remain in place for years.

The tunneled catheter is considered for patients who require lifelong or long-term infusion therapy such as PN or chemotherapy. Tunneled catheters may also be placed for apheresis procedures, for example, when a patient requires stem cells for bone marrow transplant. There are also tunneled catheters for hemodialysis.

The catheter is “tunneled” in the subcutaneous tissue between an “entrance” and an “exit” site. The exit site is where the catheter extrudes, usually in the lower area of the chest. The entrance site is where the catheter enters the venous circulation, generally in the area of the clavicle, and will appear as an incision (Fig. 8-8). A synthetic “cuff” attached to the catheter lies in the subcutaneous tissue along the tunnel tract; the cuff can be seen on the photograph of a tunneled catheter (Fig. 8-9). Over time, the tissue attaches to the cuff to stabilize the catheter and hold it in place. This cuff is located approximately halfway between the entrance and exit sites. It becomes embedded with fibroblasts within 1 week to 10 days after insertion, which reduces the chances for accidental removal and minimizes the risk of ascending bacterial infection. Within 7 to 10 days of catheter insertion, scar tissue grows onto the cuff, anchoring the catheter and preventing microorganisms from migrating up the tunnel. The tunneling/cuff also serves to seal the path from the exit site to the
vein, which reduces the risk of bloodstream infection. After the site is well healed, the tunneled catheter is difficult to dislodge and may be managed without a dressing (Gorski et al., 2016a). Surgeons, radiologists, and specialist advanced practice nurses place tunneled catheters.

Tunneled catheters are often made of silicone elastomers, but they may also be made of polyurethane. They may be single lumen or have multiple lumens with varying diameters.

**ADVANTAGES**

1. Potentially repairable if catheter cracks/tears
2. Low risk of catheter-associated bloodstream infection
3. May remain in place for months to years
4. May not require dressing after tunnel tract is well healed

**DISADVANTAGES**

1. More costly surgical placement and removal (compared with nontunneled CVADs/PICCs)
2. External catheter requires long-term maintenance and attention
3. Body image concerns due to living with external catheter

**Insertion of Tunneled Catheters**

Subcutaneously tunneled catheters are inserted under ultrasound or fluoroscopy with the patient under local or general anesthesia. During insertion, the venipuncture site may be made at a point near the subclavian (Fig. 8-10) or internal jugular vein. The catheter can be inserted using MST, as previously discussed, or using a cutdown technique. A subcutaneous tunnel from the venipuncture site down the chest wall is created, leading to an exit site somewhere on the chest. The catheter is pulled from the exit site through the tunnel to the
vein entry site or, for a valved catheter, the catheter is pulled from the vein entry site to the exit site (Camp-Sorrell & Matey, 2017). The catheter may be sutured to the skin at the catheter exit site; these sutures are removed in 10 days to 6 weeks or longer in the case of immunosuppression. A dressing is applied over the catheter insertion site after catheter placement.

Figure 8-10 Subclavian insertion site for a tunneled catheter.

NURSING POINTS OF CARE

SUBCUTANEOUSLY TUNNELED CUFFED CATHETERS

- Subcutaneously tunneled cuffed catheters are long-term catheters, and patients or their caregivers will learn to care for their catheter independently.
- The catheter may or may not require clamping between infusions; if an open-ended (nonvalved) catheter is used, clamp it at all times. This is a safety issue because if the needleless connector accidentally disconnects, there is risk of air embolism. If the catheter has an integral valve in the catheter tip or hub, a clamp is not necessary, and the catheter will not come with a clamp. It is always important to refer to the manufacturer’s directions regarding care and management issues.
- Keep all sharp objects away from the catheter. Never use scissors or pins on or near the catheter.
- If the catheter leaks or breaks, take a nonserrated (without teeth) clamp and clamp the catheter between the broken area and the exit site. Cover the broken part with a sterile gauze bandage and tape it securely. Do not
use the catheter. Notify the authorized prescriber (e.g., physician, nurse practitioner, physician assistant).

- Protect the catheter when the patient is showering or bathing by covering the entire catheter with transparent dressing or clear plastic wrap. There are also specific products for this use. Cover the connections and protect hub connections from water contamination.
- A dressing may not be required on well-healed catheters.

**NURSING FAST FACT!**

Refer to Chapter 9 for general complications associated with CVADs, both local and systemic.

### Implanted Vascular Access Ports

The implanted vascular access port is another type of long-term CVAD that has been used for vascular access since the 1980s. Originally, implanted ports were targeted in oncology patients who required frequent intermittent vascular access for chemotherapy administration. This is still a common indication for implanted port use. Other patient populations include those with intermittent long-term infusion needs, such as patients with hemophilia, cystic fibrosis, and sickle cell disease, and patients who desire a completely implanted device despite daily use; an example is the patient on PN who wants to be able to swim. The implanted port provides safe and reliable vascular access and offers patients improved body image, reduced maintenance, and potentially a better quality of life than with the external CVAD.

The implanted port is a surgically placed and completely implanted CVAD that is placed in the operating room or in the interventional radiology suite. The port consists of a silicone catheter attached to a reservoir or “port,” which is made of titanium or plastic (Figs. 8-11, 8-12). The center of the port is covered with a dense silicone septum. There are ports available with two lumens. The port septum is accessed using a noncoring needle. Most ports can tolerate many hundreds of needle punctures, and the manufacturer’s directions will provide specific information about port access. Most often, ports are located in the chest; however, there are “peripheral” ports where the port body is located in the antecubital area. Despite its name, the peripheral port is a CVAD with the catheter threaded through a vein of the upper arm and the tip located in the SVC. When the port is not accessed for use, the only external evidence is a small protrusion in the skin. Port care is minimal, usually requiring regular access for flushing if the port is not being actively used. Historically, locking the port with 5 mL of heparin (10-100 units per mL) was performed on a monthly or every other month basis. Research is now suggesting that normal saline may be as effective as heparin in maintaining the patency of the port (Gorski et al., 2016a; Camp-Sorrell & Matey, 2017).
Of note, there are also ports with catheters placed and located in the hepatic artery and the peritoneum. These types of ports are for highly specialized infusion therapies and are not addressed in this textbook. Epidural ports are addressed in Chapter 10. The nurse must be aware and knowledgeable about the type of implanted port before accessing it for an infusion.

ADVANTAGES

1. Low risk of catheter-associated bloodstream infection
2. Minimal maintenance required; no dressing unless being actively used for infusion
3. Ability to sample blood for laboratory studies
4. May remain in place for months to years
5. Improved body image; no external evidence of port other than small "bump"
6. Few limitations on patient activity; ability to swim when not accessed

**Disadvantages**

1. More costly device and placement
2. Requires use of a noncoring needle to access the port
3. Pain during needle insertion may be an issue for some patients
4. Minor surgical procedure is necessary to remove the device

**Insertion**

The port is usually inserted in the operating room or interventional radiology suite. The surgeon makes an incision in the upper to middle chest, usually near the collarbone, to form a pocket to house the port. The silicone catheter is inserted via cutdown into the SVC; the port is then placed in the subcutaneous fascia pocket. The port contains a reservoir leading to the catheter. The incision for the port pocket is sutured closed, and a sterile dressing is applied. This area should be monitored until the incision has healed, about 10 days to 2 weeks after insertion.

**Accessing the Port**

If the port is not routinely used, it should be flushed and locked every 1-2 months or according to the manufacturer's recommendations. Implanted port access is a skill that must be validated with a competency assessment. Simulation models are helpful for training and practice. However, ports can be challenging to access because of issues such as deep placement, and it is necessary to have a skilled preceptor observe a nurse's first-time port access. To learn how to access an implanted port, including how to administer an I.V. push medication and a continuous infusion, see Figure 8-13 and follow the guidelines listed in Procedures Display 8-2 at the end of this chapter. Infiltration or extravasation of solutions or medications can occur if the needle is not in place through the septum of the port and the position is not confirmed, or if the needle dislodges (see Chapter 9 for CVAD complications).

Patients and nurses must always verify placement by ensuring the ability to easily aspirate blood and by ensuring that there is no swelling or discomfort during flushing or infusion. The needle should be secured before the infusion is initiated, and the site observed for signs such as swelling or the presence of pain or burning.

As with all vascular access procedures, proper hand hygiene is critical. Accessing the port requires adherence to aseptic technique (i.e., wearing a mask and sterile gloves) (Gorski et al., 2016b). Should the patient require a continuous infusion via the implanted port, there is insufficient evidence to recommend an optimal time for replacement of the noncoring needle (Gorski et al., 2016a, p. 558), although typical practice is to remove and replace the needle every 7 days. A transparent dressing can be left in place with the needle and changed every 5 to 7 days. If a gauze dressing is used, it must be changed every 48 hours.
Some nurses may use a gauze dressing under the transparent dressing to stabilize the access needle; if it does not obscure the catheter–skin junction, the dressing is not considered a gauze dressing and can be changed at least every 5 to 7 days (Gorski et al., 2016a, p. S58).

**INS Standard:** Access the implanted vascular access port with the smallest-gauge noncoring needle to accommodate the prescribed therapy (Gorski et al., 2016a, p. S58).

Some patients may require attention to pain management during port access. It is important that the nurse explore patient preferences and feelings related...
to access. Most often, topical analgesic creams or patches are used, such as prescription EMLA (contains lidocaine and prilocaine) or an over-the-counter anesthetic cream (e.g., ELA-Max). Although transdermal creams are effective, the disadvantage is the time duration to gain an anesthetic effect, which can be up to 1 hour.

Other pain management strategies include distraction or relaxation techniques and use of ice over the port site for several minutes before site preparation and access (Gorski et al., 2016a-2016b).

**Deaccessing an Implanted Port**

After hand hygiene is performed, nonsterile gloves are worn and the dressing is removed. The port is stabilized using the thumb and forefinger of the nondominant hand. The needle device is grasped with the dominant hand and removed following the directions of the safety needle. It is very important that the nurse understand the safety mechanism when removing the noncoring needle. When it is removed from the port the needle often may “pull,” and there is risk of rebound and accidental needlestick to the nurse’s fingers during the removal process should the safety features not be engaged.

**INS Standard:** Adhere to aseptic technique during implanted port access including the use of sterile gloves and mask (Gorski et al., 2016a, p. S58).

Refer to Procedures Display 8-3 at the end of this chapter for full instructions on deaccessing an implanted port.

Table 8-3 compares CVADs, with advantages and disadvantages of each.

<table>
<thead>
<tr>
<th>Type and Use</th>
<th>Available Features</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Nontunneled CVAD</strong></td>
<td>Antimicrobial impregnated or antithrombotic catheter material Single or multiple lumens Valved or nonvalved Power injectable</td>
<td>Can be inserted at the bedside Less expensive than subcutaneously tunneled or implanted port Can be removed by nurse Can be exchanged over guidewire</td>
<td>Short-term device (usually days) Increased risk for infection compared with peripheral I.V. catheter or long-term CVADs Maintenance site care and dressing Need to protect from water</td>
</tr>
<tr>
<td><strong>PICC</strong></td>
<td>Antimicrobial impregnated or antithrombotic catheter material Single or multiple lumens Valved or nonvalved Power injectable</td>
<td>Short-term (days) to longer-term device (weeks to months) Usually inserted at bedside Lower risk of insertion-related complications (compared to non-tunneled CVADs)</td>
<td>Increased risk for catheter-associated venous thrombosis Maintenance site care and dressing changes required Location in arm may be challenging to manage long term</td>
</tr>
</tbody>
</table>
Table 8-3  Comparison of Central Venous Catheters—cont’d

<table>
<thead>
<tr>
<th>Type and Use</th>
<th>Available Features</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Subcutaneously</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Tunneled CVAD</strong></td>
<td>Single or multiple lumens</td>
<td>Low risk for infection</td>
<td>More costly device and surgical placement and removal</td>
</tr>
<tr>
<td></td>
<td>Valved or nonvalved</td>
<td>Repairable</td>
<td>Requires noncoring needle to access</td>
</tr>
<tr>
<td></td>
<td>Power injectable</td>
<td>May remain in place for months to years</td>
<td>Pain during needle insertion may be an issue for some patients, although anesthetic options are available</td>
</tr>
<tr>
<td></td>
<td></td>
<td>May not require dressing after tunnel track</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>is well healed</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Decreased care and maintenance costs</td>
<td></td>
</tr>
<tr>
<td>Implant ports</td>
<td>Single or double lumen</td>
<td>Low risk for infection</td>
<td>More costly surgical placement and removal</td>
</tr>
<tr>
<td></td>
<td>Valved or nonvalved</td>
<td>May remain in place for months to years</td>
<td>Requires noncoring needle to access</td>
</tr>
<tr>
<td></td>
<td>Power injectable</td>
<td>Low care and maintenance costs</td>
<td>Pain during needle insertion may be an issue for some patients, although anesthetic options are available</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Monthly maintenance locking</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>No activity restrictions</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Improved body image as no external catheter</td>
<td></td>
</tr>
</tbody>
</table>

CVAD Care and Maintenance

Assessment

Assessment, including the CVAD site, catheter patency, and need for catheter, is an important aspect of catheter care and maintenance and is critically important to ensuring positive patient outcomes. Assessment related to the CVAD site should address the following:

- Signs of local infection, such as erythema, drainage, swelling, and induration
- The tunnel tract or port pocket area is assessed for pain, tenderness, or edema for patients with subcutaneously tunneled CVADs or implanted ports.
- Signs of catheter-associated venous thrombosis, including swelling in the arm, shoulder, chest, or neck; pain along the extremity, in the shoulder, chest, neck, jaw, or ear; or dilated collateral veins over the arm, neck, or chest on the placement side of the CVAD (see Chapter 9)
• Presence of fluid leakage at the insertion site that might be indicative of a crack in the catheter or possible thrombotic problems
• Patient complaints of pain or evidence of pain or tenderness when the area is gently palpated
• Integrity of the dressing and the stabilization device/method used
• Evidence of outward migration of the catheter. The external length of the CVAD extruding from the site should be measured at the time of placement so that any suspected catheter migration can be objectively validated by subsequent measurements.
• Catheter patency: Each lumen of a patent CVAD should be easy to flush (i.e., without any resistance) and should yield a free-flowing blood return with aspiration.

Beyond assessment of the CVAD site, vital signs and a general head-to-toe assessment should be performed. Laboratory test results should be checked for abnormalities; for example, an increase in the white blood cell count may be indicative of infection. Finally, the need for the central line is reviewed as part of the assessment process. To summarize, positive outcomes include:

• The catheter exit site is clean and free of blood or drainage, erythema, and edema; the dressing is intact; and there is no pain, fever, or evidence of thrombosis.
• The CVAD flushes easily and yields a free flowing blood return with aspiration.

Abnormalities (including signs and symptoms) are reported to the authorized prescriber. Frequency of site assessment is dependent on the patient’s condition, organizational policies, and the health-care setting. In most hospitals, CVAD site assessment is done at least every 8 hours. For patients with long-term CVADs in alternative settings such as long-term care facilities, the site should be checked at least daily and possibly more often, based on how often the CVAD is being used for infusion therapy. For home-care patients, the site should be assessed by the nurse at every home visit, and patients should be taught to inspect their site at least every day (Gorski et al., 2016a; Gorski, 2017).

INS Standard: Assess the catheter–skin junction site and surrounding area for redness, tenderness, swelling, and drainage through visual inspection and palpation through the intact dressing and through patient reports about any discomfort, including pain, paresthesias, numbness or tingling (Gorski et al., 2016a, p. S81).

Site Care and Dressing Changes
Site care is performed regularly in conjunction with dressing changes for external CVADs, which include PICCs and nontunneled and subcutaneously tunneled catheters. Regular site care is required to cleanse the skin and reduce the presence of microorganisms on the skin around the catheter insertion site,
which are a potential source of catheter-associated bloodstream infection. The basic steps included in site care and dressing changes include:

- Removal of the old dressing and stabilization device, if used
- Providing skin antisepsis using an acceptable antiseptic
- Assessing the condition of the insertion site, surrounding skin, and catheter (as outlined in the previous section)
- Replacing the stabilization device and dressing

The preferred skin antiseptic agent for ongoing site care is >0.5% chlorhexidine in alcohol solution (Gorski et al., 2016, p. S82) and the usual concentration used is actually is 2-3.15% chlorhexidine. Although chlorhexidine is preferred due to its residual antimicrobial activity, other acceptable solutions include tincture of iodine, an iodophor (povidone-iodine), or 70% alcohol (Gorski et al., 2016a, p. S82). When applying chlorhexidine, a back-and-forth scrubbing method using friction for at least 30 seconds is recommended. It is important to allow the antiseptic to fully dry before replacing the dressing.

For patients who are sensitive or allergic to chlorhexidine or alcohol and for children younger than 2 months of age, povidone-iodine is considered an acceptable disinfectant. To be most effective, povidone-iodine requires at least 1.5 to 2 minutes of contact on the skin (Gorski et al., 2016a). It is applied using swab sticks. Each swab stick of povidone-iodine is applied using either a back-and-forth scrubbing method or concentric circles beginning at the catheter insertion site, then moving outward. It is important to recognize that the practice of applying antiseptics in concentric circles is based on “traditional” practice rather than research. This is certainly an area of practice that lacks evidence and needs research to validate the procedure. Povidone-iodine should not be removed with alcohol after application, but in the case of neonates, the dried povidone-iodine is removed with sterile water or 0.9% sodium chloride to reduce the risk for thyroid disorders (Gorski et al., 2016a, S82).

Use of a central line dressing kit is recommended because it standardizes the dressing change procedure and improves time efficiency by eliminating the need to gather individual supplies (Fig. 8-14).

For newly placed subcutaneously tunneled CVADs, the dressing change procedure is the same as for nontunneled CVADs or PICCs. Once the tunnel is healed, a dressing may not be required. If the patient is not immunosuppressed and healing at the insertion site is complete, site care may be limited to daily inspection and cleansing with soap and water while the patient is bathing. Should a patient with a long-term subcutaneously tunneled catheter, managed at home without a dressing, be admitted to the hospital, organizational policies generally require a dressing because of the increased risk for infection in the inpatient setting.

Options for catheter dressings include the transparent semipermeable membrane (TSM) dressing or the gauze and tape dressing. Advantages to TSM dressings include continuous visual inspection of the catheter site and cost-effectiveness because of less frequent dressing changes. Gauze dressings may be appropriate for
the patient who experiences site drainage, perspires excessively, or has sensitivity to TSM dressings. TSM dressings are replaced if they are damp, loosened, or visibly soiled or if moisture, drainage, or blood is present—at least every 5 to 7 days—whereas gauze dressings should be changed every 2 days or if the site requires visual inspection (Gorski et al., 2016a, p. S82). Dressings are always changed earlier than the scheduled 2- or 7-day interval if loosened, dislodged, or wet or if blood or drainage is present, as the risk for infection is increased due to the growth of microorganisms on the skin. It is not acceptable to “reinforce” an existing dressing by adding more tape. The problem of failing to maintain a dry and intact dressing over central lines in hospital settings has been documented (Morrison, Raffaele, & Brenneman, 2017).

Antimicrobial dressings, such as chlorhexidine-impregnated dressings, are recommended for use (Saldar et al., 2014). Because the efficacy of these dressings has not been demonstrated beyond 14 days after placement, when intraluminal sources of microbial contamination are the primary source of BSI, there is wide variance in practice of the use of these dressings for long-term CVAD use in home care or for patients in long-term care hospitals or nursing homes. Chlorhexidine dressings include a small, round foam dressing that incrementally releases chlorhexidine; it is placed around the catheter at the exit site and covered with a transparent dressing. There is also a transparent dressing with a built in
gel pad of aqueous chlorhexidine (Figs. 8-15, 8-16). There are also silver-impregnated antiseptic dressings. The Oncology Nursing Society recommends use of a CHG-sponge dressing for implanted port access that exceeds 4-6 hours (Camp-Sorrell & Matey, 2017).

It is important to recognize the importance of maintaining an intact dressing. Based upon results from a large randomized controlled trial, when there were more than two dressing changes for disruption (soiled, dressing coming off), there was a more than a threefold increase in the risk of bloodstream infection (Timsit et al., 2012). For patients with high-risk CVAD site insertions such as those via the femoral or internal jugular veins, dressing disruption is a problem as it can be difficult to maintain dressings in these areas. With documented increases in bloodstream infection related to dressing disruption, new methods to secure the catheter dressing with additional adhesives are being explored and implemented in some organizations. Dressings specially designed for specific or problematic areas are also available (Fig. 8-17).

EBP In accordance with the INS standards (Gorski et al., 2016, p. S82) as based upon a meta-analysis of randomized controlled trials, chlorhexidine-impregnated dressings should be used with CVADs to reduce infection risk. Even when organizations show a low baseline central line–associated bloodstream infection (CLABSI) rate, further reduction in CLABSI rate has been demonstrated with use of chlorhexidine-impregnated dressings (Safdar et al., 2014).

**Figure 8-15** Tegaderm CHG dressing over PICC. (Courtesy of 3M Medical Division, St. Paul, MN.)
Figure 8-16  Biopatch®-impregnated foam dressing around a CVAD. (Courtesy of J&J Wound Management, Division of Ethicon, Inc., Somerville, NJ.)

Figure 8-17  SorbaView Shield Contour TSM dressing over nontunneled CVAD placed via internal jugular vein. (Courtesy of Centurion, Williamston, MI.)
Site care and dressing changes are performed using aseptic technique. Refer to Procedures Display 8-4 at the end of this chapter.

**INS Standard:** Label the dressing with the date performed or date to be changed based on organizational policies and procedures (Gorski et al., 2016a, p. S81).

**Administration Set Changes**
Administration sets are regularly changed based on the type of infusion (continuous or intermittent) and type of infusate as follows:

- Aseptic technique is adhered to at all times when changing any administration tubing.
- Primary and secondary continuous administration sets used to administer fluids other than lipids, blood, or blood products should be changed no more frequently than every 96 hours.
- Primary intermittent administration sets are changed every 24 hours (i.e., administration sets taken down after each infusion and CVAD locked between infusions). A sterile cap is placed on the male end of the administration set between infusions.
- Administration sets used to deliver PN with lipid emulsions are changed every 24 hours.
- Intravenous fat emulsion administration sets are changed every 12 hours.
- Administration sets and add-on filters that are used for blood and blood components are changed after administration of each unit or at the end of 4 hours, whichever comes first.
- When any administration set is suspected of being contaminated, or when the integrity of the product is in question, it should be changed (Gorski et al., 2016a, pp. S84-S85).

**Flushing and Locking**
As discussed in Chapter 6, catheters are flushed after each intermittent infusion to clear any medication from the catheter and to prevent contact between incompatible medications or I.V. solutions. If not properly flushed, a precipitate can form, essentially blocking the catheter, or thrombotic occlusion can occur as a result of blood clotting within the catheter lumen. Catheters are flushed with preservative-free 0.9% sodium chloride. Catheters are locked with a solution left instilled in the catheter to prevent occlusion in between intermittent infusions.

The INS recommends either saline or low-concentration heparin to lock CVADs as there is insufficient evidence to recommend one solution over the other (Gorski et al., 2016, p. S79). In a subsequently published review of the literature, the researchers found also no evidence supporting heparin locking for central lines, asserting that occlusion prevention is based on proper flushing and locking technique used with saline (Pittiruti et al., 2016).
However, based upon a home-care trial, recommendations included consideration for 10 units per mL heparin over use of saline as heparin locking was associated with a tendency toward reduced occlusion problems in a randomized controlled trial (Gorski et al., 2016; Lyons & Phalen, 2014). And a 2016 study that included over 14,000 PICCs in hospitalized patients found that PICCs that were flushed with saline and locked with heparin were significantly less likely to become occluded (Smith et al., 2017). The evidence continues to emerge regarding the best locking solution as well as the frequency of locking; therefore, there remains variation in protocols between organizations.

Rather than a smooth, continuous flush, current recommendations are to use a pulsatile procedure (e.g., “push and pause” or “stop and start”) that results in turbulence within the catheter, theoretically reducing occlusion risk (Gorski et al., 2016; Pittiruti et al., 2016); however, studies in process may change these recommendations.

Also, alternative locking solutions may be used for CVADs in some situations, for example, ethanol may be used in patients with a history of bloodstream infections. Ethanol, sodium citrate, tauroldine, and ethylenediaminetetraacetate (EDTA) have been used as alternative locking solutions in patients with heparin-induced thrombocytopenia (Gorski et al., 2016a). Such solutions must be made by a compounding pharmacy because they are not available in single-dose syringes or containers. It is important to review and follow organizational policies and procedures.

**Cultural and Ethnic Considerations: Heparin**

Because heparin is most often obtained from porcine intestine or bovine lung, it may present a cultural issue for some patients. Hindus, Sikhs, and Muslims do not approve of some animal-derived products if there are other alternatives. Informed consent should be sought for the use of animal- or human-derived products for several religions (Eriksson, Burcharth, & Rosenberg, 2013).

**NURSING FAST FACT!**

Heparin-induced thrombocytopenia is a rare but life- and limb-threatening immunological reaction caused by platelet activation resulting in a hypercoagulable state leading to arterial thrombosis as a result of heparin exposure.

**Needleless Connectors**

Needleless connectors are placed on the hub of the CVAD. They are designed to accommodate the tip of the syringe or I.V. tubing for catheter flushing or
I.V. administration. A review of important aspects of needleless connectors is given below (see Chapters 5 and 6 for further information):

- There are different types of needleless connectors, including simple devices (e.g., split septum) and complex devices. Complex devices include negative, positive, and neutral needleless connectors. To reduce the risk of blood reflux and thus catheter occlusion, the nurse must understand proper flushing technique in relation to the type of needleless connector (refer to Chapters 5 and 6).
- Needleless connectors are changed when the I.V. administration set is changed, when residual blood is present in the device, and whenever the integrity of the product is compromised or is suspected of being contaminated. Manufacturer's guidelines will provide further information regarding frequency of change, including whether the connectors should be replaced after blood withdrawal. Also, to prevent contamination of blood cultures drawn through a CVAD, the needleless connector is replaced before the blood culture sample is drawn.
- The needleless connector must be disinfected before any access into the CVAD. INS (Gorski et al., 2016a, p. S68) recommends the following disinfectant agents: 70% alcohol, povidone-iodine, or >0.5% chlorhexidine/alcohol solution.
- Although the optimal disinfection (i.e., “scrubbing”) time is not known, many organizations use a 15-second scrub. Shorter scrub times may be acceptable based on the design of the needleless connector and the disinfectant product used.
- Alternative products, including those especially designed for scrubbing the catheter hub or needleless connector in less time, are available.
- Protective alcohol disinfection caps are available that are placed on the needleless connector of locked CVAD lumens between infusions. (See Chapter 5, Figure 5-18.) Advantages of these products include reduced contamination and elimination of “human factor” issues that require nurses to have disinfection supplies at the bedside and to use them consistently; the caps provide the nurse with an easy-to-use solution (Moureau & Flynn, 2015).

**NURSING FAST FACT!**

Needleless connectors are a known source for contamination via the intraluminal route, that is, through the lumen of the catheter; failure to disinfect a needleless connector for flushing or medication administration is a well-recognized problem (Moureau & Flynn, 2015). Cultures of needleless connectors on nontunneled CVADs and PICCs in an ICU setting showed that they were contaminated 44% of the time (Holroyd, Vasilopoulos, Rice, Rand, & Fahy, 2017).
NOTE: Refer to the manufacturer’s guidelines for specific device usage.

**NURSING FAST FACT!**

If you have a multilumen catheter, remember to change the needleless connectors on all lumens.

**Catheter Repair**

Catheter damage can occur when excessive pressure is exerted while flushing or when an accidental cut is made by scissors or the catheter clamp. Nurses as well as patients must be knowledgeable about immediate actions to take in the event of catheter damage. Air can enter the catheter through the tear, causing an air embolism. Patients should be provided instructions on how to immediately clamp or fold the catheter to prevent blood loss or air embolism, and they should be informed to notify the nurse.

Some CVADs may be repairable. Catheter repair kits are available and are specific to the manufacturer and size of the catheter. Risks versus benefits must be considered when weighing the appropriateness of catheter removal versus catheter repair (Gorski et al., 2016a, p. S111). Factors to consider include risk for infection from the damaged catheter, catheter type and potential for repair, expected duration of catheter need, and patient safety. Patient benefits from catheter repair include avoidance of the risk, cost, and disruption in life associated with another catheter insertion procedure; potential risks include the possibility of CR-BSI resulting from the damaged catheter or the catheter repair procedure. The risk of catheter-associated infection is reduced by nursing competence and use of sterile technique while performing the repair.

Other options for managing a damaged or ruptured catheter include a catheter exchange procedure or insertion of a new catheter in a different site. The catheter exchange procedure involves replacing the catheter in the same site using a guidewire; this procedure is performed under the same level of aseptic technique and following the central line insertion bundle interventions.

**Catheter Removal**

Removal of a tunneled catheter or implanted port is generally performed by a physician, physician’s assistant, or nurse practitioner. For tunneled catheters, it is important that the subcutaneous cuff be completely removed to prevent healing delay and abscess formation (Gorski et al., 2016a, p. S93).

Table 8-4 summarizes the care and maintenance of the four types of CVADs.
Table 8-4 Summary of Care and Maintenance of Central Vascular Access Devices

<table>
<thead>
<tr>
<th>Care/Maintenance</th>
<th>Standards of Care</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dressings</strong></td>
<td>Sterile dressings should be applied and replaced routinely.</td>
</tr>
<tr>
<td></td>
<td>Gauze dressings are replaced at least every 2 days.</td>
</tr>
<tr>
<td></td>
<td>Transparent semipermeable membrane (TSM) dressings are replaced at least every 5–7 days.</td>
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<tr>
<td></td>
<td>If gauze is used in conjunction with a TSM dressing, it is considered a gauze dressing and must be changed every 48 hours.</td>
</tr>
<tr>
<td></td>
<td>Use a chlorhexidine impregnated dressing for at least the first 14 days after CVAD placement.</td>
</tr>
<tr>
<td></td>
<td>Sterile dressings should be applied and replaced routinely.</td>
</tr>
<tr>
<td></td>
<td>Gauze dressings are replaced at least every 2 days.</td>
</tr>
<tr>
<td></td>
<td>Transparent semipermeable membrane (TSM) dressings are replaced at least every 5–7 days.</td>
</tr>
<tr>
<td></td>
<td>If gauze is used in conjunction with a TSM dressing, it is considered a gauze dressing and must be changed every 48 hours.</td>
</tr>
<tr>
<td></td>
<td>Use a chlorhexidine impregnated dressing for at least the first 14 days after CVAD placement.</td>
</tr>
<tr>
<td><strong>Administration Set Changes</strong></td>
<td>Primary and secondary continuous administration sets used to administer fluids other than lipids, blood, or blood products should be changed no more frequently than every 96 hours.</td>
</tr>
<tr>
<td></td>
<td>Primary intermittent infusion sets should be changed every 24 hours.</td>
</tr>
<tr>
<td></td>
<td>Administration sets used to administer lipid-containing parenteral nutrition (PN) solutions are changed every 24 hours.</td>
</tr>
<tr>
<td></td>
<td>Intravenous fat emulsion administration sets are changed every 12 hours.</td>
</tr>
<tr>
<td></td>
<td>Blood sets and add-on filters should be changed after administration of each unit or at the end of 4 hours, whichever comes first. Any administration set that is suspected of being contaminated, or any product whose integrity is in question, should be changed.</td>
</tr>
<tr>
<td><strong>Flushing and Locking</strong></td>
<td>Always use a 10-mL size syringe to reduce risk of catheter damage.</td>
</tr>
<tr>
<td></td>
<td>Flush CVADs using preservative-free 0.9% sodium chloride.</td>
</tr>
<tr>
<td></td>
<td>Minimum flushing volume should be equal to twice the internal volume of the catheter system (e.g., catheter plus any add-on devices).</td>
</tr>
<tr>
<td></td>
<td>A pulsatile flushing technique of short boluses of sodium chloride followed by brief pauses (e.g., “start-stop” technique) may be beneficial in clearing catheter of internal lumen deposits.</td>
</tr>
<tr>
<td></td>
<td>Locking solution volume should be equal to the internal volume of the CVAD and any add-on devices, plus 20%.</td>
</tr>
<tr>
<td></td>
<td>Lock CVADs using either preservative-free 0.9% sodium chloride or heparin 10 units/mL.</td>
</tr>
<tr>
<td><strong>Needless Connectors</strong></td>
<td>Disinfect with 70% alcohol using a twisting motion for at least 15 seconds before every access, or use special products developed for disinfection according to manufacturer’s directions.</td>
</tr>
<tr>
<td></td>
<td>Consider use of alcohol disinfection caps on unused CVAD lumens between infusions.</td>
</tr>
</tbody>
</table>

Source: Gorski et al., 2016a.

**NOTE:** All add-on devices (extension tubing sets, injection caps, filters, syringes) should have Luer-lock connections to reduce risk of accidental disconnection.
NURSING POINTS OF CARE

CARE AND MAINTENANCE

Nursing Assessment
• Signs of local infection, such as erythema, drainage, swelling, and induration
• Patients with subcutaneously tunneled CVADs or implanted ports: Assess tunnel tract or port area for pain, tenderness, and edema
• Signs of catheter-associated venous thrombosis
• Presence of fluid leakage at the insertion site indicative of a crack in the catheter or possible thrombotic problems
• Patient complaints of pain or evidence of pain or tenderness
• Integrity of the dressing and the stabilization device/method used
• Evidence of outward migration of the catheter
• Catheter patency
• Vital signs

Key Nursing Interventions
1. Regular site care and dressing changes
   a. At least every 5–7 days if using a TSM dressing
   b. At least every 2 days if using a gauze dressing
   c. More often if dressing is damp, loosened, or visibly soiled
   d. Use a chlorhexidine impregnated dressing for at least the first 14 days after CVAD placement.
2. For continuous infusions, change administration sets at least every 96 hours; for intermittent infusions (CVAD locked between infusions), change set every 24 hours. Replace tubing used to administer blood or blood products every 4 hours; replace tubing used to administer lipids every 12 hours.
3. Flush CVAD with 0.9% sodium chloride to assess patency and to prevent contact between incompatible solutions/medications.
4. Lock unused lumens of CVAD with 0.9% sodium chloride or low-concentration heparin to maintain patency in accordance with organizational protocols.
5. Use a noncoring needle to access implanted ports; change the needle every 7 days if running a continuous infusion via the port. Maintain a chlorhexidine dressing around the noncoring needle for access lasting beyond 4–6 hours.
6. Clamp the unused lumens of nonvalved CVADs at all times.
7. Keep sharp objects away from the CVAD; never use scissors or pins on or near the catheter.
8. Protect CVAD when patient is showering or bathing by covering the entire catheter with transparent dressing or clear plastic wrap. Cover the connections and protect hub connections from water contamination.
9. Avoid taking blood pressure (BP) measurements or placement of a tourniquet over the site/upper extremity of the PICC. Use an alternate extremity for BP measurement.

10. Document the following:
   a. Location of insertion site
   b. Assessment of the catheter and insertion site
   c. Condition of catheter tract (subcutaneously tunneled catheters) and surrounding tissue
   d. External catheter length, if present
   e. Site care and type of I.V. site dressing
   f. Flushing/locking solutions, amount, time
   g. Administration set changes
   h. Patient response to catheter and patient education

**AGE-RELATED CONSIDERATIONS**

**The Pediatric Patient**

Pediatric Central Vascular Access

The same four categories of CVADs used in adults—nontunneled, PICCs, subcutaneously tunneled, and implanted vascular access ports—are also used for pediatric infusion therapy for similar indications. As with adults, it is important to assess the infant or child early during the hospital stay to determine the most appropriate VAD. Selection criteria include:

- Length and type of anticipated therapies
- Age and weight
- Diagnoses
- Condition of the vasculature (some children have difficult venous access that may lead to preference for a CVAD)
- Current clinical condition
- Number of different infusion therapies. A child receiving multiple medications and/or blood products will benefit from a CVAD.

Nontunneled CVADs are used for short-term access in the critically ill child. The external jugular vein is more commonly accessed in infants (Doellman, 2014). In contrast to that of adults, the femoral site of pediatric patients is not contraindicated and in fact is a common insertion site in the critical care setting (Association for Vascular Access (AVA) Pediatric Special Interest Group, 2015). PICCs are also commonly placed in infants and children. PICC sites include the arm in children of all ages and the leg, foot, or scalp/neck veins in infants. The vein of choice for the upper arm is the basilic because of its larger diameter and fewer valves; the lower extremity (saphenous vein) may be used if the child is nonmobile (AVA Pediatric Special Interest Group, 2015). Long-term central venous access, often with subcutaneously tunneled catheters, is an integral part of managing children with cancer, certain congenital malformations, or gastrointestinal (GI) malfunction, as well as those who need long-term access for medication or blood products. Implanted ports may be placed in children who have ongoing intermittent infusion needs, such as those with severe hemophilia requiring regular factor replacement.

In infants, the umbilical vein and artery are additional routes for venous access for the first few days after birth. The umbilical cord includes three vessels: one thin-walled vein with a large-diameter lumen and two thick-walled arteries with small-diameter lumens.
CHAPTER 8  Central Vascular Access

(Doellman, 2014). The umbilical vein is preferred in emergency infusions and can be used for up to 2 weeks. Catheters placed in the vein can be used also for CVP measurement, venous blood sampling, prostaglandin administration, and exchange transfusions. The catheter tip for umbilical vein catheters is located in the inferior vena cava near the junction with the right atrium (Gorski et al., 2016a, p. S61). The umbilical artery catheter is used for hemodynamic monitoring, arterial blood gas measurements, and obtaining blood for other laboratory work; dwell time should be limited to no more than 5 days (Gorski et al., 2016a, p. S61).

The INS Standards address some specific practice criteria for infusion in the pediatric patient. In relation to CVAD use, included are:

1. The nurse verifies that informed consent for treatment of neonatal and pediatric patients, as well as for patients deemed emancipated minors, is documented.
2. The nurse providing infusion therapy for neonatal and pediatric patients is knowledgeable and possesses technical expertise with respect to this population.
3. The nurse providing infusion therapy should have knowledge and demonstrated competency in the areas of:
   a. Anatomy and physiology related to neonatal and pediatric patients and their effect on physical assessment, VAD and non-VAD selection, insertion procedures, and use of specialized equipment
   b. Growth and development stages
   c. Physiological characteristics and their effect on drug and nutrient selection (Gorski et al., 2016a)

Care and Maintenance of Central Vascular Access Devices in Children

Use chlorhexidine with care in premature infants and infants under 2 months of age due to risks of skin irritation and chemical burns. However, chlorhexidine preparations are commonly used due to their effectiveness in skin antisepsis, and they were reported as the primary skin antiseptic agent used in neonatal intensive care units (Sharp, 2014). If povidone-iodine is used for skin antisepsis, the dried povidone-iodine is removed with sterile 0.9% sodium chloride (USP) or sterile water (Gorski et al., 2016a, p. S82). As mentioned earlier in the chapter, the rationale is to avoid absorption of the povidone-iodine that may contribute to thyroid disorders in infants.

Home Care Issues

Most patients who require home infusion therapy will have a CVAD in place rather than a peripheral I.V. catheter. CVADs are commonly used in home administration of antimicrobial medications, PN, chemotherapy, biological therapy, and other medications. The most commonly used type of CVAD is the PICC. For home-care patients, the emphasis on patient education is especially strong. Home-care patients will be assuming many facets of self-care related to their VAD. The patient is responsible for living day to day with the CVAD and is likely to be participating in self-infusion of prescribed medications.
Patient Education

Patient instructions for CVADs should include:

- Type of CVAD, purpose and description of the device
- Proper care of the device
- Precautions aimed at infection prevention and other complications, including aseptic technique and hand hygiene
- Signs and symptoms to report, such as increased temperature, discomfort, or pain

Continued
Nursing Diagnoses Related to Central Venous Access | Nursing Outcomes Classification (NOC) | Nursing Interventions Classification (NIC)
---|---|---
Ineffective protection, related to: Treatment regimen; placement of CVAD | Health-promoting behavior; endurance; immune status | Infection prevention and bleeding precautions
Infection, risk of related to: Environmental exposure to pathogens; immunosuppression; invasive procedures | Infection control, risk control and detection | Infection control practices and infection protection
Skin integrity impaired, related to external factors: VAD; irritation from I.V. solution; inflammation; infection | Tissue integrity: skin | Skin surveillance; wound care, risk identification
Disturbed body image: Alteration in body function (e.g., long-term need for CVAD/infusion) | Body image, self-esteem, acceptance of health status, coping, identity | Body image enhancement
Deficient knowledge related to: Unfamiliarity with information resources (CVAD and information provided); alteration in cognitive functioning; information misinterpretation; lack of exposure | Knowledge: disease process, medication; personal safety; prescribed activity; treatment procedures; treatment regimen | Teaching: Disease process and CVAD care and maintenance
Family process, interrupted related to: Shift in health status of a family member; situation transition secondary to hospitalization | Family coping; family social climate; family functioning | Family integrity promotion, family process maintenance, normalization promotion
Anxiety (mild, moderate, and severe) related to: situational crisis (placement of CVAD/need for infusion therapy) | Anxiety level; anxiety self-control, coping | Anxiety-reduction strategies

Sources: Ackley, Ladwig, & Makic, 2016.
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Chapter Highlights

- The decision to place a CVAD is based on a thorough assessment that includes patient health problems, patient’s vascular integrity, type of prescribed infusion therapy, anticipated duration of I.V. therapy, and patient’s needs/preferences with lifestyle.
- A CVAD is defined by placement of the catheter tip in the central vasculature, specifically in the lower superior vena cava (SVC), near its junction with the right atrium.
- The major categories of CVADs include nontunneled CVADs, PICCs, subcutaneously tunneled cuffed catheters, and implanted vascular access ports.
- CVAD features include catheter material, antimicrobial properties, presence of valves, number of lumens, and power injectability.
- The central line insertion bundle is followed with CVAD insertion; this includes a checklist to ensure that all procedures are properly followed during the insertion. If there is a breach, the procedure is stopped and restarted correctly.
- Although no specific limitations are set on CVAD dwell time, the following are guidelines for choosing a specific type of CVAD based upon anticipated duration of infusion therapy:
  - Nontunneled percutaneous catheters: Days to weeks, primarily in acute care settings
  - PICCs: Days to months, usually less than 1 year
  - Subcutaneously tunneled CVADs: Months to years
  - Implanted vascular access ports: Months to years
- After insertion of the central line, confirmation of proper tip location must be obtained before any infusion is administered.

Care and Maintenance Issues

- Regular site care and dressing changes are required. Site care for TSM dressings is performed every 5 to 7 days. Site care when using gauze dressings is at least every 2 days. The use of chlorhexidine dressings is associated with a decrease in risk for infection.
- Only 10-mL or larger syringes are used to flush central lines because excessive pressure from smaller-barreled syringes can damage or rupture the line.
- Nurses managing CVADs must be trained in their use: Follow manufacturer guidelines; comply with agency protocols and policies; and be fully competent in the assessment, planning, intervention, and evaluation of the patient.
- CVADs are flushed with 0.9% sodium chloride to establish patency and between medications/solutions to prevent precipitation.
- Unused lumens of CVADs are locked to maintain patency between infusions. Locking solutions include 0.9% sodium chloride and low-concentration heparin and saline. Alternative solutions are considered for patients with a history of heparin-induced thrombocytopenia or frequent bloodstream infections.
- Needleless connectors must be disinfected properly before each use. Special products such as alcohol disinfection caps may be used.
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Thinking Critically: Case Study

As a new graduate, you have been asked to change a complicated abdominal dressing on a patient postoperatively. This patient is receiving chemotherapy via a tunneled catheter. As you are cutting off the dressing, you accidentally puncture the catheter.

Case Study Questions
1. What do you do?
2. How could this have been avoided?

Media Link: Chapter post tests and answers are provided on DavisPlus, along with case studies and critical thinking activities.

References


Steele, D., & Norris, C. M. (2014). Cutting peripherally inserted central catheters may lead to increased rates of catheter-related deep vein thrombosis. *Journal of Infusion Nursing* 37(1), 466-472.


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**PROCEDURES DISPLAY 8-1**

**Discontinuation of a Short-Term Vascular Access Device (Nontunneled Catheter or Peripherally Inserted Central Catheter)**

**Note:** If a culture of the catheter tip is ordered, see Chapter 2 Procedures Display.

**Equipment Needed**

- Gloves
- Suture removal set, if needed
- CVAD dressing kit

**Delegation**

This procedure cannot be delegated to an licensed practical/vocation nurse (LPN/LVN) or nursing assistive personnel (NAP). The practitioner needs competency training for central venous access care and maintenance.
## PROCEDURES DISPLAY 8-1

### Discontinuation of a Short-Term Vascular Access Device (Nontunneled Catheter or Peripherally Inserted Central Catheter)—cont’d

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Confirm order for removal of the PICC or nontunneled catheter.</td>
<td>1. An order is required.</td>
</tr>
<tr>
<td>2. Introduce yourself to the patient.</td>
<td>2. Establishes the nurse–patient relationship</td>
</tr>
<tr>
<td>3. Verify the patient’s identity using two forms of identification.</td>
<td>3. Patient safety</td>
</tr>
<tr>
<td>4. Elevate the bed.</td>
<td>4. Conducive to a successful procedure and prevents back injury to the practitioner</td>
</tr>
<tr>
<td>5. Position the patient in supine or Trendelenburg position.</td>
<td>5. Reduces risk for air embolism during catheter removal</td>
</tr>
<tr>
<td>6. Perform hand hygiene.</td>
<td>6. Single most important means of infection prevention</td>
</tr>
<tr>
<td>7. Don gloves.</td>
<td>7. Standard precautions</td>
</tr>
<tr>
<td>8. Discontinue infusion.</td>
<td>8. The infusion must be discontinued before removal of the catheter.</td>
</tr>
<tr>
<td>10. Remove the dressing and securement device and discard.</td>
<td>10. Prepares for procedure; aseptic technique</td>
</tr>
<tr>
<td>11. Remove gloves and perform hand hygiene.</td>
<td>11. Allows catheter removal</td>
</tr>
<tr>
<td>12. Open central line kit and don fresh gloves.</td>
<td>12. Removes any contaminants on or around the exit site that could migrate into the CVAD removal site and cause contamination after the catheter is removed</td>
</tr>
<tr>
<td>13. Perform skin antisepsis at insertion site with chlorhexidine/alcohol or other acceptable skin antiseptic.</td>
<td>13. Reduces risk of air embolism during removal</td>
</tr>
<tr>
<td>14. Carefully clip and remove any sutures (if present).</td>
<td>14. (e.g., recent myocardial infarction, glaucoma).</td>
</tr>
<tr>
<td>15. Ask patient to perform Valsalva maneuver during procedure, unless contraindicated</td>
<td>15. Reduces risk of air embolism during removal</td>
</tr>
</tbody>
</table>

*Continued*
PROCEDURES DISPLAY 8-1  
Discontinuation of a Short-Term Vascular Access Device (Nontunneled Catheter or Peripherally Inserted Central Catheter)—cont’d

Procedure | Rationale
--- | ---
16. Place the 4 × 4 gauze over the CVAD site and hold it in place with the nondominant hand. | 16. Prevents air embolism
17. Withdraw the CVAD from the vein in one smooth, steady motion; continue to hold the 4 × 4 gauze over the site. (Do not pull if resistance is met.) | 17. Reduces risk of catheter breakage and potential catheter embolism
18. Maintain firm pressure over the exit site until bleeding stops or for a minimum of 30 seconds. | 19. Prevents postremoval air embolism
19. Cover the site with petroleum gauze and sterile occlusive dressing. | 20. Prevents postremoval air embolism
20. Instruct the patient to remain in a recumbent position for 30 minutes. | 21. Prevents bleeding
21. Leave the pressure dressing in place for at least 24 hours. | 22. Ensures entire catheter has been removed
22. Inspect integrity of the removed CVAD. Compare length of catheter to original insertion length. | 23. Prevents the spread of microorganisms
23. Dispose of all equipment in biohazard container and perform hand hygiene. | 24. Maintains a legal record and communication with the health-care team
24. Document the patient’s response to CVAD removal, appearance of the site, dressing regimen, condition and length of catheter, and any interventions implemented. |
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Equipment Needed
CVAD dressing kit, which should include sterile gloves, mask, sterile drape, transparent semipermeable membrane (TSM) dressing, antiseptic solution applicators (chlorhexidine alcohol preferred)
Needleless connector
Noncoring needle with extension set
Prefilled sterile prefilled syringe containing 10 mL of 0.9% sodium chloride (labeled sterile for placement on a sterile field)
Chlorhexidine-impregnated foam dressing (depending on institutional policy)
Sharps container

Delegation
This procedure cannot be delegated to an LPN/LVN or nursing assistive personnel (NAP). The practitioner needs competency training for CVAD care and maintenance.

Preprocedure
Assess patient tolerance of procedure and evaluate for need for local anesthetic to reduce pain during needle insertion. For example, if using an anesthetic cream, it must be placed on the site approximately 60 minutes prior to access.

Procedure
1. Confirm order and organizational procedure.
2. Introduce yourself to the patient.
4. Perform hand hygiene.
5. Elevate the bed level.
6. Position the patient either in a comfortable reclining position or in a chair with a pillow behind the shoulder.
7. Palpate the area of the port.

Rationale
1. An order is required. Organizational procedures should be followed.
2. Establishes the nurse–patient relationship
3. Patient safety
4. Single most important means of infection prevention
5. Conducive to successful access and prevents back injury to the practitioner
6. Provides comfort for the patient and access to the port
7. Locates the port septum and increases success with port access

Continued
8. Instruct the patient to turn head away from the port site. If unable to move head, consider having patient wear a mask.

9. Place sterile barrier on clean surface and open CVAD dressing kit; open and drop sterile prefilled saline syringe, noncoring needle/extension set, and needleless connector onto sterile barrier.

10. Put on mask and sterile gloves; attach needleless connector to noncoring needle/extension set and prime with 0.9% sodium chloride to purge all of the air.

11. Perform skin antisepsis by applying chlorhexidine/alcohol solution using back-and-forth scrubbing motion for at least 30 seconds and allow to fully dry.

12. Palpate and stabilize port using sterile gloved nondominant hand.

13. Insert the noncoring needle perpendicular to the septum, pushing firmly through skin and septum until the needle tip contacts the back of the port.

14. Aspirate for blood return to confirm patency; flush with the attached 10 mL of 0.9% sodium chloride.

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>8. Instruct the patient to turn head away from the port site. If unable to move head, consider having patient wear a mask.</td>
<td>8. Prevents introduction of microorganisms</td>
</tr>
<tr>
<td>9. Place sterile barrier on clean surface and open CVAD dressing kit; open and drop sterile prefilled saline syringe, noncoring needle/extension set, and needleless connector onto sterile barrier.</td>
<td>9. Ensures adherence to aseptic technique during the procedure</td>
</tr>
<tr>
<td>10. Put on mask and sterile gloves; attach needleless connector to noncoring needle/extension set and prime with 0.9% sodium chloride to purge all of the air.</td>
<td>10. Adherence to aseptic technique; infection prevention</td>
</tr>
<tr>
<td>11. Perform skin antisepsis by applying chlorhexidine/alcohol solution using back-and-forth scrubbing motion for at least 30 seconds and allow to fully dry.</td>
<td>11. Skin antisepsis is a critical step in reducing the risk for bloodstream infection.</td>
</tr>
<tr>
<td>12. Palpate and stabilize port using sterile gloved nondominant hand.</td>
<td>12. Locates the correct position of the port septum.</td>
</tr>
<tr>
<td>13. Insert the noncoring needle perpendicular to the septum, pushing firmly through skin and septum until the needle tip contacts the back of the port.</td>
<td>13. Accesses the port correctly</td>
</tr>
<tr>
<td>14. Aspirate for blood return to confirm patency; flush with the attached 10 mL of 0.9% sodium chloride.</td>
<td>14. Verifies correct needle placement and patency of the port</td>
</tr>
</tbody>
</table>
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PROCEDURES DISPLAY 8.2

Accessing an Implanted Port for a Continuous Infusion—cont’d

Procedure
15. Stabilize noncoring needle with sterile tape; place sterile gauze to support wings if needed, making sure gauze does not obscure needle site. a. Cover the needle and gauze with TSM dressing.

16. Initiate the prescribed therapy.

17. Document in the patient record:
   - Size/length of noncoring needle
   - Site assessment/type of dressing
   - Date and time of access
   - Presence of blood return, ease of flushing
   - Anesthetic methods, if used
   - Patient tolerance of the procedure

Rationale
15. Protects accessed port site and reduces risk of needle dislodgement

17. Maintains a legal record and communication with the healthcare team

Source: Gorski et al., 2016b.

PROCEDURES DISPLAY 8.3

Deaccessing an Implanted Port

Needed equipment
Gloves
Sterile gauze dressing
Alcohol swabs
10 mL of sodium chloride
Two 10-mL prefilled saline syringes
Prefilled syringe of heparin, if ordered
Occlusive dressing

Delegation
This procedure cannot be delegated to LVN/LPN or nursing assistive personnel (NAP). The practitioner needs competency training for central venous access care and maintenance.

Continued
PROCEDURE: DEACCESSING AN IMPLANTED PORT—CONTD

**Procedure**

To deaccess the needle from the port:

1. Introduce yourself to the patient.
2. Verify patient identity using two forms of ID.
3. Perform hand hygiene.
4. Put on gloves.
5. Disinfect the needleless connector with 70% isopropyl alcohol using a scrubbing motion and allow to dry.
6. Attach syringe of 0.9% sodium chloride to needleless connector and flush the port.
7. Disinfect needleless connector again and attach syringe of prescribed heparin and lock the port; follow flushing guidelines for positive-displacement devices and negative-displacement devices.
8. Palpate the port with nondominant hand and stabilize with thumb and index finger.
9. Grasp needle with dominant hand and remove device, engaging safety mechanism.
10. Apply gauze pressure dressing to site if bleeding occurs.
11. Discard the needle in biohazard container; remove gloves and perform hand hygiene.

**Rationale**

1. Establishes the nurse–patient relationship
2. Patient safety
3. Single most important means of infection prevention
4. Standard precautions
5. Critical step in infection prevention
6. Maintains the integrity of the port and prevents occlusions
7. Maintains patency of port between infusions
8. Reduces discomfort with deaccess procedure
9. Reduces risk of needlestick injury
10. Covers the puncture site to prevent infection
11. OSHA guidelines to prevent needlestick injuries; infection control procedure
Equipment Needed
CVAD dressing kit, which should include sterile gloves, mask, sterile drape, transparent semipermeable membrane (TSM) dressing, antiseptic solution applicators (chlorhexidine alcohol preferred), single-use measuring tape
Clean gloves
Stabilization device

Delegation
Do not delegate to an LPN/LVN or nursing assistive personnel (NAP) unless it is part of the state nursing practice for LPN/LVN and is included in the policies and procedures for the institution. All nurses require education and competency training for CVAD care and maintenance.

Procedure
1. Review organizational procedure.
2. Introduce yourself to the patient.
4. Perform hand hygiene.

Rationale
1. Policies and procedures provide a framework for standard of care at the institution.
2. Establishes the nurse–patient relationship
3. Patient safety
4. Single most important means of infection prevention

Continued
PROCEDURES DISPLAY 8-4

CVAD Dressing Change—cont’d

Procedure
5. Place patient in comfortable reclining position, ensuring that site is accessible.
6. Open CVAD dressing kit establishing an aseptic field; open stabilization device package and drop onto barrier.
7. Put on mask and clean gloves (mask should be on top of sterile supplies in CVAD dressing kit).
8. Remove existing transparent dressing by slowly loosening it at the catheter hub and while anchoring catheter to skin, gently remove dressing, moving it toward the insertion site.
9. Remove stabilization device per manufacturer’s directions.
10. Inspect insertion site for signs and symptoms of local site infection. If present, notify the licensed prescriber.
11. Measure and verify that external catheter length corresponds to initial placement measurement. If it does not, notify the licensed prescriber before continuing use.
12. Remove gloves and perform hand hygiene.
13. Don sterile gloves.
14. Perform skin antisepsis.
   a. Chlorhexidine solution: Apply using back-and-forth motion for at least 30 seconds (preferred).

Rationale
5. Promotes cooperation with the procedure and facilitates your ability to perform the procedure
6. Ensures adherence to aseptic technique during site care procedure
7. Standard precautions
8. Prevents accidental dislodgement or removal of nontunneled catheter
9. The stabilization device is removed and replaced at least every 7 days.
10. Identifies complications associated with the CVAD
11. Identifies any external catheter migration; significant migration means that catheter tip may no longer be located in the superior vena cava (SVC)
12. Infection prevention
13. Aseptic technique
14. Ensures proper and thorough cleansing, skin antisepsis, and removal of debris. Reduces microbial growth around catheter insertion site.
## PROCEDURES DISPLAY 8-4
### CVAD Dressing Change—cont’d

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>b. Povidone-iodine: Note that povidone-iodine must remain on the skin for at least 2 minutes or longer to dry completely for adequate skin antisepsis.</td>
<td>15. Reduces risk of catheter dislodgement</td>
</tr>
<tr>
<td>c. Note: The prepared site should be at least the size of the dressing (2–4 inches).</td>
<td>16. Occlusive dressing required for CVAD to inhibit entry of microorganisms</td>
</tr>
<tr>
<td>15. Apply new stabilization device according to manufacturer’s directions.</td>
<td>17. Infection prevention</td>
</tr>
<tr>
<td>16. Apply a new transparent dressing over the exposed catheter, including the hub.</td>
<td>18. Maintains proper documentation and communicates dressing change information to all who care for the patient</td>
</tr>
<tr>
<td>17. Remove gloves and discard; dispose of all used materials. Perform hand hygiene.</td>
<td>19. Maintains a legal record and communication with the health-care team</td>
</tr>
<tr>
<td>18. Label dressing with the nurse’s initials, date, and time.</td>
<td></td>
</tr>
<tr>
<td>19. Document the procedure in the patient’s permanent record, including assessment data, condition of the removed dressing, appropriate intervention data, external catheter length, and evaluation of patient’s response to the procedure.</td>
<td></td>
</tr>
</tbody>
</table>

Reference: Gorski et al., 2016b.
Chapter 9
Complications of Infusion Therapy: Peripheral and Central Vascular Access Devices

LEARNING OBJECTIVES
After completing this chapter, the reader will be able to:
1. Define terms related to the complications of vascular access devices.
2. Differentiate between local and systemic complications.
3. Describe risk factors and preventative interventions for local complications.
4. Identify noncytotoxic vesicant medications/solutions.
5. Discuss interventions shown to decrease risk for bloodstream infections.
6. Identify risk factors and preventative interventions for systemic complications.
7. Identify complications and risks associated with central vascular access devices.
8. Document relevant information related to vascular access device–related complications.

Glossary

Air embolism (venous air embolism) A sudden obstruction of a blood vessel caused by air introduced into the circulation
Aseptic non-touch technique (ANTT) Based on a theoretical and practice framework, hand hygiene, and presence of an aseptic field promote aseptic technique, but effective “non-touch” technique ensures it (ANTT, 2017). Critical to ANTT is the understanding of key parts and key sites. Key parts are the critical parts of the procedure equipment that, if contaminated, are most likely to cause infection. Key sites include open wounds and medical device access sites (e.g., I.V. sites).
Catheter malposition Position of the central vascular access device tip outside the superior vena cava
Catheter occlusion Inability to infuse or inject fluid into a catheter; inability to aspirate blood from a catheter
Circulatory overload Increased blood volume, often caused by transfusions or excessive I.V. fluid administration
Ecchymosis  A bruise caused by escape of blood from injured vessels

Embolism  A sudden obstruction of a blood vessel by a clot or foreign material formed or introduced elsewhere in the circulatory system and carried to the point of obstruction by the bloodstream

Extravasation  Escape of a vesicant medication/solution from the vein into the surrounding tissue

Fibrin sheath  A covering over a catheter formed by the action of thrombin on fibrinogen; the fibrin sheath potentially can grow and cover the entire catheter, potentially leading to catheter occlusion

Hematoma  A swelling comprising a mass of blood confined to subcutaneous tissue and caused by break in a blood vessel

Hemothorax  Blood in the pleural cavity caused by rupture of blood vessels

Infiltration  Escape of a nonvesicant medication/solution from the vein into the surrounding tissue

Phlebitis  Inflammation of the inner layer (tunica intima) of a vein

Pneumothorax  The presence of air or gas in the pleural cavity between the lung and chest wall

Pulmonary edema  Accumulation of extravascular fluid in lung tissues and alveoli

Sepsis  The presence of pathogenic microorganisms progresses to a serious and often fatal clinical syndrome that is characterized by organ dysfunction

Speed shock  A systemic reaction that occurs when a substance is rapidly introduced into the circulation

Thrombophlebitis  Venous inflammation with thrombus (clot) formation

Thrombosis  Formation or presence of a blood clot; clotting within a blood vessel that may cause interruption of blood flow

Venous spasm  Sudden constriction of the vein

Vesicant  Any medication or fluid capable of causing tissue injury, such as necrosis or tissue damage, when it escapes from the vein

Introduction

The placement and the presence of a vascular access device (VAD) put patients at risk for complications during both the insertion process and the dwell time. Systemic complications such as bloodstream infection (BSI), air embolism, and circulatory overload are very serious and can be life-threatening, yet are preventable when evidence-based prevention and care practices are employed. The impact of some local complications, such as phlebitis or infiltration, is minimized when the nurse provides thorough and frequent assessments, educates the patient and family members, and identifies early signs and symptoms that allow for prompt action. In this chapter, complications are categorized as local, systemic, and central VAD (CVAD) related. The etiology, signs and symptoms, preventative interventions, and treatment are addressed for each complication. Documentation points are also provided.
Local Complications

Local complications of infusion therapy occur as adverse reactions or trauma to the surrounding venipuncture site. Thorough assessment is imperative to prompt identification and intervention. Good venipuncture technique is one important factor related to the prevention of many local complications associated with VAD placement. Local complications include hematoma, phlebitis/thrombophlebitis, infiltration/extravasation, local infection, nerve injury, and venous spasm. Looking to the future, the use of technology (e.g. ultrasound/near infrared light) will be commonly used to identify and quantify local I.V. complications such as thrombophlebitis and infiltration.

Hematoma

*Description and Etiology*

The terms **hematoma** and **ecchymosis** are used to describe formations resulting from the infiltration of blood into the tissues at the venipuncture site. Loss of integrity in a vessel wall as a result of disease or trauma allows blood to escape into the surrounding area. This complication is often related to venipuncture technique. Patients who bruise easily can develop a hematoma from vein trauma during insertion of a large-gauge catheter used to initiate I.V. therapy. Patients receiving anticoagulant therapy and long-term steroid therapy are at particular risk for bleeding from vein trauma (Fig. 9-1).

![Figure 9-1 Hematoma. (Courtesy of Beth Fabian, CRNI.)](image)
A hematoma is caused more often by incorrect manipulation technique and rarely by spontaneous rupture of the vein. It may be caused by:

- Poor venipuncture technique in which the cannula passes through the distal vein wall
- Opening of the flow clamp for the infusion before the tourniquet is removed
- A cannula too large for the vessel, resulting in rupture of the vein
- Pressure of the tourniquet on fragile skin

**NOTE:** To dilate veins in the older adult, use a blood pressure cuff or other techniques described in Chapter 6.

**Signs and Symptoms**

Signs and symptoms of hematoma include:

- Discoloration of the skin (i.e., ecchymoses) surrounding the venipuncture (immediate or slow)
- Site swelling and discomfort
- Inability to advance the cannula all the way into the vein during insertion
- Resistance to positive pressure during catheter flushing

**Prevention**

Techniques for prevention of hematoma formation include:

1. Use an indirect method rather than a direct approach for starting a peripheral I.V. (P.I.V.). This decreases the chance of piercing through the vein, which then causes seepage of blood into the subcutaneous tissue (see Chapter 6 for venipuncture techniques).
2. Use vein visualization techniques to improve cannulation success (see Chapters 5 and 6).
3. Apply the tourniquet just before venipuncture.
4. For older adult patients, for patients taking corticosteroids, or for patients with thin, fragile skin, use a small-gauge catheter, preferably 22- or 24-gauge. Use a blood pressure cuff rather than a tourniquet to fill the vein so that you have better control of the pressure exerted on the vein; in some cases, it is best to avoid using a tourniquet.
5. Be very gentle when performing venipuncture.

**NURSING FAST FACT!**

The presence of either ecchymoses or hematomas limits future use of the affected veins.
**Treatment**

1. Apply direct, light pressure using a sterile 2- × 2-inch gauze pad over the site for 2 to 3 minutes after catheter or needle removal.
2. Have the patient elevate the extremity on a pillow to maximize venous return.
3. Apply ice to the area to prevent further enlargement of the hematoma.

**Documentation**

Document presence of ecchymotic areas and nursing interventions.

**Phlebitis/Thrombophlebitis**

**Description and Etiology**

Phlebitis is an inflammation of the delicate inner lining (the tunica intima) of the vein. It is characterized by pain, inflammation, and tenderness along the vein and is a common complication associated with PIVs. Phlebitis may result in other complications such as thrombosis formation (thrombophlebitis) and, potentially, BSI, although the link between phlebitis and BSI is not well established (Hadaway, 2012).

Phlebitis is attributed to damage from chemical irritation, mechanical trauma, and bacteria. Chemical phlebitis results from infusate damage to the tunica intima. Solutions with a dextrose concentration greater than 10% and high osmolarity (>900 mOsm/L) are associated with vein damage when they are administered via a PIV catheter (Gorski et al., 2016a, p. S51). Some medications are inherently irritating and associated with increased phlebitis risk. Examples include some antimicrobials (e.g., amphotericin B, imipenem-cilastatin, nafcillin), potassium, and amiodarone (Gahart, Nazareno, & Ortega, 2017).

Chemical damage to the vein may also result from failure to allow the skin antiseptic solution to fully dry prior to catheter insertion. Vein irritation results when the antiseptic is pulled into the vein during catheter insertion.

Mechanical vein trauma occurs when the catheter irritates or injures the endothelial cells lining the vein wall. This may occur during insertion, when a large catheter is placed in a small vein or at a point of flexion, or when a catheter lacks adequate stabilization, causing catheter movement that irritates the vein wall. During placement of a midline peripheral catheter or a peripherally inserted central catheter (PICC), mechanical phlebitis may result if the catheter is advanced too rapidly into the vein. Symptoms occur soon after placement and tend to be transient. However, the catheter generally should be removed if the symptoms persist beyond 24 to 48 hours.

Bacteria can also cause phlebitis, and the consequences can be serious, including catheter-related bloodstream infection (CR-BSI). Bacteria may be introduced through poor aseptic technique during insertion or during catheter access or maintenance care. Phlebitis may not be evident during peripheral catheter dwell time but may appear after removal. Called “postinfusion phlebitis,” this becomes apparent up to 48 hours after the catheter is removed. Types of phlebitis are summarized in Table 9-1.
CHAPTER 9  Complications of Infusion Therapy

Table 9-1  Types of Phlebitis

<table>
<thead>
<tr>
<th>Types of Phlebitis</th>
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<tbody>
<tr>
<td>Mechanical Phlebitis</td>
</tr>
<tr>
<td>Chemical Phlebitis</td>
</tr>
<tr>
<td>Bacterial Phlebitis</td>
</tr>
<tr>
<td>Postinfusion Phlebitis</td>
</tr>
</tbody>
</table>

Mechanical Phlebitis

Mechanical vein trauma occurs when the catheter irritates or injures the endothelial cells lining the vein wall. This may occur during insertion, when a large catheter is placed in a small vein or at a point of flexion, or when the catheter lacks adequate stabilization, causing catheter movement that irritates the vein wall.

Chemical Phlebitis

Chemical phlebitis results from infusate damage to the tunica intima. Infusates with a dextrose content greater than 10% and a high osmolarity (>900 mOsm/L) cause vein damage when administered via a peripheral I.V. catheter. Also, failing to allow the antiseptic solution to fully dry prior to catheter insertion may cause irritation when antiseptic is pulled into the vein during insertion. Some drugs are known to cause irritation and phlebitis. Always review a drug reference source to learn about characteristics of the infusate.

The type of catheter material may increase the risk of phlebitis. Several different materials are used in the manufacture of catheters. Catheters made of silicone elastomer and polyurethane have a smoother microsurface, are thermoplastic, are more hydrophilic, become more flexible than polytetrafluoroethylene (Teflon) at body temperature, and cause less venous irritation.

Bacterial Phlebitis

Bacteria can cause phlebitis, and the consequences can be serious, including catheter-related bloodstream infection. Bacteria may be introduced through poor aseptic technique during insertion, or during catheter access or maintenance care. Suppurative or purulent thrombophlebitis is characterized by the presence of purulent drainage in the vein. This serious complication is associated with bloodstream infection and requires surgical removal of the vein.

Postinfusion Phlebitis

Postinfusion phlebitis is associated with inflammation of the vein that usually becomes evident within 48 hours after the cannula has been removed, so the site should be monitored for that time period. On discharge, patients should be instructed on signs and symptoms of phlebitis and on whom to contact if it occurs (Gorski et al., 2016a, p. S96).

Host factors that may also contribute to risk of phlebitis include fragile vessels, a predisposition toward thrombosis (hypercoagulable state), high hemoglobin levels, female gender, and underlying medical disease (e.g., diabetes, infectious diseases, cancer, immunodeficiency) (Dychter, Gold, Carson, & Haller, 2012; Helm, Klausner, Klemperer, Flint, & Huang, 2015; Zingg & Pittet, 2009) (Table 9-2). In
a prospective study of 1000 patients, risk factors for phlebitis that were statistically significant included female gender, bruised insertion site, placement of the PIV on the patient’s dominant side, and infusion of flucloxacillin (not available in the United States) (Marsh et al., 2017). Notably, phlebitis was the most common cause of catheter failure in this study at a rate of 17%.

**NOTE:** Peripheral phlebitis can result in a prolonged hospitalization unless treated early.

**INS Standard:** If phlebitis occurs, the nurse should determine the possible etiology of the phlebitis—chemical, mechanical, or bacterial phlebitis—and implement appropriate interventions for midline catheters and PICCs. Remove the short peripheral catheter (Gorski et al., 2016a, p. S96).

### Signs and Symptoms

Local signs and symptoms associated with phlebitis include:

- Erythema at the site; may be evident over length of vein (streak formation)
- Pain at site
- Local swelling
- Palpable cord along the vein
INS Standard: Use a standardized phlebitis scale that is valid, reliable, and clinically feasible (Gorski et al., 2016a, p. S96) (see Table 9-3 for an example).

Prevention
The risk for phlebitis is reduced by the following:

1. Assess the appropriateness for PIV administration, considering infusate characteristics and anticipated duration of the infusion.
2. Consider, and advocate for, a midline catheter or CVAD (e.g., PICC) for:
   a. Infusion therapies anticipated to last longer than several days (e.g., >5 days) and/or
   b. Irritating infusates, for osmolarity greater than 900 mOsm/L, or for dextrose concentrations in excess of 10%.
3. Choose the smallest-gauge cannula appropriate for the infusate; in most cases, a 22- to 24-gauge catheter is selected.
4. Avoid placing PIV catheters in areas of flexion (e.g., wrist). If an area of flexion must be used, use a joint stabilization device.
5. Perform proper hand hygiene prior to all I.V. procedures.
6. Wear clean gloves during PIV insertion and maintain “aseptic non-touch technique” (ANTT, 2017) with catheter insertion.
   - Prepare the skin with an antiseptic and allow it to fully dry prior to catheter insertion.
   - Do not touch prepared skin after antisepsis.
   - Do not touch catheter portion of PIV after protective sheath is removed.
7. Ensure that the catheter is adequately stabilized in place to minimize catheter movement within the vein.
8. Infuse solutions at the prescribed rate. Do not attempt to catch up on delayed infusion time.
9. Assess the site at least every 4 hours for signs of complications; every 1 to 2 hours when administering irritating infusates, when the patient is sedated or has cognitive limitations and cannot report changes, and/or when the PIV is placed in a high-risk location such as an area of flexion;

<table>
<thead>
<tr>
<th>Grade</th>
<th>Clinical Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No clinical symptoms</td>
</tr>
<tr>
<td>1</td>
<td>Erythema at access site with or without pain</td>
</tr>
<tr>
<td>2</td>
<td>Pain at access site, with erythema and/or edema</td>
</tr>
<tr>
<td>3</td>
<td>Pain at access site with erythema and/or edema, streak formation, and palpable venous cord</td>
</tr>
<tr>
<td>4</td>
<td>Pain at access site with erythema and/or edema, streak formation, palpable venous cord &gt;1 inch in length, purulent drainage</td>
</tr>
</tbody>
</table>

Source: INS (Gorski et al., 2016b), with permission.
and assess the site hourly for pediatric and neonatal patients (Gorski et al., 2012; Gorski et al., 2016a).

**Treatment**

Standard treatment of phlebitis is the application of warm compresses, limb elevation, and analgesics or anti-inflammatory agents as needed. In addition, INS (Gorski et al., 2016a, p. S96) recommends the following:

- **CRITICAL THINKING:** Determine the potential etiology, whether chemical, mechanical, or bacterial. Use this information in planning for ongoing venous access. For example, if the etiology is likely an irritating infusate and there is a continued need for infusion, consider the need for an alternate access device, such as a midline catheter or PICC.

**Documentation**

Document the site assessment, the phlebitis rating (1, 2, 3, or 4), whether the licensed independent practitioner (LIP) was notified, and the treatment provided. Document the discontinuation of the PIV catheter and the location of the new I.V. site, if replaced. Document all observable symptoms and the patient’s subjective complaints, such as “feels tender to touch” and “it hurts.” Document the actions taken to resolve the problem and the time of LIP notification.

**NURSING FAST FACT!**

If the inflammation is likely the result of bacterial phlebitis, a much more serious condition may develop if the patient is not treated. Untreated bacterial phlebitis can lead to catheter-related bloodstream infection and sepsis.

**Infiltration/Extravasation**

**Description and Etiology**

When I.V. fluid escapes from the vein into the surrounding tissue, the complication called *infiltration* or *extravasation* has occurred. The difference between these two terms relates to the type of I.V. fluid. *Infiltration* is defined as the inadvertent administration of a *nonvesicant* medication or solution into the surrounding tissue, whereas *extravasation* is the inadvertent administration of a vesicant medication into the surrounding tissue (Gorski et al., 2016a). A *vesicant* is a medication or fluid capable of causing injury, such as necrosis or tissue damage, when it escapes from the vein. Infiltration is a common complication occurring at a rate of 14% in a prospective study (Marsh et al., 2017).

Many antineoplastic (cytotoxic) drugs used in cancer treatment are classified as vesicants. These drugs can be divided into two categories: DNA binding and non–DNA binding. The vesicants that bind directly to the nucleic acids in DNA result in progressive tissue destruction, while non–DNA binding agents remain contained locally and cause less tissue damage (Camp-Sorrell & Matey, 2017).
The pharmacological causes of noncytotoxic infusates include high osmolarity (e.g., calcium chloride, 50% dextrose), vasoconstrictor drugs (e.g., dopamine), and extremely acidic/alkaline drugs (e.g., phenytoin).

The Infusion Nurses Society developed an evidence-based list of noncytotoxic vesicant drugs/solutions. This list was established based on literature reviews, case reports, and drug literature. A final list of vesicants was developed using a red and yellow color scheme. Higher-risk infusates were classified as red; this list includes well-recognized vesicants with multiple citations and reports of tissue damage upon extravasation. Intermediate-risk infusates, classified as yellow, were associated with fewer reports of extravasation but are recognized as vesicants; published drug information and infusate characteristics indicate caution and potential for tissue damage (Gorski et al., 2017). The list can be found in Table 9-4.

Table 9-4  Noncytotoxic Vesicant List (Source: INS, with permission)

The first step in reducing the risk of extravasation is to identify and recognize medications and solutions that are associated with tissue damage when the solution escapes from the vascular pathway.

<table>
<thead>
<tr>
<th>Red List</th>
<th>Yellow List</th>
</tr>
</thead>
<tbody>
<tr>
<td>Well-recognized vesicants with multiple citations and reports of tissue damage upon extravasation</td>
<td>Vesicants associated with fewer published reports of extravasation; published drug information and infusate characteristics indicate caution and potential for tissue damage</td>
</tr>
<tr>
<td>Calcium chloride</td>
<td>Acyclovir</td>
</tr>
<tr>
<td>Calcium gluconate</td>
<td>Amiodarone</td>
</tr>
<tr>
<td>Contrast media, nonionic</td>
<td>Arginine</td>
</tr>
<tr>
<td>Dextrose concentration ≥12.5%</td>
<td>Dextrose concentration ≥10% to 12.5%</td>
</tr>
<tr>
<td>Dobutamine</td>
<td>Mannitol ≥20%</td>
</tr>
<tr>
<td>Dopamine</td>
<td>Nafcilin</td>
</tr>
<tr>
<td>Epinephrine</td>
<td>Pentamidine</td>
</tr>
<tr>
<td>Norepinephrine</td>
<td>Pentobarbital sodium</td>
</tr>
<tr>
<td>Parenteral nutrition solutions exceeding 900 mOsm/L</td>
<td>Phenobarbital sodium</td>
</tr>
<tr>
<td>Phenylephrine</td>
<td>Potassium ≥60 mEq/L</td>
</tr>
<tr>
<td>Phenytoin</td>
<td>Vancomycin hydrochloride</td>
</tr>
<tr>
<td>Promethazine</td>
<td></td>
</tr>
<tr>
<td>Sodium bicarbonate</td>
<td></td>
</tr>
<tr>
<td>Sodium chloride ≥3%</td>
<td></td>
</tr>
<tr>
<td>Vasopressin</td>
<td></td>
</tr>
</tbody>
</table>

Source: INS, used with permission.
Severe infiltrations and vesicant extravasation may result in patient injuries that include potentially permanent functional impairment and even loss of limb, requiring long-term treatment (Gorski et al., 2017). Such injuries may result in malpractice cases. Refer back to the “Malpractice Case Example” and Figure 1-1 in Chapter 1. Additional photographs of extravasations are found in Fig. 9-2 and Fig. 9-3. The severity of damage is related to the type, concentration, and volume of fluid infiltrated into the interstitial tissues. Infiltration/extravasation may also occur with a CVAD. Some risk factors include:

- Needle dislodgement/improper needle access with implanted vascular access ports
- Deeply placed ports
- Catheter attached to an implanted port that separates or fractures internally
- Catheter migration and subsequent malposition into the tissue
- Loss of catheter integrity (e.g., hole/crack in the catheter)
- Presence of a fibrin sleeve along the catheter that allows the medication to backtrack along the fibrin sleeve to the catheter insertion site (Hill et al., 2013).

The INS categorizes risk factors for infiltration/extravasation into three areas: mechanical, pharmacological/physiological, and obstructive (Gorski et al., 2016a, p. S99). Mechanical factors include:

- Small, fragile veins/poor vein condition
- Large catheters causing mechanical friction of the vein

![Figure 9-2](image)

**Figure 9-2** Infiltration of vancomycin into subcutaneous tissue, causing blistering of skin. (Courtesy of Beth Fabian, CRNI.)
Catheter dislodgement resulting from joint movement when a PIV catheter is placed in an area of flexion

Failure to adequately stabilize catheter; notably, there was less infiltration (statistically significant) when the catheter was adequately secured (Marsh et al., 2017)

Overmanipulation of the I.V. catheter

Multiple attempts at venipuncture, or puncture of the vein wall during venipuncture

Use of an infusion pump during infiltration or extravasation. Although infusion pumps do not cause infiltration, it is important to recognize that infusion pumps also do not detect infiltration. When an I.V. catheter has infiltrated, the fluid or medication will continue to infuse and worsen the problem.

Pharmacological factors also play an important contributing role. As stated earlier, medications or solutions characterized by an acidic or alkaline pH and/or high osmolarity can damage the endothelial cells of the vein, increasing the risk for venous rupture. Other pharmacological factors include drugs that cause vasoconstriction, which can cause ischemic necrosis within the vein, and the medication’s ability to bind with DNA.

Obstructive factors include blood clot formation and lymphedema. For example, blood clot formation above the PIV may force the infusate into the tissue at the catheter insertion site, thereby causing infiltration.
Assessment of the I.V. site and the venous pathway up the extremity is essential to identifying infiltration or extravasation. Early recognition of infiltration/extravasation is vital to limiting the volume of fluid and reducing the risk for tissue injury. Signs and symptoms that may occur at or around the site include:

- Cool skin temperature at the PIV site
- Skin that appears blanched and taut
- Patient complaints of skin tightness, pain, burning, or discomfort
- Swelling at, above, or below the insertion site
- Decreased mobility of the extremity
- Leaking of fluid from the insertion site
- Absence of a blood return or presence of a “pinkish” blood return
- Changes in infusion flow quality

It is helpful to compare both of the patient’s extremities when assessing for infiltration (Fig. 9-4). There is also new technology available for infiltration detection, as discussed in Chapter 5 (Fig. 5-29).

Complications associated with infiltration/extravasation include:

1. **Ulceration and possible tissue necrosis**: The severity of tissue damage depends on many variables, including infusate characteristics (e.g., vesicant), the amount of drug infiltrated, and the venipuncture site. Ulceration is not immediately apparent; the ulcer may actually take days or weeks to develop.

2. **Compartment syndrome**: Muscles, nerves, and vessels are in compartments confined in inflexible spaces bound by skin, fascia, and bone. When fluid inside a compartment increases, the venous end of the capillary bed becomes compressed. If vessels cannot carry away the excessive fluid, hydrostatic pressure rises, leading to vascular spasm, pain, and muscle necrosis inside the compartment. Functional muscle changes can occur within 4 to 12 hours of injury. Within 24 hours, ischemic nerve damage can result in functional loss.

3. **Complex regional pain syndrome (CRPS)**: This may result from a severe infiltration/extravasation. It is a chronic pain condition that is believed to result from dysfunction in the central or peripheral nervous system. It is characterized by dramatic changes in the color and temperature of the skin over the affected limb or body part, accompanied by intense burning pain, skin sensitivity, sweating, and swelling. When the symptoms are clearly associated with a nerve injury, it is called CRPS II (National Institute of Neurological Disorders and Stroke, 2017). One theory is that CRPS is caused by a triggering of the immune response, which leads to the characteristic inflammatory symptoms of redness, warmth, and swelling in the affected area that represent a disruption in the healing process. (Gorski et al., 2016a, p. S98).
Prevention

The risk for infiltration/extravasation is reduced when risk factors are mitigated and with adequate and continuous assessment of the site.

1. Assess the appropriateness for PIV administration, considering infusate characteristics and anticipated duration of the infusion.
2. Consider a CVAD (e.g., PICC) for high-risk infusates.
3. Use the smallest-gauge-size catheter to accommodate the infusion therapy and select larger veins (e.g., forearm) for better hemodilution when administering irritating infusates if a CVAD is not indicated. Avoid use of small veins in the hand or fingers.
4. Place new PIVs above previously used sites. Any infusate administered below a previously used, and potentially damaged, vein may infiltrate into the damaged area.
5. Avoid placing PIV catheters in areas of flexion (e.g., wrist, antecubital), which increases the risk of catheter dislodgement and infiltration. If placement in an area of flexion is necessary, use of a joint stabilization device (e.g., arm board) is recommended. If used, apply it in a manner that allows visual assessment of the PIV site.
6. Any one nurse should not attempt PIV placement more than two times, and total attempts are limited to no more than four (Gorski et al., 2016, p. S64). The effects of multiple placement attempts include pain, delayed treatment, limited future vascular access, increased cost, and increased

Figure 9-4 Infiltration. Compare both arms when assessing for infiltration (note that the left arm is swollen compared with the right arm).
risk for complications. If a nurse has made two unsuccessful attempts, the nurse with the best skills should evaluate the patient's veins and make further attempts at PIV insertion only if venous access is felt to be adequate. Patients with difficult vascular access require a careful assessment of VAD needs and collaboration with the health-care team to discuss appropriate options.

7. Stabilize catheter to minimize catheter movement within the vein.

8. Assess the patency of the catheter before every drug administration; this includes flushing and aspirating for a blood return. If one is unable to obtain a blood return, there should be a high suspicion of infiltration.

9. Turn patients carefully. Infiltration and swelling may occur as a result of placing hands underneath the patient during turning. Occlusion or restriction of blood flow causes fluid to back up in the vessels, resulting in infiltration and dependent edema below rather than above the I.V. site (Fig. 9-5).

**Figure 9-5** Infiltration and swelling below the I.V. site occurring after hands were placed underneath the patient during turning. Occlusion or restriction of blood flow caused fluid to back up in the vessels, resulting in infiltration and dependent edema below rather than above the I.V. site. (Courtesy of Beth Fabian, CRNI.)
10. Instruct patient to immediately report any pain, burning, or swelling with infusion.

11. Assess the site at least every 4 hours for signs of complications; every 1 to 2 hours when administering irritating infusates, when the patient is sedated or has cognitive limitations and cannot report changes, and/or when the PIV is placed in a high-risk location such as an area of flexion; and hourly for pediatric and neonatal patients (Gorski et al., 2012; Gorski et al., 2016).

12. Additional strategies for vesicant administration:
   a. Ensure knowledge and competence of nurses administering vesicants, including venipuncture skills, use of CVADs, and assessment for signs/symptoms of extravasation.
   b. Use sound decision making in relation to venous access, devices, and infusions:
      i. Do not use a site older than 24 hours.
      ii. Do not use steel needles to administer vesicants.
      iii. Use smooth, pliable veins.
      iv. Avoid injured/sclerosed veins, areas of flexion, small veins, lower extremities, and extremity with altered venous return or diminished sensation.
      v. Administer any vesicant infusion exceeding 30 to 60 minutes via a CVAD whenever possible.
   c. Advocate for a CVAD when administering vesicant agents whenever possible (Gorski et al., 2017).
   d. Administer vesicants through the side arm of a free-flowing infusion of a hydration solution whenever possible.
   e. Check patency before, during, and after vesicant administration.
   f. In addition to visual assessment of site, verify presence of blood return before infusion and assess site frequently during the infusion.

**NURSING FAST FACT!**

Immobilized patients and patients with muscular weakness or paralysis of an extremity may have edema of an extremity that is not related to infiltration of an I.V. site. Accurate assessment of the cannula and infusion site is the key to differentiation.

**Treatment**

1. Stop infusion immediately when infiltration/extravasation is suspected. Attempt to aspirate any residual drug/I.V. fluid before removal; do not flush the PIV (Gorski et al., 2016a, p. S99).
2. Notify LIP immediately of any extravasation or significant infiltration (e.g., >25 mL and/or presence of pain or numbness).
3. Use warm or cold compresses as appropriate (Gorski et al., 2016a, p. S100). Cooling promotes vasoconstriction, which limits dispersion of the drug in the tissue. Heat promotes vasodilation, which enhances drug dispersal. Cold is recommended for extravasation of certain vesicants, contrast media, and hyperosmolar fluids. Heat is recommended for certain cytotoxic drugs, including the vinca alkaloids.

4. Elevate the infiltrated extremity. This is recommended because it promotes reabsorption of the infiltrate (Doellman et al., 2009).

5. Assess the site regularly after an infiltration/extravasation at a frequency based on the type of infusate and individual patient needs.

6. Instruct patient to report any worsening of signs or symptoms, such as changes in extremity mobility or sensation, or elevated temperature.

7. Pharmacological antidotes may be used to treat extravasations in accordance with organizational policies and LIP orders. Examples include:
   - Phentolamine is indicated for extravasation of vasopressors (e.g., dopamine) because it reduces local vasoconstriction and ischemia; terbutaline and topical nitroglycerin may also be used.
   - While not an “antidote,” hyaluronidase is used in extravasation of some hyperosmolar solutions (e.g., calcium chloride), radiographic contrast media, and plant alkaloids (e.g., vincristine). This enzyme increases tissue permeability and facilitates absorption and dispersion of the drug into the tissue (Gorski et al., 2016a, p. S100).

8. Provide the patient education addressing symptoms to report to the clinician, how to manage pain, and any follow-up care.

**NOTE:** Do not apply excessive pressure to the area because it will disperse fluid farther into surrounding tissues.

**NOTE:** The goal of pharmacological antidotes is to lessen tissue injury.

**EBP** The importance of vigilant nursing assessment in detection of infiltration injuries was highlighted in a case study review of three infants who suffered significant infiltrations of I.V. fluids with subsequent development of compartment syndrome. Signs of infiltration included tissue blanching, decreased capillary refill time, and severely restricted active/passive range of motion of the extremity. Restricted joint movement was considered an important finding because infant “chubbiness” made swelling difficult to detect, and infants cannot express specific areas of pain or discomfort. Of note, I.V. fluids were delivered via infusion pumps that did not alarm with the infiltrations. Fasciotomies were performed on all three infants with full recovery (Talbot & Rogers, 2011).
**Documentation**

Comprehensive documentation of an extravasation or significant infiltration event in the patient's medical record is vital for medical and legal purposes. Medical record documentation is the key to understanding the events that occurred. Documentation of the infiltration/extravasation should include:

- Date/time of event
- VAD type; number/location of PIV attempts
- Presence of blood return prior to and during administration of vesicant
- Fluid/medication infused and method of infusion (e.g., I.V. push)
- Patient report of symptoms
- Estimated volume of infiltration; amount of fluid aspirated
- Status of circulation at, above, and below the insertion site, including skin color, capillary refill, and circumference of both extremities at the site.
- Description of the site: Anatomic location, size of infiltrated area, signs/symptoms as listed above
- Photograph site in accordance with organizational policy
- Initial and follow-up interventions
- Notification of LIP
- Use of any antidotes, dosages, administration
- Patient education provided

Severe infiltrations and extravasations, especially those that cause tissue damage, should be tracked as part of the organizational quality improvement program.

**NURSING FAST FACT!**

Never increase the flow rate to determine the infiltration of a vesicant. Assessment of the site around the catheter tip is important, as is questioning the patient about discomfort at the access site. When extravasation or infiltration is suspected, discontinue the infusion immediately. An extravasation or severe infiltration should always result in immediate reporting, appropriate intervention, and completion of an unusual occurrence report.

**NURSING FAST FACT!**

Joint stabilization devices (e.g., splints/arm boards) should be well padded and applied so that they do not cause nerve damage, constrict circulation, or cause pressure areas. They should be removed at frequent intervals, and nurse-assisted range-of-motion exercises should be performed. Inadequate or improper use of such devices can result in pressure ulcers, circulatory constriction, infiltration, and nerve injury. Policies and procedures should be established to guide their use.
Local Infection

Description and Etiology
This section is limited to the presence of signs and symptoms of a local infection at the VAD insertion site. It is important to recognize, however, that the presence of a local site infection increases the risk of a BSI because microbial colonization at the site can migrate into the catheter tract and along the catheter surface, gaining access to the circulation. One of the most serious forms of PIV-related infection occurs when an intravascular thrombus surrounding the cannula becomes infected, leading to purulent drainage from the insertion site. This is referred to as suppurative or purulent thrombophlebitis (Hadaway, 2012).

INS Standard: Catheter-related infection includes exit-site, tunnel, port pocket, or CR-BSI (Gorski et al., 2016a, p. S106).

Local infections at the exit site are preventable with use of hand hygiene, skin antisepsis, and employment of ANTT for catheter insertion and all catheter-related care (see Chapter 2). Local infections may be related to:

- Inadequate hand hygiene
- Inadequate skin cleansing and skin antisepsis at the time of catheter placement
- Inadequate skin cleansing and skin antisepsis or failure to adhere to aseptic technique with implanted port access
- Failure to adhere to aseptic technique during VAD insertion
- Placement of catheters in emergent situations that are not changed within 48 hours
- Poor technique in maintaining and monitoring the VAD site
- Lack of catheter stabilization, which allows catheter movement and thus migration of pathogens on the skin into the catheter tract

Signs and Symptoms
Signs and symptoms of local infection include:

- Redness, swelling, induration, and/or drainage at the site
- Elevated body temperature that may/may not be present and, if present, is indicative of possible systemic infection

Tissue damage from extravasation can lead to prolonged healing, potential infection, necrosis, multiple débridement surgeries, cosmetic disfiguration, loss of limb function, and even amputation.
Prevention

In accordance with the INS Standards, interventions used to prevent local infections include the following:

1. Perform proper hand hygiene prior to all I.V. procedures.
2. Choose the catheter type, insertion site, and technique based on which pose the lowest risk of infections for the type and duration of infusion therapy. For adult patients, avoid the femoral site for CVAD placement and the lower extremity for PIV placement.
3. Wash the patient’s skin with soap and water prior to VAD placement if the site is visibly dirty.
4. Clip hair using a scissors or disposable-head surgical clippers if there is excess hair at the site. Never shave because microabrasions from shaving may increase the risk of infection. It is important to recognize that intact skin is the body’s first line of defense against infection, and when skin integrity is compromised, there is a potential portal of entry for microorganisms.
5. Wear clean gloves during PIV insertion and maintain “aseptic non-touch technique” (ANTT, 2017) with catheter insertion and with site care of all VADs.
   - Prepare the skin with an antiseptic and allow it to fully dry prior to catheter insertion.
   - Do not touch prepared skin after antisepsis. If there is a need to palpate the prepared site, sterile gloves are required.
   - Do not touch catheter portion of PIV after protective sheath is removed.
   - Place new dressings over insertion sites without touching the side that will go over the skin/insertion site (after paper backing is removed).
   - When placing a VAD using ultrasound, sterile gel is applied to the skin and a sterile sheath cover or a sterile large transparent membrane dressing is placed over the ultrasound probe (Gorski et al., 2016a, S45).
6. Adhere to central line insertion bundle interventions for CVAD placement.
   - Hand hygiene, maximal sterile barrier precautions, and alcoholic chlorhexidine solution for skin antisepsis; avoid femoral insertion (adults). Use a standardized checklist to ensure adherence to aseptic technique (see Chapters 2 and 8).
7. Ensure that the catheter is adequately stabilized in place to minimize catheter movement within the vein.
8. Maintain intact dressing. If the site is bleeding or oozing or the patient is diaphoretic, a gauze dressing may be preferred.
9. Use a chlorhexidine-impregnated dressing. Use these dressings with caution in premature neonates and for those with fragile skin or complicated skin pathologies due to risk of contact dermatitis and pressure necrosis (Gorski et al., 2016a, S83).
10. Instruct the patient to keep catheter site/dressing dry. Instruct patient on how to protect the site while bathing.
11. Assess insertion site regularly (Gorski et al., 2016a).
NOTE: See Chapter 2 for further information on infections at cannula sites.

**Treatment**

When there is a suspected local site infection, the LIP should be immediately notified.

1. Any purulent drainage at the PIV or CVAD site should be cultured and gram stained (Gorski et al., 2016a).
2. A PIV should be removed and consideration given to culturing the catheter tip.
3. Collaborate with the LIP regarding whether the CVAD should be removed.
4. Topical as well as systemic antimicrobial treatment may be indicated.
5. Cultures are obtained prior to administration of any antibiotics. It is important to follow organizational policy when obtaining any cultures to avoid contaminated specimens.

**Documentation**

Document the assessment of the site, culture technique, sources of culture, notification of the LIP, and any treatment initiated.

NOTE: Culture technique procedures are addressed in Chapter 2.

**Nerve Injury**

**Description and Etiology**

Because veins and nerves often lie in close proximity to each other, inadvertent injury to a nerve during venipuncture is a risk. When planning to place a PIV or perform phlebotomy, it is important to recognize that certain sites should be avoided and/or used with caution because of nerve proximity (see Chapter 6). Nerves specifically related to risk of injury with catheter placement in the arm include the radial and the median nerves.

The consequences of nerve injury may be minor and self-limiting, with symptoms that resolve without intervention, or they may be major. A direct-puncture nerve injury may result in formation of a neuroma, which is a mass of connective tissue and nerve fibers that prohibit regeneration of nerves at the site of injury (Gorski et al., 2016a, p. S102). Surgical removal may be required.

Nerve compression injury may occur as a result of infiltration or extravasation of an infusion. A compartment syndrome may occur when the I.V. fluid or medication collects in tight spaces bound by the fascia, bone, muscle, and skin. The increased pressure of the fluid decreases perfusion in the area, which can lead to irreversible nerve damage and loss of function. Early identification of infiltration/extravasation reduces such risk.
Signs and Symptoms

Signs and symptoms of direct-puncture nerve injury include:

- Immediate symptoms with PIV, midline, or PICC placement, including sharp, acute pain at the venipuncture site
- Sharp shooting pain up or down the arm
- Sensation of pain that changes in severity depending on needle position, “pins and needles” sensation, or an “electric shock” feeling
- Pain or tingling discomfort in the hand or fingertips

Monitor closely for the following signs of impending compartment syndrome as a result of a severe infiltration/extravasation, which may lead to nerve compression injury:

- Pain, pallor, paresthesia (e.g., numbness, tingling), paralysis, and/or pulselessness (Talbot & Rogers, 2011)
- Restricted joint movement and resistance to passive motion (Talbot & Rogers, 2011)

Prevention

The risk for nerve injury as a result of PIV placement is reduced when the following recommendations are followed:

1. If the patient complains of paresthesias, numbness, or tingling on catheter insertion, remove the catheter immediately and notify the LIP promptly. Rapid attention may prevent permanent injury (Gorski et al., 2016a, p. S102).
2. Avoid the cephalic vein above for about 3 to 5 inches above the thumb or styloid process due to potential for nerve damage (Samarakoon et al., 2011; Vialle et al., 2001).
3. Avoid the ventral surface of wrist.
4. Avoid the antecubital area for routine PIV placement.
5. Avoid excessive probing for the vein.
6. Reduce risk for infiltration/extravasation as discussed in the section on infiltration/extravasation.

Intervention: Suspected Direct Pressure Nerve Injury

1. Remove the catheter and notify the LIP promptly because rapid attention may prevent permanent injury (Gorski et al., 2016a, p. S102).
2. Apply pressure to the site to prevent a hematoma.
Intervention: Suspected Nerve Compression Injury

1. Immediately notify the LIP when compression nerve injury is suspected.
2. Discontinue the infusion.
3. Assess swollen area for paleness and pulselessness, which indicate that tissue necrosis and nerve compression injury are developing.
4. Place the affected limb at the level of the heart. Elevation is contraindicated because it decreases arterial flow (Rasul, 2017).
5. Anticipate possibility of surgery for fasciotomy to release pressure.
6. Complete an unusual occurrence report. This type of unusual occurrence would be considered a sentinel event (see Chapter 1).

NOTE: Irreversible nerve damage begins after 6 hours of tissue hypertension (Rasul, 2017).

Documentation

Document the patient’s complaints, duration of complaints, treatment, and length of time to resolve the problem. Document the time the LIP was notified.

Venous Spasm

Description and Etiology

A spasm is a sudden, involuntary contraction of a vein or artery resulting in temporary cessation of blood flow through a vessel (Alexander, Corrigan, Gorski, & Phillips, 2014). Venous spasm can occur suddenly and for a variety of reasons. The spasm usually results from the administration of a cold infusate or an irritating solution, or from too-rapid administration of an I.V. solution or viscous solution (e.g., blood product). Venous spasm may also occur during PICC or midline catheter removal. Venous spasm is related to:

- Administration of cold infusates
- Mechanical or chemical irritation of the intima of the vein

Signs and Symptoms

Signs and symptoms of venous spasms include:

- Cramping or sharp pain above the I.V. site
- Resistance to PICC/midline catheter removal

Prevention

Venous spasm can be prevented. Techniques used to prevent vasospasm include:

1. Ensure adequate dilution of medications.
2. Administer the medication/I.V. solution at the prescribed rate.
3. Allow refrigerated medications and parenteral solutions to reach room temperature before administering them.
4. Use a fluid warmer for rapid/large-volume transfusions in accordance with organizational policies.
**Treatment**

1. Apply warm compresses to warm the extremity and decrease flow rate until the spasm subsides.
2. If spasm is not relieved, remove catheter and restart with a new cannula.
3. If resistance to midline/PICC removal persists, interventional radiology should be consulted for evaluation and catheter removal.

**Documentation**

Document the patient’s complaints, interventions, and response to interventions.

**Systemic Complications**

Systemic complications are serious and can be life-threatening. Such complications include catheter-associated BSI, circulatory overload, air embolus, and speed shock. With appropriate preventative interventions and ongoing monitoring, these complications are preventable.

**Bloodstream Infection**

**Description and Etiology**

BSI, defined as the presence of bacteria in the blood, is a serious and potentially life-threatening complication of VADs. Considered a preventable complication, central line associated BSI (CLABSI) is a publicly reported outcome on the hospital compare website (https://www.medicare.gov/hospitalcompare/search.html?) and it impacts reimbursement in acute care hospitals (Brooks, 2016). The scope, terminology, and pathogenesis of BSIs are addressed in Chapter 2. The risk for CR-BSIs in the home setting is low, although there are limited current data documenting the prevalence. Prevention of CVAD-related infections is a National Patient Safety Goal for hospitals (The Joint Commission [TJC], 2017).

Although most of the literature is focused on BSIs associated with central VADs, BSI associated with PIV catheters is also a research focus. Although evidence indicates a low rate, because of the large number of PIV catheters that are used, even a low rate translates into a large number of BSIs per year (Hadaway, 2012).

The microorganisms most frequently associated with I.V. catheters include *Staphylococcus epidermidis* and other coagulase-negative staphylococci, *methicillin-resistant Staphylococcus aureus*, *Enterobacteriaceae*, *Candida*, Corynebacterium spp., and other gram-negative rods (Association for Professionals in Infection Control and Epidemiology [APIC], 2015). A BSI can progress to sepsis, which is a systemic infection caused by pathogenic microorganisms or their toxins resulting in a profound systemic reaction. It is a serious and often fatal clinical syndrome that is characterized by organ dysfunction. It often begins with fever, chills,
tachycardia, and tachypnea and can advance to septic shock, adult respiratory
distress syndrome, and death.

**Biofilm**

It is recognized that all catheters form a “biofilm” on the device shortly after inser-
tion. A biofilm is a community of microorganisms that stick to each other on the
catheter surface. Biofilm development occurs when, immediately after insertion,
plasma proteins attach to the catheter. Platelets and white blood cells also adhere
to the catheter surface, forming a matrix; microbes interact with the matrix and
colonize the catheter (APIC, 2015). Microbes from the skin and dermal layers
are potentially introduced during catheter insertion; they also can gain access
to the internal catheter surface during any access procedure (e.g., flushing) and
become irreversibly adherent. A BSI can occur if biofilm bacteria detach from either
the external or internal catheter surface. Although microorganisms that are dis-
persed as single cells can be killed by host defenses, a BSI can result if dissemination
of the microbes is more extensive or if the host defenses are compromised. Because
of the presence and nature of biofilm adherence, every effort must be made to
reduce the introduction of microorganisms into the catheter/bloodstream. This
means practicing hand hygiene and aseptic technique during the insertion, taking
care with every catheter access, and maintaining the device.

**Catheter Management to Prevent Catheter-Related Bloodstream Infections**

Catheter management to prevent infections focuses on insertion practices, care
and maintenance, and appropriate use of available technologies. TJC (2017)
National Patient Safety Goals direct the organization to implement the following
evidence-based interventions to reduce the risk of central line–associated blood-
stream infection (CLABSI). While intended specifically for acute care settings,
the recommendations apply to VAD management in any setting.

Specific recommendations from the INS Standards (Gorski et al., 2016a)
supporting the National Patient Safety Goals are listed below as the 13 goals:

1. Educate all staff involved in CVAD use about CLABSI and prevention
   on hire and annually.
   a. Assign VAD insertion and/or VAD management and surveillance only
to individuals and/or teams with infusion therapy education, training,
and validated competency.
2. Educate patients and families about CLABSI.
   a. Include proper care of the VAD and precautions for preventing infec-
tion, including aseptic technique and hand hygiene.
3. Implement policies and practices to reduce CLABSI risk.
   a. Use ultrasound guidance to place CVADs.
   b. Use CVAD with minimum number of ports (lumens) for management
   of the patient. More lumens are associated with more catheter manipu-
lation, which increases risk of microorganisms entering the I.V. system.
   c. Do not submerge catheter or catheter site in water.
d. Maintain aseptic technique during (Chapter 2) insertion and care of CVADs.

e. Replace dressings every 2 days if using gauze dressings, every 5-7 days if using transparent dressings and prn if drainage present under dressing, if loosened, soiled, or wet. The presence of a non-intact, damp dressing or drainage around the site provides a culture medium for bacterial growth, which increases the risk of infection.

f. Use of chlorhexidine-impregnated dressings for at least the first 14 days after CVAD insertion. While the efficacy of these dressings has not been demonstrated beyond 14 days after placement (Safdar et al., 2014), some organizations use for the duration of placement.

g. When adherence to aseptic technique cannot be ensured (e.g., during medical emergencies), replace as soon as possible (i.e., within 48 hours).

h. Monitor sites visually or by palpation through an intact dressing. Note that an intact dressing is characterized by all of the dressing edges adhered to the skin. It is not acceptable to add extra tape to secure a dressing that is becoming loosened with its edges lifting from the skin. Instead, the dressing should be replaced along with site care to reduce the growth of microorganisms around the insertion site.

i. Do not use antimicrobial ointment or creams on insertion sites because of increased risk of fungal infections and antimicrobial resistance.


5. Provide CLABSI infection rate data and prevention outcome measures to staff.

6. Use a catheter checklist and standardized protocol at the time of insertion.

7. Perform hand hygiene prior to catheter insertion or use.

8. Avoid the femoral site (adults).

9. Use a standardized supply cart or kit that contains all needed supplies for insertion.

10. Use a standardized protocol for sterile barrier precautions during CVAD insertion.

11. Use an antiseptic for skin preparation during CVAD that is cited in scientific literature or endorsed by professional organizations.

a. Prepare clean skin with >0.5% chlorhexidine/alcohol preparation before CVAD placement and during dressing changes. For patients who have a contraindication for chlorhexidine, 70% alcohol or povidone iodine are considered acceptable antiseptics.

b. Allow antiseptic to fully dry prior to CVAD placement.

12. Use a standardized protocol to disinfect catheter hubs and injection ports (e.g., needleless connector) before access.

a. Scrub needleless connector with an appropriate antiseptic (chlorhexidine, 70% alcohol, povidone-iodine) and access only with sterile devices. Maintain ANTT: Do not touch prepared needleless connector.
after disinfection and connect to tip of flush syringe or male Luer end of I.V. tubing without touching the tips after the protective cover is removed.

b. Consider the use of disinfectant caps.

13. Evaluate all CVADs and remove them when they are no longer necessary.

Another intervention is daily bathing with chlorhexidine-impregnated washcloths for patients in intensive care units (ICUs). This is recommended as a special approach in organizations with high rates of infection despite adherence to basic recommendations as previously listed (Marschall et al., 2014). Additional infection prevention measures recommended by INS (Gorski et al., 2016a) include the following, which address reducing risk of infection with peripheral as well as central VADs:

- Do not place PIVs in the lower extremity in adults.
- Replace catheters placed during an emergent situation (and thus under less than aseptic conditions) as soon as possible and no later than 48 hours.
- Maintain an intact dressing over the catheter site.
- Use a sutureless securement device to reduce the risk of infection.
- Consider use of an antimicrobial or antiseptic-impregnated CVAD in adults whose catheter is expected to remain in place for longer than 5 days.
- Change the needleless components no more often than every 96 hours.
- Do not use any container of parenteral fluid that has visible turbidity, leaks, cracks, or particulate matter.

**Signs and Symptoms**

Signs and symptoms of BSI include fever, chills, backache, nausea, malaise, headache, and hypotension.

Signs and symptoms of sepsis include all those of BSI and advancing to:

- Profuse, cold sweat
- Tachycardia
- Increased respirations or hyperventilation
- Evidence of decreased perfusion or dysfunction of vital organs
- Change in mental status
- Hypoxemia (measured by pulse oximetry)
- Elevated lactate levels
- Diminished urine output
- Elevated white blood cell count

**EBP** Four percent of patients in U.S. hospitals acquire at least one health care–associated infection; primary bloodstream infections account for 11.1% of those infections, which translates to about 71,900 bloodstream infections annually (Magill et al., 2014). The estimated cost of a bloodstream infection in the United States averages $70,696 (range: $40,412 to $100,980) adjusted for 2012 dollars (Agency for Healthcare Research and Quality, 2013).
Treatment

The steps in treating suspected BSI/septicemia include:

1. Report signs and symptoms to the LIP immediately.
2. Anticipate an order for blood cultures. Ideally, a dedicated phlebotomy team is assigned to obtain blood cultures (refer to Chapter 2: Procedures Display: Steps in Culturing Catheter–Skin Junction, Catheter, Infusate, and Blood).
   a. Paired blood cultures drawn from a peripheral venipuncture and obtained from a CVAD are used to diagnose CLABSIs.
   b. When obtaining a blood culture specimen from a CVAD, change the needleless connector prior to obtaining the sample, disinfect the needleless connector with antiseptic solution and allow it to dry (reduces risk for contaminated specimen), and collect blood sample in the volume recommended for the culture bottles (Gorski et al., 2016a, p. S87).
3. Anticipate clinical management of a suspected BSI with a CVAD as follows:
   a. A functioning CVAD may be left in place for a hemodynamically stable patient. Antimicrobial treatment will be initiated possibly including antimicrobial locks (see Chapter 8).
   b. The CVAD will be removed if there is clinical deterioration or persistent/relapsing bacteremia.
4. Anticipate an order for the peripheral or central catheter tip culture if the CVAD was removed.
5. If a peripheral cannula is in place, restart a new I.V. system in the opposite extremity. This includes changing not only the PIV but also the solution container and I.V. tubing.
6. Administer antibiotics, fluid replacement, vasopressors, and oxygen as prescribed.
7. Monitor the patient closely.
8. Anticipate possible transfer to the ICU, depending on the severity of the symptoms.

Documentation

Document the signs and symptoms, LIP notification, all treatments/interventions instituted, and patient response.

INS Standard: The infection rate should be calculated according to a standard formula (Gorski et al., 2016a, p. S21).
Calculation:
\[
\frac{\text{Number of infections}}{\text{Total number of I.V. catheter-days}} \times 1000 = \text{Infection rate/1000 catheter-days}
\]

**Circulatory Overload and I.V. Fluid Administration**

**Description and Etiology**

Circulatory overload may be caused by infusing excessive amounts of isotonic or hypertonic crystalloid solutions or blood transfusions too rapidly, by failure to monitor the I.V. infusion, or by too-rapid infusion of any fluid in a patient compromised by cardiopulmonary or renal disease. If the condition is allowed to persist, heart failure, shock, and cardiac arrest can result.

Pulmonary edema may result from circulatory overload when left ventricular filling pressure suddenly increases. Fluid is shifted from the pulmonary capillaries into the interstitial space and alveoli (Capriotti & Frizzell, 2016). Patients at risk for circulatory overload and pulmonary edema are those with cardiovascular disease or renal disease as well as elderly patients. Any sodium chloride solution should be used cautiously in high-risk patients. Hypertonic sodium chloride solutions (3% and 5%) given to correct profound sodium deficits can lead to pulmonary edema and must be monitored aggressively (Chapter 4).

Fluid overload and pulmonary edema are related to:
- Overzealous infusion of I.V. fluids, especially those that contain sodium
- Compromised cardiovascular or renal systems

**Signs and Symptoms**

Signs and symptoms of circulatory overload include:
- Increase in blood pressure or heart rate, bounding pulse
- Intake > output
- Weight gain over a short period of time
- Increase in central venous pressure
- Jugular venous distention
- Cough
- Presence of edema (eyes, dependent, over sternum)
- Pulmonary edema:
  - Moist crackles in lungs
  - Severe dyspnea
  - Anxiety, restlessness
  - Blood-tinged sputum
  - Pallor
  - Cyanosis
  - Hypoxia, with severe respiratory distress
  - Oxygen saturation less than 90% on room air
- Diagnostic tests: Arterial blood gases (ABGs), blood urea nitrogen (BUN), and serum creatinine to evaluate renal function; natriuretic peptide levels may be increased; chest radiograph
Prevention

The risk for circulatory overload is reduced through the following actions:

1. Review the patient’s cardiovascular history and risk factors for circulatory overload.
2. Monitor intake and output and daily weights for all patients receiving I.V. fluids.
3. Monitor patients for signs and symptoms, especially when infusing sodium chloride solutions, and know the solution’s physiological effects on the circulatory system.
4. Maintain flow at the prescribed rate.
5. Never “catch up” on I.V. solutions that are behind schedule; instead, recalculate all infusions that are not on time.
6. Report changes, including increased body weight, intake > output.
7. Administer fluids using electronic infusion devices (EIDs) with dose-error reduction systems and anti-free-flow administration sets.

Treatment

Report signs and symptoms of circulatory overload to LIP promptly. The goal of treatment is to decrease pulmonary venous and capillary pressures, improve cardiac output, and correct underlying pathology.

1. Position the patient in a semi-Fowler position.
2. Decrease I.V. flow rate per orders.
3. Keep the patient warm to promote peripheral circulation.
4. Monitor vital signs.
5. Monitor fluid volume status through daily weights and intake and output measurements.
6. Drug therapy: Anticipate the administration of loop diuretics to decrease pulmonary congestion. Vasodilators maybe used to decrease pulmonary vascular pressure (nitroprusside or nitroglycerin) and morphine sulfate to cause venous dilation.
7. Administer oxygen therapy as ordered with dose titrated to patient response (intubation and mechanical ventilation may be necessary).
8. A pulmonary artery catheter may be placed to monitor hemodynamic status, including cardiac output.

Documentation

Document the signs and symptoms, LIP notification, all treatments/interventions instituted, and patient response. Record vital signs, intake and output, and weights.

Venous Air Embolism

Description and Etiology

Venous air embolism is a potentially lethal but preventable complication in relation to VADs. Two conditions must be present to cause a venous air embolism: direct communication between a source of air and the vasculature, and a
pressure gradient favoring passage of air into the circulation (Natal & Doty, 2016). The pathophysiology is as follows:

- The entry of a bolus of air into the vascular system creates an air lock at the pulmonic valve and prevents ejection of blood from the right side of the heart.
- The right side of the heart overfills with blood, and the force of ventricular contractions increases in an attempt to eject blood past the occluding air pocket.
- These forceful contractions break small air bubbles loose from the air pocket. Minute air bubbles are subsequently pumped into the pulmonary circulation, causing even greater obstruction to the forward flow of blood as well as local pulmonary tissue hypoxia.
- Pulmonary hypoxia results in vasoconstriction in the lung tissue, which further increases the workload of the right ventricle and reduces blood flow out of the right heart. This leads to diminished cardiac output, shock, and death unless interventions are implemented immediately.

Small amounts of air are broken up in the capillary bed and absorbed into the circulation without symptoms. However, it has been asserted that even small bubbles of air have the potential to cross into arterial circulation and create cerebral or coronary ischemic events (Wilkins & Unverdorben, 2012). Although it is not current standard practice, these authors suggest the consistent use of air-eliminating filters with I.V. infusion. Minimally, it is critical that air be aspirated not only from I.V. tubing but also from syringes, needleless connectors, and other add-on devices (e.g., extension tubing sets).

The risk for air embolism may be associated with the following procedures or clinical situations:

- During placement or removal of a CVAD
  - Pressure in the central veins decreases during inspiration and increases during expiration. If an opening into a central vein exposes the vessel to the atmosphere during the negative inspiratory cycle, air can be “sucked” into the central venous system in much the same manner that air is pulled into the lungs.
- Catheter breakage or fracture
- Presence of a persistent catheter tract following CVAD removal
- Disconnection between the catheter and the I.V. administration set or needleless connector in the absence of a catheter clamp
- Inadvertent infusion of air into the administration set
  - Failure to prime the administration set
  - Adding a new I.V. bag to a line that has run dry without clearing the line of air
  - Loose connections that allow air to enter the system
NOTE: It is estimated that 5 mL/kg of air is required for significant injury including shock and cardiac arrest (e.g., ~340 mL in a 150-pound patient); however, complications have been reported with as little as 20 mL of air injected I.V. (Natal & Doty, 2016).

**Signs and Symptoms**

Signs and symptoms of air embolism include:

- Light-headedness and weakness
- Pulmonary findings: Dyspnea, cyanosis, tachypnea, expiratory wheezes, cough, pulmonary edema
- Cardiovascular findings: Palpitations, “mill wheel” murmur; weak, thready pulse; tachycardia; tachydyssrhythmias; substernal chest pain; hypotension; jugular venous distention
- Neurological findings: Change in mental status, altered speech, confusion, coma, anxiouslyness, seizures
- Agitation and anxiety (e.g., feelings of “impending doom”) are not uncommon (Cook, 2013).

If untreated, these signs and symptoms lead to hemiplegia, aphasia, generalized seizures, coma, and cardiac arrest.

**Prevention**

Techniques used to prevent air embolism include:

1. Prime all air from administration sets, syringes, and any add-on devices (e.g., needleless connectors, extension tubing).
2. Use only Luer-lock devices within the I.V. administration set.
3. Check administration set junctions for securement, especially when getting patients in and out of bed.
4. Check infusion system regularly for air bubbles, an empty infusion container, leakage or disconnection, or cracks at the catheter hub.
5. Ensure that the CVAD is clamped during administration set and needleless connector changes. If no clamp is present, place patient in a position with the CVAD exit site at or below heart level and have patient perform a Valsalva maneuver during the procedure.
6. Trace all lines from the catheter hub to the fluid container to prevent missed connections.
7. Add new I.V. solution containers before the previous solution runs completely dry.
8. During CVAD removal:
   - Position patient in supine position or Trendelenburg position if tolerated.
   - Instruct patient to perform Valsalva maneuver during removal unless contraindicated; if so, have patient exhale during removal.
   - Remove catheter slowly and place immediate pressure over exit site until hemostasis is achieved.
Apply an occlusive dressing with a petroleum-based ointment/gauze and cover with transparent dressing; maintain in place for at least 24 hours until epithelialization is complete.

* Have patient remain in supine position 30 minutes after removal (Cook, 2013; Gorski et al., 2016a, p. S108).

**Treatment**

Immediate actions are required in the event of suspected air embolism:

1. Prevent more air from entering system (clamp catheter, occlude catheter exit site).
2. Place patient in left lateral Trendelenburg position. This causes the air to rise in the right atrium, preventing it from entering the pulmonary artery.
   a. If patient cannot tolerate this position, use the left lateral decubitus (left side, head flat) position (Cook, 2013).
3. Activate code system/rapid response team.
4. Administer 100% oxygen and intubate for significant respiratory distress or refractory hypoxemia.
5. Maintain systemic arterial pressure with fluid resuscitation and vasopressors/beta-adrenergic agents if necessary.
6. Monitor vital signs.

**NURSING FAST FACT!**

The complications of air emboli include shock, death, neurological injury, and/or myocardial infarction.

**NURSING FAST FACT!**

A pathognomonic indicator of an air embolism is a loud, churning, drumlike sound audible over the precordium, called a “mill wheel murmur.” This symptom may be absent or transient.

**EBP Failure to place an occlusive dressing after removal of a CVAD may have caused a patient to suffer a fatal air embolism in a case report. Steps followed in the institutional protocol included placing patient in supine position during device removal, patient holding his breath during removal, direct pressure to site, and covering site with gauze and tape. The patient then got up to dress himself in preparation for discharge and suddenly slumped over onto his bed. A disparity between procedures for CVAD removal and introducer catheter sheath removal (followed by the nurse) was identified. The authors assert the need for trustworthy and consistent policies, procedures, and protocols (Clark & Plaizier, 2011).**
Documentation
Document the signs and symptoms, LIP notification, all treatments/interventions instituted, and patient response.

Speed Shock
Description and Etiology
Speed shock is a systemic reaction that occurs when a foreign substance, usually a medication, is rapidly introduced into the circulation. Rapid injection permits the concentration of medication in the plasma to reach toxic proportions, flooding the organs rich in blood—the heart and the brain. The vital organs, therefore, are “shocked” by a toxic dose. Syncope, shock, and cardiac arrest may result.

The causes of speed shock include:

• I.V. medications or solutions are administered too rapidly.
• The flow control clamp is inadvertently left completely open.
• The EID is programmed incorrectly.

Signs and Symptoms
Signs and symptoms of speed shock include:

• Dizziness
• Facial and neck flushing
• Patient complains of severe pounding headache
• Tightness in the chest
• Hypotension
• Irregular pulse
• Progression of shock

Prevention
Speed shock is preventable as follows:

1. Review information about drug and implications of adverse effects resulting from rapid administration.
2. Use an EID with high-risk drugs. Do not bypass the drug library or override alerts when using “smart pumps.”
3. Monitor the infusion rate for accuracy before “piggybacking” in a medication.
4. Administer I.V. push medications over the appropriate time frame. Use a watch or a clock with a second hand or with a digital display of minutes and seconds (Institute for Safe Medication Practices [ISMP], 2015). Usually the label on the medication syringe will indicate the time (e.g., administer over 3–5 minutes); if it is not labeled, the nurse should consult with the pharmacist.
NURSING FAST FACT!

More than 50% of nurses administered I.V. push medications incorrectly based on an assessment of technique during a competency skills day. Proper technique in I.V. push medication administration should be assessed as a nursing competency in nursing curricula (Carter, Gelchion, Saitta, & Clark, 2011).

**Treatment**

If you suspect speed shock, do the following:

1. Stop infusion immediately.
2. Activate code system/rapid response team.
3. Administer antidote or resuscitation medications as ordered.
4. Begin cardiopulmonary resuscitation (CPR) if cardiac arrest occurs.

**NOTE:** See Chapter 10 for appropriate steps in delivery of I.V. push medications.

**Documentation**

Document the medication or fluid administered, and the signs and symptoms. Also document the LIP notification, the treatment initiated, and the patient response. Table 9-5 provides a summary of local and systemic complications.

<table>
<thead>
<tr>
<th>Table 9-5 Local and Systemic Complications</th>
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<tbody>
<tr>
<td><strong>Complication</strong></td>
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<tr>
<td><strong>Local</strong></td>
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<tr>
<td>Hematoma</td>
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<td>Phlebitis</td>
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## Table 9-5  Local and Systemic Complications—cont’d

<table>
<thead>
<tr>
<th>Complication</th>
<th>Signs and Symptoms</th>
<th>Treatment</th>
<th>Prevention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infiltration/extravasation</td>
<td>Coolness of skin around site&lt;br&gt;Taut/blanched skin&lt;br&gt;Edema above or below insertion site&lt;br&gt;Backflow of blood absent&lt;br&gt;Slowed infusion rate For extravasation: Complaints of pain&lt;br&gt;Burning or stinging at insertion site&lt;br&gt;Blisters</td>
<td>Stop infusion and remove catheter. Apply cool/warm compresses as indicated by type of infusate. Elevate extremity. Follow guidelines if extravasation occurs. Use antidote when appropriate.</td>
<td>Choose smallest I.V. cannula that is appropriate for infusion.&lt;br&gt;Stabilize catheter to prevent mechanical irritation.&lt;br&gt;Avoid placing PIV in areas of flexion.&lt;br&gt;Do not use veins that have a previous venipuncture.&lt;br&gt;Avoid antecubital fossa.&lt;br&gt;Turn the patient carefully.&lt;br&gt;Assess site frequently.&lt;br&gt;Advocate for CVAD for continued need of irritating/vesicant solutions or medications.</td>
</tr>
<tr>
<td>Nerve injury</td>
<td>Immediate sharp pain during venipuncture&lt;br&gt;Shooting pain up arm&lt;br&gt;Pain or tingling in hand or fingertips</td>
<td>Stop venipuncture. Notify LIP. Apply pressure.</td>
<td>Avoid lateral surface of wrist, antecubital area, ventral surface of wrist.&lt;br&gt;Avoid probing.&lt;br&gt;Reduce risk for infiltration or extravasation as above.</td>
</tr>
<tr>
<td>Local Infection</td>
<td>Redness, swelling, induration and/or drainage at site</td>
<td>Discontinue catheter; culture site and cannula. Apply sterile dressing over the site. Administer antibiotics as ordered.</td>
<td>Proper skin cleansing and attention to skin antisepsis at time of placement&lt;br&gt;Aseptic technique during venipuncture and site maintenance&lt;br&gt;Central line bundle interventions for CVAD placement</td>
</tr>
<tr>
<td>Venous Spasm</td>
<td>Cramping or sharp pain at I.V. site associated with infusion&lt;br&gt;Resistance to PICC or midline removal</td>
<td>Apply a warm compress. Restart the infusion if spasm continues. Consult with interventional radiology for resistance to line removal.</td>
<td>Dilute medications. Keep I.V. solution at room temperature. Administer infusion at prescribed rate.</td>
</tr>
<tr>
<td>Systemic</td>
<td></td>
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<tr>
<td>Bloodstream Infection</td>
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<td></td>
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<tr>
<td>Fever and chills&lt;br&gt;Diaphoresis&lt;br&gt;Tachycardia&lt;br&gt;Tachypnea</td>
<td></td>
<td>Notify the LIP. Restart new I.V. system. Obtain cultures.</td>
<td>Hand hygiene&lt;br&gt;Aseptic technique with all aspects of infusion-related care</td>
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</tbody>
</table>

*Continued*
### Table 9-5  \hspace{1em} \text{Local and Systemic Complications—cont’d}

<table>
<thead>
<tr>
<th>Complication</th>
<th>Signs and Symptoms</th>
<th>Treatment</th>
<th>Prevention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circulatory Overload and Pulmonary Edema</td>
<td>Rapid weight gain Increase in BP, heart rate&lt;br&gt;Bounding pulse&lt;br&gt;Edema&lt;br&gt;Intake &gt; output&lt;br&gt;Rise in central venous pressure&lt;br&gt;Shortness of breath&lt;br&gt;Crackles in lungs&lt;br&gt;Cough&lt;br&gt;Distended neck veins&lt;br&gt;Restlessness and headache</td>
<td>Call rapid response team.&lt;br&gt;Decrease I.V. flow rate.&lt;br&gt;Place the patient in a high-Fowler position.&lt;br&gt;Keep the patient warm.&lt;br&gt;Monitor vital signs.&lt;br&gt;Administer oxygen as ordered.&lt;br&gt;Administer drug therapy.&lt;br&gt;Administer oxygen therapy.</td>
<td>Monitor the infusion.&lt;br&gt;Maintain flow at the prescribed rate.&lt;br&gt;Monitor intake and output, daily weights.&lt;br&gt;Know the patient’s cardiovascular history.&lt;br&gt;Do not “catch up” infusions; instead, recalibrate.&lt;br&gt;Use EIDs that have dose-error reduction systems and anti-free-flow administration sets.</td>
</tr>
<tr>
<td>Air Embolism</td>
<td>Light-headedness&lt;br&gt;Dyspnea, cyanosis, tachypnea, expiratory wheezes, cough&lt;br&gt;Mill wheel murmur, chest pain, hypotension&lt;br&gt;Change in mental status, confusion coma, seizures</td>
<td>Call rapid response team.&lt;br&gt;Place patient in Trendelenburg position.&lt;br&gt;Administer oxygen as ordered.&lt;br&gt;Monitor vital signs.</td>
<td>Remove all air from administration sets.&lt;br&gt;Use Luer-lock connections.&lt;br&gt;Follow protocol for catheter removal.</td>
</tr>
<tr>
<td>Speed Shock</td>
<td>Dizziness&lt;br&gt;Facial flushing&lt;br&gt;Headache&lt;br&gt;Tightness in chest&lt;br&gt;Hypotension&lt;br&gt;Irregular pulse&lt;br&gt;Progression of shock</td>
<td>Stop infusion immediately.&lt;br&gt;Call rapid response team.</td>
<td>Use an EID.&lt;br&gt;Monitor the infusion rate.&lt;br&gt;Administer I.V. push medications over appropriate time frame.</td>
</tr>
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</table>
CHAPTER 9  Complications of Infusion Therapy

NURSING POINTS OF CARE

PERIPHERAL I.V. COMPLICATIONS

Nursing Assessment

- Ask about and document subjective complaints from patient regarding the I.V. site.
- Assess infusion system and PIV catheter regularly for:
  - Integrity of the infusion system: all connections secure, accuracy of infusion rate, expiration dates of the infusate, dressing, administration set
  - Signs and symptoms of complications: redness, swelling, drainage, tenderness, pain
  - Dressing integrity
  - Catheter stabilization
  - Catheter patency
- Assess cardiac and renal function.
- Assess for age-related risks.
- Determine baseline weight.
- Monitor intake and output.
- Assess and monitor vital signs and pain level.
- Monitor for adverse/side effects of the infusion therapy.

Key Nursing Interventions

1. Determine if a drug or solution has vesicant or irritant qualities and advocate for a CVAD if appropriate.
2. Perform hand hygiene prior to and after any PIV-related care.
3. Maintain aseptic technique with PIV placement and access procedures.
4. Maintain an intact dressing.
5. Administer fluids that have reached room temperature.
6. Administer I.V. medications at prescribed rate; use an EID as appropriate.
7. Perform site checks and document at regular intervals.
8. Rotate the PIV site as clinically indicated based on condition of site; remove PIV at first signs of complications.

Central Vascular Access Device Complications

Complications that are specifically associated with CVADs fall into two groups: insertion-related complications and complications associated with indwelling CVADs. There are a number of complications that can occur during the catheter insertion procedure. Venous air embolism, venous spasm, and nerve injury are possible during catheter insertion and have been previously described. In this section, CVAD insertion–related complications of pneumo- and hemothorax and pinch-off syndrome are addressed. CVAD malposition may occur during
insertion as well as anytime during the catheter dwell time. Other complications associated with the catheter dwell time include CLABSI (previously addressed under Bloodstream Infection), CVAD-associated skin impairment, catheter occlusion and catheter-associated venous thrombosis.

**Pneumothorax/Hemothorax**

*Description and Etiology*

During insertion of the CVAD via the subclavian vein, the introducer may inadvertently cause trauma to the lungs, potentially resulting in a pneumothorax or a hemothorax. A pneumothorax is created by the collection of air in the pleural space. A hemothorax occurs when blood enters the pleural cavity as a result of trauma or transection of a vein during insertion.

Although a pneumothorax used to be one of the more common insertion-related complications, it is less common today because standard practice includes the use of ultrasound to guide CVAD insertions, which is associated with decreased insertion-related complication rates (Gorski et al., 2016a, p. S45). In fact, very low complication rates by nurse-led CVAD placement services have been demonstrated (Alexandrou et al., 2012).

*Signs and Symptoms*

Signs and symptoms of pneumothorax include:

- Sudden onset of chest pain or shortness of breath during the procedure
- On auscultation, a crunching sound heard with heartbeat (caused by mediastinal air accumulation); decreased breath sounds
- Dyspnea, persistent cough
- Tachycardia

Signs and symptoms of hemothorax include:

- Sudden onset of chest pain with mild to severe dyspnea
- Bleeding into the pleural cavity
- Tachycardia
- Hypotension
- Delayed symptoms of dusky skin color, diaphoresis, hemoptysis
- Dullness of affected side of chest disclosed by percussion
- Decreased or absent breath sounds detected by auscultation

*Prevention*

1. Use of ultrasound to guide CVAD insertion
2. Only highly skilled and competent professionals should insert CVADs
3. Careful assessment of patient for signs and symptoms during insertion

*Treatment*

1. Oxygen is usually administered, and a chest tube may be inserted for pneumothorax or hemothorax.
2. Monitor vital signs.
3. Apply pressure over the vein entry site.
4. Remove the catheter.

**Documentation**

Document the insertion site, signs and symptoms, and all interventions. Document verification of the catheter tip location.

**Pinch-off Syndrome**

**Description and Etiology**

Catheter pinch-off syndrome is a rare but significant and often unrecognized complication. It occurs when the CVAD enters the costoclavicular space medial to the subclavian vein and is positioned outside the lumen of the subclavian vein in the narrow area bounded by the clavicle, first rib, and costoclavicular ligament. Catheter compression causes intermittent or permanent catheter obstruction and, because of the “scissoring” effect of catheter compression between the bones, can result in catheter tearing, transection, and catheter embolism, most often to the right heart or pulmonary artery (Hill et al., 2013).

**Signs and Symptoms**

Pinch-off syndrome may occur with implanted ports or nontunneled or subcutaneously tunneled CVADs inserted via the subclavian vein. Signs and symptoms include:

- Intermittent and positional occlusion
- Difficulty with flushing, infusing, aspirating
- Frequent occlusion alarms
- Occlusion relieved by specific postural changes (e.g., rolling the shoulder back or raising the arm), which open the angle of the costoclavicular space
- Patients in whom catheter partially or completely transects internally may have no symptoms, whereas other patients may experience chest pain, palpitations, swelling in the area of the CVAD, or pain with catheter flushing (Alexander et al., 2014; Hill et al., 2013).

**NOTE:** Radiographic confirmation of the catheter and proper position of the patient during radiography are crucial. It is important to note that because raising the arms or shrugging opens the costoclavicular angle, the films should be taken with the patient upright and with arms by the side (Hill et al., 2013).

**Prevention**

1. Use ultrasound guidance for catheter placement. The use of ultrasound was associated with prevention of pinch-off syndrome in implanted port placement (Osawa et al., 2013).
2. Insert the catheter lateral to the midclavicular line to decrease the risk (Alexander et al., 2014).
Treatment

1. The catheter should be removed.

Documentation

Document any intermittent positional flushing and infusion difficulties, signs and symptoms, radiographic confirmation, and interventions.

Central Vascular Access Device Malposition

Description and Etiology

Malposition of the CVAD can occur during the insertion process—“primary CVAD malposition”—or at any time during the dwell period—“secondary CVAD malposition” (Gorski et al., 2016a, p. S115). Malposition is simply defined as the catheter tip being in a suboptimal or aberrant location, with the optimal position of the CVAD tip being in the superior vena cava (SVC) near its junction with the right atrium. Aberrant locations include contralateral innominate and subclavian veins, internal jugular veins, azygos veins, thoracic veins, right atrium, and right ventricle.

Primary malposition results when the catheter passes into an aberrant location during the catheter insertion procedure. Contributing factors for primary malposition include failure to use visualization technology (e.g., ultrasound), multiple attempts and needle passes, and lack of skill by the CVAD inserter (Alexander et al., 2014). During the insertion procedure, anatomic abnormalities (e.g., persistent left SVC) or vessel stenosis may also contribute to malposition. The guidewire can puncture the vasculature, and extravascular CVAD tip malposition can cause cardiac tamponade and intrathoracic infiltration/extravasation (Gorski et al., 2016a, p. S114).

Secondary malposition of the catheter tip, also called “tip migration,” can occur at any time. Causes include changes in intrathoracic pressure associated with coughing or sneezing, presence of heart failure, neck and arm movement, or forceful flushing of the catheter as occurs with power injection (Gorski et al., 2016a, p. S115). Tip migration can occur with improper care, for example, when the catheter is repositioned during routine care and the tip is accidentally dislodged or advanced into the body. Tip migration may also result from external catheter movement of the CVAD out of the insertion site, which could result from excessive arm movement in patients with PICCs or from inadequate CVAD stabilization. Malposition of the catheter tip increases the risk for catheter occlusion and venous thrombosis (Gorski et al., 2016a, p. S112; Smith et al., 2017).

Signs and Symptoms

Signs and symptoms that may indicate CVAD malposition include the following:

- Patient experiences symptoms associated with pneumothorax/hemothorax if the pleural covering of the lung has been punctured.
- Change in catheter function is noted. Inability to flush, infuse, or aspirate blood can mean the catheter tip is no longer at the desired position.
- Tip migration into the right atrium may result in dysrhythmias, and the patient may experience palpitations.
Catheter tip migration to the internal jugular vein has been associated with patient reports of hearing ear “gurgling” or the sound of a running stream rushing past the ear.

Patient complains of headache or pain, swelling, redness, or discomfort in the shoulder, arm, or neck, which may indicate catheter migration.

Changes in the length of the external catheter segment may mean the catheter tip has migrated.

**Prevention**

1. Only highly skilled and competent professionals should insert CVADs.
2. Ensure that CVAD is stabilized at the insertion site and take care during CVAD site care and stabilization procedures not to inadvertently pull the catheter out of the exit site.

**Treatment**

1. Because visualization technologies are used during catheter insertion, quick identification of problems is possible. Catheters can be repositioned using techniques such as rapid flushing and appropriate body positioning.
2. Guidewire exchange has been used with success for placing a new catheter without repeated percutaneous cannulation.
3. When tip migration is suspected at any time during catheter dwell, notify the LIP and obtain order to hold infusions until correct catheter placement is confirmed and corrected.
4. Never reinsert a catheter that has been inadvertently pulled out from the exit site. Stabilize it in place and report to the LIP. A chest x-ray should be ordered and obtained to verify correct tip placement.

**Documentation**

Document the insertion site and positioning of patient, signs and symptoms, type of catheter used, and all interventions. Document radiography or other technology used to verify CVAD tip placement.

**NURSING FAST FACT!**

Appropriate CVAD tip placement in the SVC is always verified prior to catheter use.

**CVAD-Associated Skin Impairment**

**Description and Etiology**

CVAD-associated skin impairment (CASI) is a recently named complication of CVADs. Due to the often complex nature of patients who have CVADs, such as those who have nutritional deficiencies, cancer, renal impairment, and hematologic disorders, there is an increased risk for skin damage associated with routine CVAD site management. CASI is defined as “an occurrence of drainage, erythema, and or other manifestation of cutaneous abnormality,
including but not limited to vesicle, bulla, erosion, or tear, at a CVAD site in the underlying area of a dressing which persists 30 minutes or more after removal of the dressing” (Broadhurst, Moureau & Ullman, 2017). An algorithm, primarily based upon expert opinion, was developed to guide assessment and identification and management of CASI. The identification and management of CASI is briefly described in this section.

**Signs and Symptoms**

Within the algorithm, four types of skin impairment are identified:

- Exit site infection: which was addressed earlier in this chapter
- Skin injury: *skin stripping* which may occur as a result of traumatic tape or dressing removal and characterized by shiny skin and shallow irregular skin lesions; *skin tear* which is caused by shear and friction and characterized by partial or full thickness tissue damage; and *tension blisters* which can be caused by shear force as a result of distention of skin underneath the dressing or for example, when a joint or other area of movement is covered with unyielding tape.
- Skin irritation: *irritant contact dermatitis*, a nonallergic reaction that is often seen within the area of exposure such as the dressing; *allergic contact dermatitis* which may be characterized by redness, vesicles, and pruritis; allergens can include the antiseptic solution, the dressing, or a skin barrier solution. There may be changes in skin color, burning and itchy skin.
- Noninfectious weeping and oozing drainage at the insertion site: It is important to assess the characteristics of the drainage such as color, consistency, odor and amount. (Broadhurst et al., 2017)

**Prevention**

Proper dressing application and removal will reduce the risk of CASI. Use of skin barrier solution prior to placing the dressing is recommended in the algorithm and also by INS (Gorski et al., 2016a). It is extremely important to always allow the skin antiseptic agent to fully dry before placing any dressing over the CVAD site.

**Treatment**

Treatment is based upon the suspected cause. Exit site infection is previously addressed. When reactions occur, consideration is given to changing the brand of dressing product or an alternative non-alcohol skin antiseptic agent (e.g. povidone-iodine) (Broadhurst et al., 2017). Consideration for referring to and collaborating with a wound care specialist is often warranted.

**Documentation**

Document characteristics of the insertion site and surrounding area, type of antiseptic agent, dressing, and any skin barriers used. Include interventions implemented to treat CASI and any referrals/interprofessional collaboration.
Catheter Occlusion

**Description and Etiology**

Catheter occlusion is a common complication encountered with CVADs. Catheter occlusion is characterized by:

- Inability to aspirate blood
- Inability to flush/infuse
- Sluggish flow
- Increasing occlusion alarms with the use of EIDs

Occlusion is a significant complication because it may delay or cause interruptions in infusion therapy. Also, untreated catheter occlusion may result in secondary complications such as loss of venous access, cost/risks of catheter replacement, and risk for BSI. Catheter occlusion may result from mechanical, precipitate, or thrombotic causes.

Mechanical occlusions may result in partial or complete obstruction of the VAD. Causes may be attributed to either external (outside of the body) or internal problems. Causes of internal mechanical problems include pinch-off syndrome and catheter malposition as addressed in subsequent sections of this chapter. It is also possible that the catheter tip abuts the blood vessel wall, blocking the ability to aspirate blood on occasion. For example, having the patient cough or change positions may result in ability to aspirate blood. Persistent problems should result in reevaluation of catheter placement. Causes of external mechanical obstruction include:

- Clamped catheter
- Kinked I.V. tubing
- Obstructed I.V. filter
- Constriction of catheter by a suture

The second possible cause of occlusion is precipitate formation. Factors contributing to drug precipitation include:

- Inadequate flushing between incompatible medications
- Infusion of incompatible medications (e.g., phenytoin, diazepam, ganciclovir, acyclovir, ampicillin, imipenem, heparin, vancomycin, ceftriaxone, parenteral nutrition solutions, and all calcium preparations) (Gorski et al., 2016b).
- Lipid emulsions causing occlusion by leaving a waxy buildup on the catheter wall. This is more likely to occur with three-in-one parenteral nutrition (PN) solutions, which include the amino acids, dextrose, lipids, and additives in a single container.

The third and most common cause of occlusion is thrombotic catheter occlusion. This type of occlusion occurs when fibrin or blood within and around the CVAD or within the reservoir of implanted ports slows down or disrupts catheter flow. Accumulation of deposits leads to obstruction of the infusion. It is important.
to recognize that any artificial device placed in the body, including a CVAD, is coated with plasma proteins, blood cells, and fibrin as the coagulation cascade is initiated by the body. The device is covered by a fibrin sheath as a result of a natural protective bodily response (Hill et al., 2013). This fibrin growth may cause catheter occlusion and require intervention. The presence of a thrombotic occlusion may contribute to CLABSI because the presence of a blood clot in or around the catheter serves as a rich culture medium for microbial growth. Therefore, it is clinically important to recognize and treat thrombotic occlusion. Four categories of thrombotic occlusion are commonly described in the literature (Hill et al., 2013):

1. **Fibrin tail**: A layer of fibrin resides on the tip of the CVAD. The tail can grow as more cells and blood components are deposited. With fibrin tails, it is possible to flush the catheter and administer infusions. However, when aspiration of blood is attempted, the tail acts as a one-way valve as it is pulled over the catheter tip. The ability to flush but not aspirate blood is considered a partial occlusion and sometimes is referred to as “withdrawal occlusion” (Fig. 9-6).

2. **Fibrin sheath or sleeve**: A layer of fibrin forms around the external surface of the catheter, potentially coating the entire exterior wall and tip of the catheter (Fig. 9-7). When a significant fibrin sheath develops and encases the catheter tip, any medication/solution that is administered can travel retrograde (“backtrack”) along the sheath to the catheter insertion site, resulting in an infiltration/extravasation. Infusate may be observed on the skin (nontunneled catheters), in the subcutaneous tunnel (tunneled catheters), or in the subcutaneous pocket of implanted ports.

3. **Intraluminal occlusion**: Fibrin or blood clot accumulates within the internal catheter lumen. Flow through the catheter becomes sluggish and

![Figure 9-6](image)
may progress to a complete occlusion, in which case it is not possible to flush or aspirate blood from the catheter.

- Frequently, the cause is blood remaining in the catheter or the portal body of the implanted vascular access port after inadequate catheter locking or retrograde flow (Figs. 9-8 and 9-9). Also, poor flushing technique after blood sampling may allow layers of fibrin to accumulate over time, narrowing or obstructing the lumen.
4. **Mural thrombus:** This is caused by catheter tip irritation against the inner lining of the vein (tunica intima). An accumulation of fibrin causes the CVAD to adhere to the vessel wall. A mural thrombus may lead to catheter-associated venous thrombosis, which is addressed in the next section. Contributing factors include frequent attempts at cannulation and use of rigid catheters that cause damage to the tunica intima.

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**NURSING FAST FACT!**
The presence of a blood clot in or around the catheter increases the risk for BSI because a blood clot is a nidus for microbial growth.

**Signs and Symptoms**
- Inability to aspirate blood; the INS defines a blood return as “blood that is the color and consistency of whole blood upon aspiration” (Gorski et al., 2016a, p. S146).
- Resistance to flushing
- Sluggish infusion
- Complete inability to flush or infuse
- Frequent infusion pump alarms
- Leaking of fluid from the insertion site as fluid tracks back along a fibrin sheath

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**NURSING FAST FACT!**
A properly functioning catheter is patent, should be easy to flush, and should yield a free-flowing blood return on aspiration. This applies to all lumens of the CVAD.

**Prevention**
1. Ensure/verify proper catheter tip placement in the SVC near its junction with the right atrium.
2. Make sure the catheter and tubing do not have kinks or closed clamps.
3. Assess suture placement, if present; check for tightness that may cause catheter kinking.
4. Use SASH (saline-administer-saline-heparin) technique, flushing the CVAD with saline before and after each medication administration and after any blood withdrawal.
5. Know the type of needleless connector used by your organization and use a proper clamping technique after CVAD flushing or access:
   - Positive-pressure needleless connectors: Do not clamp CVAD until after flush syringe is disconnected.
• Negative-pressure needleless connectors: Apply pressure to syringe barrel, close catheter clamp, then remove syringe.
• Neutral-pressure needleless connectors: Clamping sequence does not matter.
7. Use 1.2-micron filter for administration with lipid infusions and with three-in-one parenteral nutrition solutions.
8. Consult with pharmacist to help identify causative agents and solutions and avoid potential drug or solution incompatibilities.

Treatment

1. Rule out/resolve any mechanical causes, such as a clamped CVAD, kinked I.V. tubing, or an obstructed filter.
2. If unable to flush an implanted port, attempt reaccess and flushing.
3. Attempt positional changes. Instruct patient to cough or change position. It is possible that the catheter tip abuts the blood vessel, and a position change may result in aspiration of blood. However, if this is a persistent problem, radiographic evaluation of catheter placement is indicated.
4. If mechanical causes are ruled out, intervention is based on the suspected cause of occlusion.
5. Catheter salvage is always preferred over catheter replacement.
6. For suspected precipitate formation, collaborate with the LIP for an order to treat and follow organizational procedures. The following solutions can be instilled into the CVAD in a volume that approximates the CVAD internal priming volume; the solution is left in the catheter for at least 60 minutes before it is withdrawn (Hill et al., 2013):
   • Instill 0.1 N hydrochloric acid to dissolve low-pH drug precipitates (e.g., vancomycin).
   • Instill sodium bicarbonate 8.4% to dissolve high-pH drug precipitates (e.g., phenytoin).
   • Instill 70% ethanol or sodium hydroxide to restore patency to catheters with suspected buildup of lipids.
   • Be aware that use of alcohol solutions such as ethanol or ethyl alcohol may damage catheters made of some types of polyurethane and that manufacturer’s instructions should be reviewed and followed.
7. For suspected thrombotic occlusion, collaborate with the LIP for an order to treat and follow organizational procedures.
   • Obtain an order for alteplase (low dose, e.g., 2mg/2mL concentration).
   • Perform hand hygiene and maintain aseptic technique throughout procedure.
   • Prepare alteplase in 10-mL syringe; reconstitute per manufacturer’s directions or use as pharmacy prepared (preferred).
   • Disinfect the needleless connector with antiseptic solution.
   • Attach alteplase syringe.
For inability to withdraw blood or sluggish flow, unclamp catheter and gently instill medication into CVAD.

With a complete occlusion, never push medication into CVAD; a “negative-pressure” method must be used.

Unclamp CVAD and, while holding syringe vertical, gently aspirate until plunger reaches approximately 8-mL mark, then slowly release plunger. This step may be repeated several times. The idea is to create a vacuum by aspirating air or catheter dead space to allow alteplase into the CVAD.

Clamp catheter, and secure device to patient and label “DO NOT USE.”

Allow the agent to dwell in catheter.

Recommendations for alteplase: Allow to dwell for 30 minutes and then assess for blood return. If successful, discard aspirated blood, flush CVAD with 0.9% sodium chloride solution, and resume infusion as ordered.

If not successful, allow alteplase to dwell for another 90 minutes and reassess for blood return. If not successful, a second dose may be used.

**Thrombolytic Administration**

It is important to understand the process of fibrinolysis or dissolving of the fibrin clot. In the presence of a blood clot, tissue plasminogen activator (tPA) is released. The tPA converts plasminogen to plasmin, which is the activated enzyme that breaks down the blood clot. The drug alteplase is a recombinant form of the naturally occurring tPA. Cathflo Activase® (alteplase) (Genentech, 2017) is currently the only U.S.-approved thrombolytic for catheter clearance; it is safe for use in all health-care settings, including the home (Hill et al., 2013). The dosage is 2 mg/mL, and it is instilled into the occluded CVAD. There is a dosage adjustment for pediatric patients weighing less than 30 kg; the dosage is adjusted to 110% of the internal lumen volume of the occluded catheter, not to exceed 2 mg/2 mL (Genentech, 2017).

**Catheter-Associated Venous Thrombosis**

**Description and Etiology**

Venous thrombosis, or formation of a blood clot in a vein, may occur in the veins of the upper extremities or chest, most often associated with presence of a CVAD or a diagnosis of cancer. In fact, the incidence of venous thrombosis is increasing, very likely because of increasing use of CVADs (Grant et al., 2012). Based upon a review of pediatric literature, the rate is also increasing in children, again linked to increasing use of CVADs (Jaffray, Bauman & Massicotte, 2017). The consequences of catheter-associated venous thrombosis include symptomatic pulmonary embolism (one in 10 cases), recurrent deep vein thrombosis (2% annual rate), and postthrombotic syndrome (about one-fifth of cases) (Grant et al., 2012). Postthrombotic syndrome is a late complication of venous thrombosis with symptoms of chronic pain, edema, and mobility issues in the affected extremity.
Virchow’s triad remains the time-honored pathophysiological explanation for the formation of venous thrombosis (Capriotti & Frizzell, 2016). Three factors are implicated in the development of a thrombus:

1. Vessel wall damage or injury. Causes include surgery or trauma, the presence of a central venous catheter, and administration of irritating solutions. Injury to the vessel wall at the catheter entry site can be related to catheter infection or exposure of the vessel wall to irritating infusates such as parenteral nutrition solutions and chemotherapeutic agents. Catheter malposition as discussed earlier may contribute to venous thrombosis.

2. Alterations in the flow of blood. Causes include venous stasis often associated with immobility, obstruction of the veins, heart failure, and varicosities. The presence of a CVAD impacts blood flow within the blood vessel.

3. Hypercoagulability of the blood. Contributing conditions include a decrease in coagulation inhibitors (e.g., antithrombin III), pregnancy, malignancy, and/or postoperative states.

There are a number of patient factors that increase the risk for venous thrombosis as summarized in the INS Standards, which are based upon a review of the literature (Gorski et al., 2016a, p. S112), including:

- History of deep vein thrombosis
- Chronic diseases associated with a hypercoagulable state including cancer, diabetes, irritable bowel syndrome, and end-stage renal failure
- Surgery and trauma
- Genetic coagulation abnormalities (e.g., factor V Leiden, prothrombin mutation)
- Pregnancy or use of oral contraceptives, surgery, and immobility
- History of multiple CVADs, especially with difficult or traumatic insertion and the presence of other intravascular devices
- Age extremes (young children, older adults); children who have a CVAD and are at the highest risk include those with malignancies, systemic infection, congenital heart disease, gastrointestinal failure, sickle cell disease, those in an intensive care unit, and those who have suffered a traumatic injury (Jaffray, Bauman & Massicotte, 2017).

There are also CVAD-related factors that increase risk, such as:

- PICCs are associated with higher risk compared with other types of CVADs; specific risk factors include insertion into smaller veins and arm movement, insertion sites in the antecubital fossa versus placement in the mid-upper arm
- Suboptimal CVAD tip location in the mid to upper portion of the SVC associated with greater rates of CVAD-associated thrombosis
- CVADs with larger outer diameters
Signs and Symptoms

- Pain in extremity, shoulder, neck, chest
- Edema, erythema in extremity, shoulder, neck, chest
- Dilated/engorged superficial veins
- Low-grade fever
- Difficulty with neck or extremity motion
- Evidence of catheter occlusion as previously discussed (i.e., inability to withdraw blood, sluggish infusion)

Prevention

1. Place CVADs in patients only when they are definitively indicated.
2. Select the smallest-diameter catheter appropriate for infusion needs. For PICCs, the catheter-to-vein ratio should be 45% or less (Gorski et al., 2016a p. S112).
3. Ensure/verify proper catheter tip placement in the SVC near its junction with the right atrium.
4. Promptly remove CVADs when they are no longer needed.

EBP In a prospective study of PICC placements by a specially trained team, the rate of catheter-associated venous thrombosis significantly decreased with an increase in placement of single-lumen 5 Fr and smaller-gauge 5 Fr triple-lumen PICCs over a 3-year period; previously 6 Fr catheters were used. The PICC venous thrombosis rate improved to 1.9% from 3.0% (P < 0.04) (Evans et al., 2013).

Treatment

Report signs and symptoms of catheter-associated venous thrombosis to the LIP promptly. Ultrasound is most often used to diagnose the presence of thrombosis. Based upon guidelines from the American College of Chest Physicians (Kearon et al., 2012), evidence-based treatment guidelines include:

1. Initial treatment with low-molecular-weight heparin, unfractionated heparin, or fondaparinux and long-term treatment for at least 3 months with a vitamin K antagonist (e.g., warfarin). The purpose is to prevent any extension of the thrombus and pulmonary embolism.
2. The CVAD can remain in place if it is functioning and is necessary for the patient's plan of care.

NOTE: Hypercoagulability increases the risk of clot or thrombus formation in either the arterial or venous circulation.

Table 9-6 summarizes CVAD-associated complications.
Table 9-6  Summary of Complications of Central Venous Access

<table>
<thead>
<tr>
<th>Complication and Cause</th>
<th>Signs and Symptoms</th>
<th>Treatment</th>
<th>Prevention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pneumothorax/ hemothorax:</td>
<td>Sudden chest pain or shortness of breath during procedure, crunching sound on auscultation, tachycardia, hypotension, decreased or absent breath sounds, bleeding into pleural cavity, hemoptysis</td>
<td>Administer oxygen. Chest tube may be inserted. Monitor vital signs. Apply pressure over the site.</td>
<td>Use of ultrasound-guided CVAD placement Radiographic verification of placement Highly skilled professional inserters Careful assessment during insertion</td>
</tr>
<tr>
<td>Catheter Malposition</td>
<td>Symptoms associated with pneumothorax, hemothorax as above Arm/neck swelling Change in catheter function (i.e., ability to flush, infuse) Ear &quot;gurgling&quot; Palpitations Change in external catheter length (between insertion site and catheter hub)</td>
<td>Notify LIP of signs/symptoms. Catheter may not require removal; interventional radiologist may be able to reposition. Rapid flush may sometimes correct malposition with single-lumen reposition.</td>
<td>Ultrasound-guided CVAD placement Radiographic confirmation of tip before use Highly skilled professional inserters Careful care and maintenance to avoid catheter dislodgement</td>
</tr>
<tr>
<td>Pinch-off Syndrome: CVAD inserted via the percutaneous subclavian site is compressed by the clavicle and the first rib; results in mechanical occlusion; can result in complete or partial catheter transaction and embolization</td>
<td>Intermittent and positional occlusion Difficulty flushing, infusing, or aspirating CVAD Occlusion relieved by specific postural changes (often relieved by rolling the shoulder or raising the arm) Infraclavicular pain or swelling</td>
<td>Remove the catheter.</td>
<td>Ultrasound-guided CVAD placement Radiographic confirmation of tip before use Highly skilled professional inserters</td>
</tr>
<tr>
<td>CVAD Associated Skin Impairment</td>
<td>Skin lesions/blisters Erythema Pruritis Weeping/oozing/ drainage in area under dressing</td>
<td>Alternative dressing product/antiseptic agent Referral to wound care specialist</td>
<td>Skin barrier solution Allow antiseptic to fully dry before dressing placement</td>
</tr>
<tr>
<td>Nonthrombotic Occlusion: Precipitation of total parenteral nutrition admixtures and drug-to-drug or drug-to-solution incompatibilities</td>
<td>Sluggish flow rates, total occlusion, inability to flush or obtain blood withdrawal</td>
<td>Attempt to restore patency using appropriate solution (e.g., HCl, sodium bicarbonate, or 70% ethanol).</td>
<td>Saline flush before and after each I.V. drug administration Use of 1.2-micron filter for three-in-one parenteral nutrition solutions and lipid infusions</td>
</tr>
</tbody>
</table>

Continued
Chapter 9  Complications of Infusion Therapy

NURSING POINTS OF CARE

COMPLICATIONS ASSOCIATED WITH CENTRAL VASCULAR ACCESS

Nursing Assessment

- Assess infusion system and CVAD regularly for:
  - Integrity of the infusion system: all connections secure, accuracy of infusion rate, expiration dates of the infusate, dressing, administration set
  - Signs and symptoms of complications: redness, swelling, drainage, tenderness, pain at insertion site, in extremity or chest based on placement site; evidence of outward catheter migration
  - Dressing integrity
  - Catheter stabilization
  - Catheter patency
  - Confirm tip placement in the SVC near junction with right atrium.
  - Obtain baseline vital signs and monitor for changes.
  - Review patient cardiovascular and neurological history.
  - Assess for age-related risks.
  - Determine baseline weight.
  - Monitor intake and output, vital signs, and pain level.
  - Monitor for adverse/side effects of the infusion therapy.

Key Nursing Interventions

1. Assist with insertion as appropriate, including correct positioning of patient and adherence to central line bundle interventions.
2. Maintain competency if performing PICC insertion.
3. Perform hand hygiene prior to and after any CVAD-related care.
4. Maintain aseptic technique with peripheral catheter placement and access procedures.
5. Use best practice for care and maintenance of catheters.
6. Maintain the integrity of the CVAD dressing.
7. Adhere to aseptic technique with all CVAD-related procedures.
8. Use no smaller than a 10-mL syringe to flush all CVADs.
9. Perform interventions as indicated (e.g., positioning, oxygen).
10. Administer I.V. medications at prescribed rate; use an EID as appropriate.

**AGE-RELATED CONSIDERATIONS**

**The Pediatric Client**

It is important to assess the infant or child early during the hospital stay and to determine the most appropriate VAD for meeting ongoing infusion needs. All complications discussed for the adult client can occur with the pediatric client. The following guidelines focus on the pediatric patient.

- Infiltration and extravasation are common complications in pediatric infusion therapy. An infiltration scale was developed to assess edema based on percentage of swelling in relation to the size of the extremity (Pop, 2012).
- Restricted joint movement is considered an important sign of infiltration in infants (Talbot & Rogers, 2011).
- Catheter stabilization and site protection are essential as younger children are less likely to understand the importance of not manipulating the insertion site (Doellman, 2014).
- Infusion rates must be carefully monitored to avoid fluid volume overload as the margin for error is small (Doellman, 2014).
- As children grow, periodic radiographic evaluation for catheter tip placement is required (Doellman, 2014).
- The catheter insertion site must be visible, and roller bandages should not be placed around or above the insertion site (Doellman, 2014).

**The Older Adult**

- Hematomas and ecchymoses are frequently seen in elderly persons. Fragile veins are easily injured.
- Age-related changes are most pronounced in those 85 years of age and older. Some examples of changes include increased risk of nephrotoxic injury (renal toxicity) and adverse reactions from drugs; age-related decreases in kidney mass, blood flow, and glomerular filtration rate; and decreased drug clearance (Smith & Cotter, 2012).
- Polypharmacy, common in the older adult population, increases the risk for adverse events and drug interactions.
- The risk of fluid overload and subsequent pulmonary edema is especially increased in older patients with cardiac disease.
- Be alert to the potential presence of infection when even low-grade temperature elevations appear for short periods.
The nursing process is a six-step process for problem-solving to guide nursing action (see Chapter 1 for details on the steps of the nursing process). The following table focuses on nursing diagnoses, nursing outcomes classification (NOC), and nursing interventions classification (NIC) for patients with local and systemic complications of infusion therapy. Nursing diagnoses should be patient specific and outcomes and interventions individualized. The NOC and NIC presented here are suggested directions for development of specific outcomes and interventions.

### Complications of Infusion Therapy

#### Home Care Issues

Home-care nurses must be aware of the risks associated with infusion therapy and peripheral and central vascular access devices (CVADs). The risk of catheter-related infections among home-care patients is low, whereas catheter occlusion problems are not uncommon. Many home-care patients have VADs in place for long periods because of extended infusion therapy needs. Because nurses are in the patient's home only intermittently, it is critically important that patients understand the signs and symptoms of potential complications (Gorski, 2017). Although home-care nurses assess catheter sites and function at each home visit, patient education is critical and must address the importance of regular site assessment and what to report. The patient should be provided with information about the VAD, potential risks, and instruction to promptly report signs or symptoms such as pain, swelling, or redness. Potential problems and complications encountered in home infusion therapy include:

- Mechanical problems
- Occlusion problems
- Catheter-associated venous thrombosis
- Malfunction of EIDs

#### Patient Education

- Instruct the patient to report any signs or symptoms of common local complications (e.g., redness, swelling, pain at site).
- Instruct the patient to report any interruption in flow rate.
- Instruct the patient on the purpose of the EID.
- Teach the client and family the symptoms of infection that should be promptly reported to the medical caregiver.

#### Nursing Process

The nursing process is a six-step process for problem-solving to guide nursing action (see Chapter 1 for details on the steps of the nursing process). The following table focuses on nursing diagnoses, nursing outcomes classification (NOC), and nursing interventions classification (NIC) for patients with local and systemic complications of infusion therapy. Nursing diagnoses should be patient specific and outcomes and interventions individualized. The NOC and NIC presented here are suggested directions for development of specific outcomes and interventions.
Chapter 9  Complications of Infusion Therapy

### Chapter Highlights

- Complications may be local or systemic; some complications are associated specifically with CVADs.
- Use of evidence-based preventative interventions is critical. Today, the attitude and expectation are that there should be no potentially preventable complications.
- Local complications include hematoma, phlebitis/thrombophlebitis, infiltration/extravasation, local infection, nerve injury, and venospasm.
- Some local complications, for example, exit site infection, can progress to systemic complications including a BSI.

<table>
<thead>
<tr>
<th>Nursing Diagnoses Related to Complications</th>
<th>Nursing Outcomes Classification (NOC)</th>
<th>Nursing Interventions Classification (NIC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anxiety (mild, moderate, or severe) related to: Threat to change in health status or situational crisis</td>
<td>Anxiety level; anxiety level self-control</td>
<td>Anxiety reduction (techniques such as use of a calm, reassuring approach, explaining all procedures)</td>
</tr>
<tr>
<td>Excess fluid volume related to compromised regulatory mechanism; excess fluid intake; excess sodium intake</td>
<td>Fluid balance, hydration</td>
<td>Fluid monitoring, fluid management</td>
</tr>
<tr>
<td>Impaired gas exchange related to: Alveolar-capillary membrane changes; ventilation-perfusion imbalance (e.g., pneumothorax)</td>
<td>Respiratory status, ventilation</td>
<td>Acid-base management; Airway management (monitor blood gases and hemoglobin levels)</td>
</tr>
<tr>
<td>Pain, acute, related to: biological injury (e.g., peripheral vascular inflammation, edema, CVAD-associated venous thrombosis); chemical injury (e.g., extravasation)</td>
<td>Pain control</td>
<td>Pain management, analgesic administration</td>
</tr>
<tr>
<td>Infection risk of related to: Environmental exposure to pathogens; immunosuppression, invasive procedures</td>
<td>Infection control, risk control and detection</td>
<td>Infection control; infection protection</td>
</tr>
<tr>
<td>Protection ineffective related to: Abnormal blood profiles, pharmaceutical agents, extremes of age</td>
<td>Blood coagulation, immune status</td>
<td>Bleeding precautions, infection prevention, infection protection</td>
</tr>
<tr>
<td>Skin integrity, impaired, external related to external factors: VAD; irritation from I.V. solution; chemical injury (extravasation)</td>
<td>Tissue integrity: Skin</td>
<td>Skin surveillance, wound care, risk identification</td>
</tr>
<tr>
<td>Decreased cardiac tissue perfusion risk for, related to: Arterial or venous blood flow exchange problems, hypovolemia, decreased systemic vascular resistance related to sepsis</td>
<td>Circulation status, Tissue perfusion: Cardiac; vital signs</td>
<td>Cardiac care, cardiac precautions, embolus precautions, vital signs monitoring and shock management: cardiac</td>
</tr>
</tbody>
</table>

Sources: Ackley, Ladwig, & Makic, 2017.
Phlebitis may result from bacterial, chemical, or mechanical causes. Infiltration is also frequently encountered and may be a minor or a major complication associated with tissue and/or nerve damage. Infiltration of a vesicant medication is called extravasation. Nerve injuries are often preventable by avoiding sites that are associated with increased risk due to the proximity of the nerves to veins. Systemic complications including BSI, air embolism, circulatory overload, and speed shock are largely preventable. Insertion-related CVAD complications including primary CVAD malposition, pneumo- and hemothorax, and pinch-off syndrome are in many cases preventable when technology (e.g., ultrasound) is used and when highly skilled and competent clinicians place the catheters. Additional CVAD complications that can occur during catheter dwell time include:

- Secondary malposition (tip migration)
- CVAD associated skin impairment
- Catheter occlusion as a result of mechanical, precipitation, and/or thrombotic causes
- Catheter-associated venous thrombosis

Thinking Critically: Case Study

A 40-year-old woman with insulin-dependent diabetes mellitus is familiar with her disease but does not take care of herself. She is currently admitted with an infected plantar ulcer and had a transmetatarsal amputation. She was discharged home on a regimen of I.V. antibiotics via a PICC, with home care follow-up.

Case Study Questions

1. What potential complications should the home-care nurse be alert for?
2. What documentation needs to be addressed at every visit?
3. What patient education needs to be reinforced at home?

Media Link: Chapter post tests and answers are provided on DavisPlus, along with case studies and critical thinking activities.

References


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Chapter 10
Infusion Medication Safety, Methods, and Routes

LEARNING OBJECTIVES
After completing this chapter, the reader will be able to:
1. Define terminology related to infusion medication methods and routes.
2. Discuss advantages and risks associated with I.V. medication administration.
3. Describe safe injection practices.
4. Identify interventions aimed at reducing risk of tubing and catheter misconnections.
5. Identify three types of drug incompatibility.
6. Describe potential consequences of drug adsorption.
7. Identify and describe the four categories of I.V. drug delivery.
8. Discuss safety issues related to the use of patient-controlled analgesia.
9. Describe advantages of and indications for subcutaneous medication and fluid infusion.
10. List potential subcutaneous infusion sites.
11. Describe advantages of and indications for intraosseous medication infusion.
12. Identify sites used in intraosseous access.
13. Differentiate between the epidural and the intrathecal space.
14. List medications that may be given via an intraspinal route.
15. Identify signs and symptoms for medication-associated complications of the intraspinal infusion route.

Glossary

Admixture Combination of two or more infusion medications/solutions
Adsorption Adhesion by a liquid or gas to the surface of a solid
Bolus Concentrated medication or solution given rapidly over a short period of time
Chemical incompatibility Degradation of a drug as a result of change in the molecular structure or pharmacological properties of a substance, which may or may not be visually observed
Compatibility  Capable of being mixed and administered without undergoing undesirable chemical or physical changes or loss of therapeutic action
Delivery system  A product that allows for the administration of medication
Distribution  Process of delivering a drug to the various tissues of the body
Drug interaction  An interaction between two drugs; also, a drug that causes an increase or decrease in another drug’s pharmacological effects
Epidural  A potential space located outside the dura mater, which is the most external protective membrane surrounding the spinal cord
High-alert medications  Medications associated with increased risk of causing patient harm when used in error
Hypodermoclysis  Administration of hydration fluids into the subcutaneous tissue
Incompatibility  Chemical, physical, or therapeutic reaction that occurs among two or more drugs or between a drug and the delivery device
Independent double check  Procedure in which 2 clinicians working apart from each other separately check each component of the medication including checking the order, calculating the dose, and comparing the results with the actual medication product (e.g., label).
Intermittent infusion  I.V. therapy administered at prescribed intervals
Intraosseous (IO)  Route by which fluids and medications are delivered to the vascular system by percutaneous insertion of a needle into the marrow cavity of a bone
Intraspinal  Spaces surrounding the spinal cord, including the epidural and intrathecal spaces
Intrathecal  Space between the arachnoid mater and the pia mater, which contains the cerebrospinal fluid; also called the subarachnoid space
I.V. push  Administration over a short period of time (minutes) of medication in a syringe directly into the vascular access device or through the injection port of an administration set
Metered volume chamber  A small container (i.e., chamber) incorporated into the I.V. administration set into which medication can be added to the primary I.V. solution; the chamber may contain from 10 to 150 mL of fluid
Patient-controlled analgesia (PCA)  A drug delivery system that dispenses a preset dose of a narcotic analgesic upon activation by the patient (e.g., pushing a button on an electronic infusion device); PCA is most commonly used with I.V. analgesic infusion but may also be used with subcutaneous and epidural infusions
Physical incompatibility  A reaction between two or more medications resulting in changes in color, haziness, turbidity, or precipitate or gas formation; usually a visible reaction
Single-dose vial  Medication bottle that is hermetically sealed with a rubber stopper and is intended for one-time use; usually does not contain a preservative
Therapeutic incompatibility  Undesirable effect occurring within a patient as a result of two or more drugs being given concurrently
Introduction

Infusion medications may be administered by several routes that are described in this chapter. The I.V. route is by far the most common. Medications and solutions may also be administered via the subcutaneous (SC) tissue. SC administration is a common way to administer opioid analgesics in the palliative care or hospice patient. Many other medications and hydration fluids also may be administered subcutaneously. The intraosseous (IO) route is a quick means to vascular access in emergent care for delivery of critical care medications and fluids. The intraspinal route may be used to deliver a variety of anesthetic, analgesic, and other medications for patients in acute care and for those with longer-term needs beyond the hospital setting. Other less common and very specialized routes are used to administer chemotherapy, including the intravesicular route for bladder cancer, the intraperitoneal route, and the intra-arterial route for chemotherapy administration directly into an organ (e.g., brain, liver, head, neck, pelvis) (Polovich, Olsen, & LeFebvre, 2014). Because they are so specialized, they are not addressed in this text.

Safe Delivery of Infusion Therapy

Standards of Practice

The Infusion Therapy Standards (Gorski et al., 2016) identify some general requirements aimed at safe administration of infusion medication, including:

- Review of information regarding the prescribed medication/solution, including indications, dosing, acceptable infusion routes/rates, compatibility data, and adverse/side effects for appropriateness, prior to administration.
- Performance of a medication reconciliation at each care transition and when a new medication(s) is ordered to reduce the risk of medication errors, including omissions, duplications, dosing errors, and drug interactions.
- Performance of an independent double check by two clinicians for an organization’s selected high-alert medications that pose the greatest risk of harm.
- Verification of the patient’s identity by using at least two identifiers prior to administration.
- Use of technology, when available, to verify medications prior to administration (e.g., barcode scanning, use of electronic infusion devices [EID] with dose-error reduction software (“smart pumps”).

Orders

Infusion administration begins with obtaining and verifying the orders from the licensed prescriber (e.g., physician, nurse practitioner, physician assistant). There is a great potential for patient harm and death from errors related to infusion medications. This is because the effects of an infusion are immediate, and it is difficult, if not impossible, to reverse the pharmacological effects once administered. As a hospital best practice recommendation, the Institute for Safe
Medication Practices (ISMP, 2017) recommends that all appropriate antidotes, reversal agents, and rescue agents be readily available (e.g., naloxone for opioid toxicity, epinephrine for anaphylaxis). Errors are known to occur at various times, such as during prescribing, storage, preparation, dispensing, administration, and monitoring. To reduce the risk for errors:

- Weigh each patient as soon as possible on admission and during each outpatient/emergency department encounter. Do not use “stated” or “estimated” or “historical” weights. This is a best practice recommendation from the ISMP (2017). The rationale for this recommendation is that many medications are weight based.
- Verify the completeness of the order. Orders should include:
  - I.V. medication dosage, route, frequency or time of administration, special considerations
    Example: 1000 mg vancomycin I.V. every 12 hours; obtain serum creatinine and vancomycin trough levels twice per week.
  - Standardized dosing protocols should be used for emergency drugs and high-alert medications.
- Use verbal orders only when medically necessary.
- Use a standardized “read-back” of the order when accepting a verbal or telephone order. Note that telephone orders are regularly taken in alternate sites (e.g., home care and long-term care facilities) by necessity because physicians are generally not available on-site.
- Accept only abbreviations approved by the organization.
- Review the order for appropriateness of the prescribed therapy in relation to the patient’s age, condition, type of vascular access device (VAD), dose, rate, and route of administration.
- Inspect the infusate to ensure that it is properly labeled, that there is no evidence of leakage/discholoration, that it is the right drug or solution, that the dose is correct, that the expiration or beyond-use date has not passed, and that the drug or solution has been properly stored.
- Verify the patient’s identity using two independent identifiers before initiating the infusion.

**Compounding of Medications**

Infusion medications and solutions that are compounded and prepared in a central pharmacy where accuracy and sterility can be met are used, in accordance with United States Pharmacopeia (USP) <797> (USP, 2008). The USP details procedures and requirements for compounding sterile preparations and sets standards applicable to all practice settings in which sterile preparations are compounded. These standards have been widely adopted, are enforced by many state boards of pharmacy, and may be used by accreditation organizations (e.g., The Joint Commission [TJC]) in surveys. Of note, the USP <797> is currently undergoing revision.

The INS Standards (Gorski et al., 2016, p. S39) specifically state that the clinician administer pharmacy-prepared or commercially available infusion products whenever possible. There are situations where the nurse must reconstitute
medications. An example is the thrombolytic medication alteplase (CathFlo Activase), which is commonly used to “declot” central lines. In many hospital settings, the pharmacy mixes the drug and transports it to the nursing unit; however, in other hospitals and most often in alternate care settings (e.g., home care), the nurse will reconstitute the drug. Referred to as an immediate-use compounded sterile preparation (CSP) by the USP, the medication must be started within 1 hour of preparation or be discarded (USP, 2008). As a best practice, the Institute for Safe Medication Practices (ISMP, 2017) recommends an independent double check verification to ensure that the proper ingredients (medication/diluent) are added, including the proper volume of each ingredient prior to its addition to a final container.

Attention to aseptic technique is critical when preparing immediate-use medications and should include the following safe injection practices as defined by the Centers for Disease Control and Prevention (CDC) (n.d.):

- Use aseptic technique to avoid contamination of sterile injection equipment.
- Do not administer medications from a syringe to multiple patients, even if the needle or cannula on the syringe is changed. Needles, cannulae, and syringes are sterile, single-use items; they should not be reused for another patient or for accessing a medication or solution that might be used for a subsequent patient.
- Use fluid infusion and administration sets (i.e., I.V. bags, tubing, and connectors) for one patient only and dispose appropriately after use. Consider a syringe or needle/cannula contaminated once it has been used to enter or connect to a patient’s I.V. infusion bag or administration set.
- Use single-dose vials for parenteral medications whenever possible.
- Do not administer medications from single-dose vials or ampules to multiple patients or combine leftover contents for later use.
- If multidose vials must be used, both the needle or cannula and syringe used to access the multidose vial must be sterile.
- Do not keep multidose vials in the immediate patient treatment area and store in accordance with the manufacturer’s recommendations; discard if sterility is compromised or questionable.
- Do not use bags or bottles of I.V. solution as a common source of supply for multiple patients.

**Tubing and Catheter Misconnections**

The issue of tubing and catheter misconnections, that is, the accidental or intentional connection of two devices that are not compatible, has received much attention over the years. Many administration sets have Luer connections that allow the linkage of tubing that should not be connected. The risk is especially great in hospitalized patients who have multiple catheters, tubes, and drains, which all appear similar. Examples of misconnections include I.V. solutions connected to epidural catheters and vice versa, enteral feeding sets connected to a central VAD (CVAD), and oxygen tubing connected to an I.V. port (U.S. Food and Drug Administration [FDA], 2017). New design standards are being
developed for tubing connectors for high-risk medical applications (e.g., enteral, respiratory, neuraxial), so that unrelated devices cannot connect with each other.

For nurses who work in high risk settings, such as intensive care, patients may receive multiple continuous I.V. infusions, most often via several EIDs. The visual and physical complexity of multiple I.V. containers, pumps, administration sets, and I.V. poles can be overwhelming. The risk of mixing up I.V. rates, interruptions in therapy during transitions in therapies, and infection control risks due to multiple accesses to the I.V. system is great (AAMI Foundation, 2016).

To improve safety and reduce the risk for misconnections and errors in infusion administration, implement the following:

- Trace all catheters/administration sets/add-on devices between the patient and the container before connecting or reconnecting any infusion device, at each care transition to a new setting or service, and as part of the hand-off process (Gorski et al., 2016, p. S126).
- Never force connections; when effort is needed to make a connection, there is a good chance that the connection should not be made.
- Use only adapters that are clearly indicated for a specific application. Additionally, the need for an adapter may mean that the connection should not be made.
- Label high-risk catheters (e.g., epidural, intrathecal, arterial).
- Label primary I.V. administration sets in 2 locations; near the EID but not on it and just above the injection port closest to the patient using preprinted labels with a standardized format (AAMI Foundation, 2016)
  - Distinguish the injection port used for I.V. push medications by applying a visually prominent and different label (AAMI Foundation, 2016)
  - Separate I.V. infusions and minimize tangled tubings and align the I.V. container with the corresponding EID/EID channel; use patient gowns with snaps, ties, or Velcro at the shoulder (AAMI Foundation, 2016)
  - Route lines (e.g., tubes, catheters) with different purposes in unique and standardized directions (e.g., route I.V. lines toward the patient's head, route enteral feeding lines toward the patient's feet) (Gorski et al., 2016, p. S126).
- Instruct the patient, caregivers, and unlicensed assistive personnel to obtain assistance from licensed staff whenever there is a real or perceived need to connect or disconnect devices or infusions (exception: home-care patients/caregivers who are competent and independent in infusion administration) (Gorski et al., 2016, p. S126).
- Never use a standard Luer syringe for oral medications or enteral feedings. The ISMP has specified that oral liquids not commercially available as a unit dose product be dispensed by the pharmacy in an oral syringe (marked “oral use only”) as a best practice (ISMP, 2017).
Principles of I.V. Medication Administration

Advantages

The advantages of administering fluids and medications via the I.V. route include (1) direct access to the circulatory system, (2) a route for administration of fluids and drugs to patients who cannot tolerate oral medications, (3) a method of instant drug action, and (4) a method of instant drug administration termination. This route offers advantages over the SC, intramuscular (IM), and oral routes in certain clinical situations (Table 10-1).

Drugs that cannot be absorbed by other routes because of the large molecular size of the drug or destruction of the drug by gastric secretions can be administered directly to the site of distribution, the circulatory system, with I.V. infusion. Drugs with irritating properties that cause pain and trauma when given via the IM or SC route can be given intravenously. When a drug is administered intravenously, there is rapid drug action, which is an advantage in emergency situations. The I.V. route also provides for instant drug termination if sensitivity or adverse reactions occur. This route provides for control over the rate at which drugs are administered. Prolonged action can be controlled by administering a dilute medication infusion intermittently over a prolonged time period.

I.V. medications are administered to obtain rapid therapeutic or diagnostic responses or as delivery routes for solutions or medications that cannot be delivered by any other route. Nurses administering the solution or medication are accountable for achieving effective delivery of prescribed therapy and for evaluating and documenting deviations from an expected outcome; responsibility includes the implementation of corrective action.

**INS Standard:** The clinician reviews information regarding the prescribed medication/solution including indications, dosing, acceptable infusion routes/rates, compatibility data, and adverse reactions/side effects for appropriateness prior to administration (Gorski et al., 2016, p. S125).

<table>
<thead>
<tr>
<th>Table 10-1</th>
<th>Advantages and Disadvantages of I.V. Medication Administration</th>
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<tbody>
<tr>
<td><strong>Advantages</strong></td>
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<tr>
<td>1. Direct access to the circulatory system.</td>
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<tr>
<td>2. A route for drugs that irritate the gastric mucosa.</td>
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<tr>
<td>3. A route for instant drug action.</td>
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<td>4. A route for delivering high drug concentrations.</td>
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<tr>
<td>5. Instant drug termination if sensitivity or adverse reaction occurs.</td>
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<tr>
<td>6. Provides a route of administration in patients in whom use of the gastrointestinal tract is limited/contraindicated.</td>
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<tr>
<td><strong>Disadvantages/Risks</strong></td>
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<tr>
<td>1. Risk for drug interactions due to drug stability issues or incompatibilities.</td>
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<tr>
<td>3. Speed shock if administered too rapidly.</td>
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<tr>
<td>4. Risk for VAD complications (e.g., infiltration/extravasation/phlebitis).</td>
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</table>
Risks

Despite the advantages of I.V. medication, there are also risks not found with other medication administration routes (see Table 10-1). The advantage (as discussed earlier) of immediate, systemic effects with I.V. infusion is also a risk in the event of a drug administration error. As stated earlier, it is difficult, or impossible, to reverse the pharmacological effects after I.V. administration. Other risks specific to the administration of I.V. drugs include potential drug interactions; drug loss via adsorption of I.V. containers and administration sets; potential errors in compounding techniques; and the potential complications of speed shock, extravasation of vesicant drugs, and phlebitis (see Chapter 9).

Drug Stability and Compatibility

Drug Stability

Stability refers to the length of time that a drug retains its original properties and characteristics (Turner & Poole, 2014). Factors that affect stability include pH, number of additives in the solution (e.g., parenteral nutrition solutions contain many additives), dilution, time (e.g., some drugs, once mixed, are stable only for a few hours), light exposure, temperature, order in which additives are put into the solutions, and type of container (e.g., insulin adsorption in polyvinyl chloride [PVC] containers). The pH is one of the most important factors (Turner & Poole, 2014) because most drugs are stable in a very narrow pH range.

Drug Incompatibility

Incompatibility is an undesirable reaction that occurs between the drug and the solution, the container, or another drug (Turner & Poole, 2014). There are three types of drug incompatibility: physical, chemical, and therapeutic. Incompatibility may occur when:

- Several drugs are added to a large volume of fluid to produce an admixture
- Drugs in separate solutions are administered concurrently or in close succession via the same I.V. line
- A single drug is reconstituted or diluted with the wrong solutions
- One drug reacts with another drug’s preservative

Physical Incompatibility

A physical incompatibility refers to a visible reaction that occurs, such as changes in color, haziness, turbidity, precipitate formation, and gas formation. The most common type of physical incompatibility is precipitate formation.

Some precipitation may be microcrystalline (i.e., smaller than 50 microns) and not apparent to the eye. Use of a 0.22-micron inline filter reduces the amount of microcrystalline precipitates. Such particulate matter can result in occlusion of pulmonary capillaries.

The presence of calcium in a drug or solution increases the risk for precipitation if it is mixed with another drug. Ringer’s solution preparations contain calcium, so check carefully for compatibility before adding any drug to this solution. Other physical incompatibilities caused by insolubility include the
increased degradation of drugs added to sodium bicarbonate and the formation of an insoluble precipitate when sodium bicarbonate is combined with other medications in emergency situations.

The following are important recommendations regarding physical drug incompatibilities:

- Do not mix drugs prepared in special diluents with other drugs.
- When administering a series of medications, each drug should be prepared in a separate syringe/infusion container. This will lessen the possibility of precipitation. Insolubility may also result from the use of an incorrect solution to reconstitute a drug.
- Follow the manufacturer’s directions for reconstituting drugs and remember that pharmacy-prepared medications are preferred to reduce the risk of contamination and instability.

**NURSING FAST FACT!**

To prevent physical I.V. drug incompatibility during administration, best practice is to always flush the infusion device with 0.9% sodium chloride before and after each medication infusion. However, some drugs (e.g., amphotericin B) are not compatible with sodium chloride. In such cases, use 5% dextrose in water for flushing before and after administration. The dextrose should always be flushed from the catheter with 0.9% sodium chloride because the dextrose can provide nutrients supporting microbial growth if allowed to dwell in the catheter lumen (Gorski et al., 2016, p. S77).

**Chemical Incompatibility**

A chemical incompatibility involves the degradation of the drug, which may occur for a variety of reasons, for example, drug decomposition (Turner & Poole, 2014). It is differentiated from physical incompatibility in that the reaction may not be visible. The most common cause of chemical incompatibility is the reaction between acidic and alkaline drugs or solutions, which results in a pH level that is unstable for one of the drugs. A specific pH or a narrow range of pH values is required for the solubility of a drug and for the maintenance of its stability after it has been mixed.

**Therapeutic Incompatibility**

A therapeutic incompatibility is an undesirable effect that occurs in the patient as a result of two or more drugs being given concurrently. An increased therapeutic or a decreased therapeutic response is produced. This incompatibility may occur when therapy dictates the use of two antibiotics. For example, the effects of penicillin may be antagonized by bacteriostatic antibiotics such as chloramphenicol and erythromycin (Gahart, Nazareno, & Ortega, 2016).

Therapeutic incompatibility may go unnoticed until the patient fails to show the expected clinical response to the drug or until peak and trough levels of the drug show a lack of therapeutic levels. If an incompatibility is not suspected, the patient may be given increasingly higher doses of the drug in an
attempt to obtain the therapeutic effect. When more than one antibiotic is prescribed for intermittent infusion, it is generally best to stagger the time schedule so that each antibiotic can be infused individually.

**Adsorption**

Adsorption is the attachment of a liquid or gas to a solid surface. In infusion therapy, some infusion drugs and solutions adsorb to glass or plastic. With adsorption, the patient receives a smaller amount of the drug than was intended. The amount of adsorption is difficult to predict and is affected by the drug concentration, solution of the drug, amount of surface contacted by the drug, and temperature changes.

An example of adsorption is the binding of insulin to plastic and glass containers. The insulin rapidly adsorbs to I.V. containers and tubing until all potential adsorption sites are saturated. The potency of insulin may be reduced by at least 20% and possibly up to 80% before it reaches the vein (Gahart et al., 2016). Methods for reducing adsorption include use of additives such as albumin, electrolytes, vitamins, or other medications or use of a syringe pump that has less surface area for adsorption (Gahart et al., 2016). Another example of a medication that is readily adsorbed into PVC bags or administration sets is nitroglycerin. Non-PVC tubing and non-PVC or glass bottles should be used.

As discussed in Chapter 5, di(2-ethylhexyl)phthalate (DEHP), a known toxin, is a plasticizer used in making PVC bags soft and pliable. DEHP is lipophilic and can leach into lipid-based solutions. In the package inserts, many drug manufacturers recommend nonphthalate delivery systems. The INS Standards (Gorski et al., 2016, p. S85) recommend DEHP-free administration sets for administration of lipid-based infusates. Many companies are manufacturing nonphthalate I.V. bags and tubing to prevent this problem.

**Cultural and Ethnic Considerations: Drug Administration**

Genetic predispositions to different rates of metabolism cause some patients to be prone to overdose reactions to the “normal dose” of medication, whereas other patients are likely to experience a greatly reduced benefit from the standard dose of the medication.

In ethnic and cultural groups (e.g., Chinese Americans) that have a high incidence of glucose-6-phosphate dehydrogenase (G6PD) deficiency, which causes fragility of the red blood cells, administration of some drugs (e.g., analgesics, some antimicrobials) may result in anemia. Caffeine, a component of many drugs, is excreted more slowly by Asian Americans. Chinese Americans may also require smaller doses of certain drugs even after body weight and surface are taken into consideration (Chang, 2017).

**NURSING FAST FACT!**

- Be knowledgeable of the pharmacological implications relative to patient clinical status and diagnosis.
- Verify that all solution containers are free of cracks, leaks, and punctures.
I.V. Medication Administration

I.V. medications may be infused via four basic administration methods: continuous infusion, intermittent infusion, direct injection or I.V. push, and patient-controlled analgesia (PCA). Factors in the choice of administration method include the type of medication or I.V. solution, the patient’s condition, and the desired drug effects.

Continuous I.V. Infusions

A continuous infusion is given over several hours to several days or longer. Some examples of solutions or medications administered as a continuous infusion include parenteral nutrition, hydration fluids, and medications requiring constant plasma concentrations such as nitroprusside and dobutamine. EIDs are used to ensure an accurate flow rate. The ISMP (2017) recommends the use of EIDs with dose-error reduction software for all high-alert medication infusions.

**ADVANTAGES**

- Constant serum levels of medications are maintained.

**DISADVANTAGES**

- Potential for fluid overload
- Potential for incompatibilities between the infusion and any other I.V. medications administered through the same VAD or through a port of the administration set
- Accidental bolus infusion can occur if the medication is not adequately mixed with the solution.

Intermittent I.V. Infusions

Intermittent infusions are used with medications that are mixed in a smaller volume of fluid (e.g., 50 mL) and infused over a short period of time (e.g., 30–60 minutes) at regular intervals. For example, antibiotics are most often administered as intermittent infusions. Methods of delivering intermittent infusions include “piggyback” infusions, simultaneous infusions, metered volume chambers, and primary administration sets.

The piggyback infusion is a very commonly used method. An I.V. solution is attached to a primary administration set, which is the main tubing carrying the infusion from the container to the patient (see Chapter 5). A secondary administration set is attached to the primary set, entering the tubing at a port with a back check valve. When the drug infusion is completed, the primary I.V. solution then resumes. Although the primary infusion is interrupted during the secondary infusion, the drug from the intermittent infusion container comes in contact with the primary solution below the injection port; therefore, the drug and the primary solution must be compatible (Fig. 10-1A).

In a simultaneous infusion, the main I.V. solution and the drug I.V. solution are infused at the same time through a port near the I.V. catheter. A risk associated with this method is blood reflux back into the VAD when the secondary infusion of the medication is completed because no back check valve is used, as with a piggyback infusion set (Fig. 10-1B).
The metered volume chamber is used less often today and is most often used in pediatric settings. The primary solution is added to the chamber (may hold 100–150 mL; neonatal chambers 10–50 mL), and the medication is added to the chamber via a syringe (Fig. 10-2).

Finally, a small solution container of medication may be attached to a primary administration set and infused directly into the patient’s I.V. catheter; there is no secondary set. This method is often used in home-care settings and other
alternate sites. Use of an elastomeric infusion pump (see Chapter 5) is another way to deliver an intermittent medication through a primary set. The balloon of the reservoir holds the medication, and the preattached I.V. tubing is primed. When the clamp is opened, the medication is infused at a rate based on an integrated flow restrictor. This method is also commonly used in alternate sites for intermittent medication administration.

**ADVANTAGES**

- A larger drug dose can be administered at a lower concentration per milliliter than with the I.V. push method.
- Peak flow concentrations occur at periodic intervals.
- The risk of fluid overload is decreased.
- Metered volume chamber: The volume of fluid in which the drug is diluted can be adjusted.

**DISADVANTAGES**

- Increased drug concentration in the intermittent solution can cause vein irritation and phlebitis.
- The administration rate may not be accurate unless it is electronically monitored; too rapid a rate can potentially lead to speed shock and/or fluid overload.
- Primary administration set method: I.V. set changes can result in wasting a portion of the drug that remains in the I.V. tubing.
• Risk for incompatibility can occur if the administration set is not adequately flushed between medication administrations.

• Metered volume chamber:
  • A portion of the medication can be left in the tubing after the chamber empties.
  • Incompatibilities may develop when the chamber, which is usually within the primary line, is used for multiple drug deliveries.
  • Labeling of the chamber must coincide with the drug being delivered. To reduce the risk of medication errors when multiple drugs are delivered, the chamber must be labeled with each drug that is administered.

**NURSING FAST FACT!**
Consider the volume of fluid delivered with an intermittent infusion as part of the patient’s overall intake when calculating intake.

**NURSING FAST FACT!**
Drug incompatibility is a greater risk with the simultaneous infusion method.

**NURSING POINTS OF CARE**
**INTERMITTENT I.V. INFUSION DELIVERY**

• Ensure the compatibility of the I.V. solution and medication, both the solution in the primary system and the diluent in the secondary system.
• Assess the I.V. site and the patency of the catheter including verification of a blood return prior to infusion.
• Use the correct amount and type of diluent solution.
• Use the correct rate of administration.
• Determine the correct primary line port in which to infuse the medication.
• Affix the correct label to the secondary bag, with start date and hour, and discard date and hour and your initials.
• Calculate the amount of medication to be added to the volume-controlled set.
• High-alert medications: Use an independent double check process in accordance with organizational policy.

**I.V. Push**
Direct injection, or “I.V. push,” is the administration of I.V. medication in a syringe directly into the patient’s VAD or through the injection port of a continuous infusion. This method is used with drugs that require rapid serum concentrations. In the home-care setting, I.V. push is often used for selected antimicrobials, including
some in the cephalosporin group (e.g., ceftriaxone), and for medications such as furosemide or factor replacement for patients with hemophilia.

The Institute for Safe Medication Practices (ISMP, 2015) found a lack of established safety standards associated with the I.V. push method and published a compilation of safe practices. Some of the safety issues include:

- A lack of direction for the rate of I.V. push administration from drug resources or use of ambiguous terms such as “I.V. bolus” or “slow” I.V. push
- Use of commercially available prefilled flush syringes to prepare or reconstitute medications
- Lack of dedicated locations to prepare medications aseptically and wide variability in preparation and administration procedures
- Lack of review of safe I.V. injection practices during new hire orientation

It is important to recognize risks associated with I.V. push medications. Speed shock is a systemic reaction that occurs when a substance is rapidly introduced into the circulation (discussed further in Chapter 9). Symptoms include dizziness, facial flushing, headache, and medication-specific symptoms and can progress to chest tightness, hypotension, irregular pulse, and anaphylaxis.

A key recommendation from the ISMP (2015) is that I.V. push medications be prepared in a ready-to-administer form to minimize any manipulation of the syringe (e.g., no further diluting). It is also critical to administer the medication at the rate recommended by the manufacturer, with specific advice to use a watch or a clock with a second hand or with a digital display of minutes and seconds (see Fig. 10-3). The label on the medication syringe should indicate the rate (e.g., administer over 3 to 5 minutes); if the syringe is not labeled, the nurse should consult with the pharmacist. Refer to Procedures Display 10-1 at the end of this chapter.

**NURSING FAST FACT!**

Studies have shown frequent lapses in correct I.V. push administration, including the fact that nurses often administer I.V. push medications too rapidly (Carter, Gelchion, Saitta, & Clark, 2011).

**ADVANTAGES**

- Barriers of drug absorption are bypassed.
- The drug response is rapid and usually predictable.
- The patient is closely monitored during the full administration of the medication.

**DISADVANTAGES**

- Adverse effects occur at the same time and rate as therapeutic effects.
- Increased risk of adverse effects and toxicity because serum drug concentrations are sharply elevated.
- Speed shock is possible from too-rapid administration of medication.
NURSING POINTS OF CARE

I.V. PUSH MEDICATIONS

- In most cases, the medication should be prepared by the pharmacy. However, if mixing is required on the unit/in a home setting, use only single-use vials for mixing and diluting medication and employ aseptic technique and mix/dilute in accordance with manufacturer’s instructions for preparation and organizational procedures.
- Determine the amount of time needed to administer the medication.
- Identify any drug/solution incompatibilities with existing running infusions.
- Establish VAD patency by flushing the VAD with 0.9% sodium chloride (USP) and aspirating for a blood return before administration.
- Maintain aseptic technique.
- High-alert medications: Use an independent double check process with another clinician in accordance with organizational policy.
- Most medications are delivered slowly, between 1 and 10 minutes (example: morphine I.V. push delivery of 15 mg or a fraction thereof is recommended over 4–5 minutes; Gahart et al., 2016).
Patient-Controlled Analgesia

PCA is a method of pain management that allows the patient to deliver his or her own analgesic dose when needed. It is a common method of pain management, particularly in postoperative patient care. It is also used in palliative care and hospice care settings in the management of chronic pain. The goal of PCA is to provide the patient with good pain management with minimal sedation. Putting patients in control of their own pain management makes sense because only they know how much they are suffering. It is more desirable to use small doses of narcotics frequently than large doses of narcotics infrequently.

PCA infusion is delivered with a specific type of EID that is programmed to administer a prescribed amount of analgesic to the patient when activated by the patient pressing a button. PCA pumps may be programmed for only a dose on demand but may also be used in conjunction with a continuous basal infusion of drug, primarily in hospice and palliative care. There are ambulatory PCA pumps available for the home-care patient (See Chapter 5, Figure 5-34).

It is important to recognize that opioids are considered high-alert medications in acute care, community/ambulatory care, and long-term care by the Institute for Safe Medication Practices (ISMP, 2011, 2014, 2016a). The INS Standards recommend consideration for use of an independent double-check procedure prior to initiating the PCA and when the syringe/solution container, drug or rate is changed (Gorski et al., 2016). The Standards further state that “special attention should be given to drug, concentration, dose, and rate of infusion according to the order and as programmed into the EID, in order to reduce the risk of adverse outcomes and medication errors” (Gorski et al., 2016, p. S131).

Not all patients are good candidates for PCA. The patient must be able to cognitively understand the relationship between pain, activating the dose button, and achieving a goal of good pain control. Some patients are at greater risk for adverse outcomes. Patient risk factors for oversedation and respiratory depression associated with opioid use are listed in Table 10-2.

**INS Standard:** Assess the patient for the appropriateness of PCA therapy and the patient's comprehension of, and ability to participate in, the intended therapy (Gorski et al., 2016, p. S131).

The risks associated with “PCA by proxy” have been addressed in the literature (ISMP, 2016b). With PCA in general, no other person should be activating the drug dose. Well-meaning nurses and family members have delivered the PCA medication doses with results of oversedation, respiratory depression, and even death.
It is important to recognize that a basic safeguard of PCA is that the excessively sedated patient will be too sleepy to activate the dose; therefore, the risk for opioid-induced respiratory depression is minimized. This safeguard is lost if others are activating the PCA dose.

However, when the patient cannot actively participate in PCA, the patient may be assessed for the appropriateness of “authorized agent-controlled analgesia” (AACA) (Gorski et al., 2016). As identified in a position paper by the American Society for Pain Management Nursing (ASPMN) (Cooney et al., 2013), with AACA, a consistent, available, and competent person may be authorized by the prescriber and educated to activate the dose button when the patient is unable to do so.

<table>
<thead>
<tr>
<th>Table 10-2 Patient Risk Factors for Oversedation and Respiratory Depression With Patient-Controlled Analgesia</th>
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<tbody>
<tr>
<td>• Older adults (&gt;60 years old, risk increases with increasing age)</td>
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<tr>
<td>• Morbid obesity</td>
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<tr>
<td>• Snoring</td>
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<tr>
<td>• No recent opioid use</td>
</tr>
<tr>
<td>• Postoperative patients who have had upper abdominal or thoracic surgery</td>
</tr>
<tr>
<td>• Long duration of anesthesia</td>
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<tr>
<td>• Taking other sedative medications</td>
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<tr>
<td>• Preexisting cardiopulmonary disease or major organ failure (e.g., renal failure, chronic obstructive pulmonary disease)</td>
</tr>
<tr>
<td>• Obstructive sleep apnea or other sleeping disorder</td>
</tr>
<tr>
<td>• Continuous basal infusions for opioid-naïve patients or those with obstructive sleep apnea</td>
</tr>
</tbody>
</table>

Gorski et al., 2016; The Joint Commission, 2012.

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However, when the patient cannot actively participate in PCA, the patient may be assessed for the appropriateness of “authorized agent-controlled analgesia” (AACA) (Gorski et al., 2016). As identified in a position paper by the American Society for Pain Management Nursing (ASPMN) (Cooney et al., 2013), with AACA, a consistent, available, and competent person may be authorized by the prescriber and educated to activate the dose button when the patient is unable to do so.

EBP It is acknowledged that PCA is safe for pediatric patients and that although the practice is widely used, safety data are lacking. The safety of morphine administration via PCA versus I.V. morphine in pediatric patients was examined in a large study using discharge data from 42 children’s hospitals in the United States. There were 45,445 nonsurgical patients and 63,528 surgical patients eligible for the data analysis. Using the risk of cardiopulmonary resuscitation (CPR) and mechanical ventilation as representative for severe opioid-related adverse events (oversedation and respiratory depression), the researchers found that PCA for surgical and nonsurgical patients was not associated with an increased risk of receiving CPR or mechanical ventilation. PCA was associated with slightly better safety outcomes than I.V. morphine (Faerber et al., 2017).

Patients should be carefully monitored to prevent respiratory depression and other adverse events due to PCA. The ASPMN (Jarzyna et al., 2011) has published evidence-based guidelines aimed at monitoring opioid-induced sedation and respiratory depression. Key recommendations include:

• Development of an individualized plan for monitoring based on risk factors, iatrogenic risks, and pharmacological regimen
• Outlining of monitoring practices in organizational policies and procedures
Use of serial sedation and respiratory assessments

- Perform during wakefulness and during sleep.
- Use sedation scales that have acceptable validity and reliability.
- Count respirations for a full minute and qualify according to rhythm and depth of chest excursion while patient is in restful/sleep state.
- Do not transfer patients between levels of care during peak effect of medication.

- If respiratory depression (e.g., rate <8–10 per minute), evidence of advancing sedation, poor respiratory effort, snoring or other noisy respiration, or oxygen desaturation is present, the patient should be aroused immediately and instructed to take deep breaths. Additional interventions may be required (e.g., opioid reversal with naloxone).

- Technology-supported monitoring should be considered.
  - Continuous pulse oximetry
  - Capnography monitoring (measurement of end-tidal CO$_2$), a more sensitive measure and early indicator of respiratory compromise

Monitoring should be more vigilant when patients are at greater risk, such as during peak medication effects, the first 24 hours postoperatively, with dosage increases, with changes in opioid medication, and with changes in route of administration (Jarzyna et al., 2011).

**NURSING FAST FACT!**

When opioids are administered, the potential for opioid-induced respiratory depression is always considered.

**Adverse Events and Patient-Controlled Analgesia**

Errors related to programming the opioid concentration are of particular concern. When higher concentrations are erroneously programmed, a lower dose will be delivered, compromising pain management. On the other hand, erroneously entering a lower concentration will increase the dose, which has led to adverse drug events, including fatalities. Recommendations from the ISMP (2008) include:

- Limiting the concentrations available in the organization
- Distinguishing custom drug concentrations by the pharmacy, such as different-colored pharmacy labels and specific instructions
- Matching the medication administration record to the PCA label so that there is less confusion when comparing the product label to the medication order
- Use of barcode technology
- Use of smart pumps
- Use of independent double checks

In 2012, TJC issued a Sentinel Event Alert related to the use of opioids and adverse events, including deaths, which occurred in hospitals and were reported
to TJC’s Sentinel Event database (2004–2011) (TJC, 2012). Errors occurred as follows:

- 47% wrong dose errors
- 29% improper monitoring
- 11% others, such as excessive dosing, drug interactions, and adverse drug reactions

TJC emphasizes the critical need for judicious and safe prescribing and administration of opioids, and appropriate monitoring of patients.

**PCA ADVANTAGES**

- When patients are in control and know they can get more immediate pain relief by pushing a button, they are more relaxed.
- Analgesia is most effective when a therapeutic serum level is consistently maintained.
- Patients whose postoperative pain is controlled are better able to ambulate, cough, and deep breathe.

**PCA DISADVANTAGES/RISKS**

- Opioid administration is associated with excessive sedation and potential respiratory depression. Patients at increased risk must be identified, and all patients should be carefully monitored.
- Not all patients are appropriate candidates, including those whose level of consciousness, psychological condition, or limited intellectual capacity cannot safely manage PCA.
- Misprogramming PCA concentration has been identified as a significant source of error, but errors in initiating PCA infusion can occur at any point in the programming process.
- There is a risk of someone other than the patient pushing the button on a PCA pump. Place warning labels “For patient use only” on the button. Remind patients and visitors that PCA is for patient use only unless there is a plan in place for AAC.

** EB P** A follow-up survey to evaluate the effectiveness, perceived benefits, and shortcomings of existing monitoring practices was performed by the ASPMN. Overall, a lack of a standard of care for monitoring patients for opioid-induced respiratory depression was identified. The national survey included 147 responses from 90 health-care institutions across the United States. Some findings in relation to PCA included the following: only one-third of patients received increased frequency and timing of monitoring; continuous pulse oximetry was used only about one-third of the time; only about 2% of respondents had access to capnography monitoring; and variations were found in the definition of respiratory depression, with most respondents not considering quality of breaths during assessment. A lack of a standard of care is a factor contributing to adverse events. Since the guidelines were published (Jarzyna et al., 2011), the ASPMN has focused on educational presentations, and a follow-up survey is planned to evaluate the effectiveness of these efforts (Willens, Jungquist, Cohen, & Polomano, 2013).
Only the patient should push the PCA button unless there is a clear plan in place for AACA.

NURSING POINTS OF CARE

PCA ADMINISTRATION

- PCA is a philosophy of treatment rather than a single method of drug administration.
- Assess the patient’s baseline vital signs, cognitive status, and pain level.
- Set the pump for the loading dose (if ordered), basal rate (not used with opioid-naïve and postoperative patients but often used with palliative care patients), demand dose, lockout interval, and 1-hour or 4-hour lockout dose limit.
- Validation by a second clinician or caregiver should be made before initiation and administration of PCA, and when the syringe, solution container, drug, or rate/dose is changed.
- Put the button that controls dosing within reach of the patient.
- Monitor for potential adverse events, including excessive sedation and respiratory depression.
- Consider use of continuous pulse oximetry to maintain pulse oxygen above 90% and/or capnography.
- Use a sedation scale to monitor patients with I.V. PCA.

SAFE PRACTICE RECOMMENDATIONS TO PREVENT ERRORS ASSOCIATED WITH PCA THERAPY

1. Limit the variety of medications used for PCA.
2. Improve access to information.
   a. Develop a quick reference sheet on PCA that includes programming tips as well as maximum dose warnings.
3. Improve label readability.
   a. Match the sequence of information that appears on PCA medication labels and order sets with the sequence of information that must be entered into the PCA pump.
4. Highlight the drug concentration on the label.
5. Ensure staff competence with PCA infusion pump use.
   a. Involve nurses in selection and evaluation of PCA pumps to ensure patient safety.
6. Consider the possibility of error.
   a. If the patient is not responding to the PCA doses, consider the possibility of an error, especially before administering a bolus dose. Re-verify the drug, concentration, pump settings, and line attachment.
7. Use an independent double check process as follows.
   a. Clearly define a manual, independent double-check process for clinicians to follow when verifying PCA medications, pump settings via a confirmation screen, the patient's identity, and line attachments.
   b. Whenever available, use barcode technology and use smart PCA pumps that alert clinicians to potential programming errors.
8. Assess the proximity of the PCA pump to the general infusion pump
   a. To decrease the potential for I.V. line mix-ups and possible medication errors.
9. Educate the patient and caregiver(s).

INS Standard: Provide patient and caregiver education appropriate to duration of therapy and care setting and include the purpose of PCA therapy, operating instructions for the EID, expected outcomes, precautions, potential side effects, and contact information for support services (Gorski et al., 2016, p. S131).

NURSING POINTS OF CARE
DELIVERY OF I.V. MEDICATION

Nursing Assessments
- Review patient diagnoses.
- Perform medication reconciliation.
- Review medication history or adverse/side effects.
- Review allergies before starting the medication.
- Assess current medications for potential drug interactions/incompatibility issues.
- Assess vital signs.
- Weigh the patient.
- Identify patient-related factors that may alter the patient's response to the drug, such as age or renal, hepatic, and cardiovascular function.
- Assess need for and appropriateness of I.V. medication infusion beyond the acute care setting (e.g., home care, long-term care setting).

Key Nursing Interventions
1. Follow the rights of medication administration.
2. Verify order before administering the drug.
3. Check expiration date on medication container.
4. Determine the correct dilution, amount, and length of administration time as appropriate.
5. Administer medications using the appropriate infusion method.
6. Maintain aseptic technique at all times.

Continued
7. Monitor for:
   a. Signs/symptoms of VAD site complications (e.g., phlebitis, infiltration)
   b. Laboratory values as appropriate (e.g., drug levels, renal function)
   c. Therapeutic response
   d. Adverse reactions/side effects
   e. Intake and output
8. Maintain I.V. access.
9. Dispose of unused or expired drugs in accordance with regulations and organizational policy.
10. For I.V. PCA:
    a. Monitor sedation level.
    b. Monitor respiratory rate, rhythm, and chest excursion; count respirations for full minute.
    c. Monitor oxygen saturation via pulse oximetry and monitor end-tidal CO$_2$ using capnography if available.
    d. Intervene promptly if excessive sedation.
    e. Intervene promptly if respiratory depression present.

Other Infusion Medication Routes

Subcutaneous

The SC administration of medications or fluids is an alternative option to I.V. infusion and increasingly used as an infusion route. As a brief review of anatomy, the SC tissue is located beneath the dermal layer of the skin. It contains blood vessels, nerves, and adipose tissue. Fluids or medications administered subcutaneously are absorbed into the blood vessels located in the SC space. Although the rate of achieving maximum concentration of a medication is slower, there is similar bioavailability by both the SC and the I.V. administration routes (Arthur, 2015). Human recombinant hyaluronidase (HRH) is a medication that can be used to facilitate and hasten the absorption of SC fluids or medications and is injected just before or with the SC agent. The INS Standards recommend consideration for the use of hyaluronidase to facilitate the dispersion and absorption of hydration fluids and other SC-administered drugs (Gorski et al., 2016).

Advantages to SC infusion include decreased cost and ease of access compared with I.V. access. Minimal skill is required, allowing some patients and caregivers to learn SC access (Arthur, 2015). The Emergency Nurses Association (2015) recommends the SC route as an alternative for patients with difficult peripheral venous access.

There are two main categories of SC infusion therapy: medication administration and fluid administration. Continuous SC infusion (CSI) of opioid drugs (for pain management) is a common practice in palliative care and hospice settings. While dose conversions for all opioids are not well established, in the case of morphine 1 mg of morphine I.V. is close to 1 mg of morphine SC (Weisman,
Other medications administered via CSI include insulin, deferoxamine (iron chelation for iron overload), some antiemetics and some antibiotics, steroids, and immunoglobulin therapy (Arthur, 2015; Younger et al., 2015). While an optimal infusion rate for CSI of medications is unknown, infusion rates of 3 to 5 mL/hr are commonly reported (Gorski et al., 2016). However, with SC immunoglobulin infusions, rates of 15 to 25 mL/hr are not uncommon, but it is important to follow the manufacturer’s specific recommendations for SC rates.

SC infusion of isotonic fluids is called hypodermoclysis. This was a widely used mode of infusion until the 1950s, when complications from improper care related to poor patient selection, incorrect rates of administration, and poor choices of fluids led to the severe decline of this infusion modality. Today, hypodermoclysis is recognized as a relatively easy, low-risk, and cost-effective method for delivery of hydration fluids in patients with mild to moderate dehydration (Arthur, 2015; Caccialanza, Constans, Cotogni, Zaloga, & Pontes-Arruda, 2016). The isotonic fluids most commonly administered include 0.9% sodium chloride and 5% dextrose in water.

Hypodermoclysis is used often in long-term care facilities to manage mild dehydration in the older patient and is increasingly being used in the home-care setting. Pediatric patients with limited or difficult venous access are also candidates for hypodermoclysis, although there is scarce evidence for use in this population (Rouhani, Meloney, Ahn, Nelson, & Burke, 2011). Up to 1500 mL over 24 hours (approximately 60 mL/hr) can be delivered to a single SC site, and up to 3 L may be given using two different sites. Specially designed SC infusion sets allow for simultaneous infusion via two or more sites (Fig. 10-4).

![Figure 10-4 ClearView™ MS: multiple-site subcutaneous delivery set. (Courtesy of Norfolk Medical, Skokie, IL.)](image-url)
Devices used to access the SC tissue include over-the-needle catheters (i.e., small-gauge [24-gauge] catheters) used for peripheral I.V. insertion and specially designed SC needles (Figs. 10-5, 10-6). With an over-the-needle catheter, the tissue is entered at a 30- to 45-degree angle, depending on the thickness of the tissue. Specially designed SC sets are inserted at a 90-degree angle.

**Figure 10-5** Aqua-C™ hydration set for hypodermoclysis and ClearView™ Sub-Q. A clear disk allows for ongoing subcutaneous site assessment. (Courtesy of Norfolk Medical, Skokie, IL.)
Key issues related to device placement as addressed in the INS Standards (Gorski et al., 2016) include the following:

- **Site selection**: Any area where there is adequate SC tissue and the skin is intact (no evidence of bruising, irritation) can be used. The most common sites include the abdomen (avoid area around navel because of blood vessel proximity), anterior thighs, subclavian chest wall, upper back, and upper arm.
- **Site preparation**: As with placement of any VAD, skin antisepsis is an important step. Attention to proper hand hygiene and washing of visibly dirty skin with soap and water followed by skin antisepsis are critical steps. Antiseptic agents include 70% alcohol, povidone iodine, and >0.5% chlorhexidine in alcohol solution.
- **Device insertion**: Use a small-gauge (24–27) device and follow the manufacturer’s directions for use with any device. Once placed, the device should be aspirated to ensure that there is no blood return, which confirms that the device is in the tissue and not in a small blood vessel.
- **Device securement and dressing**: A transparent semipermeable dressing is placed over the site, which allows for continuous site observation and assessment.

The infusion is set up the same as with an I.V. A standard I.V. administration set is used for hypodermoclysis, and the use of gravity administration using a manual flow regulator is common (See Chapter 5). When administering CSI of medications, an EID is usually used. Mechanical, non-electronic syringe pumps are often used, especially with immunoglobulin administration. Refer to Procedures Display 10-2 at the end of this chapter.

Complications related to SC infusions are generally minor. They include itching or burning at the site, erythema, induration, pain, leaking, bleeding, infection, and tissue slough. Some edema is expected with hypodermoclysis but will subside as the fluid is absorbed. Complications are managed by ongoing site assessment and site rotation as clinically indicated. The infusion rate may need to be reduced, and use of a plastic-type infusion device instead of a steel needle should be considered.

Site rotation is an important aspect related to SC infusions. For hypodermoclysis, the site should be changed after 1500 to 2000 mL of fluid has been administered in a single site. Depending on tolerance and site assessment, the site may need to be rotated earlier. When administering medications via CSI, the
recommendation is every 2 to 7 days and as clinically indicated, based on the integrity of the access site (Gorski et al., 2016). The nurse’s assessment of individual patient tolerance is an important aspect when considering frequency of site rotation.

Candidates for SC administration include:

- Patients unable to take medications by mouth
- Patients with evidence of mild to moderate dehydration
- Patients with limited or difficult venous access
- Patients requiring continuous medication delivery
- Patients in whom medication can be administered subcutaneously

**EBP** In a review of the literature on the use of SC infusion for hydration or nutrition, SC infusion was found to be a safe and effective technique for fluid administration that is associated with minimal complications. The use of hyaluronidase to facilitate fluid absorption was also reviewed. Based upon the studies reviewed, the researchers concluded that hyaluronidase is most likely to be beneficial when larger volumes of fluid are required or when fluids are infused at higher rates. Furthermore, there is a known risk of allergic reaction to hyaluronidase, and adding hyaluronidase increased complexity, costs of SC infusions, and risks of fluid overload (Caccialanza et al., 2016).

**Hypodermoclysis Advantages**

- Ease of initiation and maintenance by RN or licensed vocational nurse (LVN)/licensed practical nurse (LPN)
- Can reduce the need for emergent/hospitalization as the SC route can be implemented in all health-care settings
- Less complex, less cost, and simpler administration method as compared with the I.V. route

**Hypodermoclysis Disadvantages**

- Not appropriate for patients with severe dehydration who require a larger volume of fluid replacement
- Limited number of medications appropriate for SC route

**Nursing Points of Care**

**Continuous Subcutaneous Infusions**

- A number of medications can be administered subcutaneously; use of SC opioids is common in hospice and palliative care.
- Isotonic fluids can be administered via hypodermoclysis.
- Suitable sites for SC infusion include posterior upper arms, subclavicular chest, anterior thighs, upper back, and upper arms.
- Rotate the site every 2 to 7 days for continuous medication infusions or after 1500–2000 mL of fluid has been administered in a single site (hypodermoclysis).
**Intraosseous**

The timely delivery of fluids and medications is critical for a patient in need of emergency treatment for injuries or underlying disease. A relatively easy and rapidly accessed vascular route is via the matrix of the bone, which is called the IO route. The primary indication for the IO route is emergent use in patients with limited or no vascular access. The IO route is recommended by the American Heart Association (AHA) as a standard for alternative vascular access and is cited in the algorithms for the AHA’s Advanced Cardiac Life Support and Pediatric Advanced Life Support treatment protocols (AHA, 2015). The IO route also may be used in nonemergent situations when the patient is at risk for increased morbidity or mortality if access is not obtained. The INS Standards address the potential use of the IO route in nonemergent clinical situations for patients with poor vascular access and for patients at increased risk for morbidity or mortality without rapid access, such as during shock, life-threatening or status epilepticus, extensive burns, major traumatic injury, or severe dehydration (Gorski et al., 2016). Technology has evolved to make access to the IO route easy and cost-effective for use in all age groups.

The long bones of the body have two ends: the diaphysis and the epiphysis. The epiphysis is spongy bone, whereas the diaphysis contains hard bone with a hollow interior space called the medullary cavity. The IO space is the spongy cancellous bone of the epiphysis and the medullary cavity of the diaphysis. The IO space is like a noncollapsible vein (Fig. 10-7). Within this space are thousands of tiny intertwined blood vessels, which absorb any fluid, like a sponge, and enable rapid transportation to the central circulation (Hunsaker & Hillis, 2013). Bone marrow, which consists of blood, blood-producing cells, and connective tissue, fills the space. Within the IO space, blood flow is steady even during states of shock. Crystalloids, colloids, blood products and many medications can be administered via the IO route, and dosages are the same as with the I.V. route (Dev, Stefan, Saun, & Lee, 2014). Insertion sites include proximal and distal tibia and proximal humerus in both adults and children, the distal femur in children, and the sternum in adults (Gorski et al., 2016) (Fig. 10-8).

There are a variety of IO devices that are easy to use and very fast, providing access within seconds. Pain management during insertion and infusion should always be considered, especially in the conscious patient. The use of lidocaine is recommended, both subcutaneously at the intended site and into the IO space prior to starting an infusion (Gorski et al., 2016). There are three categories of IO devices. It is important to emphasize that any nurse who inserts an IO device must be educated, trained, and deemed competent in access and device use.

1. **Manual:** A hollow, steel needle with a removable trocar. It is inserted by applying pressure and twisting the device. The manual method is dependent on the preparation and insertion time, the patient’s condition, and the skill of the inserter. The steel needles are difficult to insert in adult bones because of the density and hardness of the bone.
2. Impact driven: A spring-loaded device with a hollow needle and removable trocar. The device triggers penetration into the sternum or the tibia via direct force.

3. Powered drill: A battery-operated drill with a hollow needle and removable stylet. The device can be used to drill the needle to the appropriate depth into IO space. This type of device can be used for IO access into the proximal and distal tibia and the humeral head in adults and pediatrics, and the distal femur as well in pediatrics (Figs. 10-9 and 10-10).

Placement of an IO device is confirmed by assessment of the needle position, sensation of loss of resistance upon bone penetration, and absence of any signs of infiltration upon flushing the device with 0.9% preservative-free sodium chloride solution. The ability to aspirate bone marrow also confirms placement; however, it is not always possible to obtain (Gorski et al., 2016, p. S121).

It is important to recognize that the IO route is a temporary route, and the device should not be allowed to dwell more than 24 hours (Gorski et al., 2016). Complications are rare with IO access. The most common complication is infiltration/extravasation from IO device dislodgement and associated compartment syndrome; due to small bones and use of too-long needles,
Infants and children are at greater risk (Gorski et al., 2016). Other rarely reported complications include iatrogenic fracture, infection, fat emboli, and osteomyelitis. The risk of infectious complications is increased if the infusion is prolonged or if bacteremia is present during the time of insertion (Gorski et al., 2016).

**Indications for IO access:**

1. Pediatric and adult patient resuscitation
2. To provide access in patients who require urgent vascular access when peripheral I.V. access is difficult or impossible (e.g., those with trauma, obesity, diabetes)
3. Prehospital emergency access by paramedic staff

**Figure 10-8** Sites for intraosseous infusions. A, Tibia; B, pediatric tibia; C, proximal humerus; D, distal tibia.
ADVANTAGES

- Rapid vascular access
- Easy device stabilization
- Most medications and solutions can be infused via IO.
- Blood samples drawn IO can be used for laboratory studies.
- Rare complications

EBP Success rates of first attempts and procedure times for IO access were compared to CVAD placement in a prospective, observational study. The population included 40 adults undergoing resuscitation, each receiving simultaneous IO and CVAD access. Success rates on first attempt were significantly higher for IO cannulation than for CVAD catheterization (85% vs. 60%, p = 0.024), and procedure times were significantly lower for IO access compared with CVADs (2.0 vs. 8.0 minutes, p <0.001). Complications included failure to gain IO access (n = 6) and need for two or more CVAD placement attempts (n = 16). There were no other complications reported. The researchers conclude that IO access is more efficacious with a higher success rate on first attempt and a lower procedure time compared with CVAD placement (Leidel et al., 2012).

Figure 10-9 Arrow®EZ-IO® drill and products. (Courtesy of Teleflex, Morrisville, NC.)
Figure 10-10 Arrow®EZ-IO steps. A, site preparation; B, insertion of drill; C, hub removal; D, flush; E, infusion. (Courtesy of Teleflex, Morrisville, NC.)

Disadvantages

- Pain on insertion and during infusion (manageable)
- Limited dwell time (<24 hours)

Absolute contraindications:

- Compartment syndrome in the targeted extremity
- Previously used IO site or recent failed attempt at IO
Fractures at or above the site  
Previous orthopedic surgery/hardware  
Presence of infection or severe burns near the insertion site  
Local vascular compromise  
(Gorski et al., 2016, p. S121).

**NURSING POINTS OF CARE**  
**INTRAOSSEOUS INFUSIONS**

- Premedication with lidocaine subcutaneously at the site and into the IO space is recommended.  
- Allows for rapid intravascular access.  
- Mechanically easier to perform than I.V. access.  
- Most medications and solutions may be administered via the IO route, without dosage adjustments.  
- Dwell time should not exceed 24 hours.

**Intraspinal**  
Analgesic, anesthetic, and adjuvant medications may be administered via an intraspinal route. Intraspinal access devices are defined as those placed in the epidural or intrathecal spaces in the spinal cord. An access device placed into the intraventricular space in the brain is also sometimes categorized as an intraspinal device (Gorski et al., 2016). Access to the intraventricular space is gained via a device called an Ommaya reservoir, which is implanted surgically under the scalp, providing access to the cerebrospinal fluid (CSF). It is a dome-shaped device with a self-sealing silicone reservoir attached to a catheter (Fig. 10-11). As with an implanted venous access port, the reservoir is accessed with a needle. As a highly specialized infusion route, it is addressed only briefly. In many cases, a licensed prescriber administers medications via the intraventricular route. Because many chemotherapy drugs do not cross the blood–brain barrier, this route is sometimes used to treat primary central nervous system (CNS) tumors. Other medications such as antibiotics or antifungals may also be given via the intraventricular route. Additionally, it may be used as an alternative to repeated lumbar punctures for CSF access (Elledge, 2017).

Intraspinal infusions via the epidural or intrathecal route may be used to control pain with surgical procedures or childbirth. Intraspinal infusions may also be indicated for long-term pain management, as occurs in patients who have not achieved pain relief despite escalating analgesic doses or in those who are experiencing excessive systemic side effects. In addition, chemotherapy may be given via an intraspinal catheter for neurological cancers or neoplastic meningitis (Elledge & Stovall, 2017).

For pain management, drugs are administered directly to opiate receptor sites located in the spinal cord. Pain impulses are intercepted before they are
transmitted to the brain. There is less CNS depression associated with intraspinal analgesic administration.

**Anatomy of the Spinal Cord and Epidural and Intrathecal Spaces**

The spinal cord begins at the base of the skull and passes through the vertebral canal of the spinal column. The spinal cord is located within the vertebral bones and protective connective tissue. In the adult, the spinal cord ends at the first or second lumbar vertebra.

The cord consists of a central region of gray matter surrounded by bundles of white matter. The gray matter is shaped like a butterfly (Fig. 10-12). The dorsal horn (posterior) of the spinal cord is rich in opioid receptors, and medications administered intraspinally directly bind with these receptors to block pain transmission. The 31 pairs of spinal nerves are named according to their positions with respect to associated vertebrae: 8 cervical, 12 thoracic, 5 lumbar, and 5 sacral, plus 1 coccygeal. The area of the body affected by an intraspinal infusion is dependent on where the tip of the catheter is located in relation to the sensory nerves and the areas they innervate. Dermatomes are delineated areas of skin that are innervated by a segment of the spinal cord.
Figure 10-12  A. Cross-sectional view of the spinal cord. B. Intraspinal anatomy. Note epidural and spinal (intrathecal) spaces.
The spinal cord and the brain are surrounded by three meninges that protect and suspend the brain and spinal cord within the cranial cavity and the vertebral canal (Drake, Vogl, & Mitchell, 2015). The meninges are as follows (Fig. 10-12):

1. The dura mater is the outermost layer. It is a tough membrane consisting of dense fibrous connective tissue.
2. The arachnoid mater is the middle layer, which is located against, but not adherent to, the internal surface of the dura mater. It is a thin and delicate membrane.
3. The pia mater is a vascular membrane that firmly adheres to the surface of the spinal cord.

In between the arachnoid and the pia mater is the subarachnoid space, which contains CSF. The subarachnoid space is also called the intrathecal space. Medications in the CSF flow in two directions: primarily to the brain (rostral flow) and passively toward the base of the spine. Rostral spread of drugs can increase drug effects away from the targeted area.

**Epidural Versus Intrathecal Medication Administration**

The epidural space is the space surrounding the spinal cord and its meninges. This space contains fatty tissue, veins, spinal arteries, and nerves. It is considered a potential space that is not created until medication or air is injected. Medications administered via the epidural route must pass through the dura mater. Medications administered via the epidural route are about one-tenth of an I.V. dose and about 10 times greater than an intrathecal dose (Elledge & Stovall, 2017) (see Fig. 10-12B).

Intrathecal medications are administered directly into the subarachnoid, or intrathecal, space where the CSF circulates; therefore, they do not have to pass through any membranes. For this reason, medication doses are very low, about one-tenth of an epidural dose. The intrathecal route is often used for long-term drug administration through long-term catheter systems. In addition to the low doses of medication required, potential advantages of intrathecal access compared with epidural access include ease of catheter placement, superior analgesia in the presence of epidural pathology (e.g., metastatic disease), and a lower incidence of catheter problems, such as catheter migration or tip occlusion (Reisfield, Foutz, & Wilson, 2016). Specific indications for intrathecal access include widespread pain, multiple pain locations, pain more distant from the catheter site, or pain poorly responsive to epidural therapy.

Intraspinal devices are aspirated prior to medication administration as part of an assessment of placement. With an epidural catheter, aspiration should ascertain the absence of fluid or blood; with an intrathecal catheter, aspiration should ascertain the presence of spinal fluid and absence of blood (Gorski et al., 2016).
**Types of Catheters and Administration Systems**

Catheters may be temporary or long term. Temporary catheters typically are used for no longer than a week. They may be used for postoperative analgesia or during labor, or they may be placed as part of a trial in a patient who might benefit from long-term intraspinal pain management. Short-term catheters may also be placed in patients with limited life expectancy in palliative care (Reisfield et al., 2016). Long-term or permanent catheters include:

- **Subcutaneously tunneled catheter:** Surgically placed catheter with a synthetic cuff to hold it in place. It is generally tunneled around the flank area to an exit site in the abdominal area. Advantages include ease of activities of daily living and decreased risk of catheter dislodgement.
- **Implanted port:** Surgically placed device that is also tunneled through the skin so that the port exits in the abdominal area (see Fig. 10-13). The

![An external catheter connected to an ambulatory infusion pump](Image)

![An implantable pump](Image)

![An implantable port connected to an ambulatory infusion pump](Image)

**Figure 10-13** Methods of epidural administration. (Courtesy of Smith Medical, Inc., St. Paul, MN.)
port, like an implanted venous port, is accessed using a noncoring needle. Advantages include ease of activities of daily living, decreased risk for catheter dislodgement, and low risk for infection.

- Completely implanted system that includes a catheter and an implanted infusion pump: This is an expensive and complex system (Fig. 10-13). Access to the implanted infusion pump is via a noncoring needle. The pump typically is refilled with medication every 2 to 8 weeks (Elledge & Stovall, 2017). The pump can be programmed externally via a computer.

**Intraspinal Medication Administration**

Medications administered via an intraspinal catheter include opioids, local anesthetic agents, clonidine, baclofen, and sometimes chemotherapy agents. Medications must be preservative-free because preservatives are potentially neurotoxic. Morphine is the most commonly administered intraspinal opioid. It is a hydrophilic agent and has a high affinity for the opiate receptors in the dorsal horn of the spinal cord. Hydrophilic opioids decline more slowly in the CSF; which results in more rostral, or upward, spread. Because of this, delayed respiratory depression can occur. Hydromorphone may also be used, and although it is also hydrophilic, there is less rostral spread. Fentanyl and sufentanil are lipophilic, which results in faster analgesia and less rostral spread. Fentanyl clears rapidly but may be less available to the opiate receptors.

Local anesthetics may be used in conjunction with opioids. Bupivacaine is the most frequently used. Clonidine, an antihypertensive medication, may be used to treat neuropathic pain when given intraspinally. Table 10-3 provides a summary of intraspinal medications.

There are various approaches to the administration of narcotics and anesthetics via the intraspinal route: a single-bolus injection of opioid or local anesthetic, a continuous infusion of opioid with or without local anesthetics, or a continuous infusion of opioid with a patient-activated bolus.

A single injection of an opioid may be used for procedures that produce a short course of postoperative pain. This method may be appropriate for a patient having a cesarean section or vaginal hysterectomy, or for a patient after a same-day surgical procedure. Care must be taken to avoid the inadvertent administration of additional opioids by another route, which may oversedate the patient and cause respiratory depression.

Continuous infusion is administered for short or long periods of time. Patients with pain from surgery, trauma, and acute medical disorders creating severe pain may benefit from short-term continuous infusions. Long-term patients include those with chronic intractable cancer or those with back or pelvic pain. Patients with chronic spasticity may be treated with the drug baclofen given intraspinally.
### Table 10-3 Epidural and Intrathecal Medications

<table>
<thead>
<tr>
<th>Type of Medication</th>
<th>Actions and Issues</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Opioids</strong></td>
<td></td>
</tr>
<tr>
<td>Fentanyl</td>
<td>Bind with opiate receptors. Morphine is hydrophilic; slower movement through cerebrospinal fluid results in longer duration of action and slower clearance; more rostral spread; risk for respiratory depression.</td>
</tr>
<tr>
<td>Hydromorphone</td>
<td></td>
</tr>
<tr>
<td>hydrochloride</td>
<td></td>
</tr>
<tr>
<td>Morphine sulfate</td>
<td></td>
</tr>
<tr>
<td>Sufentanil</td>
<td></td>
</tr>
<tr>
<td>Anesthetic agents</td>
<td>Given in low doses to block nerve fibers with minimal sensory and motor effect. May be used in conjunction with opioids and reduce opioid dose. Have long duration of action. Toxicity signs and symptoms include tinnitus, metallic taste, slow speech, irritability, twitching, seizures, circumoral tingling, numbness. Side effects include motor blockade, hypotension, diarrhea, urinary retention.</td>
</tr>
<tr>
<td>Most often bupivacaine and ropivacaine</td>
<td></td>
</tr>
<tr>
<td><strong>Baclofen</strong></td>
<td>Used primarily for spasticity in patients with neurological disorders but may be combined with other medications for pain control. Side effects include hypotonia, sedation, constipation, erectile dysfunction, loss of sphincter control, respiratory depression.</td>
</tr>
<tr>
<td><strong>Clonidine</strong></td>
<td>Centrally acting alpha-2 adrenergic agonist used to treat chronic neuropathic pain. Side effects include hypotension, sedation, dry mouth, bradycardia.</td>
</tr>
<tr>
<td><strong>Ziconotide</strong></td>
<td>Nonopioid analgesic administered intrathecally. Used with refractory pain in patients with cancer, chronic pain. Side effects include dizziness, nausea, asthenia, sedation, diarrhea, confusion, ataxia.</td>
</tr>
</tbody>
</table>

Most commonly intraspinal medication is administered by a certified RN anesthetist or an anesthesiologist, and the catheter is managed by the staff nurse. Administration of medication by a nurse through an intraspinal catheter must be based on an order from a licensed prescriber and in accordance with rules and regulations with each state’s board of nursing and organizational policies, procedures, and/or practice guidelines. Nursing responsibilities also include (1) patient and family education, (2) site and dressing assessment and management, and (3) evaluation of pain relief.

**NURSING FAST FACT!**

Patients should be frequently monitored for the first 24 hours after starting an intraspinal infusion. Recommendations include every hour for the first 24 hours followed by assessment every 4 hours (Gorski et al., 2016, p. S119).
ADVANTAGES OF INTRASPINAL MEDICATION ADMINISTRATION

- Permits control or alleviation of severe pain without the sedative effects
- Permits delivery of smaller doses of a narcotic to achieve the desired level of analgesia
- Allows for continuous infusion, if needed
- Can be used for short-term or long-term therapy
- Does not produce motor paralysis

DISADVANTAGES/RISKS OF INTRASPINAL MEDICATION ADMINISTRATION

- Only preservative-free opioids can be used.
- Medication-related complications include pruritus, paresthesia, urinary retention, and respiratory depression.
- Catheter-related risks include infection, dislodgement, and leaking.
- Intraspinal catheters and medications must be clearly labeled as a specialized infusion system as a safety precaution to prevent inadvertent I.V. infusion.

INS Standard: Administer only preservative-free medications via an intraspinal route (Gorski et al., 2016, p. S118).

NURSING FAST FACT!

Ineffective pain control should be reported to the licensed prescriber which may specifically be the anesthesiologist who is managing care of the epidural catheter.

MONITORING THE PATIENT WITH AN INTRASPINAL CATHETER

Careful monitoring is critical for patients with an intraspinal catheter. For the first 24 hours after an intraspinal infusion is placed and initiated, the patient is monitored for response to the therapy and for any adverse reactions as outlined in Table 10-4.

CARE AND MANAGEMENT OF INTRASPINAL CATHETERS

Temporary epidural catheters should be handled carefully during site care because they are easily dislodged. In acute-care, short-term catheterization, often only the anesthesiologist will change the dressing, if needed (see Fig. 10-14). Chlorhexidine dressings are recommended because research has demonstrated a reduction in exit site colonization and a decreased risk for CNS-related infection (Gorski et al., 2016; Kerwat et al., 2015).

Patients who have long-term external intraspinal catheters in place require regular site care and dressing changes. Permanent catheters have a synthetic
Key steps in the dressing procedure include:

1. Gather needed supplies and establish a sterile field with antiseptic solution and dressings.
2. Perform hand hygiene. Don gloves and mask.
3. Remove the old dressing and discard.

### Table 10-4 Monitoring Parameters for the Patient Receiving an Intraspinal Infusion

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pain rating, at rest and with activity</td>
<td></td>
</tr>
<tr>
<td>Vital signs</td>
<td></td>
</tr>
<tr>
<td>Level of sedation</td>
<td></td>
</tr>
<tr>
<td>Infusion pump: Number of bolus doses, if patient-controlled epidural analgesia; correctness of administration parameters</td>
<td></td>
</tr>
<tr>
<td>Fetal status, response of patient in labor</td>
<td></td>
</tr>
<tr>
<td>Presence of adverse reactions: Pruritus, nausea, urinary retention, orthostatic hypotension</td>
<td></td>
</tr>
<tr>
<td>Changes in sensory or motor function</td>
<td></td>
</tr>
<tr>
<td>Status of dressing (e.g., intact)</td>
<td></td>
</tr>
<tr>
<td>Measurement of external catheter length (changes may indicate potential migration)</td>
<td></td>
</tr>
<tr>
<td>Signs of infection/epidural abscess: Back pain, tenderness, erythema, drainage, fever, malaise, neck stiffness, progressive numbness</td>
<td></td>
</tr>
<tr>
<td>Oxygen saturation levels, CO$_2$ levels per organizational policy</td>
<td></td>
</tr>
</tbody>
</table>

Gorski et al., 2016.

![Figure 10-14 Epidural site covered with SorbaView® Shield transparent dressing. (Courtesy of Centurion Medical Products, Williamston, MI.)](image)

cuff that acts as a protective barrier against bacterial migration and secures the catheter. Key steps in the dressing procedure include:

1. Gather needed supplies and establish a sterile field with antiseptic solution and dressings.
2. Perform hand hygiene. Don gloves and mask.
3. Remove the old dressing and discard.
4. Perform hand hygiene and don sterile gloves. Apply antimicrobial solution without alcohol (usually povidone iodine) in a circular motion, starting at the exit site and working outward. Allow the solution to air-dry.

5. Apply a new dressing, gauze or transparent, and make sure that the catheter is well secured to reduce the risk for inadvertent dislodgement. Use a chlorhexidine dressing per organizational policy. Transparent dressings are most often used and are changed at least every 7 days in conjunction with site care.

6. Check that the catheter is coiled near the insertion site, which will prevent accidental dislodgement.

7. Document the dressing change, assessment of the exit site, and patient’s tolerance of the procedure.

**NURSING FAST FACT!**

The potential for catheter tip migration should be routinely assessed by checking for changes in external catheter length.

**COMPPLICATIONS ASSOCIATED WITH INTRASPINAL PAIN MANAGEMENT**

Medication-related side effects of intraspinal medication administration include pruritus, nausea and vomiting, respiratory depression, urinary retention, hypotension, and constipation. Pruritus is a common side effect that may be an allergic-type reaction or may be caused by stimulation of histamine in response to opioid administration. Tolerance tends to develop to this side effect with long-term administration. Cool clothing and diversion may help. Also, low doses of the opioid antagonist naloxone can be administered to relieve pruritus without reversal of analgesia. Nausea and vomiting are less common with intraspinally administered opioids. Urinary retention is a common side effect that is theorized to be a result of inhibition of the parasympathetic nervous system on the bladder. This may require intermittent catheterization.

Conditions requiring immediate licensed prescriber notification include:

- Inadequate pain relief. This can occur for three reasons: catheter migration, insufficient dosages of opioid and local anesthetics, and undetermined surgical complication.
- Respiratory depression from epidural or intrathecal narcotic administration. Vital signs, including assessment of respiratory rate for a full minute, should be regularly assessed. Naloxone should be available to reverse the depressant effects of a narcotic.
- Extreme dizziness as a result of orthostatic hypotension or excessive opioid effect
- New onset of paresthesia or paresis
- Pain at the insertion site
- Displacement or migration of the epidural catheter. Catheter migration may occur as follows: (1) An epidural catheter can migrate through the
dura mater into the intrathecal space, leading to an opioid overdose; or (2) the catheter may migrate into an epidural vein or SC space, creating inadequate pain relief.

- Infections. These are rare from epidural catheters, but precautions should be instituted to ensure aseptic technique during the catheter insertion process and during any exit site care and infusion procedures. If an infection develops elsewhere in the body, the patient should be evaluated for removal of the epidural catheter.
- Excessive drowsiness or confusion occurring when too much narcotic is being administered. This is usually improved by decreasing the amount of epidural narcotic infusion. Titrating an opioid antagonist such as naloxone (Narcan) or an agonist/antagonist subcutaneously may reverse side effects without eliminating the analgesia.

**NURSING FAST FACT!**

If catheter migration is suspected, the licensed prescriber should be notified and catheter placement verified by an anesthesiologist.

**NURSING POINTS OF CARE**

**ADMINISTRATION OF INTRASPINAL PAIN CONTROL**

- Nurses caring for intraspinal catheters must demonstrate competency in maintenance, assessment of placement, and function of the access device and have an understanding of anatomy and physiology, neuropharmacology, and potential complications.
- Only preservative-free medications are administered via the intraspinal route to prevent nerve damage.
- Preservative-free morphine, which is water soluble and has a slower onset of action and longer duration of action, is generally the first choice of opioid analgesic. Lipid-soluble fentanyl and sufentanil penetrate the dura mater faster than water-soluble opioids, providing a faster onset of action but a shorter duration of action.
- Aseptic technique, including donning of mask and gloves, is used when accessing, caring for, and maintaining an intraspinal access device.
- For intraspinal infusions, a 0.2-micron filter that is surfactant free, particulate retentive, and air eliminating must be in place.
- Epidural devices should be aspirated to ascertain the absence of spinal fluid and blood before medication administration (Gorski et al., 2016, p. S119).
Intrathecal devices should be aspirated to *ascertain the presence* of spinal fluid and the absence of blood prior to medication administration (Gorski et al., 2016, p. S119).

- Inspect the catheter–skin junction visually and palpate for tenderness daily through the intact dressing.
- The potential for catheter migration should be monitored by assessing for changes in external catheter length, changes in pain control, or increase in side effects.
- After insertion of the external catheter, lay the exposed catheter length cephalad along the spine and over the shoulder. Tape the entire length of the exposed catheter in place to provide stability and protection.
- Evaluate the effects of the drug on the patient's alertness. Caregivers should also be taught to observe for levels of sedation.
- Clearly label the intraspinal access device and administration set as a specialized infusion system to prevent accidental infusion of fluids or medications (Gorski et al., 2016, p. S118).

**Infusion Medication Delivery**

**General Guidelines**

Nursing responsibilities related to infusion drug administration are summarized as follows:

1. Identify whether a prescribed route or method of administration (e.g., continuous or intermittent I.V., I.V. push, SC, IO) is appropriate.
2. Whenever feasible, administer solutions and medications that are prepared by and dispensed from the pharmacy or that are commercially prepared (Gorski et al., 2016).
3. Medications admixed outside of the pharmacy, pharmacy-labeled solutions, and medications labeled for emergent use should be initiated within 1 hour of preparation (Gorski et al., 2016).
4. Check all labels (drugs, diluents, and solutions) to confirm appropriateness for infusion use.
5. Use a filter needle or straw when withdrawing I.V. medications from ampules to eliminate possible pieces of glass (Gorski et al., 2016).
6. Ensure adequate mixing of all drugs added to a solution.
7. Examine solutions for clarity and any possible leakage.
8. Use an independent double check for the organization’s identified high-alert medications.
9. Use only single-dose vials for parenteral additives or medications.
10. Monitor the patient for therapeutic response to the medication.

The eight rights of safe medication administration are summarized in Table 10-5.
Older adults and pediatric patients require special consideration when infusion medications are to be delivered. Each poses special problems that must be carefully addressed to ensure safe infusion therapy. Medications may have many greater side effects and adverse consequences in these populations.

### Pediatric Patients

**Medication Administration**

Delivering medication to children requires that the nurse have expert knowledge of the techniques for the delivery of medication and for the calculation of formulas. A nurse administering infusion therapy to pediatric patients must possess the knowledge necessary to ensure the safety and efficacy of the treatment. This includes understanding the unique physiological differences between children and adults, as well as the appropriate dosing and administration methods for pediatric medications.

**Table 10-5**  
**Eight Rights of Medication Administration**

1. **Right patient**
   - Verify identity using two patient identifiers.
   - Ask patient to identify himself/herself.
   - Technology: Barcode
2. **Right medication**
   - Review medication order against the medication label.
3. **Right dose**
   - Review medication dose against medication label.
   - Confirm appropriateness of the dose using a current drug reference.
   - Technology: Smart pump use; do not bypass drug library.
   - Independent double checking of high-risk medications.
   - Calculate the dose and have another nurse independently calculate the dose as well.
4. **Right route**
   - Review order for the appropriateness of the ordered route.
   - Make sure patient can take or receive the medication by the ordered route.
   - Make sure infusion drug is appropriate for the type of vascular access device.
5. **Right time**
   - Review order for frequency of medication.
   - Double-check that you are giving the ordered dose at the correct time.
   - Confirm when the last dose was given.
6. **Right documentation**
   - Document administration AFTER giving the ordered medication.
   - Document other specific information as necessary, such as laboratory values reviewed prior to administration (e.g., vancomycin trough level, serum creatinine).
7. **Right reason**
   - Confirm the rationale for the ordered medication.
   - **INS Standard:** Review the order for appropriateness of prescribed therapy for the patient’s age and condition (Gorski et al., 2016, S125).
8. **Right response**
   - Make sure that the drug led to the desired effect.
   - **INS Standard:** Evaluate and monitor response to and effectiveness of the prescribed therapy; documenting patient response, adverse events, and interventions; communicating the results of laboratory tests; and achieving effective delivery of the prescribed therapy (Gorski et al., 2016, S126).
necessary to verify, calculate, administer, and accurately control the rate of the prescribed therapy.

Strategies for safe delivery of medications to children include:

- Monitor weight accurately. Include weight changes in shift reports.
- Perform staff competency checks annually in weighing children, using scales on the unit.
- Collaborate with biomedical engineers regarding the frequency of quality assurance and calibration checks of scales.
- Require nurses to verify accuracy of dose recommendations and calculations on the original drug and I.V. fluid prescription forms.
- Acquire current medication manuals that provide necessary information for safe administration of I.V. medications.
- Use “smart pumps” an imbedded computer system to reduce drug dosing errors through the presence and use of a drug library (see Chapter 5).

Medication errors occur more frequently in the pediatric inpatient population. There are a number of reasons for this:

- Availability of different dosage forms of same medication
- Few standardized dosing regimens for children than for adults
- Variance among children in body weight, body surface area (BSA), and organ maturity (e.g., renal and hepatic function)
- Children are often unable to communicate adverse reactions.
- Limited physiological capacity to buffer medication errors (Gonzales, 2010)

Based on a systematic review of the literature, Gonzales (2010) found that antibiotics, sedative medications, and opioids were most often involved in medication errors. Medication errors occurred because of distractions, interruptions, miscommunication, incorrect dose calculation, and lack of knowledge, and such errors tended to be underreported.

**Calculations for Delivery of I.V. Medications in Pediatric Patients**

Most medications for children are dosed based on body weight or BSA.

**Body Weight**

Many drugs are ordered in milligrams per kilogram of body weight.

<table>
<thead>
<tr>
<th>Formula</th>
<th>Case example: Child weighs 35 pounds. Requires ampicillin for treatment of sepsis. The pediatric dose ordered is 100 mg/kg/24 hours in equally divided doses every 4 hours (Gahart et al., 2016).</th>
</tr>
</thead>
<tbody>
<tr>
<td>Convert pounds to kilograms (1 kg = 2.2 pounds) (weigh patient in kg to reduce risk of calculation errors)</td>
<td>35 pounds divided by 2.2 pounds/kg = 15.9 kg</td>
</tr>
<tr>
<td>Calculate 24 dose in milligrams</td>
<td>15.9 kg · 100 mg/day = 1590 mg</td>
</tr>
<tr>
<td>Calculate dose based on frequency</td>
<td>1590 mg/day divided by six doses per day = 265 mg every 4 hours</td>
</tr>
</tbody>
</table>
**Body Surface Area**

As with adults, many chemotherapy drugs are dosed according to BSA. BSA requires measurement of height and weight and is reflected in meters squared (M²). A nomogram can be used to calculate the BSA; however, there are many online calculators for BSA (see table below).

<table>
<thead>
<tr>
<th>Formula</th>
<th>Case example: Child weighs 35 pounds and is 95 cm tall. Requires cytarabine 200 mg/M²/24 hours for treatment of leukemia (Gahart et al., 2016).</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measure height</td>
<td>95 cm</td>
</tr>
<tr>
<td>Convert pounds to kilograms (1 kg = 2.2 pounds)</td>
<td>35 pounds divided by 2.2 pounds/kg = 15.9 kg</td>
</tr>
<tr>
<td>Calculate BSA*</td>
<td>0.63 M²</td>
</tr>
<tr>
<td>Calculate dose in milligrams</td>
<td>200 mg/M² · 0.63 M² = 126 mg</td>
</tr>
</tbody>
</table>

*Cornell University Medical School website (www-users.med.cornell.edu/~spon/picu/calc/bsacalc.htm) used for body surface area (BSA) calculation.

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**NURSING FAST FACT!**

It is critically important to ensure the accuracy of pediatric weights. Weights are susceptible to data entry errors in the electronic medical record, such as omission, addition, or transposition of a digit, or entry of the right data into the wrong patient’s medical record. Erroneous weights result in dosing errors (Hagedorn et al., 2017).

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**Methods of Administration: Metered Volume Chamber Sets**

Metered volume chamber sets may be used with children for safety in delivery of medication and solutions, although the increasing use of EIDs and syringe pumps has reduced their usage. The administration set is used with a 250- to 500-mL solution container to ensure decreased risk of fluid overload. This method allows a limited amount of fluid to be available to the patient because the chamber is filled with only 1 to 2 hours’ duration of the prescribed fluid volume. Frequent monitoring and refilling of the metered volume chamber by the nurse are required. Metered volume chamber sets are also used for intermittent medication infusion when the primary solution is compatible with the medication.

**Methods of Administration: Retrograde Infusion Administration**

Retrograde infusion is an alternative to drug administration by syringe pumps. It is used in the general pediatric area and less often in the neonatal intensive care units. A specific retrograde administration set is required for this purpose. The tubing volume varies but generally holds less than 1 mL. An access port
is located at each end of the tubing. Use the following steps for retrograde infusion:

1. Attach the retrograde tubing and prime along with the primary administration set. The tubing functions as an extension set when it is not used to administer medication.
2. To administer the medication, attach a medication-filled syringe to the port proximal to the patient and connect an empty syringe to the port most distal from the patient.
3. Make sure the clamp between the port and the child is closed, and then inject the medication distally up the tubing (this prevents your patient from receiving medication as a bolus dose). The fluid in the retrograde tubing is displaced upward into the tubing and the empty syringe.
4. Remove both syringes and open the lower clamp. The medication is then infused into the patient at the prescribed rate by the EID.

**The Older Adult**

The older adult is more susceptible to adverse drug reactions. Physiological changes associated with aging may have an impact on or alter drug metabolism. There is a decrease in total body water and a relative increase in body fat that may affect water- and fat-soluble medication bioavailability. Changes on all levels of bodily function—cellular, organic, and systemic—occur as a result of the normal aging process. Because many older adults have multiple diseases, they are more likely to be taking multiple medications, increasing the risk of drug interactions. Because of the decline in organ function with aging, older adults are more likely to experience drug toxicity. It is important to realize that drug side effects in older adults, such as an increase in confusion, may be mistaken for signs of aging. Age-related changes are most pronounced in those older than 85 years; however, there is great variability among individuals (Smith & Cotter, 2012). Physiological changes particularly pertinent to infusion nursing include the following:

- **Cardiovascular**
  - Decreased cardiac reserve
  - Increased risk for dysrhythmias
  - Increased risk for postural and diuretic-induced hypotension
- **Pulmonary**
  - Decreased respiratory muscle strength
  - Decreased cough reflex
  - Decreased response to hypoxia, hypercapnia
- **Renal**
  - Decrease in kidney mass
  - Decreased drug clearance
  - Increased risk for fluid volume overload
  - Increased risk for dehydration
- **Immune system**
  - Increased susceptibility to infection (Smith & Cotter, 2012)
Many infusion medications and solutions are safely administered in the home-care setting. These include antimicrobial drugs, parenteral nutrition, chemotherapy, analgesics for pain management, some cardiovascular medications, chelation therapy (e.g., iron unloading), factor replacement for bleeding disorders, biological drugs, enzyme replacement therapy (e.g., Prolastin), and both I.V. and SC immunoglobulin therapies (Gorski, 2017). Many infusion medications are delivered via an EID.

Other than the I.V. route, medications may also be administered in the home via the SC and intraspinal (epidural/intrathecal) routes. SC infusions include both hydration fluids (i.e., hypodermoclysis) and medications. Opioid drugs for pain management (e.g., morphine, hydromorphone) are the most common subcutaneously administered drugs in the home setting.

I.V. antimicrobial medications are the most common medication class administered in the home. Administration methods include intermittent (e.g., gravity) and continuous infusions, and I.V. push. The type of method selected is based on the characteristics of the medication (e.g., only a few antimicrobials can be given as I.V. push), the frequency of the infusion, and patient factors. In most cases, the patient or a caregiver is expected to learn how to administer the antimicrobial medications after the home-care nurse teaches the techniques and validates competency and home safety with the plan. Elastomeric pumps (see Chapter 5) are commonly used for intermittent infusions. It is very easy to teach patients how to use these pumps, and they are safe for the home environment. Programmable infusion pumps may be used for antibiotics that must be given every 4 to 6 hours, for example. In these cases, a full day’s supply of antibiotic is prepared in a container, the infusion pump is programmed to administer the dose as ordered, and the pump delivers a keep-vein-open rate between infusions. Syringe and bedside infusion pumps may also be used.

Monitoring for potential adverse reactions to the home infusion is an important role of the home-care nurse. Depending on the medication or infusion solution ordered, regular laboratory studies may be part of the monitoring process, for example, drug levels and serum creatinine levels for the patient receiving nephrotoxic medications (e.g., vancomycin, gentamicin). The nursing role includes timely review of laboratory work, ensuring that results are received by the licensed prescriber, and communicating any changes in the plan of care to the patient. Before administering each dose, the nurse should review pertinent laboratory studies.

Special attention must be paid when the first doses of an infusion medication are administered in the home and/or when there is an ongoing risk for severe antibody/anaphylactic reactions (e.g., some biological drugs, immunoglobulin therapy). Emergency drugs (e.g., epinephrine, diphenhydramine) must be available in the home with orders and protocols.
Home Care Issues—cont’d

established for their use. Additional criteria for first-dose administration include:

- The patient should have no history of severe drug reactions and minimal medication allergies.
- All nurses should be certified in basic life support.
- The nurse should remain in the home for the entire duration of the first-dose administration.
- Telephone access must be available (Gorski, 2017).

Patient education is crucial to safe home infusion of medications. Home-care situations vary in terms of the patient’s ability to manage the infusion. Based on the type of infusion and the patient’s or caregiver’s ability, the level of independence in home infusion therapy will vary. For example, drugs/fluids with a high risk for adverse reactions with every infusion, such as I.V. immunoglobulin therapy and other biological drugs, are administered by the nurse, whereas in most cases, self-administration of antimicrobial drugs is typically taught to the patient or caregiver.

NURSING FAST FACT!

When programmable infusion pumps are used, in general the pharmacist programs and locks the program into the pump. Double-check systems should be in place in the pharmacy prior to dispensing the infusion pump and medications to the home. The nurse must also review and verify the infusion pump program against the drug label and against the medication order. When infusion pump parameters are changed in the home (e.g., increasing a PCA dose), the home-care agency should have systems in place for a double check, for example, calling the pharmacy on the telephone and reading the infusion pump parameters to the pharmacist (Gorski, 2017).

Patient Education

- Patient education related to I.V. medication administration is vital for all health-care settings. When infusion medication will continue beyond the acute care setting, patient education should begin before hospital discharge to facilitate a smooth transition to home care.
- Education should include expected actions and adverse effects of the medication(s), VAD placement, care and management, and signs and symptoms to report (Gorski et al., 2016).

Continued
Patient Education—cont’d

- Medication administration should address infection prevention (i.e., hand hygiene and aseptic technique), infusion delivery method, frequency of administration, and proper catheter flushing.
- Include troubleshooting instructions and telephone numbers to call for 24-hour assistance.
- Re-address education as needed throughout the course of care.
- Use of a checklist is helpful and provides a method for documenting the completion of patient education.

Patient Education Related to PCA

- Make sure the postoperative patient is alert enough to understand the directions for use of PCA. Make sure hearing aids or glasses are in place before instruction.
- Instruct on how to use PCA.
- Instruct on when to push the bolus button.
- Instruct on when to communicate with the nurse (e.g., pain not controlled with PCA, feeling of sedation).
- Discuss fears (of addiction to medication, receiving too much medication).
- Discuss expected outcomes for the patient: Pain scale use, prevention of breakthrough pain, and early ambulation.

Nursing Process

The nursing process is a six-step process for problem-solving to guide nursing action (see Chapter 1 for details on the steps of the nursing process). The following table focuses on nursing diagnoses, nursing outcomes classification (NOC), and nursing interventions classification (NIC) for patients with medication administration via I.V. and alternate modalities. Nursing diagnoses should be patient specific and outcomes and interventions individualized. The NOC and NIC presented here are suggested directions for development of specific outcomes and interventions.

<table>
<thead>
<tr>
<th>Nursing Diagnoses Related to Infusion Medication Administration</th>
<th>Nursing Outcomes Classification (NOC)</th>
<th>Nursing Interventions Classification (NIC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anxiety (mild, moderate, and severe) related to:</td>
<td>Coping; anxiety level</td>
<td>Anxiety reduction strategies</td>
</tr>
<tr>
<td>Threat to or change in health status;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>misconceptions regarding therapy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Comfort impaired, related to illness-related symptoms: Pruritus</td>
<td>Comfort level; symptom control; coping</td>
<td>Pruritus management; distraction</td>
</tr>
</tbody>
</table>
Advantages of I.V. medications include the fact that they provide a direct access to the circulatory system, a route for instant drug action, a route for delivering high drug concentrations, instant drug termination if sensitivity or an adverse reaction occurs, and a route of administration in patients in whom use of the gastrointestinal tract is limited.

Disadvantages and risks of I.V. medications include the potential for harm from errors due to immediate medication effects, drug interactions due to incompatibilities, drug adsorption, errors in compounding of medication, speed shock, and vascular access device complications such as infiltration/extravasation and phlebitis.

Drug incompatibilities fall into three broad categories: physical, chemical, and therapeutic.

Four main methods of I.V. medication administration include continuous infusion, intermittent infusion, I.V. push, and patient-controlled analgesia.

The SC route may be used to administer certain medications (e.g., opioids) and fluids (hypodermoclysis).

IO access for medication infusion is used in adults and children in emergency care, severely dehydrated patients, adults in whom peripheral

Chapter Highlights

- Advantages of I.V. medications include the fact that they provide a direct access to the circulatory system, a route for instant drug action, a route for delivering high drug concentrations, instant drug termination if sensitivity or an adverse reaction occurs, and a route of administration in patients in whom use of the gastrointestinal tract is limited.
- Disadvantages and risks of I.V. medications include the potential for harm from errors due to immediate medication effects, drug interactions due to incompatibilities, drug adsorption, errors in compounding of medication, speed shock, and vascular access device complications such as infiltration/extravasation and phlebitis.
- Drug incompatibilities fall into three broad categories: physical, chemical, and therapeutic.
- Four main methods of I.V. medication administration include continuous infusion, intermittent infusion, I.V. push, and patient-controlled analgesia.
- The SC route may be used to administer certain medications (e.g., opioids) and fluids (hypodermoclysis).
- IO access for medication infusion is used in adults and children in emergency care, severely dehydrated patients, adults in whom peripheral
I.V. access is impossible, and for rapid and reliable prehospital emergency access.
- Analgesic, anesthetic, and antispasmodic medications may be administered via intraspinal catheters for acute and chronic pain management and spasticity control for patients with neurological disorders.
- Only preservative-free medications can be delivered by the intraspinal routes.

Thinking Critically: Case Study

Mrs. Robertson is 1 day postoperative from an abdominal hysterectomy. She has an epidural catheter in place. Her baseline vital signs are blood pressure 110/80; respiration 18 breaths/min, and pulse 72 bpm. Your assessment finds she is difficult to arouse, but she does respond to simple commands. She is able to move her legs and can squeeze your fingers. Her blood pressure is 90/60, pulse 100 bpm, and respirations 14 breaths/min. She is moaning in pain but is unable to rate her pain on the pain scale.

Case Study Questions
1. What further assessments need to be done?
2. What further actions should the nurse initiate?
3. What could be the reason for her change in status?

References


CHAPTER 10  Infusion Medication Safety, Methods, and Routes


PROCEDURES DISPLAY 10-1
Administration of Medication by the Direct (I.V.) Push: Peripheral Catheter

Equipment Needed
Disinfectant (e.g., 70% alcohol wipes)
Two prefilled syringes of 0.9% sodium chloride
Labeled medication prepared by pharmacy in syringe

Delegation
This procedure cannot be delegated.

Procedure
1. Verify the authorized prescriber’s order.
2. Verify that the patient is not allergic to the prescribed medication.
3. Introduce yourself to the patient.
5. Perform hand hygiene.
6. Explain procedure to patient and its expected outcome, potential adverse reactions, and signs/symptoms to report.
7. Scan the barcodes on RN identification badge, the patient’s wristband, and the drug label (if barcode system is used).
8. Disinfect the needleless connector (intermittent administration) or the injection port of the I.V. administration set) with antiseptic using a scrubbing motion and allow to dry. Many organizations require at least a 15-second scrub.

Note: If administering medication with a running I.V. solution, the medication

Rationale
1. A written order is a legal requirement.
2. Patient safety
3. Establishes nurse–patient relationship
4. Patient safety
5. Single most important means of infection prevention
6. Prepares patient for procedure
7. To ensure correct medication administration

Continued
PROCEDURE RATIONALE

MUST be compatible with the I.V. solution.

9. Attach syringe of sodium chloride and begin to flush and then slowly aspirate for blood. Slowly flush the solution; disconnect and discard.

10. Repeat Step 8.

11. Attach medication syringe and inject slowly over the time indicated on the syringe label or according to pharmacist; disconnect and discard. Use a timer or watch to ensure correct rate of administration.

12. Repeat Step 8.

13. Attach second syringe of sodium chloride and slowly inject the sodium chloride at the same rate as the medication was injected.

Note: There are different types of needleless connector devices, so be sure you know which devices are used in your facility.

14. a. For negative-displacement devices: Flush all solution into the catheter lumen, maintain force on the syringe plunger as a clamp on the catheter or extension


10. Infection prevention

11. Slow injection reduces the risk for speed shock and provides time for the nurse to observe the patient for adverse effects. Studies have indicated nurses often administer I.V. push medications too rapidly.

12. Infection prevention

13. To decrease the chance of a “bolus” of medication. To lock the VAD after the intermittent I.V. push medication, positive pressure must be maintained within the lumen of the catheter during and after administration of a flush solution to prevent reflux of blood into the Luer-activated systems. Follow guidelines below.
Procedure Rationale

set is closed, and then disconnect the syringe.
b. For positive-displacement device: Flush all solution into the catheter lumen, disconnect the syringe, and then close the catheter clamp.
c. For neutral-displacement device: Flush all solution into the catheter lumen; it does not matter if the catheter clamp is closed before or after the flush procedure.

15. Assess patient response and any side effects/adverse reactions; ensure plan is in place for ongoing monitoring.
16. Discard all used supplies per organizational policy.
17. Perform hygiene.
18. Document the procedure.

15. Patient safety
18. Maintains a legal record

PROCEDURES DISPLAY 10-2
Administration of Continuous Subcutaneous Medication Infusion

Equipment Needed
Transparent semipermeable membrane (TSM) dressing
Prepackaged dedicated subcutaneous set from manufacturer
Antiseptic solution (>0.5% chlorhexidine in alcohol)
Sterile 10-mL syringe
Prescribed fluids or prefilled medication container or cassette
Infusion pump (medication infusion)
PROCEDURES DISPLAY 10-2

Administration of Continuous Subcutaneous Medication Infusion—cont’d

Delegation
This procedure can be delegated to LPN/LVN as allowed by the nurse practice act.

Procedure
1. Verify authorized prescriber’s order.
2. Verify that the patient is not allergic to the prescribed medication.
3. Gather all equipment.
4. Introduce yourself to the patient.
5. Verify the patient’s identity using two patient identifiers.
6. Perform hand hygiene.
7. Explain procedure to patient and its expected outcomes, potential adverse reactions, and signs/symptoms to report.
8. Assess skin and select insertion site with adequate subcutaneous tissue: a fat fold of at least 1 inch (2.5 cm) when thumb and forefinger are pinched together. Site selection is also based on the patient’s anticipated mobility and comfort.
   *Note: Avoid areas that are scarred, infected, irritated, edematous, bony, or highly vascularized.*
9. Don gloves.
10. Prime the administration set and prepare pump per manufacturer’s directions.
11. Perform skin antisepsis with chlorhexidine gluconate and

Rationale
1. A written order is a legal requirement.
2. Patient safety
3. Organization
4. Establishes nurse–patient relationship
5. Patient safety
6. Single most important means of infection prevention
7. Prepares patient for procedure.
8. Reduces risk for infection.
9. Standard precautions
PROCEDURES DISPLAY 10-2
Administration of Continuous Subcutaneous Medication Infusion—cont’d

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Let dry. <em>(Note: If skin is visibly dirty, wash with soap and water prior to skin antisepsis.)</em></td>
<td></td>
</tr>
<tr>
<td>2. Follow the manufacturer’s labeled use and direction for access device placement; prime set with 0.9% sodium chloride.</td>
<td></td>
</tr>
<tr>
<td>3. Lift the skin up into a small mound between the thumb and index finger.</td>
<td></td>
</tr>
<tr>
<td>4. Insert the primed subcutaneous infusion device into the skin.</td>
<td>14. Ensures secure entry of the needle into the subcutaneous tissue and not into muscle</td>
</tr>
<tr>
<td>5. Aspirate subcutaneous device using sterile syringe.</td>
<td>15. Presence of blood may be indicative of entry into blood vessel. Remove and replace device in new site if positive blood aspirate.</td>
</tr>
<tr>
<td>6. Stabilize the device, secure connection junctions, and apply TSM dressing over the site.</td>
<td>16. Protects the site and stabilizes the catheter or needle to prevent dislocation.</td>
</tr>
<tr>
<td>7. Initiate therapy and adjust the rate per order and medication label.</td>
<td>17. Accurate medication administration</td>
</tr>
<tr>
<td>8. Discard used equipment and supplies in the appropriate receptacle.</td>
<td></td>
</tr>
<tr>
<td>9. Remove gloves and perform hand hygiene.</td>
<td></td>
</tr>
<tr>
<td>10. Document in the patient’s permanent medical record.</td>
<td>20. Maintains a legal record</td>
</tr>
</tbody>
</table>

Sources: Gorski et al., 2016.
Chapter 11
Transfusion Therapy

LEARNING OBJECTIVES
After completing this chapter, the reader will be able to:

1. Define terminology related to transfusion therapy.
2. Identify antigens and antibodies in the blood system.
3. Identify donor screening tests performed by the transfusion service.
4. Differentiate between allogeneic, autologous, and designated blood donation.
5. Describe nursing implications related to patient blood management.
6. Describe commonly transfused blood components and indications for transfusion.
7. Describe key procedural steps in transfusion of blood components.
8. Discuss potential alternatives to blood transfusion.
9. Discuss potential complications of blood transfusions and immediate interventions.
10. Discuss implications for blood transfusion in neonatal and pediatric patients.

Glossary

**ABO system**  Blood group of antigens that reside on structurally related carbohydrate molecules

**ADSOL**  Additive solution of 100 mL containing saline, dextrose, and adenine that is added to packed red blood cells

**Agglutinin**  An antibody present in the blood that attaches to an antigen that causes clumping, or agglutination; agglutinins cause transfusion reactions when blood from a different group is transfused

**Agglutinogen**  An antigen that stimulates production of an agglutinin

**Allergic reaction**  Reaction from exposure to an antigen to which the person has become sensitized

**Allogeneic**  Blood transfused to someone other than the donor

**Allogeneic/homologous donation**  Blood donation by someone other than the recipient

**Alloimmunization**  Development of an immune response to alloantigens; occurs during pregnancy, blood transfusions, and organ transplantation
Antibody  A protective substance that resides in plasma produced by B lymphocytes in response to an antigen; antibodies identify and neutralize or destroy antigens

Antigen  A substance that induces an immune system response

Autologous/Autotransfusion donation  Originating within an individual, especially a factor present in tissues or fluids; donation of a unit of blood to be reinfused, if needed, back to the original donor

Blood component  Product made from a unit of whole blood such as platelet concentrate, red blood cells, fresh frozen plasma, or cryoprecipitate

Crossmatch  The process of mixing a sample of the donor's red blood cells with the recipient's serum (major crossmatching) and mixing a sample of the recipient's blood with the donor's serum (minor crossmatching) to determine compatibility

Cryoprecipitate  A plasma component rich in fibrinogen and other clotting factors

Delayed transfusion reaction  Adverse effect occurring after 48 hours and up to 180 days after transfusion

Directed/designated donation  Use of blood or components from a specific donor for a specific patient

Febrile reaction  Nonhemolytic reaction to antibodies formed against leukocytes

Fresh frozen plasma  Collection of the fluid portion of the circulating blood by separation and then freezing the plasma within 8 hours of collection

Hemoglobin  Respiratory pigment of red blood cells having the reversible property of taking up oxygen or releasing oxygen

Hemolysis  Rupture of red blood cells, with the release of hemoglobin

Hemolytic transfusion reaction  Blood transfusion reaction in which an antigen–antibody reaction in the recipient is caused by an incompatibility between red blood cell antigens and antibodies

Human leukocyte antigen (HLA)  Used for tissue typing and relevant for transplant histocompatibility; essential to immunity

Hypothermia  Abnormally low body temperature

Immunohematology  Study of blood and blood reactions as they relate to immune systems and their response

Microaggregate  Microscopic collection of particles such as platelets, leukocytes, and fibrin that occurs in stored blood

Packed red blood cells  A blood product consisting of concentrated cells, most of the plasma having been removed

Patient blood management  An evidence-based and multidisciplinary approach to optimizing the care of patients who might require transfusion

Pheresis  Derived from the Greek word *aphairesis*, meaning “to take away”; used to denote the removal of blood, the separation into component parts, the retention of only the parts needed, and the return of the rest to the donor (e.g., removal of plasma is plasmapheresis)
Plasma  Fluid portion of the blood, composed of a mixture of proteins in solution
Platelets  An irregularly shaped, disc-like cell that functions in clotting
Refractory  Not responsive or readily yielding to treatment
Rh system  Second most important system determining compatibility; Rh antigens are inherited and located on the surface of red blood cells; classified as positive or negative based on whether D antigen is present
Serum  Term used to describe plasma after fibrinogen has been removed
Thrombocytopenia  Abnormally small number of platelets in the blood

Introduction

To ensure the delivery of safe transfusion therapy, nurses must possess a knowledge and understanding of the blood system, basic immunohematology, and the theory and practical management of the transfusion of blood components. Today, patient blood management (PBM) is the standard of care aimed at optimizing the care of patients who might require a blood transfusion.

The manufacture and distribution of blood products is overseen by the U.S. Food and Drug Administration (FDA), although the FDA does not directly inspect transfusion services. Rather, the FDA accepts inspections sanctioned by the Centers for Medicare & Medicaid Services (CMS), which are most often based on certificates of accreditation from an approved organization. The AABB (formerly the American Association of Blood Banks) is a major accreditation organization for hospital transfusion services. Safe transfusion practices are critical. Transfusion errors are likely to occur in three areas: labeling of the pretransfusion sample, patient identification at the bedside (a major nursing responsibility), and the initial decision to transfuse (i.e., appropriateness for transfusion).

The first part of this chapter presents the fundamental concepts of immunohematology and blood grouping, along with the criteria for donor blood, including designated, autologous, and donation. Blood components, administration equipment, administration techniques for each blood component, and management of transfusion reactions are presented in the second part of the chapter.

Basic Immunohematology

Immunohematology is the science that deals with antigens of the blood and their antibodies. The antigens and antibodies are genetically inherited and determine each person’s blood group. An antigen is a substance capable of stimulating the production of an antibody and then reacting with that antibody in a specific way. Antigens of the blood are also called agglutinogens. Any substance that can elicit an immunological response is an antigen and is located on the blood cell membrane. The three antigens on the red blood cells (RBCs) that cause problems and are routinely tested for are A, B, and Rh D. The human leukocyte antigen (HLA) is located on most cells in the body except mature erythrocytes. Antibodies are found in the plasma or serum.
Antigens (Agglutinogens)

ABO System

The ABO system was developed in 1901 by Dr. Karl Landsteiner. The most significant antigens in the blood are the surface antigens A and B, which are located on the RBC membranes in the ABO system (Table 11-1). The name of the blood type is determined by the name of the antigen on the RBC. Individuals who have A antigen on the RBC membrane are classified as group A; B antigens, group B; A and B surface antigens, group AB; and neither A nor B antigens, group O. Table 11-2 provides an ABO compatibility chart.

Unique to the ABO system is the presence of antibody in the serum of persons who lack the corresponding antigen; that is, the antibody is present even when the body is not stimulated with the foreign antigen. These naturally occurring antibodies are responsible for the rapidity and severity of reactions that occur when ABO-incompatible blood is administered. This phenomenon occurs occasionally in other blood systems but appears to be ubiquitous within the ABO system. As a result, if antigen A is present on the RBC, then antibody

Table 11-1  ABO Blood Grouping Chart

<table>
<thead>
<tr>
<th>Blood Groupings</th>
<th>Recipient Antigens on Red Blood Cells</th>
<th>Antibodies Present in Plasma</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>A</td>
<td>Anti-B</td>
</tr>
<tr>
<td>B</td>
<td>B</td>
<td>Anti-A</td>
</tr>
<tr>
<td>AB</td>
<td>A and B</td>
<td>None</td>
</tr>
<tr>
<td>O</td>
<td>None</td>
<td>Anti-A and Anti-B</td>
</tr>
</tbody>
</table>

Table 11-2  ABO Compatibilities for Red Blood Cell Components

<table>
<thead>
<tr>
<th>Recipient↓</th>
<th>O NEG</th>
<th>O POS</th>
<th>A NEG</th>
<th>A POS</th>
<th>B NEG</th>
<th>B POS</th>
<th>AB NEG</th>
<th>AB POS</th>
</tr>
</thead>
<tbody>
<tr>
<td>O NEG</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>O POS</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A NEG</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A POS</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B NEG</td>
<td>✓</td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B POS</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AB NEG</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>AB POS</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

Note: The universal red blood cell donor is O-negative; the universal recipient is AB-positive.
to B (anti-B) is present in the serum. If antigens A and B are present, no antibody exists in serum; conversely, if no antigen is present, then both anti-A and anti-B are present in the serum. Table 11-3 provides ABO compatibility for plasma.

**Cultural and Ethnic Considerations: Blood Types and Rh Factor**

The prevalence of blood groups varies among cultures and races. Types A, B, and O blood are more equally distributed among Japanese and Chinese people. A very high prevalence for type O blood has been found among Native Americans, with some incidence of type A blood and a very low incidence of type B blood. Among Caucasians, the prevalence for type O is 45%, whereas 51% of African Americans and 57% of Hispanic people have type O. Because type O is in high demand and routinely in short supply, minority and diverse populations play a critical role in meeting the constant need for blood (American Red Cross, n.d.; BabyMed.com, 2017).

**Rh System**

After A and B, the most significant RBC antigen is the D antigen, which was discovered in 1940 by Drs. Landsteiner and Wiener. The Rh system is so called because of its relationship to the substance in the RBCs of the rhesus monkey. There are approximately 50 Rh-related antigens; the five principal antigens are D, C, E, c, and e. A person who has D antigen is classified as Rh-positive; one lacking the D antigen is Rh-negative. The majority of the population is classified as D–Rh-positive. The prevalence of D–Rh-negative is approximately 15% to 17% among people of European descent, 3% to 5% in African Americans, and rare in persons of Asian descent (Denomme & Westhoff, 2014). There are no naturally occurring anti-D antibodies; however, D antibodies build up easily in D-negative recipients when stimulated with D-positive blood. Therefore, typing is done to ensure that D-negative recipients receive D-negative blood. Because the Rh-antigen resides on the RBC, an Rh-negative recipient should receive Rh-negative blood if the components might contain RBCs. Rh-negative blood can be administered to Rh-positive persons. Table 11-4 lists the most common blood types.

<table>
<thead>
<tr>
<th>Table 11-3</th>
<th>ABO Compatibility for Fresh Frozen Plasma</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Recipient</strong></td>
<td><strong>Donor Unit</strong></td>
</tr>
<tr>
<td>A</td>
<td>A or AB</td>
</tr>
<tr>
<td>B</td>
<td>B or AB</td>
</tr>
<tr>
<td>AB</td>
<td>AB</td>
</tr>
<tr>
<td>O</td>
<td>O, A, B, or AB</td>
</tr>
</tbody>
</table>
The HLA antigen was originally identified on leukocytes, but it has been established that HLA is present on most cells in the body. The HLA system includes a complex array of genes and their protein products. HLA is located on the surface of white blood cells (WBCs), platelets, and most tissue cells. HLA typing, or tissue typing, is important in patients with transplants or multiple transfusions. The HLA system is very complex and is essential to immune regulation and cellular differentiation. It is generally viewed as second in importance only to the ABO antigens in influencing the survival of transplanted solid organs (Bray, Pollack, Gebel, & Bray, 2014, p. 475).

The HLA system is important in transfusion therapy because HLA antigens and antibodies play a role in complications of transfusion therapy, such as platelet refractoriness, febrile nonhemolytic transfusion reaction (FNHTRs), transfusion-related acute lung injury (TRALI), and post-transplant and post-transfusion graft-versus-host disease (GVHD). The HLA antigen of the donor unit can induce alloimmunization in the recipient.

The incidence of HLA alloimmunization and platelet refractoriness among patients receiving repeated transfusion ranges from 20% to 71% (Bray et al., 2014). For example, in the refractory state, platelet transfusions fail to increase the recipient’s platelet count.

**Antibodies (Agglutinins)**

An antibody is a protein that reacts with a specific antigen. Each blood antibody has the same name as the antigen with which it reacts. For example, anti-A reacts with antigen A. The antibodies anti-A and anti-B are produced spontaneously in the plasma after birth and usually mature in the first 3 months of life.
Antibodies of the blood system are also referred to as agglutinins; that is, when stimulated by a specific antigen, they bind to the antigen to cause clumping. In the case of an RBC incompatibility, the interaction of the antibody with the like antigen (e.g., anti-B with antigen B) causes the RBCs to clump together.

Antibodies, also known as immunoglobulins (Igs) or immune antibodies, circulate throughout the body, interacting with and aiding in the destruction of potentially harmful microorganisms and toxins. There are five categories of Ig molecules in human blood: IgA, IgD, IgE, IgG, and IgM. These antibodies are classified as either complete or incomplete. The naturally occurring antibody in the blood, which occurs within the inherited blood group (ABO), is from the class of antibodies called immunoglobulin M (IgM). These antibodies have the ability to cause agglutination in the presence of RBC that exhibit the corresponding antigen.

Other Blood Group Systems
The International Society of Blood Transfusion (ISBT) recognizes 34 blood group systems. The ABO and Rh systems are best known and clinically most significant. The most important aspect of blood groups in transfusion medicine is whether the antibodies are hemolytic and have potential to cause hemolytic transfusion reactions (HTRs) and hemolytic disease of the fetus and newborn (Storry, 2014).

Pretransfusion Testing
At the time of donation, every unit of blood intended for homologous (allo- geneic) and directed (designated) donation undergoes the following tests by the transfusion service:

1. The ABO group must be determined by testing the RBCs with anti-A and anti-B and the recipient’s serum or plasma with A and B RBCs.
2. The Rh type must be determined with anti-D serum. Units that are D-positive must be labeled as Rh-positive.
3. Donor blood is tested for clinically significant antibodies.
4. All donor blood must be tested to detect transmissible disease. The blood component must not be used for transfusion unless the test results are nonreactive, negative, or within the normal range. Blood in the United States is tested for the following:

   **Viruses**
   - Hepatitis B virus (HBV)
   - Hepatitis C virus (HCV)
   - HIV types 1 and 2
   - West Nile virus (WNV)
   - Human T-cell lymphotropic virus

   **Bacteria**
   - Syphilis
   - *Trypanosoma cruzi*, a protozoan parasite transmitted by insects (Galel, 2014)
5. Each unit must be appropriately labeled. The label must include the following information: name of the component, type and amount of anticoagulant, volume of unit, required storage temperature, name and address of collecting facility, a reference to the circular of information, type of donor (i.e., volunteer, autologous), expiration date, and donor number (Fig. 11-1).

NURSING FAST FACT!

Since 2006, the FDA has required that blood and blood components contain specific labeled barcoded information about (1) the unique facility identifier (registration number), (2) the lot number relating to the donor, (3) the product code, and (4) the ABO group and Rh type of the donor. These four pieces of information must also be present in eye-readable format (FDA, 2014).

Blood Donor Collection Methods

Allogeneic/Homologous

The term allogeneic, or homologous, donation describes transfusion of any blood component that was donated by someone other than the recipient. Most transfusions are provided by volunteer donors.

Figure 11-1 Correct labeling of a unit of blood.
Guidelines for Allogeneic Donation

Donor selection for homologous collection is based on a limited physical examination and a medical history to determine the safety of the donated unit. Strict criteria have been established for selection of prospective donors:

1. Donor history questionnaire (DHQ). In October 2006, the FDA (2006) recognized the DHQ in a final guidance document that is currently used by the majority of blood centers in the United States (Eder & Muniz, 2014). The AABB recommends the use of specific donor screening materials, which can be found on the following website. An abbreviated DHQ is available for frequent donors.

Website
FDA: www.aabb.org/tm/questionnaires/Pages/dhqaabb.aspx

2. Age: Conform to applicable state law or ≥16 years old
3. Provisions must be made for donors not fluent in English or who are illiterate
4. Provisions for donors who are hearing or vision impaired

NOTE: Although blood centers certainly feel a moral and ethical obligation to accommodate blood donation from those who are not fluent in English, cannot read, have visual/hearing or other physical disabilities, safety for the blood supply always takes priority. The final authority for such decisions about donors rests with the donor center’s physician (Eder & Muniz, 2014).

5. Hemoglobin (Hgb) and hematocrit (Hct) of at least 12.5 g/dL and 38%, respectively, in males and females
6. Temperature: Less than or equal to 37.5°C (99.5°F) measured orally
7. No evidence of localized skin infection at site of venipuncture for blood collection
8. Donation interval: 8 weeks after whole blood donation; 16 weeks after 2-unit RBC collection; 4 weeks after infrequent plasmapheresis and ≥2 days after plasma-, platelet-, or leukapheresis
9. Medications: The DHQ medication deferral list contains the required deferrals (Fig. 11-2).

Designated or Directed Donors

Directed (designated) donation refers to the donation of blood from selected friends or relatives of the patient. Most blood centers and hospitals provide this service. Designated donations have been requested more frequently because of the concern over the risk of transfusion-transmitted diseases. However, there is no evidence that directed donations are safer than blood provided by transfusion services (Eder & Muniz, 2014). Relatives or friends who may be members of a risk group may feel forced into donating and hesitate to identify themselves as a risk group member. Figure 11-3 identifies the unit as designated or directed to a specific recipient.
**Guidelines for Designated Donation**

The selection and screening of directed donors are the same as for other homologous (allogeneic) donors, except that the units collected are labeled for a specific recipient. The designated donor must pass all the history and screening tests required, and the unit must be compatible with the intended recipient.

---

### Medication Deferral List

SOME MEDICATIONS MAY AFFECT YOUR ELIGIBILITY TO DONATE BLOOD.

**PLEASE TELL US IF YOU...**

<table>
<thead>
<tr>
<th>Are being treated with the following types of medications...</th>
<th>or have taken...</th>
<th>which is also called...</th>
<th>anytime in the last,...</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Anti-platelet agents (usually taken to prevent stroke or heart attack)</strong></td>
<td>Feldene</td>
<td>piroxicam</td>
<td>2 days</td>
</tr>
<tr>
<td></td>
<td>Effient</td>
<td>prasugrel</td>
<td>7 days</td>
</tr>
<tr>
<td></td>
<td>Brilinta</td>
<td>ticagrelor</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Plavix</td>
<td>clopidogrel</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ticlid</td>
<td>ticlopidine</td>
<td>14 days</td>
</tr>
<tr>
<td></td>
<td>Zontivity</td>
<td>vorapaxar</td>
<td></td>
</tr>
<tr>
<td><strong>Anticoagulants or “blood thinners” (usually to prevent blood clots in the legs and lungs and to prevent strokes)</strong></td>
<td>Xarelto</td>
<td>rivaroxaban</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fragmin</td>
<td>dalteparin</td>
<td>2 days</td>
</tr>
<tr>
<td></td>
<td>Lovenox</td>
<td>enoxaparin</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pradaxa</td>
<td>dabigatran</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Eliquis</td>
<td>apixaban</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Savaysa</td>
<td>edoxaban</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Coumadin</td>
<td>warfarin</td>
<td>7 days</td>
</tr>
<tr>
<td></td>
<td>Warilone</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Jantoven</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Heparin, low molecular weight heparin (unless listed separately)</td>
<td>heparin</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Arixtra</td>
<td>fondaparinux</td>
<td></td>
</tr>
<tr>
<td><strong>Acne treatment</strong></td>
<td>Accutane</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Amnesteem</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Absorica</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Claravis</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Myorisan</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sorret</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Zenatane</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>isotretinoin</td>
<td>1 Month</td>
</tr>
<tr>
<td><strong>Hair loss remedy</strong></td>
<td>Propecia</td>
<td>finasteride</td>
<td></td>
</tr>
<tr>
<td><strong>Prostate symptoms</strong></td>
<td>Proscar</td>
<td>finasteride</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Avodart</td>
<td>dutasteride</td>
<td>6 Months</td>
</tr>
<tr>
<td></td>
<td>Jalyn</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Basal cell skin cancer</strong></td>
<td>Erivedge</td>
<td>vismodegib</td>
<td>24 months</td>
</tr>
<tr>
<td><strong>Relapsing multiple sclerosis</strong></td>
<td>Aubagio</td>
<td>teriflunomide</td>
<td>24 months</td>
</tr>
<tr>
<td></td>
<td>Sotiantane</td>
<td>acitretin</td>
<td>36 months</td>
</tr>
<tr>
<td></td>
<td></td>
<td>etretinate</td>
<td>Ever</td>
</tr>
<tr>
<td><strong>Psoriasis</strong></td>
<td>Tegison</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Hepatitis exposure</strong></td>
<td>Hepatitis B Immune Globulin</td>
<td>HBIG</td>
<td>12 months</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Experimental Medication or Unlicensed (Experimental) Vaccine</strong></td>
<td></td>
<td></td>
<td>12 months, or as indicated by Medical Director</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Growth hormone from human pituitary glands</strong></td>
<td></td>
<td></td>
<td>Ever</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Insulin from Cows (Bovine or Beef Insulin) manufactured in the United Kingdom</strong></td>
<td></td>
<td></td>
<td>Ever</td>
</tr>
</tbody>
</table>

* No longer available in US

DO NOT discontinue medications prescribed or recommended by your physicians in order to donate blood.

DHQ Medication Deferral List v2.0
Effective April 2017 (Revised: Erivedge)

**Figure 11-2** Medication deferral list (source: www.aabb.org/tm/questionnaires/Documents/dhq/v2/DHQ%20Medication%20Deferral%20List%20v2.0.pdf).
Medication Deferral List

Some medications affect your eligibility as a blood donor, for the following reasons:

Anti-platelet agents affect platelet function, so people taking these drugs should not donate platelets for the indicated time; however, you may still be able to donate whole blood.

Anticoagulants or "blood thinners" are used to treat or prevent blood clots in the legs, lungs, or other parts of the body, and to prevent strokes. These medications affect the blood's ability to clot, which might cause excessive bruising or bleeding when you donate.

Isotretinoin, finasteride, dutasteride, acitretin, and etretinate can cause birth defects. Your donated blood could contain high enough levels to damage the unborn baby if transfused to a pregnant woman. Once the medication has been cleared from your blood, you may donate again.

Erivedge (Vismodegib), Anbagio (teriflunomide) can cause birth defects or the death of an unborn baby if transfused to a pregnant woman. Once the medication has been cleared from your blood, you may donate again.

Growth hormone from human pituitary glands was prescribed for children with delayed or impaired growth. The hormone was obtained from human pituitary glands, which are in the brain. Some people who took this hormone developed a rare nervous system condition called Creutzfeldt-Jakob Disease (CJD, for short).

Insulin from cows (bovine, or beef, insulin) is an injected medicine used to treat diabetes. If this insulin came to the United States from the United Kingdom (where "mad cow disease" has occurred) it could contain material from cattle that have "mad cow disease." Although no cases of the human type of "mad cow disease" have been reported in people treated with bovine (beef) insulin, there is concern that someone exposed to "mad cow disease" through beef insulin could transmit it to someone who receives their blood.

Hepatitis B Immune Globulin (HBIG) is an injected material used to prevent hepatitis B infection following a possible or known exposure to hepatitis B. HBIG does not prevent hepatitis B infection in every case, therefore, persons who have received HBIG must wait to donate blood.

Experimental Medication or Unlicensed (Experimental) Vaccine is usually associated with a research study, and the effect on the safety of transfused blood is unknown.

Donors SHOULD NOT discontinue medications prescribed or recommended by their physician in order to donate blood.

Autologous Donors

Autologous donation is the collection, storage, and reinfusion of a recipient's own blood. This is also called autotransfusion. Autologous donations have decreased dramatically since the 1990s (Eder & Muniz, 2014). Decreased interest in autologous donations reflects the decline in viral risk associated with allogeneic blood transfusion; the higher cost and minimal medical benefit of
autologous blood makes it a less desirable option. The use of autologous blood avoids the possibility of alloimmunization because it does not contain foreign RBCs, platelets, and leukocyte antigens. The risk of exposure and disease transmission is also eliminated. Because of this, the use of autologous blood is regarded as safer than homologous transfusion. However, risks associated with labeling and documentation remain. The same precautions used for preparing and administering a homologous blood component must be observed.

**Donation Requirements**

1. An order from the patient’s physician.
2. All blood collection shall be completed more than 72 hours before the time of surgery or transfusion.
3. Vital signs are the same as for allogeneic donor selection.
4. There is a deferral for conditions presenting risk of bacteremia.
5. Hgb is greater than or equal to 11 g/dL, or Hct is greater than or equal to 33%.
6. Candidates must be evaluated by the transfusion service (Eder & Muniz, 2014).

**Advantages**

- Eliminates the risk of alloimmunization (sensitization to RBCs, platelets, and leukocyte antigens).
Eliminates the risk of exposure to blood-borne infectious agents.
Expands the blood resources.
Reduces the need for allogeneic blood (decreases dependence on the volunteer donor supply).
Provides an option for patients who find homologous transfusion unacceptable on religious grounds.
Allows perioperative isovolemic hemodilution.

Disadvantages
Cost of predeposited autologous blood and increased paperwork because of special handling required.
Used only for the donor-patient.

Types
There are four categories of autologous transfusion:

Preoperative Autologous Donation
- The collection and storage of the recipient’s own blood several weeks before scheduled surgery for reinfusion during or after surgery. Patients may be able to donate their own blood up to 72 hours before surgery. Approximately half of preoperatively donated units are discarded, which is a waste of resources (Ghiglione & Puca, 2014).

Acute Normovolemic Hemodilution
- Blood is collected in the operating room after anesthesia induction, with whole blood removed just before surgery so that blood lost during surgery has a lower concentration of RBCs (Ghiglione & Puca, 2014). Blood is collected and replaced with crystalloid or colloid solutions for fluid replacement. The collected blood can be stored at room temperature in the operating room but should be transfused within 8 hours (Richardson, 2014). If the operating room procedure is expected to last more than 8 hours, the blood should be refrigerated and must be transfused within 24 hours (Richardson, 2014).

Intraoperative Autologous Transfusion (Blood Recovery)
- The collection and use of shed blood during surgery. Typically, 2 units of blood are collected early in the surgery from the surgical site. Shed blood can be readministered after being concentrated and washed (washed recovered blood) with a blood recovery device, or it can be filtered and readministered (unwashed recovered blood). Unwashed recovered blood is usually reserved for the postoperative environment where small quantities of blood are collected and reinfused (Ghiglione & Puca, 2014). This blood must be reinfused within 8 hours (Richardson, 2014).

Postoperative Blood Salvage
- The salvage of blood from the surgical field in a single-use, self-contained reservoir for immediate return and reinfusion to the patient. This technique
is used most often after cardiac surgeries and, recently, with orthopedic surgeries, where shed blood volumes are high, often more than 500 mL (Ghiglione & Puca, 2014).

**NURSING FAST FACT!**

Any autologous blood must be filtered during reinfusion to eliminate the possibility of microclots or debris infusion into the patient.

**Patient Blood Management**

PBM is an evidence-based, multidisciplinary process that is designed to reduce, eliminate, or optimize blood transfusions to improve patient outcomes (Seeber & Shander, 2013). The goal of PBM is to ensure the safe and efficient use of the many resources involved in the complex process of blood component therapy. Blood management includes nursing time, technician time, medical supplies, medical devices, laboratory tests, pharmaceuticals, hospital patients, and financial resources. In terms of nursing time, it takes more than 75 minutes of nursing time from prescription through completion of transfusion (Tolich, Blackmur, Stahorsky, & Wabeke, 2013).

Dr. Robert Beal (1976), who worked with the Australian Red Cross Blood Service, said that blood transfusion is like marriage; it should not be entered upon lightly, unadvisedly, or wantonly or more often than is absolutely necessary!

Transfusion of blood products is a commonly performed procedure in the hospital setting (Tolich et al., 2013). In fact, in the United States, nearly 21 million blood components are transfused annually (American Red Cross, 2017a). Unfortunately, many blood components are not administered according to evidence-based practices, thereby consuming precious resources without benefit to patients (Tolich et al., 2013). The following facts should be considered before transfusions:

- Transfusions are not risk free. Transfusions today are the safest in history; however, they can cause some degree of harm. The leading causes of transfusion-related morbidity and mortality are unrelated to viral transmission and include bacterial contamination of platelets, transfusion errors from patient misidentification, and TRALI (Basu, Goel, & Bhattacharya, 2015; Jones & Frasier, 2015; Maynard, 2014). Blood transfusions can improve outcomes but only when used in the right patient for the right indication and in the right dose.
- Blood is a human tissue transplant (Tolich et al., 2013). Infusing blood is not different from solid organ transplant. Blood transfusions can cause
changes in the immune system function of patients, presenting a new set of immune challenges.

- Transfusions can increase health-care–associated infections.
- Transfusion education is necessary to address the gaps in education of physicians and nurses in appropriate ordering and administration of blood products.
- There are financial penalties for poor clinical outcomes related to inappropriate transfusion practices. The CMS and many commercial health insurance carriers will not pay for the cost of treating transfusion errors, bleeding complications in cardiac surgery, and a growing number of hospital-acquired infections that are increased two- to fivefold by blood transfusions.

### Strategic Approach to Blood Management

Blood should be administered only based on appropriate indications. For example, transfusions should be restricted to an Hgb level of 7 to 8 g/dL in stable, hospitalized patients and to 8 g/dL or less in the presence of clinical symptoms for patients with cardiovascular disease (Carson et al., 2012). Decisions regarding transfusion should be based on the patient’s clinical condition in conjunction with laboratory values.

The role of nurses in transfusion-related practices is critical. Some implications include:

- Reduce the risk of iatrogenic anemia from excessive laboratory testing and loss of blood. Repeated phlebotomy is implicated as a contributing factor to blood loss and the need for transfusion (Ghiglione & Puca, 2014). Nurse-driven blood conservation strategies can reduce the need for transfusion (Table 11-5).
- Check Hgb levels on admission to the hospital. Patients admitted with an Hgb less than 10 g/dL are at risk for transfusion, so an in-depth assessment of contributing factors and physical assessment should be performed.
- Recognize that iron deficiency is a major contributor to anemia and that iron studies are warranted.

### Table 11-5  Blood Conservation Methods

<table>
<thead>
<tr>
<th>Minimize laboratory draws; consolidate all daily draws.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evaluate laboratory orders for redundancy and make sure there are stop times on serial orders for testing.</td>
</tr>
<tr>
<td>Use small-volume or pediatric collection tubes.</td>
</tr>
<tr>
<td>Record the amount of blood obtained for laboratory tests and document the output.</td>
</tr>
<tr>
<td>Use point-of-care testing methods that obtain small amounts of blood via capillary puncture whenever possible (e.g., international normalized ratio [INR] meters, glucometers).</td>
</tr>
<tr>
<td>Consider the mixing method for blood sampling from central venous access devices (CVADs) (avoids blood discard before laboratory sampling) (See Chapter 7).</td>
</tr>
</tbody>
</table>

Sources: Gorski et al., 2016, p. S86; Tolich et al., 2013; Welden, 2010.
Follow all organizational procedures related to blood and blood product verification. Transfuse 1 unit of RBCs at a time; then reassess the patient (Tolich et al., 2013).

**INS Standard** Employ blood conservation strategies to reduce phlebotomy-associated blood loss, which is a significant cause of hospital acquired anemia in patients of all ages. This blood loss often results in the need for blood transfusion and its inherent risks (Gorski et al., 2016, p. S86).

**Blood Component Therapy**

Blood is a “liquid organ” with extraordinary and unique functions. Blood carries oxygen to cells, carries waste away from cells, contains disease-fighting cells, and helps in regulation of body pH and temperature. Fifty-five percent of blood is composed of plasma (fluid); the remaining cellular portion (45%) is made up of solids (RBCs, WBCs, and platelets). Blood components are briefly described below. In Table 11-6, volumes, actions and indications, infusion guidance, and special considerations for the more commonly transfused blood components are summarized.

<table>
<thead>
<tr>
<th>Blood Component</th>
<th>Volume</th>
<th>Actions and Indications</th>
<th>Infusion Guide</th>
<th>Special Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Red Blood Cells (RBCs)</strong></td>
<td>225–350 mL</td>
<td>Symptomatic anemia, Hemoglobin level of 7–8 g/dL in stable, hospitalized patients, Hemoglobin 8 g/dL or less in the presence of clinical symptoms for patients with cardiovascular disease</td>
<td>Standard blood filter (150–260 microns) Y administration set, primed with 0.9% sodium chloride, Transfuse each unit in 4 hours or less</td>
<td>Crossmatch required, ABO and Rh compatible, Each unit raises the hemoglobin 1 g and hematocrit 3%, Smaller aliquots of RBC volume can be made for use with neonatal, pediatric, or adult patients with special needs</td>
</tr>
<tr>
<td><strong>Granulocytes</strong></td>
<td>200–300 mL</td>
<td>Transfusion of granulocytes controversial, Treatment of neutropenic patients with documented infections</td>
<td>Standard blood filter Y administration set, primed with 0.9% sodium chloride, No leukocyte-reduction filter</td>
<td>Crossmatch required, ABO and Rh compatible, May be HLA matched, Note: High frequency</td>
</tr>
</tbody>
</table>

*Cotinued*
Table 11-6  Summary of Common Blood Components—cont’d

<table>
<thead>
<tr>
<th>Blood Component</th>
<th>Volume</th>
<th>Actions and Indications</th>
<th>Infusion Guide</th>
<th>Special Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Platelets, Random Donor</td>
<td>40–70 mL/unit</td>
<td>Bleeding due to thrombocytopenia or platelet function abnormality including antiplatelet drugs</td>
<td>Standard blood filter</td>
<td>Crossmatch not required ABO/Rh preferred (the amount of RBCs and platelets harvested with the platelets is generally minimal but occasionally is sufficient to elicit an antigen–antibody response) May be HLA matched Prophylactic medication with antihistamines, antipyretics may be needed</td>
</tr>
<tr>
<td></td>
<td>Usual dose: 4–10 units</td>
<td>Prevention of bleeding from marrow hypoplasia</td>
<td>Y administration set, primed with 0.9% sodium chloride Administer as rapidly as patient can tolerate; generally transfused over 1–2 hours Leukocyte reduction if indicated</td>
<td></td>
</tr>
<tr>
<td>Fresh Frozen Plasma (FFP)</td>
<td>Prepared from whole blood 200–250 mL</td>
<td>Active bleeding with multiple coagulation factor deficiencies Warfarin reversal in the presence of bleeding or in the need for an invasive procedure (e.g., surgery) Disseminated intravascular coagulation (DIC) Massive transfusions in trauma</td>
<td>Standard blood filter</td>
<td>Crossmatch not required ABO compatible Does not provide platelets 1 unit (200 mL) raises the level of clotting factor 2%–3% Requires 20 minutes of thawing time by transfusion service; infuse immediately</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>First 15 minutes: 2–5 mL per hour, then as rapidly as tolerated (up to 300 mL per hour)</td>
<td></td>
</tr>
</tbody>
</table>
# Chapter 11  Transfusion Therapy

## Table 11-6  Summary of Common Blood Components—cont’d

<table>
<thead>
<tr>
<th>Blood Component</th>
<th>Volume</th>
<th>Actions and Indications</th>
<th>Infusion Guide</th>
<th>Special Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cryoprecipitated antihemophilic factor (AHF)</strong></td>
<td>Each unit contains factor VIII, von Willebrand factor (vWF), factor XIII, fibrinogen</td>
<td>Main use today as a source of fibrinogen in acquired coagulopathies: DIC, massive hemorrhage</td>
<td>Standard blood filter</td>
<td>Crossmatch and ABO compatibility not required</td>
</tr>
<tr>
<td></td>
<td>15 mL plasma (5–10 mL/unit)</td>
<td>Alternative to factor VIII</td>
<td>Small priming volume tubing set to decrease loss of product</td>
<td>Infuse as soon as possible after thawing</td>
</tr>
<tr>
<td></td>
<td>Usual order is for 6–10 units</td>
<td></td>
<td>Administer as fast as patient tolerates</td>
<td></td>
</tr>
<tr>
<td><strong>Albumin</strong> (5% = 12.5 g/250 mL; 25% = 12.5 g/50 mL)</td>
<td>5% solution is in concentration of 250 or 500 mL; 25% solution is in concentration of 50–100 mL</td>
<td>Plasma volume expander</td>
<td>May be administered as rapidly as tolerated for reduced blood volume</td>
<td>25% albumin is hypertonic and is five times more concentrated than 5% solutions. Give with extreme caution; can cause circulatory overload</td>
</tr>
<tr>
<td></td>
<td></td>
<td>For hypovolemic shock</td>
<td>Normal rates: 2–4 mL/min for 5% solution; 1 mL/min for 25% solution</td>
<td>No type and crossmatching necessary</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Supports blood pressure during hypotensive episodes; induces diuresis in fluid overload</td>
<td>Supplied in glass bottles with tubing for administration</td>
<td>Store at room temperature</td>
</tr>
<tr>
<td><strong>Plasma Protein Fraction (PPF)</strong> (5% solution)</td>
<td>Glass: 250-mL bottle with tubing (83% albumin, 17% globulin)</td>
<td>Same as for albumin</td>
<td>Equivalent to 5% albumin</td>
<td>Has fewer purification steps than albumin</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Osmotically equal to plasma</td>
<td></td>
<td>No type and crossmatching necessary</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Has high sodium content</td>
<td></td>
</tr>
</tbody>
</table>

## Whole Blood

Whole blood is composed of RBCs, plasma, WBCs, and platelets. The volume of each unit is approximately 500 mL and consists of 200 mL of RBCs and 300 mL of plasma, with a minimum of 33% Hct. Few conditions require transfusion of whole blood. Whole blood is most often used with autologous transfusion (Nester, Jain, & Poisson, 2014). Most whole blood units are used to prepare separate RBC and plasma components to meet specific clinical needs. A whole blood unit can be centrifuged and separated into three components: RBCs, plasma, and platelet concentrate. By transfusing the patient with the specific component needed rather than with whole blood, the patient is not exposed to unnecessary portions of the blood product, and valuable blood resources are
conserved (Fig. 11-4). Whole blood requires type and crossmatching and must be ABO compatible.

**Red Blood Cells**

RBC units are prepared by removing 200 to 250 mL of plasma from a whole blood unit. The remaining packed red blood cells (PRBCs) concentrate has a

---

**Figure 11-4** Derivation of transfusible blood products.
Uses
RBCs are used to improve the oxygen-carrying capacity in patients with symptomatic anemia. The administration of RBCs should be considered only if improvement of the RBC count cannot be achieved through nutrition, drug therapy, or treatment of the underlying disease. As stated earlier, transfusions should be restricted to an Hgb level of 7 to 8 g/dL in stable, hospitalized patients and to 8 g/dL or less in the presence of clinical symptoms for patients with cardiovascular disease (Carson et al., 2012). Per the AABB (2013), RBCs should not be used to treat anemia that can be corrected with hematinic medications (e.g., iron, vitamin B₁₂, folic acid, erythropoietin). Criteria for transfusion should be based on multiple variables, including Hgb and Hct levels, patient symptoms, amount and time frame of blood loss, and surgical procedures.

Leukocyte-Reduced Red Blood Cells
A unit of RBCs contains approximately $10^8$ WBCs. Leukocyte-reduced PRBCs result from removal of the number of leukocytes to less than $5 \times 10^6$ (Nester, Jain & Poisson, 2014). Leukocyte reduction is achieved either by using filtration before transfusion or by using a special filter at the bedside during transfusion. Leukocyte-reduced RBCs require ABO compatibility (Fig. 11-5).

Uses
Leukocyte-reduced components are indicated as follows:

- To reduce the frequency of recurrent febrile nonhemolytic transfusion reactions
- To prevent transmission of cytomegalovirus (CMV)
- To reduce the incidence of HLA alloimmunization

Safety Concern: On rare occasions, patients may develop severe hypotension when leukocyte reduction is performed at the bedside. This happens more often in patients who take angiotensin-converting enzyme (ACE) inhibitors (Maynard, 2014). In general, leukocyte reduction at the time of collection is preferred over filtration at the bedside.
Washed Red Blood Cells

RBCs can be “washed” with sterile normal saline to remove unwanted plasma proteins, including antibodies and glycerol from previously frozen units (AABB, 2013). There are limited clinical indications for washed RBCs. They include IgA deficiency with anaphylactic/anaphylactoid reactions and recurrent severe reactions to unwashed RBC products. A disadvantage is that up to 20% of the RBC yield is lost during the washing procedure (Dunbar, 2014). Anticoagulant-preserved solutions are removed during the washing procedure; therefore, washed RBC units expire 24 hours after washing.

Irradiated Blood Products

Cellular blood components can be irradiated for patient populations at risk for transfusion-associated GVHD. These patients include fetal and neonatal recipients of intrauterine transfusions, immunocompromised patients, recipients of cellular components known to be from a blood relative, and those who have undergone bone marrow transplantation.
Safety Concern: The shelf life of irradiated RBCs is limited to 28 days because irradiation damages the cells and reduces their viability (AABB, 2013). Platelets and granulocytes are not damaged, so their shelf life is not affected.

Granulocytes
Granulocyte concentrations are prepared by apheresis from a single donor of whole blood. Each unit contains granulocytes and variable amounts of lymphocytes, platelets, and RBCs suspended in 200 to 300 mL of plasma.

Granulocyte infusions should be administered as soon after collection as possible because of the well-documented possibility of deterioration of granulocyte function during short-term storage. In general, the administration of granulocytes is controversial, and their use has declined (AABB, 2013; Nester, Jain & Poisson, 2014). Transfusion may not significantly increase the granulocyte count. The primary indication for granulocyte transfusion is in the treatment of neutropenic patients with documented infections unresponsive to antimicrobial therapy. Granulocytes may be transfused daily until the patient has recovered from the infection or upon return of neutrophil production.

Platelets
There are approximately 2.2 million doses of platelets transfused each year in the United States, primarily for prophylactic indications to reduce bleeding risk in patients with thrombocytopenia after cancer chemotherapy or hematopoietic progenitor cell transplantation (Kaufman et al., 2015). Platelets must be stored at room temperature and therefore have a limited shelf life of only 5 days due to the risk of bacterial growth.

Platelets live up to 12 days in the blood, do not have nuclei, and are unable to reproduce. They contain no hemoglobin. Normal platelet counts are 150,000 to 300,000/μL. Platelets can be supplied either as random-donor concentrates or from single-donor apheresis. Random-donor concentrates are prepared from individual units of whole blood by centrifuging the unit to separate the platelets. Single-donor platelet apheresis products are collected from a single donor. During pheresis, the platelets are harvested, and all unneeded portions of the blood are returned back to the donor. A single pheresis unit is equivalent to 6 to 8 units of random-donor platelets (Fig. 11-6).

Use of a single-donor unit has the obvious advantage of exposing the recipient to fewer donors and is ideal for treating patients who have developed HLA antibodies from previous transfusions and have become refractory (unresponsive).
to random-donor platelets. HLA typing may be indicated when patients become refractory to platelets after multiple transfusions.

**NURSING FAST FACT!**

One unit of platelets would be expected to increase the platelet count of a 70-kg adult by 5000 to 10,000/µL and to increase the count of an 18-kg child by 20,000/µL (AABB, 2013).

The effectiveness of platelet transfusions may be altered if fever, infection, or active bleeding is present. To determine the effectiveness of a transfusion, platelet counts may be checked 1 hour and 24 hours after transfusion. Poor platelet count recovery may also indicate that the patient is refractory to random-donor platelets.

**Plasma Derivatives**

**Plasma and Fresh Frozen Plasma**

Plasma is the liquid portion of the blood that is prepared by separating the plasma from the unit of whole blood. It contains albumin, globulins, antibodies, and clotting factors. Plasma does not contain any cellular portion of blood.

**Fresh frozen plasma** (FFP) is prepared from whole blood by separating and freezing the plasma within 8 hours of collection (Richardson, 2014). The volume of a typical unit is 200 to 250 mL. FFP does not provide platelets, and loss of factors V and VIII (i.e., the labile clotting factors) is minimal (Fig. 11-7). FFP must be thawed in a 30°C to 37°C water bath with gentle agitation or kneading. The thawing process takes up to 30 minutes; after thawing, the FFP should be transfused immediately or refrigerated and used within 24 hours.
Safety Concern: Acute allergic reaction is the most common reaction after plasma administration. Most reactions are mild with primarily local symptoms such as hives. Rarely do anaphylactic reactions occur (DomBourian & Holland, 2012).

Cryoprecipitated Antihemophilic Factor

Cryoprecipitated antihemophilic factor (AHF) is prepared from FFP and is the insoluble portion of plasma that remains as a white precipitate after FFP is thawed at 4°C under special conditions. The cold-insoluble precipitate is refrozen. Cryoprecipitate has a shelf life of 1 year. AABB standards require that cryoprecipitate contain at least 80 units of factor VIII and 150 mg of fibrinogen per unit (Dumont, Papari, Aronson, & Dumont, 2014. It is the only concentrated source of fibrinogen and in today’s practice is used for its fibrinogen content (Nester, Jain, & Poisson, 2014). The frozen component is thawed in a protective plastic overwrap in a water bath at 30° to 37°C for up to 15 minutes. It should not be used if there is evidence of container breakage or thawing during storage.

In the 1980s, the discovery of HIV and other disease contamination of the blood supply changed the picture as many persons with hemophilia contracted HIV and HCV. Today, the uses of cryoprecipitate have declined due to the development of factor products without human plasma, through recombinant technology, that are used for hemophilia treatment. Cryoprecipitate may be used in conditions with systemic fibrinolysis, such as those resulting from certain types of chemotherapy or disseminated intravascular coagulation (DIC); however, virus-inactivated fibrinogen concentrates have largely replaced the use of cryoprecipitate.
Recombinant Factor Replacement Products

Today, most of the factor replacement products used in managing hemophilia are derived from recombinant DNA rather than processed from donated plasma.

**Administration**
- Usually administered by slow IV bolus infusion in the acute or home-care environment. Infusion time varies by product, so it is important to follow the manufacturer’s directions.
- Packaged in kits that include a vial of factor (powder), a diluent, and a mixing device; most with a built-in filter. Sometimes, a steel needle IV device is included in the kit.
- Generally supplied by the blood center. Stored in refrigerator or at room temperature (as directed by the manufacturer); shelf life up to 2 years.
- Dosage varies and is based on units per kilogram.

**Factor VIII**

Hemophilia A is a deficiency of coagulation factor VIII that occurs in about 1:10,000 males (Hitch, 2013). Factor VIII replacement either is used routinely for patients with severe hemophilia or may be used situationally in moderate to mild cases, such as patients undergoing prophylactic therapy with planned surgery or with a traumatic event.

**Factor IX**

Hemophilia B is a deficiency of coagulation factor IX that occurs in about 1:50,000 males (Hitch, 2013).

**Safety Concern:** Patients can develop antibodies to replacement factor, making it more difficult to control bleeding. This may require higher doses or a bypassing agent that allows clotting to occur without factor VIII or IX (Hitch, 2013).

**Albumin and Plasma Protein Fraction**

Albumin is a natural plasma protein that is commercially extracted from plasma (Richardson, 2014). It supplies 80% of the osmotic activity of plasma and is the principal product of fractionation (dividing plasma into its component parts). It is administered as plasma protein fraction (PPF) or as purified albumin. Both products (albumin and PPF) are derived from donor plasma, prepared by the cold alcohol fractionation process, and then subsequently heated. Because of the extended heating process, neither product transmits viral diseases, and neither product contains clotting factors. Normal serum albumin is composed of 96% albumin and 4% globulin and other proteins. It is available as a 5% (isotonic) or 25% (hypertonic) solution. PPF is available only in a 5% solution.

**NOTE:** Additional information on albumin as a plasma expander is provided in Chapter 4.
PPF and 5% albumin are isotonic solutions and therefore are osmotically equivalent to an equal volume of plasma. They cause a plasma volume increase, are used interchangeably, and share the same clinical uses. Both are used primarily to increase plasma volume after sudden loss of intravascular volume, as seen in patients with hypovolemic shock from trauma or surgery. Their use may also be indicated in individual cases to support blood pressure during hypotensive episodes or to induce diuresis in those with fluid overload by assisting in fluid mobilization. The plasma derivatives lack clotting factors and other plasma proteins and therefore should not be considered plasma substitutes. Neither component (albumin or PPF) will correct nutritional deficits or chronic hypoalbuminemia.

Twenty-five percent albumin is hypertonic and is five times more concentrated than 5% albumin. This hyperosmotic product is used to draw fluids out of tissues and body cavities into intravascular spaces. This solution must be given with caution. Principal uses for 25% albumin include plasma volume expansion, hypovolemic shock, burns, and prevention or treatment of cerebral edema.

**NURSING FAST FACT!**

Albumin 25% must not be used in dehydrated patients without supplemental fluids or in those at risk for circulatory overload.

**Administration**

Albumin and PPF are supplied in glass bottles. Depending on the brand, albumin in 5% concentrations is available in units of 50-, 250-, 500-, and 1000-mL vials, and 25% concentrations are supplied in units of 20-, 50-, and 100-mL vials (Richardson, 2014). Manufacturers recommend that the solution be used within 4 hours of opening. Depending on the manufacturer, the solutions are sometimes supplied with an infusion set. If no administration set is provided, a standard administration set without a filter is used. Blood transfusion sets and filters are not required for infusion of albumin.

**Alternatives to Blood Transfusions**

Alternatives to blood transfusion focus on management of anemia and blood loss prevention. Many new strategies are now being used in blood management because of the shortages in the U.S. blood supply, risks associated with blood transfusions, and lack of evidence for the efficacy of blood transfusions under certain conditions, along with blood product ordering practice inconsistencies. The following are some alternatives to blood transfusions or transfusion augmentations.

1. Augmentation of volume with colloid solutions
2. Autologous cell salvage
3. RBC substitutes
Augmentation of Volume With Colloid Solutions
Using allogeneic blood to maintain blood volume is not appropriate; plasma expanders can be used for this purpose. Crystalloid and colloid volume expanders are discussed in Chapter 4.

Intraoperative Autologous Transfusion (Blood Recovery)
As discussed earlier, intraoperative autologous transfusion is the collection of blood that would otherwise be lost during a surgical procedure. Collection systems remove debris and return the blood to the patient.

Red Blood Cell Substitutes
A variety of means have been explored to provide the oxygen-carrying capacity of Hgb without using RBCs. The goal of creating an Hgb substitute that is as safe as donor cells continues to be “elusive” (Nester, Jain, & Poisson, 2014).

Erythropoietic-Stimulating Agents
Erythropoietin is an endogenous hormone secreted by the kidneys that stimulates RBC production in the bone marrow. Recombinant human erythropoietin is successfully used for dialysis patients who experience anemia as a result of kidney disease. It can increase a patient’s Hgb level before a surgical procedure where major blood loss is anticipated, and it is used for patients receiving chemotherapy for malignancy. It should be used with caution because of its thromboembolic risks. Furthermore, the majority of preoperative anemia is related to iron deficiency, and simple iron replacement is indicated (Ghiglione & Puca, 2014).

White Blood Cell Growth Factors
Recombinant granulocyte colony-stimulating factor (G-CSF) is used to stimulate the production of granulocytes. Patients receiving chemotherapy have seen the greatest benefit of these medications. A dangerously decreased WBC count that puts the patient at risk for infection is a dose-limiting side effect of many cancer chemotherapy drugs. G-CSF products help maintain levels at near-normal, allowing patients to continue to receive scheduled doses of chemotherapy. It is administered subcutaneously or by IV push.

Administration of Blood Components
The procedure for obtaining a blood component from a hospital transfusion service varies from institution to institution. Regardless of the specific institutional procedure, certain essential guidelines must be followed (Table 11-7).

Step 1: Recipient Consent
Recipient consent for transfusion must be obtained from patients who are competent to make such decisions. Documents of informed consent must contain
indications, risks/benefits, possible side effects, and alternatives to transfusion with allogeneic blood components (Maynard, 2014).

**Step 2: Verifying the Authorized Prescriber’s Order**

The authorized prescriber’s initial order for the clinical laboratory must specify the type of component to be prepared for the patient (e.g., an order for type and crossmatch for RBCs). A second order for the transfusionist should specify:

- The patient’s name and other identifiers
- The component to transfuse
- Any special processing required for the component (e.g., washing, irradiation, or filtration)
- The number of units or volume to be administered
- Date and time of infusion
- Flow rate or duration of the transfusion; this may be described in the organizational policy (Maynard, 2014)

**NOTE:** When multiple types of components are transfused, the order should specify the sequence in which they are to be transfused. Orders must specify any premedications to be given before transfusion.

**Step 3: Pretransfusion**

*Laboratory Testing*

Once the order has been obtained, the transfusion service initiates a series of steps to ensure the provision of compatible components. The laboratory must have a sample of the patient’s blood, which generally must be drawn within 3 days of that of the individual being transfused; the draw date is considered day 0 (Maynard, 2014).
Identification Wristband

Most transfusion agencies require patients to be identified with an armband that matches that of the recipient to the intended product. Barcode-based ID systems are available for safety in transfusion.

Testing of Transfusion Recipient’s Blood Specimen

ABO group and Rh type must be determined to transfuse ABO- and Rh-compatible components. Compatibility testing, or “crossmatch,” is performed between the recipient’s plasma and the donor’s RBCs to ensure that the specific unit intended for transfusion to the recipient is not incompatible. Blood samples from the donor and recipient are mixed and incubated under a variety of conditions and suspending medium. If the recipient’s blood does not agglutinate the donor cells, compatibility is indicated. Transfusion service personnel are responsible for providing serologically compatible blood for transfusion.

When testing is complete, transfusion therapy can begin. The transfusion service has two objectives: (1) to prevent antigen–antibody reactions in the body and (2) to identify an antibody that the recipient may have and to supply blood from a donor who lacks the corresponding antigen. The testing of donor blood and recipient blood is intended to prevent adverse effects of transfusion therapy.

Labeling of Blood and Blood Components With the Recipient’s Information

At the time of issue, the following must be in place:

- A tag or label indicating the recipient’s two independent identifiers and the donor unit number; the compatibility test interpretation, if performed, must be attached securely to the blood container.
- A final check of records maintained in the transfusion service for each unit of blood or component must be made:
  - Two independent identifiers, one of which is usually the patient’s name
  - The recipient’s ABO group and Rh type
  - The donor unit or pool identification number
  - Donor’s ABO group and, if required, Rh type
  - Interpretation of the crossmatch tests (if performed)
  - Date and time of issue
  - Special transfusion requirements (e.g., CMV reduced risk, irradiated, antigen-negative)
- A process must exist to confirm that the identifying information, the request, the records, and the blood or component are all in agreement, and that any and all discrepancies have been resolved before issue (Downes & Shulman, 2014).

Step 4: Vascular Access; Selecting and Preparing the Equipment

It is important for the transfusionist to determine whether a central or peripheral IV line is in place and whether it is acceptable for infusion of blood components.
Selecting the proper equipment includes the catheter and solution as well as obtaining administration sets, special filters, blood warmers, and electronic monitoring devices.

**Vascular Access**

The recommendation for catheter size is dependent on how quickly the blood needs to be administered. An 18- to 20-gauge catheter is often the catheter of choice for peripheral transfusions. However, a 22- to 24-gauge catheter may be used for pediatric patients or those with small or fragile veins, such as in the older adult patient or those who have experienced repeated venipuncture, such as patients with cancer. Central vascular access devices may also be used for transfusions. When smaller catheters are used, blood dilution and use of an infusion pump are helpful. Of note, units that have the preservative solution ADSOL do not require additional dilution (Maynard, 2014).

**EBP** A common misconception is the belief that RBCs must be administered through a large bore catheter to avoid destruction of the cells during the transfusion. Based upon a review of the literature, there was consistent evidence supporting the fact that catheter gauge does not adversely affect blood transfusion (Makic, Martin, Burns, Philbrick & Rauen, 2013). Rather, hemolysis of cells is influenced by adding excessive force or pressure during the transfusion. The researchers state that nursing assessment guide choice of catheter gauge in nonurgent transfusions.

**NOTE:** It is important that vascular access be obtained before the component is received at the patient’s bedside.

**Equipment**

**Solution**

No medication or solution other than 0.9% sodium chloride should be administered simultaneously with blood components through the same tubing (AABB, 2013). The use of dextrose in water or hypotonic solutions can cause RBC hemolysis as a result of cell swelling. Lactated Ringer’s solution is not used because it contains enough ionized calcium to overcome the anticoagulant effect of CPDA-1 and allows small clots to develop.

**INS Standard** Administer blood or blood components with 0.9% sodium chloride. No other solutions or medications should be added to or infused through the same administration set with blood or blood components unless they have been approved by the FDA for this use (Gorski et al., 2016, p. S136).
NOTE: The AABB (2013) allows exceptions to the restrictions mentioned earlier when:
1. The drug or solution has been approved by the FDA for use with blood administration.
2. There is documentation in the literature showing that the addition is safe and does not adversely affect the blood components.

**Administration Sets**

Blood administration sets are available as a Y-type tubing or as single-lead tubing. Y-type administration sets allow for infusion of 0.9% sodium chloride before and after each blood component. A Y-type set also allows for dilution of RBCs that are too viscous to be transfused at an appropriate rate by allowing for sterile transfer of saline into the unit. Platelets and cryoprecipitate should be infused through a filter similar to the standard blood filter but with a smaller drip chamber and shorter tubing so that less priming volume is needed. A syringe device designed specifically for platelets and cryoprecipitate may also be used to administer these products.

Blood administration sets come with an inline filter. Most routine blood filters have a pore size of 170 to 260 microns designed to remove the debris that accumulates in stored blood. It is necessary to fill the filter chamber completely to use all the surface area. RBC filters are designed to filter 1 unit of whole blood or PRBCs. Filters used for platelets and cryoprecipitate may be used to administer multiple units. Filters are changed for two reasons: debris in the blood clogs the filter pores, slowing the rate, and the risk of bacterial contamination increases when filter-trapped blood particles are maintained at room temperature.

**INS Standard** Change the transfusion administration set and filter after the completion of each unit or every 4 hours. If more than 1 unit can be infused in 4 hours, the transfusion set can be used for a 4-hour period (Gorski et al., p. S136).

**Special Filters**

Microaggregate filters are not used routinely. These second-generation filters were developed to remove leukocytes and to complement or replace the standard clot screen. They have been replaced by third-generation leukocyte-reduction filters. Today, microaggregate filters are used for reinfusion of shed autologous blood collected during or after surgery (Maynard, 2014).

Leukocyte-reduction filters are third-generation filters used for the delivery of RBCs and platelets. Filtration may occur immediately after blood collection in the transfusion service or at the time of administration.

These filters are capable of removing more than 99.9% of the leukocytes present in the unit, which decreases the risk of febrile transfusion reactions, the risk of HLA alloimmunization, and the risk of CMV transmission (Maynard, 2014). There are different leukocyte-reduction filters for RBCs and platelets, and it is important to use the correct filter based on the blood component. It is preferred that leukocyte reduction occur prestorage shortly after unit collection.
as compared to bedside filtration. This is because bedside filtration is associated with dramatic hypotension in some patients (Maynard, 2014). These filters are more expensive than standard blood filters and require a specific order before use.

**BLOOD WARMERS**

Blood warmers are rarely needed but may be indicated when rapid transfusion is required. The transfusion of cold components may cause hypothermia and cardiac complications (Maynard, 2014). The risk of clinically significant hypothermia is heightened when trans enticing via a central vascular access device. Blood warmers are also useful for transfusions to neonates or patients with cold agglutinin syndrome.

**NOTE:** The AABB Standards (Levitt, 2014, p. 1) state that “warming devices shall be equipped with a temperature sensing device and a warning system to detect malfunctions and prevent hemolysis or other damage to blood and blood components.”

Blood is warmed only by using a specifically designed blood/fluid warmer (Richardson, 2014). Adhere to the manufacturer’s guidelines when using any of the many types of blood and fluid warmers.

**INS Standard** Use a blood warming device with a labeled indication, when clinically necessary, such as with large volume or rapid transfusions, exchange transfusions, patients with clinically significant conditions, and the neonate/pediatric population (Gorski et al., 2016, p. S136).

**NURSING FAST FACT!**

Blood components should NEVER be placed in microwave ovens or hot water baths because of damage to RBCs and the lack of temperature control, which may cause fatal complications for the patient.

**ELECTRONIC INFUSION DEVICE**

Infusion pumps may be used for transfusions. Only pumps designed for the infusion of whole blood and RBCs may be used because some infusion pumps may cause hemolysis. Pumps require the use of pump-compatible tubing. A pump’s manufacturer should be consulted for detailed information on the pump’s suitability for transfusing blood components.

**INS Standard** Electronic infusion devices (EID) can be used to deliver blood or blood components without significant risk of hemolysis of RBCs. Only EIDs that have a labeled indication for blood transfusion should be used. Follow the manufacturer’s directions for use (Gorski et al., 2016, p. S136).
Pressure Devices

The use of an externally applied pneumatic pressure device may achieve flow rates of 70 to 300 mL/min, depending on the pressure applied. The use of pressure devices has been reported to provide only a small increment in component flow rates. This is considered a safe practice in the majority of RBC transfusions (Maynard, 2014). Before use, verify the IV patency of the peripheral IV catheter. Recognize that the use of pressure may increase the risk of cell hemolysis.

**INS Standard** External compression devices, if used, should be equipped with a pressure gauge, totally encase the blood bag, and apply uniform pressure against all parts of the blood container (Gorski et al., 2016, p. S136).

Step 5: Preparing the Patient

Patient preparation begins when the transfusion of a blood component is anticipated. Urgency factors related to the transfusion may affect the amount of time available to prepare the patient for the transfusion. The steps of the nursing process are activated, including assessment and the establishment of new goals and interventions related to the transfusion.

**Patient/Family Education**

The patient’s and the patient’s family’s understanding of the need for blood, the procedure, and related concerns need to be assessed. Typically, concerns are expressed regarding the risks of disease transmission and their need to be addressed.

The patient should be instructed regarding the length of time for the procedure and the need for monitoring his or her vital signs and physical condition. Signs and symptoms that may be associated with a complication of the component to be given should be explained to the patient and family members. It is not necessary to offer graphic explanations regarding symptoms; rather, a brief description of possible symptoms should be provided, and the patient should be asked to report any different sensations after the transfusion has been started. Because transfusions typically take several hours, preparation includes making the patient physically comfortable.

**Assessment**

A baseline assessment of the patient should include the following:

- Vital signs; oxygen saturation is often included.
- Presence of any signs or symptoms that might be confused with a transfusion reaction, such as dyspnea, rashes, pruritus, chills, wheezing
- Presence of diseases that increase risk for fluid volume overload (e.g., heart failure) and may require a slower infusion rate (Maynard, 2014)

If the vital signs are abnormal, consult with the licensed independent practitioner (LIP) before initiating the transfusion. An elevated temperature may destroy cellular components at an increased rate and mask symptoms of a transfusion reaction (Maynard, 2014). Premedication with diuretics, antihistamines, or antipyretics may be necessary to help keep the vital signs at acceptable levels.
Assessment of the lungs and renal function should be documented before transfusion. The nurse should review the laboratory data (Hgb, Hct, platelets, clotting times) and anticipate how the component to be administered will affect these values over the next 24 hours. The patient should also be questioned regarding any symptoms he or she may be experiencing that could be confused with a transfusion reaction.

**Step 6: Dispensing and Transporting the Component**

As a rule, except in emergency situations, if blood is obtained from an on-site transfusion service, only one product will be issued at a time, and it must be initiated within 30 minutes (usually) or returned to the transfusion service for proper storage (Maynard, 2014). The blood component should not be obtained until the patient is ready to receive it. If blood is obtained from an off-site transfusion service, multiple units may be issued at one time. These units will be packaged to provide optimum storage conditions, and time limits for safe initiation will be detailed by the transfusion service.

**NURSING FAST FACT!**

Proper identification is essential to ensure that the blood component is going to the intended recipient. Several items must always be verified and recorded before the transfusion is initiated.

- The order should always be verified before the component is picked up.
- When the blood is issued, the intended recipient’s two independent identifiers should be verified (name, date of birth, or patient identification number and/or unique identifier given at the time the crossmatch sample is drawn).
- The donor unit or pool identification number, donor ABO group, and, if required, the Rh type should be verified.
- The notation of ABO group and Rh type must be the same on the primary blood bag label as on the transfusion form. This information is to be recorded on the attached compatibility tag or label.
The donor number must be identically recorded on the label of the blood bag, the transfusion form, and the attached compatibility tag.

The color, appearance, and expiration date of the component must be checked.

The name of the person issuing the blood, the name of the person to whom the blood is issued, and the date and time of issue must be recorded. Often this is in a book in the laboratory.

**Step 7: Initiating the Transfusion**

The identification of the unit and the recipient must be verified by the nurse and another health-care provider qualified in performing identification verification (often a second nurse). The transfusion check includes:

- **Prescriber’s order:** Check the blood or component against the prescriber’s written order to verify that the correct component and amount are being given. If leukocyte reduction or irradiation was ordered, check that this was performed.
- **Transfusion consent form:** Check that the form is completed per organizational policy.
- **Recipient identification:** The name and identification number on the patient’s identification band must be identical with the name and number attached to the unit. Usually the barcodes on the unit and the patient’s wristband are scanned as part of the identification process.
- **Unit identification:** The unit identification number on the blood container, the transfusion form, and the tag attached to the unit must agree.
- **Blood type:** The patient’s blood type should be compatible with the unit.
- **Expiration:** The expiration date and time of the donor unit should be verified as acceptable.
- **Compatibility:** The interpretation of compatibility testing must be recorded on the transfusion form and on the tag attached to the unit.
- **Appearance:** The unit should be returned if there is any discoloration, foaming, presence of bubbles, cloudiness, presence of clots or clumps, or loss of integrity of the container (Maynard, 2014).

**NURSING FAST FACT!**

- The qualified transfusionist who will administer the blood component verifies the component at the patient’s side with another qualified health-care provider; alternatively, a one-person verification process using automated identification technology such as barcoding may be used (Maynard, 2014).
- Unless the exact time is given, the component expires at midnight on the expiration date.
- Identify any discrepancies during any part of the identification process. The transfusion should not be initiated until the transfusion service is notified and any discrepancies are resolved.
Use proper hand hygiene and follow standard precautions when administering blood components. Wear gloves! When using a Y-type blood set, spike one port with 0.9% sodium chloride and prime the tubing, being sure to saturate the filter. To administer whole blood or RBCs, spike the blood container on the second port and hang it up. Turn off the 0.9% sodium chloride and turn on the blood component. It is recommended that transfusions of RBCs be started at 1 to 2 mL/min for the first 15 minutes of the transfusion (Maynard, 2014). Refer to Procedures Display 11-1 at the end of this chapter.

This small amount is large enough to alert the nurse to a possible severe reaction but small enough that the reaction probably can be successfully treated. If the patient shows signs or symptoms of an adverse reaction, the transfusion must be stopped immediately; only a small amount of blood product will have been infused. After the first 15 minutes has safely passed, the rate of flow can be increased to complete the transfusion within the amount of time indicated by the LIP or by policy. The rate of infusion should be based on the patient’s blood volume, hemodynamic condition, and cardiac status.

RBC products should be infused within a 4-hour period. When a longer transfusion time is clinically indicated, the unit may be divided by the transfusion service, and the portion not being transfused can be properly refrigerated.

**Step 8: Monitoring the Transfusion**

The patient’s vital signs should be taken within 5 to 15 minutes of initiating the transfusion and then according to organizational policy. There is little evidence requiring routine assessment of vital signs other than before initiation, shortly after starting the transfusion, and after the transfusion (Maynard, 2014).

**Step 9: Completing the Transfusion**

At the completion of the transfusion, the patient’s vital signs should be obtained. The bag and tubing are discarded in a biohazard container. At this point, another unit may be infused, the unit and line may be discontinued, the vascular access device may be locked, or a new administration set and solution container may be added.

**NURSING FAST FACT!**

Do not save previous solutions and tubing that were interrupted to give the blood component; they are considered contaminated. Restart with a fresh set and solution.
Documentation is an important part of the nursing intervention. The documentation in the patient's medical record and should include the following:

1. Medical order for transfusion
2. Documentation of recipient consent
3. Name or type of component
4. Donor unit or pool identification number
5. Date and time of transfusion
6. Pre- and post-transfusion vital signs
7. Volume transfused
8. Identification of the transfusionist
9. Any adverse events possibly related to the transfusion

Some transfusion service departments require that a copy of the completed transfusion form be returned to them. Returning the blood component after an uncomplicated transfusion is not required in all facilities. If disposal is allowed on the unit, use hospital standards in disposing the blood bag in contaminated trash.

**NOTE:** If an additional unit needs to be transfused, the institution's guidelines should be followed. A new blood administration set is to be used with each component. Blood unit administration must be completed within 4 hours.

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**NURSING POINTS OF CARE**

**DELIVERY OF BLOOD COMPONENT THERAPY**

**Nursing Assessment**

- Interview the patient regarding his or her understanding of the need for the blood component.
- Determine the patient's understanding of options as appropriate: autologous, allogeneic, and directed donations.
- Assess vital signs.
- Assess renal and cardiovascular function.
- Assess and evaluate the IV site before requesting blood component from the transfusion service.
- Review laboratory test results.
- Assess current intake and output ratios.

**Key Nursing Interventions**

1. Verify that the patient's written informed consent has been obtained.
2. Verify with another health-care provider that the blood product matches the patient's blood type.
3. Validate patient identification with two identifiers.
4. Administer blood products properly and according to organizational procedure.
5. Prime the administration system with 0.9% sodium chloride.
6. Use an EID with a labeled indication for blood transfusion, if indicated.
7. Never administer IV medications into blood or blood product lines.
8. Monitor:
   a. The IV site for signs and symptoms of complications
   b. Vital signs: Baseline (prior to transfusion), within 5 to 15 minutes of initiating transfusion, on completion of transfusion
   c. Fluid status
   d. Flow rate of the transfusion
9. Change the blood administration set after every unit of RBCs transfused or every 4 hours, whichever comes first.
10. Document the time frame of the transfusion and volume infused.
11. Document patient tolerance to first 15 minutes of transfusion.
14. Stop the transfusion immediately if a reaction is suspected and follow policy and procedure for interventions related to the reaction.
15. Notify the laboratory and the LIP in the event of a blood reaction.
16. Maintain aseptic technique and standard precautions with all transfusion/infusion procedures.
17. Evaluate the effect of transfusion on laboratory test results at 24 hours.

Complications Associated With Blood Component Therapy

Significant, and sometimes life-threatening, complications are associated with transfusion therapy (Table 11-8). Adverse reactions can be classified into immunological and nonimmunological categories. Complications are described below. Notably, the three most common reported causes of mortality associated with transfusions are transfusion-related acute lung injury (TRALI), hemolytic transfusion reactions, and transfusion-associated circulatory overload (TACO) (Mazzei, Popovsky, & Kopko, 2014). In Table 11-9, signs and symptoms, intervention, and prevention are listed in a quick-guide format.

Summary: Patient-Focused Interventions

1. Stop the transfusion immediately but keep the line open with saline. Because the blood setup contains a significant amount of blood, in some cases it is necessary to replace the saline-primed administration set (e.g., acute hemolytic transfusion reaction).

(Text continued on page 593)
Table 11-8  Risks of Transfusion Therapy

<table>
<thead>
<tr>
<th>Viral Infection</th>
<th>Estimated Risks per Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>HIV-1 and HIV-2</td>
<td>1:1,467,000</td>
</tr>
<tr>
<td>Hepatitis B virus (HBV)</td>
<td>1:843,000 to 1:1,208,000</td>
</tr>
<tr>
<td>Hepatitis C virus (HCV)</td>
<td>1:1,149,000</td>
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</tbody>
</table>

**Acute Transfusion Reactions <24 hours**

<table>
<thead>
<tr>
<th>Reaction</th>
<th>Etiology</th>
</tr>
</thead>
</table>
| Hemolytic transfusion reactions             | ABO/Rh mismatch: 1:40,000  
Acute hemolytic transfusion reaction (AHTR): 1:76,000  
Fatal HTRs: 1:1.8 million                                                                 |
| Febrile nonhemolytic transfusion reaction   | 0.1%–1% with universal leukocyte reduction                                |
| Minor allergic reaction                     | 1:100 to 1:33 (1%–3%)                                                   |
| Anaphylaxis                                 | 1:20,000 to 1:50,000                                                   |
| Transfusion-related acute lung injury (TRALI)| 1:1200 to 1:190,000                                                   |
| Circulatory overload                        | <1%                                                                      |

**Delayed Reactions**

<table>
<thead>
<tr>
<th>Reaction</th>
<th>Etiology</th>
</tr>
</thead>
<tbody>
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<td>Alloimmunization, red blood cell antigens</td>
<td>1:100 (10%)</td>
</tr>
<tr>
<td>Alloimmunization, HLA antigens</td>
<td>1:10 (1%)</td>
</tr>
<tr>
<td>Delayed hemolytic</td>
<td>1:2500 to 1:11,000</td>
</tr>
</tbody>
</table>

Sources: Galel, 2014; Mazzei et al., 2014.

---

Table 11-9  Summary of Transfusion Reactions

<table>
<thead>
<tr>
<th>Transfusion Reaction</th>
<th>Etiology</th>
<th>Signs and Symptoms</th>
<th>Key Interventions</th>
<th>Prevention</th>
</tr>
</thead>
</table>
| Acute Immediate (<24 hours) | Transfusion of ABO-incompatible red blood cells (RBCs). Hemolysis occurs when antibodies in plasma attach to antigens on the donor’s RBCs. | Fever with/without chills  
Tachycardia  
Abdominal, chest, flank, back pain  
Hypotension  
Shortness of breath  
Red/dark urine  
Shock | STOP  
TRANSFUSION!  
Get help immediately.  
Change administration set and infuse 0.9% sodium chloride.  
Treat shock.  
Maintain blood pressure (BP)/renal perfusion.  
Administer diuretics to maintain blood flow. | Exercise extreme care during the entire identification process.  
Start transfusion slowly and monitor for first 15 minutes. |
<table>
<thead>
<tr>
<th>Transfusion Reaction</th>
<th>Etiology</th>
<th>Signs and Symptoms</th>
<th>Key Interventions</th>
<th>Prevention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Febrile nonhemolytic reaction</td>
<td>Occurs as a result of antibodies directed against leukocytes or platelets.</td>
<td>Fever rise of &gt;1°C (2°F) during or shortly after transfusion; Chills; Headache; Vomiting</td>
<td>Stop the transfusion.</td>
<td>Use leukocyte-reduced blood component.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Change administration set and infuse 0.9% sodium chloride. Notify the LIP. Monitor vital signs. Anticipate order for antipyretic agents. If ordered, restart transfusion slowly.</td>
<td>Antipyretic premedication (acetaminophen, no aspirin)</td>
</tr>
</tbody>
</table>

| Transfusion-related acute lung injury (TRALI) | WBC antibodies usually from donor and WBC-activating | Fever; Respiratory failure; Hypoxemia; Hypotension | Stop transfusion. Provide respiratory support. Administer oxygen. | No mechanism to identify which patients are at risk. |

**Table 11-9 Summary of Transfusion Reactions—cont’d**
# Chapter 11 Transfusion Therapy

## Table 11-9 Summary of Transfusion Reactions—cont’d

<table>
<thead>
<tr>
<th>Transfusion Reaction</th>
<th>Etiology</th>
<th>Signs and Symptoms</th>
<th>Key Interventions</th>
<th>Prevention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transfusion- associated circulatory overload (TACO)</td>
<td>Volume overload, Greatest risk in patients older than 70 and in infants</td>
<td>Dyspnea, Orthopnea, Cyanosis, Tachycardia, Jugular venous distention, Increased BP, Cough</td>
<td>Stop the transfusion, Place patient in sitting position, Notify the LIP, Administer diuretics, Administer oxygen</td>
<td>Monitor patient frequently, Reduce flow rate in high-risk patients, Monitor intake and output</td>
</tr>
</tbody>
</table>

## Complications of Massive Transfusions

| Citrate toxicity | Rare, High-rate infusions, liver unable to keep up with the rapid administration and cannot metabolize the citrate (which chelates calcium), reducing the ionized calcium concentration in the recipient’s blood. | Cardiac dysrhythmias, Periarticular and peripheral tingling, Muscular cramps, Shivering, Light-headedness | Slow rate of infusion, Administer calcium chloride or calcium gluconate based upon symptoms of hypocalcemia. | Monitor patients with hepatic impairment. |
Table 11-9  Summary of Transfusion Reactions—cont’d

<table>
<thead>
<tr>
<th>Transfusion Reaction</th>
<th>Etiology</th>
<th>Signs and Symptoms</th>
<th>Key Interventions</th>
<th>Prevention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hyperkalemia/ hypokalemia</td>
<td>Rare Administration of blood that has been stored. Related to release of potassium from the RBCs as they go through lysis. Increased risk in patients with renal failure, in premature and newborn infants</td>
<td>Elevated/low potassium levels Slow, irregular heart rate Nausea Muscle weakness Electrocardiographic (ECG) changes Diarrhea Renal failure</td>
<td>Stop or slow the transfusion. Monitor the ECG. Notify the LIP for further interventions.</td>
<td>No preventative strategy</td>
</tr>
<tr>
<td>Hemostatic abnormalities in massive transfusions</td>
<td>Coagulopathy related to massive transfusions. Caused by dilution of platelets and clotting factors.</td>
<td>Occurs after replacement of 2–3 blood volumes Clinical evidence of bleeding Platelet count &lt;50,000 Shock and disseminated intravascular coagulation (DIC)</td>
<td>Intraoperative laboratory testing</td>
<td>No specific guidelines</td>
</tr>
</tbody>
</table>

Delayed Transfusion Reactions

| Delayed hemolytic transfusion reaction | Result of RBC antigen incompatibility other than the ABO group. Occur due to destruction of transfused RBCs by alloantibodies not discovered during the cross-match procedures | Occurs days to weeks after transfusion Fever (constitutional low grade) Malaise Jaundice (mild) Malaise Decreased hemoglobin | No acute treatment required Monitor Hgb level Renal function Coagulation profile Notify transfusion services | Identify antibodies and transfuse compatible RBCs in future. |

Continued
### Table 11-9  Summary of Transfusion Reactions—cont’d

<table>
<thead>
<tr>
<th>Transfusion Reaction</th>
<th>Etiology</th>
<th>Signs and Symptoms</th>
<th>Key Interventions</th>
<th>Prevention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transfusion-associated graft-versus-host disease (TA-GVHD)</td>
<td>Rare and fatal Viable T lymphocytes in transfusion component engraft in recipient and react against recipient tissue antigens. Highest risk in the immunocompromised patient.</td>
<td>Fever Maculopapular rash Increased levels on hepatic function tests Watery diarrhea Pancytopenia</td>
<td>No effective therapy Treatment of symptoms</td>
<td>Administer irradiated blood products in immunocompromised patients.</td>
</tr>
<tr>
<td>Iron overload</td>
<td>Multiple units (usually &gt;100) of RBCs chronically transfused. Excretion of iron from 1 unit slow.</td>
<td>Development of organ failure Signs and symptoms associated with heart failure, cirrhosis, diabetes</td>
<td>Iron chelation</td>
<td>Iron chelation</td>
</tr>
</tbody>
</table>

**Infection-Related Complications**

| Bacterial contamination | Occurs at the time of donation or in preparing the component for infusion. Highest risk in platelets | High fever Severe chills Hypotension Flushing Shock Hemoglobinuria Renal failure DIC | Stop transfusion. Aggressively treat shock and anticipate order of steroids and antibiotics. Culture patient’s blood, component, and all IV solutions. | Preventable Exercise proper care of blood product from procurement through administration. Pay attention to skin anti-sepsis prior to venipuncture during blood donation process. Inspect unit before administration and do not administer if clots, bubbles, leaks in bag, or discoloration of the blood or plasma is present. Complete transfusion within 4 hours. |

2. Reconfirm that the unit of blood is being administered to the intended recipient; document this recheck of identification. The labels on the component, patient records, and patient identification should be examined to detect any identification errors. Transfusion facilities may require repeat ABO and Rh typing of the patient on a new sample.

3. Contact the treating LIP immediately for instructions for patient care.

**Summary: Component-Focused Interventions**

1. Contact the transfusion service for directions for investigation.
2. Follow organizational policy for return of the remaining component and complete IV setup (fluid and tubing) (Maynard, 2014).

**Acute or Immediate Transfusion Reactions**

Acute or immediate adverse reactions to blood or blood products are those that occur within 24 hours of transfusion and may occur during the transfusion. The clinical significance of an acute reaction often cannot be determined by clinical history or signs and symptoms alone but requires laboratory evaluation. Signs and symptoms may be associated with more than one type of adverse reaction. In general, signs and symptoms indicative of a reaction include:

- Fever
- Chills with or without rigors
- Respiratory distress: wheezing, coughing, dyspnea
- Hyper- or hypotension
- Abdominal, chest, flank, or back pain
- Infusion site pain
- Skin reactions: urticaria, rash, flushing, pruritus, localized edema
- Jaundice/hemoglobinuria
- Nausea/vomiting
- Abnormal bleeding
- Oliguria/anuria

(Mazzei et al., 2014)

**Acute Hemolytic Transfusion Reactions**

The most serious and potentially life-threatening reaction is acute hemolytic transfusion reaction (AHTR), which occurs when the donor’s RBCs are incompatible with the patient’s plasma as a result of identification errors during the transfusion process. As few as 10 mL of the wrong blood can produce AHTR symptoms. Death from AHTR is estimated to occur in 1:1.8 million transfusions (Mazzei et al., 2014).

Extreme care during the entire identification process is the first step in prevention. Clerical and human errors involving proper patient, sample, and blood unit identification are the most common causes of AHTR. The transfusion must be started slowly, and evaluation of the patient for reactions during the first 15 minutes is needed to monitor for initial AHTR.
Febrile Nonhemolytic Transfusion Reactions

The nonhemolytic febrile reaction is manifested by a rise in temperature of 1°C (2°F) or more in association with transfusion but without any other explanation (AABB, 2013). It usually occurs as a result of reactions to antibodies directed against leukocytes or platelets. Febrile reactions occur in only 1% of transfusions; repeat reactions are uncommon. Such reactions can occur immediately or within 1 to 2 hours after transfusion is completed. Patients who experience repeated, severe febrile reactions may benefit from leukocyte-reduced components.

**NOTE:** The remainder of the implicated component should not be transfused.

Allergic Reactions

In their mild forms, allergic reactions are a common type of reaction. They are probably caused by allergens in the component or, less often, by antibodies from an allergic donor (Mazzei et al., 2014). The patient may experience mild localized urticaria, pruritus, and flushing. Allergic reactions usually occur within seconds to minutes of starting the transfusion. Most reactions respond to antihistamines. Severe anaphylactic reactions include symptoms of urticaria and angioedema but progress to severe hypotension, shock, and loss of consciousness.

**NURSING FAST FACT!**

Mild allergic reactions characterized by urticaria is the only transfusion reaction in which administration of the component may be resumed after treatment (Mazzei et al., 2014).

Transfusion-Related Acute Lung Injury (TRALI)

TRALI is a severe and life-threatening reaction characterized by symptoms associated with acute respiratory distress syndrome, such as fever, chills, dyspnea, cyanosis, and hypotension. Pulmonary edema occurs secondary to leakage of protein-rich fluid into the alveolar space (Mazzei et al., 2014). TRALI is the leading cause of transfusion-associated mortality (5%–15%) (Richardson, 2014). It most often begins within 1 to 2 hours after transfusion but can occur up to
6 hours after transfusion. TRALI is a clinical diagnosis without specific diagnostic tests; rather, it is a diagnosis of exclusion (Mazzei et al., 2014). Three main conditions need to be differentiated from TRALI:

1. Anaphylactic transfusion reactions: They usually do not include symptoms of fever and pulmonary edema.
2. TACO: This is a cardiac syndrome, whereas TRALI is not.
3. Transfusion-related sepsis: Does not usually include symptoms of respiratory distress (Mazzei et al., 2014).

Although the exact mechanism for TRALI is not known, it is associated with antibodies to leukocyte antigens and the infusion of biological response modifiers. Infusion of either is thought to initiate a sequence of events that results in cellular activation and damage of the basement membrane. TRALI has been associated with transfusion of blood components from female donors with HLA and human neutrophil antigen (HNA) antibodies (Mazzei et al., 2014; Richardson, 2014). Studies have found an increased prevalence of HLA antibodies in female blood donors with history of pregnancy (Mazzei et al., 2014).

**NOTE:** TRALI is a life-threatening complication.

**Transfusion-Associated Circulatory Overload**

The rapid administration of any blood product can lead to TACO. RBC products, plasma products, and 25% albumin are the blood components most commonly associated with circulatory overload. Patients at greatest risk are infants and adults older than 70 years (Mazzei et al., 2014). Individuals with compromised cardiac or pulmonary function are also at risk. Signs and symptoms generally occur within 1 to 2 hours of transfusion.

Patients identified as being at risk for TACO should have blood infused at a reduced rate. Recommendations are to administer blood at a rate of 1 mL/kg body weight/hr, which is about 4 hours per unit to prevent overload (Richardson, 2014). Consider administration of a diuretic when beginning the transfusion in at-risk recipients. Monitor vital signs and intake and output throughout the transfusion.

**Less Common Complications**

**Complications of Massive Transfusions**

**Citrate Toxicity**

A reaction to toxic proportions of citrate, which is used as a preservative in blood, can cause hypocalcemia. The citrate ion can combine with the recipient’s serum calcium, causing a calcium deficiency; normal citrate metabolism is hindered by the presence of hepatic disease. Patients at risk for development of citrate toxicity or a calcium deficit are those who receive large-volume transfusions or who have hepatic disease. The liver, unable to keep up with the rapid administration, cannot metabolize the citrate, which chelates calcium, reducing
the ionized calcium concentration. Hypocalcemia may induce cardiac dysrhythmias. Slow the infusion rate and, based on symptoms and blood values of calcium, administer calcium chloride or calcium gluconate solution. Do not administer calcium via the administration set infusing the blood.

**Hyperkalemia and Hypokalemia**

Potassium toxicity is a rare complication. As the blood ages during storage, potassium is released from the cells into the plasma during RBC lysis. When RBCs have been stored at 1° to 6°C, there is leakage of intracellular potassium into the plasma. Because there is rapid dilution during transfusion, redistribution of potassium into cells, and excretion, hyperkalemia is a rare problem. It may be a problem in patients with renal failure, in premature infants, and in newborns who have large transfusions. Hypokalemia is generally of greater concern because potassium-depleted donor RBCs reaccumulate this ion intracellularly, and citrate metabolism causes further movement of potassium into the cells (Mazzei et al., 2014). Single-unit transfusion is generally not a problem, but individuals who receive multiple units of aged blood may experience this reaction. Patients with renal failure, premature infants, and newborns receiving large transfusions are at risk.

**Hemostatic Abnormalities in Massive Transfusions**

Coagulopathy can be observed when massive transfusion is required for severe blood loss, especially when the lost blood is initially replaced with RBCs. It is caused by the dilution of platelets and clotting factors, which occurs as the patient loses hemostatically active blood, and by reduction of enzymatic activity (Mazzei et al., 2014).

**Delayed Transfusion Reactions**

**Delayed Hemolytic Transfusion Reaction**

Delayed HTRs are a result of RBC antigen incompatibility other than with the ABO group. Rapid production of RBC antibody occurs shortly after transfusion of the corresponding antigen as a result of sensitization during previous transfusions or pregnancies. Destruction of the transfused RBCs gradually occurs over 2 or more days or up to several weeks after the transfusion. Reactions are common but often go unnoticed.

**Transfusion-Associated Graft-versus-Host Disease**

Transfusion-associated GVHD (TA-GVHD) is a rare and dangerous complication that is almost always fatal. It occurs when viable T lymphocytes in the transfused component engraft in the recipient and react against recipient tissue antigens (AABB, 2013). In essence, the T lymphocytes proliferate and begin to attack host tissue cells. Symptoms typically occur 8 to 10 days after the transfusion and include rash, fever, and diarrhea. Patients with risk factors for TA-GVHD include those with severe cellular immunodeficiency including leukemia, lymphoma, use of immunosuppressive drugs administered post-transplant or myeloablative chemotherapy, congenital immunodeficiency disorders, and neonates (Mazzei et al., 2014). Death from bleeding or infection typically occurs within 3 weeks. There
is no cure for TA-GVHD. Gamma irradiation of all cellular components is the only way to prevent TA-GVHD (Mazzei et al., 2014).

**NURSING FAST FACT!**

Immunocompromised recipients are at risk for TA-GVHD.

### Cultural and Ethnic Considerations: Risk for Transfusion-Associated Graft-Versus-Host Disease

The degree of genetic diversity in populations affects the risk of developing TA-GVHD. In Japan the range is 1:874, whereas in France the range is 1:16,835. The difference is related to a decreased diversity in HLA antigen expression in the Japanese population (Mazzei et al., 2014).

### Iron Overload

Patients who are chronically transfused for diseases are at risk for iron overload (Mazzei et al., 2014). Diseases associated with frequent transfusion include sickle cell disease, beta-thalassemia major, and myelodysplasia (Eckes, 2011).

A unit of RBCs contains approximately 250 mg of iron. Normally, 1 to 2 mg/day of iron is excreted through sloughing of the intestinal mucosa and the skin; small amounts are excreted in urine and bile (Mir, 2016). As RBCs are destroyed, the majority of the released iron cannot be excreted and is stored in the body as hemosiderin. Hemosiderin does not circulate in the blood but is deposited in tissues. The main organs affected by this iron surplus are the liver, heart, lung, and endocrine glands. The damage to organs occurs long before clinical symptoms appear (Richardson, 2014). The consequences of unchelated iron overload include heart failure, cirrhosis, and endocrine diseases (e.g., diabetes). Patients may be treated with iron chelation therapy (e.g., I.V. or SC deferoxamine therapy).

### Infection-Related Complications

#### Transfusion-Transmitted Diseases

Despite all of the advances and attention to safety in blood banking and transfusion medicine, there are still risks to blood component therapy. Patients should be informed about alternatives to transfusion as well as the risks to them if transfusion is not undertaken. Furthermore, patients need to know about the blood center’s autologous transfusion and patient-designated donor programs.

A uniform donor history is designed to ask questions that protect the health of both the donor and the recipient. Questions asked of the donor help determine whether donating blood might endanger his or her health. If a prospective donor responds positively to any of these questions, he or she will be “deferred” or asked not to donate blood. The health history also is used to identify prospective donors who have been exposed to or who may have disease, such as HIV,
hepatitis, or malaria (AABB, 2013). Table 11-8 provides information related to the incidence of transfusion-acquired viral infections.

**Viruses**

Transfusion transmission of HIV, HCV, and HBV is “now so rare that the rate of transmission cannot be measured by prospective studies … only estimated by theoretical modeling” (Galel, 2014, p. 192). The estimated risks given in Table 11-8 are based on calculations.

**Cytomegalovirus**

CMV is a virus belonging to the herpes group that can be transmitted from a blood transfusion, primarily from WBCs present in blood components. Most adults have been exposed to CMV because the majority of blood donors have CMV antibodies (Galel, 2014). CMV infection usually is mild but may be serious or fatal for those who are immunocompromised, for low-birth-weight infants, and for bone marrow and organ transplant patients. Patients at risk for CMV infection should receive blood components from donors who are CMV-negative or components that are leukocyte reduced.

**Bacteria**

Bacterial contamination of blood components, mainly platelets, continues to cause transfusion-related death, after TRALI and hemolytic reactions (Galel, 2014). Bacteria are present in 1:3000 cellular blood components. Sources of bacteria include the donor’s skin and asymptomatic bacteria in the donor’s bloodstream. Immediately following blood collection, the level of bacteria is too low to detect or cause recipient symptoms. However, the bacteria proliferate during storage. Because platelets are stored at room temperature, the associated risk is greatest.

Attention to skin antisepsis during venipuncture preceding blood donation is a critical step. Most often, two-stage procedures involving use of chlorhexidine, alcohol, and iodophors (e.g., Betadine) are used in skin antisepsis. Also, “diversion pouches” are used to discard the first 10 to 40 mL of donor blood away from the blood collection container. This is required for all platelet collections and for whole blood collection where platelets are extracted (Galel, 2014). There are additional methods used to detect the presence of bacteria in platelets as part of quality control. Refrigerated storage limits the growth and viability of most bacteria in RBC products.

**Prions**

Prions are proteinaceous infectious particles that cause fatal infections of the nervous system called transmissible spongiform encephalopathies (TSEs). The best-known TSE disease in humans is Creutzfeldt–Jakob disease (CJD). This is a rare degenerative and fatal nervous system disorder. CJD has been transmitted via infusion or implantation of devices extracted from infected central nervous system tissues but has not been known to be transmissible via blood transfusion (Galel, 2014). Although there is no screening test for the disease, as a precaution the FDA prohibits blood donation by individuals who may be
at risk. These include potential donors who have received injections of human-derived pituitary hormone, those with a family history of CJD, and those who have undergone surgeries that involved transplanted dura mater.

Similar to CJD, variant CJD (vCJD), commonly known as the human form of “mad cow” disease, is a rare degenerative and fatal nervous system disorder. There have been four cases of vCJD transmission via blood transfusions; these occurred in the United Kingdom, where bovine spongiform encephalopathy (i.e., mad cow disease) is most endemic (Galel, 2014). There are no cases of transmission in the United States. Screening for risk is via questioning, and any patients at risk are excluded.

Infections Transmitted by Insect Vectors

**West Nile Virus**

WNV is spread by the bite of an infected mosquito. The virus can infect people, horses, and many types of birds. It was first detected in the United States in 1999, and the first documented cases of WNV transmission through organ transplantation and transfusion were noted in 2002. The most common symptoms of transfusion-transmitted WNV are fever and headache. Screening is by transfusion service interview for history of fever and headache. Blood screening with nucleic acid amplification testing (NAT) for WNV is now required by both the AABB and the FDA (Galel, 2014).

**Parasitic Infections**

A variety of parasitic infections may be transmitted through transfusions:

- **Babesia:** These are intraerythrocyte parasites; infections are acquired through tick bites. In many individuals there are no symptoms; however, in immunocompromised, elderly, and asplenic patients, infection may present as a fatal flu-like illness (Galel, 2014). There are no FDA-approved tests for blood donor screening at this time.
- **Trypanosoma cruzi:** This is a protozoan parasite that causes Chagas disease, which is usually a self-limited disease but can be severe in immunocompromised individuals. A blood donor screening test was widely implemented across the United States in 2007 (Galel, 2014).
- **Malaria:** There is no FDA-approved test. Malaria is rare in the United States, and the blood supply has been effectively protected by donor questioning.

**AGE-RELATED CONSIDERATIONS**

**Neonatal and Pediatric Patients**

Special guidelines must be applied to neonatal and pediatric patients. The most significant differences between this young group and adults are:

- Smaller blood volume. Blood volumes for pediatric patients vary with body weight. A full-term newborn has a blood volume of approximately 85 mL/kg compared with 100 mL/kg in a preterm newborn. Transfusion services must be capable of providing smaller, appropriately sized blood components to meet the needs of this population.
Because of their smaller volume of blood, neonatal and pediatric patients have a decreased ability to tolerate blood loss. Neonatal and pediatric patients have immature organ function (Josephson & Meyer, 2014).

The most frequently transfused blood component in children is RBCs, and this is often needed because of iatrogenic blood loss from repeated phlebotomy (Josephson & Meyer, 2014). Attention to blood loss from laboratory testing is critical, as outlined in Table 11-6. Transfusion is based on the presence of symptomatic anemia or target Hct levels.

Transfusion Administration Issues

The most difficult aspect of transfusion in those younger than 4 months is vascular access. The umbilical vein is most frequently used for fluids and transfusions in preterm and term infants just after birth; small-gauge catheters (24G) or needles (25G) can be safely used without causing hemolysis (Josephson & Meyer, 2014).

Because rate control with small-volume and slow-rate transfusions is important, the use of infusion pumps, such as syringe pumps, is common in the neonatal/pediatric population. As discussed earlier, the manufacturer’s infusion pump instructions should be reviewed to ensure the pump is safe to use with blood and blood products. Blood warmers are not routinely used.

Standard filtration using filters between 170 and 260 microns is required, as it is with adults. There are special pediatric transfusion administration sets that have less dead space than a standard set.

The Older Adult

The older adult receiving transfusion therapy is at increased risk for TACO. Nursing interventions include careful monitoring of intake and output, laboratory test results, and daily weight, and assessment of pulmonary and renal function.

Home Care Issues

In the 1980s, transfusing blood (i.e., RBCs, platelets) in the home-care setting was not uncommon. Such programs required extensive planning, relationships with blood centers, emergency plans and availability of emergency medications, and great attention to nurse education and competency. Today such programs are not common. The reality is that with today’s focus on blood management and available alternatives to blood transfusion, there is limited need for home-based transfusion programs. Outside of the hospital, outpatient settings such as oncology clinics are more likely and more appropriate settings for transfixing the nonhospitalized patient.

However, there are some blood component infusion therapies that are appropriate for home administration, such as factor replacement for
Home Care Issues—cont’d

patients with hemophilia. In the case of factor replacement, such infusions are often either administered in the home by a nurse or self-infused by the patient, using recombinant, rather than plasma-derived, products.

The role of the home-care nurse is important in providing patient education and in identifying and reporting signs and symptoms of delayed transfusion reactions (e.g., delayed hemolytic transfusion reaction) for patients who have received recent transfusions.

Patient Education

- Patients who are aware of the steps involved in a transfusion experience less anxiety.
- Explain how the transfusion will be given, how long it will take, what the expected outcome is, and what symptoms to report; also tell the patient that vital signs will be taken.
- The LIP has the responsibility to explain the benefits and risks of transfusion therapy as well as the alternatives and options (e.g., autologous, homologous, or directed donation) as part of the informed consent process.

Nursing Process

The nursing process is a six-step process for problem-solving to guide nursing action (see Chapter 1 for details on the steps of the nursing process related to vascular access). The following table focuses on nursing diagnoses, nursing outcomes classification (NOC), and nursing interventions classification (NIC) for patients receiving transfusion therapy. Nursing diagnoses should be patient specific and outcomes and interventions individualized. The NOC and NIC presented here are suggested directions for development of specific outcomes and interventions.

<table>
<thead>
<tr>
<th>Nursing Diagnoses Related to Transfusion Therapy</th>
<th>Nursing Outcomes Classification (NOC)</th>
<th>Nursing Interventions Classification (NIC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatigue related to: Physiological: Anemia</td>
<td>Energy conservation, endurance, nutritional status</td>
<td>Energy management (conservation and restoration)</td>
</tr>
<tr>
<td>Fear related to: Phobic stimulus, hospital procedures, unfamiliarity with environmental experiences, homologous blood transfusion, transmission of disease, fear of needles</td>
<td>Fear control</td>
<td>Anxiety reduction strategies, coping enhancements</td>
</tr>
</tbody>
</table>

Continued
Chapter Highlights

- Immunohematology is the science that deals with antigens of the blood and their antibodies.
- Blood groups are based on the antigens present on the cell surface of RBCs. The two major antigen groups are the ABO and Rh systems. Every human being has two genotypes that, when paired, determine one of four blood types (A, B, AB, or O).
- The universal RBC donor is O-negative; the universal plasma donor is AB.
- The majority of people (85%) have the Rh antigen D, making them Rh-positive. Those without antigen D are Rh-negative.
- ABO incompatibility is the major cause of fatal transfusion reactions.
- Blood donor collection methods include:
  - Allogeneic: Blood donated by someone other than the intended recipient
  - Autologous: Recipient’s own blood; collected in one of four ways: pre-operative autologous transfusion, perioperative isovolemic hemodilution, intraoperative autologous transfusion, and postoperative blood salvage
  - Designated (directed): Blood donated from selected friends or relatives of the recipient
- Blood product transfusions are indicated for:
  - Maintenance of oxygen-carrying capacity of the blood
  - Replacement of clotting factors
  - Replacement of vascular volume
Governmental agencies (e.g., FDA), accreditation organizations (e.g., AABB), and professional organizations (e.g., INS) provide guidelines and standards for the safe administration of blood products.

Biological (immune) reactions include AHTRs, delayed transfusion reactions, nonhemolytic febrile reactions, allergic reactions, TRALI, and TA-GVHD reactions.

Nonimmune complications associated with transfusion therapy include circulatory overload, citrate toxicity, potassium toxicity, hypothermia, hypocalcemia, bacterial contamination, and infectious disease transmission.

Key steps in the blood transfusion procedure are:
Step 1: Recipient consent
Step 2: Verifying the authorized prescriber’s order
Step 3: Pretransfusion
Step 4: Vascular access; selecting and preparing the equipment
Step 5: Preparing the patient
Step 6: Dispensing and transporting the component
Step 7: Initiating the transfusion
Step 8: Monitoring the transfusion
Step 9: Completing the transfusion

Thinking Critically: Case Study

At the beginning of your shift, you check on a unit of PRBCs that had been hung just prior to your shift. The unit of RBCs is infusing slowly, with approximately 200 mL left. You agitate the bag slightly and discover a pinhole at the top of the bag.

Case Study Questions

1. What do you do?
2. What legal factors are involved in this scenario?
3. What are the risks to the patient?
4. What assessments should have taken place prior to hanging this blood component?

Media Link: Chapter post tests and answers are provided on DavisPlus, along with case studies and critical thinking activities.

References


Transfusion Therapy


**PROCEDURES DISPLAY 11-1**

**Initiation of Transfusion**

**Equipment Needed**
- Solution container of 0.9% sodium chloride
- Blood or blood component
- Blood administration Y-set with standard filter (170–260 microns)
- 0.9% sodium chloride (USP)/heparin syringes as appropriate
- Antiseptic wipes
- Gloves

**Delegation**
This procedure cannot be delegated. A licensed vocational/practical nurse (LVN/LPN) or nursing assistive personnel (NAP) can assist by monitoring vital signs. *Note:* In California the LVN can administer blood and blood products through a peripheral line if state IV certified and supported by agency policy.
PROCEDURES DISPLAY 11-1
Initiation of Transfusion—cont’d

Procedure
1. Verify the authorized prescriber’s order and that informed consent is obtained in accordance with organizational policy.
2. Confirm blood is available from the transfusion service.
3. Introduce yourself to the patient.
5. Review patient understanding of the procedure and provide the patient with the opportunity to ask questions and express any concerns.
6. Perform hand hygiene throughout procedure.
7. Gather and organize needed supplies.
8. Verify patency of existing IV catheter or place new peripheral IV catheter before obtaining blood from transfusion services.
9. Assess patient condition including baseline vital signs. Notify the LIP if temperature is elevated 1°F above normal. The transfusion may be held.
10. Obtain and open Y-tubing blood administration set:
   a. Close all clamps.
   b. Spike 0.9% sodium chloride bag with one extension of Y tubing and prime tubing.
   c. Maintain clamp on other Y-tubing extension in closed position.

Rationale
1. A written order is a legal requirement. Informed consent is required for blood product administration.
2. Establishes the nurse–patient relationship
3. Patient safety
4. The patient who is well informed is better able to cope with the treatment regimen.
5. Single most important aspect of infection prevention
6. The blood component must be started within 30 minutes from removal from transfusion service.
7. Vital signs serve as baseline for the identification of changes that may transpire during the transfusion.
8. Prepare for transfusion.
d. Initiate slow infusion of 0.9% sodium chloride.

11. Obtain the blood component from transfusion service and:
   a. Inspect the component and its container for clots, bubbles, leaks in the bag, or discoloration.
   b. Compare ABO group and Rh type on the blood label to the tag attached to it and ensure that they match.
   c. Check the expiration date.
   d. Return to the unit with blood component.

12. Perform blood component verification in the presence of the patient. Verify the following:
   a. Patient identification is correct using at least two patient identifiers.
   b. Patient name is correct on all documents.
   c. Blood component is what was ordered (e.g., platelets).
   d. The numbers on the patient’s identification band correlate with those on the laboratory form and component.
   e. Blood type matches on transfusion records and blood bag.
   f. Patient is compatible with donor ABO and Rh type.
   g. Expiration date has not passed.
   h. Any product modification (e.g., irradiation)

11. Most serious reactions are the result of clerical errors. There is shared accountability between the nurse obtaining the component and the transfusion services. The presence of clots, bubbles, leaks in the bag, or discoloration may indicate bacterial contamination or inadequate anticoagulation of the unit and should not be used.

12. Less probability of error when two people verify the needed information. One person should read all of the information to the other as the second person verifies it.
PROCEDURES DISPLAY 11-1

Initiation of Transfusion—cont’d

Procedure
13. Perform hand hygiene and don gloves.
14. Spike the blood component bag with the other extension of Y tubing and prime tubing; close clamp to 0.9% sodium chloride container and open the clamp to blood component to initiate the transfusion at the rate of approximately 2 mL/min.
15. Remain near patient for 15 minutes, checking vital signs within 5–15 minutes after starting transfusion and comparing to baseline. Stop transfusion immediately if any signs or symptoms of a transfusion reaction are present; disconnect the blood administration set from the catheter hub and start a new primed administration set with 0.9% NaCl.
16. Complete RBC/platelet transfusion within 4 hours; plasma within 1 hour.
17. On completion of the transfusion, close the clamp to the blood product, open up the clamp to the saline bag, and infuse 0.9% sodium chloride to clear the IV catheter at the prescribed rate. If another unit of blood is required, a new administration set must be added. Only one administration set can be used in 4 hours.

Rationale
13. Infection prevention and standard precautions
14. Transfusions are initiated slowly so that minimal blood is transfused in the event of a reaction.
15. Most transfusion reactions occur within the first 15 minutes.
16. Increased risk for bacterial growth with longer transfusion times
17. Clears the remaining blood product that is in the tubing and maintains patency of the IV catheter
PROCEDURES DISPLAY 11-1

**Initiation of Transfusion—cont’d**

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>18. Discard the empty blood container and administration set in biohazard container.</td>
<td>18. Standard precautions</td>
</tr>
<tr>
<td>20. Document pretransfusion assessment and vital signs, vascular access device assessment, blood component, blood unit/donor/recipient identification, compatibility, and expiration date; vital signs and assessment during transfusion, volume of blood component, 0.9% NaCl administered, transfusion start and completion times; patient education. Transfusion reaction: If a transfusion reaction occurs, notify the LIP immediately; do not discard the blood container—return to transfusion services. Complete the transfusion record and place in the patient's permanent medical record. Draw post-transfusion laboratory samples as ordered. Follow agency policy on transfusion reaction. Document signs and symptoms, component administered, amount infused, time LIP notified and response, time of transfusion service notification, medication and treatment ordered and administered, patient's response, and patient outcome.</td>
<td>20. To maintain the legal record. Immediate reactions can occur within 2 hours of completion of a transfusion. To maintain proper documentation and communicate that transfusion was administered. The remainder of the blood must be sent to the laboratory transfusion service, where it can be analyzed to determine the cause of the reaction. Medication and treatment will vary depending on the type of reaction.</td>
</tr>
</tbody>
</table>

Sources: Gorski et al., 2016b; Maynard, 2014.
Chapter 12
Parenteral Nutrition

LEARNING OBJECTIVES
After completing this chapter, the reader will be able to:

1. Define terminology related to care of the patient receiving parenteral nutrition.
2. Describe the three types of malnutrition.
3. Identify the key elements of a nutritional assessment.
4. Identify at least four laboratory tests used in nutritional assessment.
5. Discuss potential interactions between drugs and nutrients in a parenteral nutrition formula.
6. Describe indications for parenteral nutrition.
7. Define total nutrient admixture.
8. Describe the advantages of cyclic parenteral nutrition.
9. Identify issues relative to parenteral nutrition administration.
10. Discuss potential complications of parenteral nutrition and associated interventions.
11. Summarize physiological differences in the pediatric patient and the older adult patient relative to parenteral nutrition.

Glossary

Amino acid   An organic compound that is the building block of protein
Anabolism    The constructive phase of metabolism; the building of complex substances in the body tissues
Anthropometry Measurement of the size, weight, and proportions of the human body
Basal energy expenditure (BEE) The amount of energy produced per unit of time under “basal” conditions
Carbohydrate A group of organic compounds including sugars, starches, and glycogen
Catabolism   The destructive phase of metabolism; the breakdown of complex substances in the body; opposite of anabolism
Cyclic parenteral nutrition Delivery of parenteral nutrition over a reduced time frame, over 8 to 18 hours rather than a 24-hour continuous infusion
Essential fatty acid deficiency (EFAD) Complication resulting from an inadequate intake of fatty acids that cannot be synthesized by the
body; thus, requiring diet modification or IV administration of specific lipids

**Fat** Biological substances that are insoluble in water but soluble in other solvents; break down into fatty acids and glycerol

**Kwashiorkor** Malnutrition characterized by decreased intake of calories with an adequate protein-calorie ratio

**Lipid injectable emulsion (ILE)** Combination of liquid, lipid, and emulsifying system for IV use; the solution has limited ability to be mixed with other solutions; note that terminology has changed; previously referred to as an IV fat emulsion (IVFE)

**Marasmus** Malnutrition characterized by decreased intake of calories with adequate amounts of protein intake

**Parenteral nutrition (PN)** Nutrients that are administered intravenously, including carbohydrates, proteins, fats, electrolytes, vitamins, and trace elements

**Peripheral parenteral nutrition (PPN)** Intravenous administration of parenteral nutrition via the peripheral veins

**Refeeding syndrome** A rare syndrome associated with the institution of nutritional support in a severely malnourished patient; resultant metabolic and hormonal changes including hypophosphatemia, which can lead to cardiac failure

**Total nutrient admixture (TNA)** A parenteral nutrition solution formula that includes amino acids, fat, dextrose, and all other additives in a single container

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**Introduction**

The American Society for Parenteral and Enteral Nutrition (A.S.P.E.N.) is a multidisciplinary professional organization of physicians, nurses, dietitians, pharmacists, allied health professionals, and researchers dedicated to patients receiving optimal nutrition care. Nutritional support nursing is a professional nursing specialty that focuses on the care of individuals with potential or known nutritional alterations. The nutrition support nurse encompasses nursing activities that focus on:

- Protection, promotion, and optimization of nutritional health and functional abilities
- Prevention of nutrition-related illness and injury
- Alleviation of suffering through the diagnosis and treatment of nutrition-related human response
- Advocacy in the care of persons, families, communities, and populations with known or potential alterations in nutrition (DiMaria-Ghalili et al., 2016)

The scope of practice includes, but is not limited to, direct patient care; consultation with nurses and other health-care professionals in a variety of clinical settings; education of patients, students, colleagues, and the public; participation in research; and administrative functions. Nurses can attain certification as a
nutrition support clinician (CNSC) through the National Board of Nutrition Support, an independent credentialing board established by ASPEN.

All nurses, whether or not specialized in nutrition support, must recognize the importance of adequate nutrition and the adverse effects of malnutrition. Specialized nutritional support, such as parenteral or enteral nutrition, is indicated in some patients and will be administered by specialized or certified nurses as well as the generalist nurse. The focus of this chapter is administration of parenteral nutrition (PN). The goals of PN are:

1. To provide all essential nutrients in adequate amounts to sustain nutritional balance during periods when oral or enteral routes of feedings are not possible or are insufficient to meet the patient’s caloric needs
2. To preserve or restore the body’s protein metabolism and prevent the development of protein or caloric malnutrition
3. To diminish the rate of weight loss and to maintain or increase body weight
4. To promote wound healing
5. To replace nutritional deficits

**Websites**
National Board of Nutrition Support Certification, Inc.: www.nutritioncare.org/NBNSC

**Malnutrition**

Nutritional balance occurs when nutrients are provided in sufficient quantities to provide energy, to support the growth of tissues, and to regulate physiological processes within the body. Nutritional balance is based on three factors: (1) intake of nutrients (quantity and quality), (2) relative need for nutrients, and (3) the ability of the body to use nutrients.

**Nutritional Deficiency**

When nutritional deficiency exists, body stores are used to provide energy for essential metabolic processes. Excess carbohydrates are stored in the muscle and liver as glycogen. Adipose tissue is the body’s long-term energy reserve of fat. Body protein is not stored in excess of the body’s needs; therefore, use of body protein without replacement adversely affects total body function.

**Malnutrition**

Malnutrition is defined as an acute, subacute, or chronic state of nutrition, in which a combination of varying degrees of overnutrition or undernutrition with or without inflammatory activity has led to a change in body composition and diminished function (A.S.P.E.N., 2017a). A.S.P.E.N. further identifies three nutrition diagnoses based on etiology for adults in clinical practice settings:

- *Starvation-related malnutrition*: Chronic starvation without inflammation (e.g., anorexia nervosa).
Chronic disease–related malnutrition: Inflammation is chronic and of mild to moderate degree (e.g., organ failure, pancreatic cancer, rheumatoid arthritis).

Acute disease– or injury-related malnutrition: Inflammation is acute and of a severe degree (e.g., major infection, burns, trauma, closed head injury).

Malnutrition is a result of diminished nutrient intake, abnormal digestion, alterations in absorption of nutrients, and/or increase in nutrient needs. Hospitalized patients who are malnourished have longer hospitalizations, more infectious and noninfectious complications, and greater risk of mortality (Mueller, Compher, Ellen, & A.S.P.E.N. Board of Directors, 2011). Clinical guidelines from A.S.P.E.N. recommend the following:

- Nutritional risk screening for all hospitalized patients (there are a number of nutritional-risk screening tools available)
- Nutritional assessment for all those patients screened to be at risk
- Nutritional support intervention for those screened and assessed to be at risk (Mueller et al., 2011)

**NURSING FAST FACT!**

- One in three patients is malnourished.
- Patients diagnosed with malnutrition have a hospital length of stay 3 times higher.
- Surgical patients with malnutrition have a 4 times higher risk of pressure ulcer development.
- The annual financial burden of disease-associated malnutrition across 8 diseases in the United States is $156.7 billion (A.S.P.E.N., 2017b).

Patients should be considered malnourished or at risk for malnutrition under the following conditions:

- Inadequate nutrient intake for 7 or more days
- Involuntary weight loss of 10% or greater of usual body weight over 6 months
- Involuntary weight loss of 5% or greater of usual body weight in 1 month (Krzywda & Meyer, 2014)

There are three broad classifications of malnutrition: marasmus, kwashiorkor, and mixed malnutrition.

**Marasmus**

Marasmus, or simple starvation, is caused by a decrease in the intake of calories with adequate protein–caloric ratio. In this type of malnutrition, a gradual wasting of body fat and skeletal muscle takes place with preservation of visceral proteins. The individual appears emaciated and has decreased anthropometric
measurements (e.g., history of weight loss) and lack of an immune response to common skin test antigens.

**Kwashiorkor**

Kwashiorkor is characterized by an adequate intake of calories but a poor intake of protein. This condition causes visceral protein wasting with preservation of fat and somatic muscle. It is seen during a period of decreased protein intake, as seen in patients on liquid diets, fad diets, and long-term use of IV fluids containing dextrose. Loss of body protein is caused by depleted circulating proteins in the plasma. Individuals may appear well-nourished or obese and have adequate anthropometric measurements, but they have decreased visceral proteins and depressed immune function.

**Mixed Malnutrition**

Mixed malnutrition is characterized by aspects of both marasmus and kwashiorkor. The person presents with skeletal muscle and visceral protein wasting, depleted fat stores, and immune incompetence. The affected person appears cachectic and usually is in acute catabolic stress. This mixed protein–calorie disorder is associated with the highest risk of morbidity and mortality (Krzywda & Meyer, 2014).

**Effects of Malnutrition**

The hazards of malnutrition for bodily function are decreased visceral protein stores, albumin depletion, and impaired immune status. Without visceral protein stores in the body, a deficiency of total body protein results first in decreased strength and endurance (loss of muscle mass) and ultimately in decreased cardiac and respiratory muscle function. Skeletal muscle wasting occurs in a ratio of about 30:1 compared with visceral protein loss. The loss of gastrointestinal (GI) function follows skeletal muscle wasting and is associated with hypoalbuminemia. Protein–calorie malnutrition is one of the most common causes of impaired immune function. Effects of malnutrition include:

- Loss of muscle mass
- Delayed wound healing
- Increased risk for infection
- Increased risk for falls
- Increased need for rehabilitation after hospitalization
- Increased cost of care
Nutritional Screening and Assessment

The purpose of nutritional screening is to identify individuals who are malnourished or who are at risk for malnutrition, thus determining the need for a more detailed nutrition assessment. Patients who are found to be at risk for malnutrition during the nutritional screening process ideally should be referred to the registered dietitian for a thorough nutrition assessment and classification of degree of malnutrition. Practice guidelines for nutrition screening from A.S.P.E.N. include:

- A nutrition screening incorporating objective data such as height, weight, weight change, primary diagnosis, and presence of comorbidities should be a component of the initial evaluation of all patients in an ambulatory, hospital, home, or alternate care setting.
- The health-care organization should determine who will perform the screening and the elements to be included.
- A procedure to rescreen patients who are not immediately identified as being at nutritional risk should also be in place (Ukleja et al., 2010).

Assessment

Performance of an overall health history provides information for identifying nutrition-related problems. It includes subjective data about the client's dietary history and related factors. The nutritional assessment encompasses anthropometric measurements, diagnostic testing, and a complete physical examination (Jensen, Hsiao, & Wheeler, 2012) (Table 12-1).

Table 12-1 Components of a Nutritional Assessment

<table>
<thead>
<tr>
<th>History</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Medical</td>
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<td>• Social</td>
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<tr>
<td>• Dietary</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Anthropometric measurements</th>
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</thead>
<tbody>
<tr>
<td>• Height and weight</td>
</tr>
<tr>
<td>• Mid-arm circumference/skinfold testing (appropriate training required)</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Laboratory assessment</th>
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</thead>
<tbody>
<tr>
<td>• Serum albumin and transferrin levels (serum albumin is included in a complete metabolic profile [CMP])</td>
</tr>
<tr>
<td>• Prealbumin and retinol-binding protein</td>
</tr>
<tr>
<td>• Serum electrolytes, serum glucose</td>
</tr>
<tr>
<td>• Liver enzymes (alanine aminotransferase [ALT], alkaline phosphatase [ALP], and aspartate aminotransferase [AST]—these are included in a CMP)</td>
</tr>
<tr>
<td>• Lipid levels</td>
</tr>
<tr>
<td>• Coagulation studies</td>
</tr>
<tr>
<td>• Vitamin/trace-element levels</td>
</tr>
<tr>
<td>• Total lymphocyte count</td>
</tr>
<tr>
<td>• Urine assays (creatinine, height index, nitrogen balance)</td>
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</tbody>
</table>

Continued
The history includes medical, weight, social, dietary, and medications. The medical history should include a specific history of weight; diseases that affect ingestion, digestion, or absorption of oral nutrients such as GI obstructions or fistulas; surgical history; presence of increased losses, such as from draining wounds and fistulas; and factors such as age and drug, alcohol, and tobacco use. The social history affecting nutrient intake includes income, education, ethnic background, and environment during mealtime, along with religious considerations. The dietary history often provides clues to the cause and degree of malnutrition. The components of a dietary history include appetite, GI disturbances, mechanical problems such as ill-fitting dentures, food allergies, medications, and food likes and dislikes (Jensen et al., 2012).

**Anthropometric Measurements**

Anthropometry is the physical measurement of subcutaneous fat and of muscle mass (somatic protein) stores, with muscle mass representing the largest concentration of body protein stores (Krzywda & Meyer, 2014). Anthropometry includes accurate measurement of height and weight. A practical measure of body size and an indirect measure of body fat are provided by the body mass index (BMI), which is defined as weight (kg)/[height (m)]^2. Interpretations of BMI are as follows:

- **BMI <18.5:** Underweight, at risk for malnutrition
- **BMI 18.5–24.9:** Desirable
- **BMI 25–29:** Overweight
- **BMI ≥30:** Obese (Centers for Disease Control and Prevention [CDC], 2015)

Serial weight measurements over time provide the most reliable and clinically relevant information for the nutritional assessment (Krzywda &
Weight loss is important because it reflects inadequate calorie intake.

Additional anthropometric measurements may include the skinfold test and the mid-arm circumference. To estimate the size of the body fat mass, a skinfold test is done on the triceps of the nondominant arm using a caliper. The mid-arm circumference is an indirect measurement of body protein stores. These measurements are compared to established tables. Limitations to such tests include variability by the clinician performing the tests and the comparative standards; appropriate training to perform such tests is required (Jensen et al., 2012; Krzywda & Meyer, 2014).

**NURSING FAST FACT!**

Weight loss greater than 10% in any time period may be clinically significant.

In simple starvation, 20% loss of body weight is associated with marked decreases in muscle tissue and subcutaneous fat, giving the patient an emaciated appearance. Gross loss of body fat can be determined not only by appearance but also by palpating a number of skinfolds. When the dermis can be felt between the fingers on pinching the triceps and biceps skinfolds, considerable loss from body stores of fat has occurred. Protein stores can be assessed by inspection and palpation of a number of muscle groups, such as the triceps, biceps, and subscapular and infrascapular muscles. The long muscles in particular are profoundly protein depleted when the tendons are prominent to palpation.

**LABORATORY ASSESSMENT**

A number of tests are used to assess a patient’s biochemical nutritional status. **Serum Albumin and Transferrin Levels.** Albumin is a major protein synthesized by the liver. Approximately 40% of protein mass is in the circulation. The serum albumin concentration is normally between 3.5 and 5.0 g/dL (Krzywda & Meyer, 2014). An albumin level of 2.8 to 3.4 g/dL represents mild protein depletion, 2.1 to 2.7 g/dL reflects moderate depletion, and less than 2.1 g/dL indicates severe depletion.

Serum transferrin is a beta globulin that transports iron in the plasma and is synthesized in the liver. Transferrin is present in the serum in concentrations from 250 to 300 mg/dL. The serum levels are affected by nutritional factors and iron metabolism. Levels lower than 100 mg/dL indicate severe depletion (Krzywda & Meyer, 2014).

**NURSING FAST FACT!**

The half-life of albumin is about 20 days, meaning that changes in protein synthesis are reflected slowly; acute changes in nutrition are not reflected (Krzywda & Meyer, 2014).
Prealbumin and Retinol-Binding Protein. Prealbumin is required for thyroxine transport and as a carrier for retinol-binding protein. The half-life of prealbumin is 24 to 48 hours, so it is sensitive to acute changes and is a more accurate indicator of protein malnutrition during refeeding.

- Normal serum concentration is 20 mg/dL.
- 10 to 20 mg/dL reflects mild depletion
- 5 to 9 mg/dL reflects moderate depletion
- Less than 5 mg/dL indicates severe depletion (Krzywda & Meyer, 2014).

Retinol-binding protein is another measurement of visceral protein status with normal values from 3 to 5 mEq/L. It is a sensitive measure to very short-term changes in nutrition, but because it is affected by stress and inflammation, the utility of retinol-binding protein is limited (Jensen et al., 2012).

Nitrogen Balance. A sensitive indicator of the body’s gain or loss of protein is its nitrogen balance. A 24-hour urine collection can be analyzed for urine urea nitrogen to determine nitrogen balance. An adult is said to be in nitrogen equilibrium when the nitrogen intake from food equals the nitrogen output in urine, feces, and perspiration. The nitrogen balance is a measure of daily intake of nitrogen minus the excretion. It is used to assess protein turnover. A positive nitrogen balance indicates an anabolic state with an overall gain in body protein for the day. A negative nitrogen balance indicates a catabolic state with a net loss of protein.

**NURSING FAST FACT!**

One gram of nitrogen is equivalent to 6.25 grams of protein. Nitrogen balance is measured by calculating total protein intake divided by 6.25 to obtain nitrogen grams, subtracting urinary nitrogen as measured by the 24-hour urine collection, and adding in factors for insensible and fecal losses. Accurate urine collection is required for this test.

Other Laboratory Tests

Serum electrolyte levels provide information about fluid and electrolyte balance and kidney function. The creatinine/height index is an indicator of muscle depletion. It requires a 24-hour urine collection to determine urinary creatinine excretion and is calculated based on ideal urinary creatinine for the patient's gender and height. Serum levels of glucose, vitamins, trace elements, liver enzymes (alanine aminotransferase [ALT], alkaline phosphatase [ALP], and aspartate aminotransferase [AST]), and lipid levels may be monitored as well as coagulation studies and hemoglobin/hematocrit levels.
Energy Requirements

Energy requirements are dependent on a number of factors, which include the body surface area (derived from height and weight), age, and gender. Total daily energy expenditure has three components:

1. basal metabolic rate (BMR) or resting metabolic rate (RMR)
2. energy expenditure associated with activity; and
3. energy required for digestion (Wooley & Frankenfield, 2012)

Energy needs can be determined from the BMR (measured in a fasting state, immediately on awakening before any activity) or resting metabolic expenditure (measured in a fasting state but some activity allowed). The RMR accounts for 60% to 75% of energy expenditure and may be measured (calorimetry) or estimated. Estimates are most commonly used, and there are a number of equations that may be used. A traditional method used to estimate basal energy expenditure (BEE) is the Harris–Benedict equation, which takes into consideration the influence of the patient’s weight in kilograms, height in centimeters, age, and gender. An easier and widely accepted method to estimate daily caloric requirements for adults is to use 20 to 35 calories/kg/day (Krzywda & Meyer, 2014).

Calorimetry

Calorimetry refers to the measurement of heat or energy metabolism. The BMR/RMR can be measured using indirect or direct calorimetry. Indirect calorimetry calculates heat consumption through the measurement of oxygen consumption and carbon dioxide (CO₂) production and is considered the most accurate method for determining energy expenditure in critically ill patients (Wooley & Frankenfield, 2012). Hospitals must have access to a metabolic cart to measure RMR, and this tool remains underutilized because of the expense and clinical expertise required. Direct calorimetry measures heat produced by the body and is not used because of the expense and the cumbersome techniques required.

Physical Examination

A critical component of the nutritional assessment is a complete physical examination. Findings from a physical examination can reflect protein/calorie malnutrition along with vitamin and mineral deficiencies. The physical examination should include evaluation of the patient’s hair, nails, skin, thorax and lungs, eyes, oral cavity, glands, heart, muscles, and abdomen, along with a neurological evaluation and evaluation of delayed healing and tissue repair (Table 12-2). The physical examination should also include objective measurements of wound healing, grip strength, skeletal muscle function, and respiratory muscle function.

NURSING FAST FACT!

Signs of nutritional deficiency are seen most often in skin, hair, eyes, and mouth (Krzywda & Meyer, 2014).
Nutritional Requirements and PN Formulations: Adults

PN formulations are based on the patient’s nutrient requirements. Basic formulas contain protein and nonprotein calories: carbohydrates and fat, along with electrolytes, vitamins, trace elements, and fluid requirements.
Fluid Requirements

Basic fluid requirements for maintenance are 30 to 35 mL/kg/day or 1500 mL for the first 20 kg plus 20 mL/kg for actual weight beyond 20 kg (Krzywda & Meyer, 2014). Factors that may increase fluid needs include significant fluid loss, as occurs with diarrhea or the presence of an enterocutaneous fistula.

Proteins/Amino Acids

Proteins are required for anabolism, that is, for tissue growth and repair and replacement of body cells. Proteins are also components in antibodies, scar tissue, and clots. Amino acids are the basic units of protein. There are eight essential amino acids needed by adults that must be supplied in the diet: isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine. There are also nonessential amino acids; these amino acids can be synthesized by the body and include alanine, aspartic acid, asparagine, glutamic acid, glycine, proline, and serine. Conditionally essential amino acids required in the diet during certain disease states include histidine, cysteine, tyrosine, arginine, and glutamine.

Protein in PN is provided as synthetic crystalline amino acids. They are available in concentrations of 3% to 20%, with and without electrolytes. There are also specialty amino acid formulations that may be used with certain disease states, such as hepatic encephalopathy and renal failure; however, these products are more expensive, and improvement of outcome with their use has not been well demonstrated (Krzywda & Meyer, 2014).

NURSING FAST FACT!

Protein requirement for maintenance of healthy adults is 0.8 to 1 g/kg/day.
- Catabolic patients require 1.2 to 2 g/kg/day.
- Chronic renal failure patients require 1.5 to 1.8 g/kg/day.
- Acute renal failure + catabolic state patients require 1.5 to 1.8 g/kg/day.
- Critically ill patients require 2.0 g/kg/day (Krzywda & Meyer, 2014).

Carbohydrates

Carbohydrates are the major source for energy and also spare body protein. When glucose is supplied as a nutrient, it is stored temporarily in the liver and muscle as glycogen. When glycogen storage capacity is reached, the excess carbohydrate is stored as fat. Carbohydrate types include dextrose (glucose), fructose, sorbitol and xylitol, and glycerol. There is not a specific requirement for carbohydrates; rather, needs are determined based on estimations of energy requirements. Carbohydrates generally provide about 50% of total calories.
Dextrose is the most commonly used source of carbohydrate in PN solutions and is commercially available in concentrations from 5% to 70%. In addition to caloric need, considerations in the amount and concentration of glucose are based on respiratory, cardiac, renal, and fluid volume status.

Dextrose may be administered with amino acids as the only nonprotein source of calories or may be administered in conjunction with lipids. When PN is administered peripherally, the final concentration of dextrose must be 10% or less to prevent vein irritation, including thrombophlebitis. Of note, glycerol is another carbohydrate that is used at times in PN formulas. The rationale for using glycerol is that it may be more protein sparing, inducing less insulin response than dextrose, but the evidence for these benefits is conflicting (Ayers, Holcombe, Plogsted, & Guenter, 2014b).

**INS Standard:** PN solutions containing final concentrations exceeding 10% dextrose should be administered through a central vascular access device (CVAD) (Gorski et al., 2016, p. S134).

**Fats**

Fat is a primary source of heat and energy. Fat provides twice as many energy calories per gram as either protein or carbohydrate. When fat is used to supply a portion of calories, less dextrose is required. In patients with glucose intolerance, this may be beneficial.

Fat is essential for the structural integrity of all cell membranes. Linoleic acid and linolenic acid are the only fatty acids essential to humans and are required to prevent essential fatty acid deficiency (EFAD). Linoleic acid is the primary essential fatty acid and is required for growth. Linolenic acid may not be necessary for adults but may be needed for proper visual and neural development in infants and young children and with certain diseases (Krzywda & Meyer, 2014). Signs and symptoms of EFAD include desquamating dermatitis, alopecia, brittle nails, delayed wound healing, thrombocytopenia, decreased immunity, and increased capillary fragility.

When fat or lipids are used as a calorie source in PN, there are fewer problems with glucose homeostasis, CO₂ production is lower, and hepatic tolerance to IV feedings may improve. In patients with respiratory failure, the use of fat as a part of the total calories allows for a decrease in glucose calories and therefore may decrease carbon dioxide production.

**NURSING FAST FACT!**
- Carbohydrates provide 3.4 calories per gram.
- Excessive dextrose intake can lead to increased production of carbon dioxide, which can cause respiratory failure.
- Hepatic dysfunction may occur from excessive dextrose intake as a result of increased synthesis and fat storage in the liver.
Lipid Administration

Primarily, IV fats are supplied by safflower or soybean oil, with egg yolk phospholipids and glycerol to provide tonicity. **Lipid injectable emulsions (ILE)** provide 1.1 kcal/mL (10% solution) or 2.0 kcal/mL (20% solution) (Gahart, Nazareno, & Ortega, 2016). Lipids may be administered as a separate infusion, concurrently with the amino acid/dextrose solution via a Y tubing, or as part of a total nutrient admixture (discussed later). Of note, ILE products are isotonic, have a pH between 6 and 9, and can be administered via a peripheral vein (Gahart, Nazareno, & Ortega, 2016). To prevent EFAD, approximately 250 mL of 20% or 500 mL of 10% ILE is required twice per week or 500 mL of 20% lipids once per week (Kumpf & Gervasio, 2012).

NOTE: A 30% ILE is available but is never given by direct IV infusion; rather, it is used by the pharmacy in admixtures (Gahart, Nazareno, & Ortega, 2016) (Fig. 12-1).

NURSING FAST FACT!

- 1 g of fat = 9 kcal
- Use of fat for a portion of the calories in the PN solution will allow for a decrease in dextrose and may improve glucose management in stress states.

Lipids are extracted from administration sets that contain di(2-ethylhexyl) phthalate (DEHP) plasticizers; therefore, non-DEHP administration sets, available with most commercially available products, are used. Lipids are always filtered with a 1.2 micron filter. Lipids may be supplied in glass containers or special non–polyvinyl chloride (non-PVC) bags (Fig. 12-1).

NURSING FAST FACT!

The initial rate of ILEs in adults should be 1 mL/min or 0.1 g of fat/min for the first 15 to 30 minutes of the infusion for a 10% solution; if no untoward effects result, the rate can be increased to 2 mL/min. For 20% solution, 0.5 mL/min or 0.1 g of fat/min for the first 15 to 30 minutes; if there are no untoward effects, the rate can be increased to 1 mL/min (Gahart, Nazareno, & Ortega, 2016).

INS Standard: Administration sets used to administer lipid-based infusates should be free of DEHP (Gorski et al., 2016, p. S134).
Electrolytes

Electrolytes may be given either in a premixed PN formula or adjusted based on the patient's status. Standard ranges for parenteral electrolytes assume normal organ function and normal losses. Electrolytes are available in several salt forms and are added or adjusted based on the patient's metabolic status. For example, potassium may be given as potassium chloride, potassium phosphate, or potassium acetate salt. The electrolytes necessary for long-term PN include sodium, potassium, magnesium, calcium, chloride, and phosphorus (see Chapter 3 for a review of the physiological roles of electrolytes).

NURSING FAST FACT!

Serum potassium levels must be closely monitored during PN administration. Patients with impaired renal function are at risk for hyperkalemia and generally require a decreased amount of potassium.

Standard daily requirements for electrolytes included in PN solutions include:

- Sodium: 1–2 mEq /kg
- Potassium: 1–2 mEq /kg
Phosphorus: 20–40 mmol
Magnesium: 8–20 mEq
Calcium: 10–15 mEq
Chloride/acetate: as needed based on acid–base status (Barber & Sacks, 2012).

Vitamins
Vitamins are necessary for growth and maintenance, as well as for multiple metabolic processes. Vitamins cannot be synthesized by the body and must be provided in the diet. Fat-soluble vitamins are vitamins A, D, E, and K. Water-soluble vitamins include vitamin C and the B complex vitamins: thiamine (B₁), riboflavin (B₂), niacin (B₃), pantothenic acid (B₅), pyridoxine (B₆), biotin (B₇), folic acid (B₉), and cyanocobalamin (B₁₂). Vitamin supplements are added to the PN formulation. There are commercially available multivitamin products. Daily recommendations for IV vitamin requirements have been established by the American Medical Association (Krzywda & Meyer, 2014).

Trace Elements
Trace elements are micronutrients found in the body in minute amounts. Basic requirements are very small, measured in milligrams. Each trace element is a single chemical and has an associated deficiency state. The functions of trace elements are often synergistic. Trace elements commonly used in PN solutions include:

- Zinc: RNA, DNA, and protein synthesis; important to wound healing
- Copper: Works with iron to form red blood cells
- Chromium: Potentiates insulin reactions
- Manganese: Antioxidant protection; involved in enzyme reactions; carbohydrate synthesis
- Selenium: Catalyst in an important antioxidant pathway (Krzywda & Meyer, 2014).

NOTE: Iron is not routinely included as a component in the PN solution. Most often, it is administered as a separate infusion when needed. Iron dextran is approved for addition to PN solutions, but it can be used only in PN solutions without fat emulsions (Ayers et al., 2014b).

Medication Administration With Parenteral Nutrition
PN solutions are complex with the potential for physicochemical interactions associated with drug–nutrient combinations. Potential interactions between drugs and the nutrients in the solution include physical changes such as precipitation, altered viscosity of the solution, changes in consistency, clumping or curdling of the solution, and loss of drug activity or toxicity (Rollins, 2012). Medications that are generally compatible with and may be added to PN include regular human insulin, heparin, and histamine receptor agonists (e.g., famotidine and ranitidine). Histamine receptor agonists are used to decrease gastric acid secretion and reduce risk for stress ulcers.
Hyperglycemia is a frequent complication of PN. It is caused by the high concentration of glucose in the PN solutions and altered glucose metabolism associated with stress and disease. Insulin aids in adequate metabolism of carbohydrates. It is chemically stable in PN and is often added to the solution. However, insulin can be adsorbed into the plastic solution container, the administration set, and the filter, so doses often need to be increased until blood glucose (BG) control is achieved (adsorption is addressed in Chapters 5 and 10).

Unfractionated heparin may be added to the PN solution to improve the clearance of fat emulsions from the bloodstream (Ayers et al., 2014b; Krzywda & Meyer, 2014). However, unfractionated heparin is not compatible with total nutrient admixture (TNA) formulations (discussed below).

Compatibility is always an issue whenever two agents are combined. Stability of the admixed component dictates the appropriate length of time that the solution may be stored before use.

**INS Standard:** Medications are not added to or coinfused with the PN solution/emulsion before or during infusion without consultation with a pharmacist regarding compatibility and stability (Gorski et al., 2016, p. S133).

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**NURSING FAST FACT!**

- Always check current information about drug compatibility with PN solutions.
- Medications are never to be “piggybacked” directly into PN solutions.
- Only regular insulin is appropriate for IV administration.

**Parenteral Nutrition Compounding**

PN solutions must be prepared and stored safety and accurately according to regulations established by the United States Pharmacopeia (USP) *<797>* entitled “Pharmaceutical Compounding: Sterile Preparations” (Ukleja et al., 2010). It is the responsibility of the dispensing pharmacist to ensure that PN is prepared, labeled, controlled, stored, dispensed, and distributed properly. Compounding of an accurate solution that is free of microbial and particulate matter is essential to the process (Barber & Sacks, 2012). PN solutions are prepared in compounding rooms that must meet certain conditions, and pharmacy personnel must wear protective equipment such as gloves, masks, and hair/shoe covers during the compounding process.

**NURSING FAST FACT!**

The USP Chapter *<797>* Pharmaceutical Compounding: Sterile Preparations (2008) details the procedures and requirements for compounding sterile preparations and sets standards that are applicable to all practice settings in which sterile preparations are compounded. These standards have been widely adopted, are enforced by many state boards of pharmacy, and may be used by accreditation organizations (e.g., The Joint Commission) in surveys. The standards are currently undergoing revision at the time of the publication of this book.
Delivery of Nutritional Support

Nutritional Support Candidates and Delivery Methods

Patients who are candidates for nutritional support are those who suffer from a multiplicity of problems. Their clinical course can be complicated by malnutrition and depletion of body protein (Fig. 12-2). Routes for delivery of nutritional support include the enteral and the IV routes.

The enteral route (i.e., tube feeding) is the preferred feeding route and is indicated for patients with a functional GI tract when oral nutrient intake is insufficient to meet needs. Options for enteral access devices include nasoenteric tubes for short-term use and long-term devices such as gastrostomy, jejunostomy, and gastrojejunostomy tubes. In contrast to PN, enteral nutrition preserves intestinal mass and structures along with hormonal, enzymatic, and immunological function (Krzywda & Meyer, 2014). Advantages to the enteral route include:

1. Maintenance of the functional integrity of the GI tract
2. Efficient utilization of nutrients
3. Ease and safety of administration
4. Lower cost compared with PN

PN may be administered via the peripheral or central veins. Figure 12-3 shows an algorithm for determining the choice of nutritional support. PN is indicated for patients including those who cannot meet their nutritional needs with enteral nutrition and for those who already are or have the potential for becoming malnourished (Mirtallo & Patel, 2012). PN may be given via a
Peripheral IV catheter for short-term feeding, or it may be given via a CVAD when long-term feeding is required, when peripheral access is limited, and/or when nutrient needs are large (Mirtallo & Patel, 2012). Examples of diagnoses associated with a need for PN include paralytic ileus, mesenteric ischemia, small-bowel obstruction, and enterocutaneous fistulas.

Peripheral Parenteral Nutrition

Peripheral parenteral nutrition (PPN) is used to nourish patients who either already are malnourished or have the potential for developing malnutrition and who are not candidates for enteral nutrition. Patients who are candidates for PPN must meet the criteria of (1) good peripheral venous access and (2) able to tolerate large volumes of fluid, 2 to 3 L/day. PPN is considered controversial; some believe that the risks of PPN outweigh the benefits because candidates for this therapy have minor nutritional deficits (Ayers et al., 2014b). Administration of PPN should be limited to 5 days. For patients who require PPN beyond 5 days, a CVAD should be placed (Worthington et al., 2017).

Figure 12-3 Routes to deliver nutritional support to adults. This clinical decision algorithm outlines the selection process for choosing the route of nutritional support in adult patients. Major considerations for selecting the feeding route and nutritional support formula include gastrointestinal function, expected duration of nutritional therapy, aspiration risk, and the potential for or actual development of organ dysfunction.
PPN is limited to solutions with an osmolarity below 900 mOsm/L, and the final dextrose concentration for a peripheral infusion should not exceed 10% due to the increased risk for phlebitis and extravasation (Gorski et al., 2017; Worthington et al., 2017).

**Advantages of PPN**
1. Avoids insertion and maintenance of a CVAD.

**Disadvantages/Limitations of PPN**
1. Contraindications include significant malnutrition, compromised renal/hepatic status.
2. Cannot be used in volume-restricted patients because higher volumes of solution are needed to provide adequate calories.
3. May cause phlebitis due to high solution osmolarity.

**NURSING FAST FACT!**
A standardized ordering sheet is used to specify the protein, calories, and electrolyte content of each solution tailored to the client. Standard PPN includes the following basic formula: final concentration of dextrose 5% to 10%; final concentration of amino acids 3%; electrolytes, trace elements, and vitamins. Lipids may be included in the formula.

**NURSING FAST FACT!**
Assess for an appropriate peripheral catheter for delivery of PPN. A midline catheter may be considered for PPN as the tip is in a larger blood vessel, allowing for better dilution of the PPN. However, the risk of phlebitis is not eliminated with a midline catheter, and there is no current research documenting the efficacy of midline catheters with PPN (Worthington et al., 2017).

**Parenteral Nutrition via a Central Vein**
PN via central vein (previously called total parenteral nutrition [TPN]) is used to provide nutrients at greater concentrations and fluid volumes than is possible with PPN. Central vascular access can be maintained for prolonged periods (weeks to years) with a variety of catheters (e.g., peripherally inserted central catheter [PICC]; see Chapter 8). The PN formula may be administered with the lipids mixed together with dextrose/amino acid components (total nutrient admixture [TNA]), or the lipids may be administered as a separate intermittent infusion. Centrally delivered PN involves both advantages and disadvantages.

**Advantages**
- Dextrose solution of 20% to 70% can be administered as a calorie source.
- May be used for patients with long-term or even lifelong needs for PN.
Caloric and nutrient needs can be met. Provides calories; restores nitrogen balance; and replaces essential vitamins, electrolytes, and minerals. Promotes tissue synthesis, wound healing, and normal metabolic function. Is nutritionally complete.

**Disadvantages**
- Requires placement of a CVAD.
- May cause metabolic complications, including glucose intolerance, electrolyte imbalances, and EFAD.
- Potential complications related to CVADs (see Chapter 9).

**Practice Criteria for PN**
- PN is delivered through a CVAD as defined by the catheter tip located in the superior vena cava at or near the cavoatrial junction.
- Verification of the catheter tip placement must be obtained before use of the catheter.
- The central line bundle interventions are followed during CVAD insertion (see Chapter 2).

**Total Nutrient Admixtures (Three-in-One Admixtures)**
TNAs are PN solutions containing dextrose, amino acids, and fat emulsions in one large solution container. TNAs are often referred to as “all-in-one solutions” or “three-in-one solutions” (3-in-1 solutions). The solution is compounded in the pharmacy and is usually milky-white and opaque, although a faint yellow hue may be evident with the addition of vitamins. “Multichamber bags” are often used in home infusion. This is defined as a container designed to promote extended stability of the PN formulation by separating some components (e.g., IV fat emulsion) from the rest of the formulation. It consists of two or more chambers separated by a seal or tubing that is clamped (Fig. 12-4). At the time of administration, the seal or clamp is opened to allow the contents of the chambers to mix and create an admixture.

TNA solutions offer some important advantages, including the following:
- All components compounded aseptically in the pharmacy
- Less manipulation during administration and less risk of contamination (compared to administering lipids as a separate infusion)
- Less nursing time required
- Less supply and equipment expense (e.g., one infusion pump and administration set)
- Better dextrose tolerance in some cases
- May be more cost-effective
- Improved fat clearance when administered over more than 12 hours (Barber & Sacks, 2012)

Disadvantages may include less solution stability and risk for separation of lipids, difficulty in visualizing precipitate or particulate matter in the solution,
more risk for drug-nutrient incompatibilities, and increased risk for catheter occlusion over time (Barber & Sacks, 2012).

Total nutrient admixtures must be administered through a 1.2-micron filter because of the risk of particulate matter (Fig. 12-5). Although bacterial contaminants such as *Staphylococcus epidermidis* and *Escherichia coli* will not be filtered out, large organisms such as *Candida albicans* will be trapped by the 1.2-micron filter (Barber & Sacks, 2012). The stability of TNA is affected by many factors, including admixture contents, storage time and conditions, addition of non-nutrient drugs, pH of the solution, and variability in temperature.

**NURSING FAST FACT!**

Examine the TNA solution for signs of instability before hanging the bag and periodically throughout administration. These solutions may “crack” as the oil separates. Instead of a uniformly white appearance, yellow oil streaks appear throughout the container, or an oil layer appears at the top of the container. It is not safe to administer a TNA with such an appearance.

Causes for this phenomenon include:

- reduced pH, which is not favorable for stability of the lipid component in the TNA
- excessive amounts of cations such as magnesium or calcium in the PN solution (Ayers et al., 2014b)
Cyclic Parenteral Nutrition

For patients requiring long-term PN support, cyclic PN is widely used. Cyclic PN is defined as administering the PN solution over a reduced time frame (e.g., 8–16 hours) instead of as a 24-hour continuous infusion. Cyclic PN is indicated for patients who have been stable on continuous PN and require long-term PN; for those receiving home PN (HPN); for patients who can handle total infusion volume in a shortened time period; and for patients who require PN for only a portion of their nutritional needs (Krzywda & Meyer, 2014).

Patients are transitioned to cyclic PN once they are stable on a 24-hour continuous infusion. The hourly rate of PN infusion is increased as the number of infusion hours is decreased. Because of the increased fluid volume and increased glucose delivery over less time, the patient is monitored carefully for signs of fluid volume excess and hyperglycemia. Symptoms of excess fluid administration should be monitored, such as weight gain resulting in edema or infusion-related shortness of breath. If too much fluid is administered during the cyclic period, the time frame should be extended.

Cyclic PN administration requires twice as many central line manipulations as continuous PN because of the initiation of the infusion and the discontinuation of the infusion every 24 hours. This increases the risk of introducing bacteria into the internal catheter lumen and thus the risk of a bloodstream
infection. Attention to aseptic technique with every catheter access is critically important.

**ADVANTAGES**

1. Allows for more physiological hormonal response and appetite stimulation because of periods of time without infusion
2. Prevents or treats hepatotoxicity induced by continuous PN; reverses fatty liver and liver enzyme elevations; faster albumin level recovery (Krzywda & Meyer, 2014)
3. For patients on long-term PN, improved quality of life by encouraging normal daytime activities and enhances psychological well-being; patient does not need to carry around an infusion pump 24 hours/day; usually run over nighttime hours for home-care patients

**DISADVANTAGES**

1. Patients must be observed for symptoms of hypoglycemia, hyperglycemia, dehydration, excessive fluid administration, and sepsis associated with central-line manipulation.
2. Patients require monitoring for hyperglycemia, which can develop during the peak flow rate (>250 mg/dL). Inability to control BG levels may require a change back to continuous PN.
3. There is also a risk for hypoglycemia generally during the first hour after cyclic PN discontinuation. BG levels should be checked whenever the patient displays symptoms of nausea, tremors, sweating, anxiety, or lethargy. Tapering the infusion rate for 1 to 2 hours at the end of the infusion may be needed (Krzywda & Meyer, 2014; Winkler, Hagan, & Albina, 2012).

**NURSING FAST FACT!**

- Cyclic PN is usually used for patients requiring long-term PN.
- The patient’s cardiovascular status must be able to accommodate higher infusion rates during the infusion period.

**EBP** A systematic literature review was conducted to evaluate the metabolic effects of cyclic PN in adults and children. Twenty-five studies were included in the review. When cyclic PN was compared to continuous infusion, the results included similar nitrogen balance. For patients on continuous PN, converting to a cyclic regimen can stabilize hepatic function tests. Risks include hyper-/hypoglycemia with abrupt initiation/discontinuation of the cyclic infusion; tapering the rate is helpful. The researchers concluded that there is a favorable risk–benefit profile of cyclic PN in most patients (Stout & Cober, 2010).
Specialized Parenteral Formulas

Some parenteral formulas are specifically designed to meet the needs of patients with certain disease states. Although current clinical evidence does not support improved outcomes with specialty formulas, they may be used in limited circumstances (Barber & Sacks, 2012). The following are some special formulas developed for the patient with renal, hepatic, and special metabolic stress needs.

Renal Formulas

Specialty PN formulations used in renal failure are composed mainly of essential amino acids and are based on a theory that nonessential amino acids can be recycled from urea (Barber & Sacks, 2012). It is believed that these formulas do not offer significant advantages and that indications for these special formulations are limited. Examples of commercial preparations include Aminess, Aminosyn-RF, and NephrAmine (Gahart, Nazareno, & Ortega, 2016). Consideration to fluid restriction is also important in patients with renal disease.

Hepatic Formulas

Protein/calorie malnutrition and nutritional deficiencies are common in hepatic diseases. Altered amino acid metabolism is a hallmark of hepatic disease, characterized by low levels of circulating branched-chain amino acid (BCAA) and elevated levels of circulating aromatic amino acids. Solutions high in BCAAs are designed for hepatic disease. Most commonly, these formulas are limited to patients with encephalopathy. The administration formulas high in BCAAs would seem to be beneficial; however, as with formulas for renal failure, controversy exists (Barber & Sacks, 2012). Examples of commercial preparations include HepatAmine and Hepatosol (Gahart, Nazareno, & Ortega, 2016).

Stress Formulas

Patients with severe metabolic stress, as occurs with infection, sepsis, and the trauma of burns, surgery, shock, and blunt or penetrating injuries, have increased breakdown of skeletal muscle (catabolism) and may require increased protein to meet increased nutritional needs. High metabolic stress formulas, which are similar to hepatic formulas, are available for this patient population. This group of patients has a predilection to break down BCAAs in muscles. Examples of stress formulas include Aminosyn-HBC, BranchAmine, FreAmine HBC, and Novamine 15% (Barber & Sacks, 2012; Gahart, Nazareno, & Ortega, 2016).

Parenteral Nutrition Orders

Life-threatening errors are possible when prescribing, preparing, and delivering PN admixtures to patients. Safe prescribing of PN requires:

- Thorough knowledge of protein and energy requirements, macro- and micronutrients, fluid homeostasis, and acid-base balance
Knowledge related to appropriate indications for PN and vascular access devices (VADs)

Clear communication among physicians, licensed independent practitioners (LIPs), dietitians, nurses, and pharmacists

Use of standardized order forms or templates and computerized prescriber order entry (Ayers et al., 2014b; Gorski et al., 2016, p. S133).

Components of a PN order are listed in Table 12-3.

**Parenteral Nutrition Administration**

**Vascular Access**

As previously discussed, the proper selection of vascular access (central vs. peripheral) depends on the type of PN formula. The hypertonic nature of PN requires the placement of a CVAD for administration. PN may be administered via any type of CVAD: nontunneled, PICC, subcutaneously tunneled, or vascular access port. The type of CVAD selected is based on a number of factors such as the anticipated duration of PN therapy and risk for thrombotic and infectious complications (Worthington et al., 2017). For patients who require long-term PN, subcutaneously tunneled catheters or implanted vascular access ports are

<table>
<thead>
<tr>
<th>Table 12-3</th>
<th>Components of Parenteral Nutrition Order Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient information (name, medical record number or other unique identifiers, birth date/age, patient location)</td>
<td></td>
</tr>
<tr>
<td>Allergies and reactions</td>
<td></td>
</tr>
<tr>
<td>Height and dosing weight</td>
<td></td>
</tr>
<tr>
<td>Diagnosis(es)/indications for PN</td>
<td></td>
</tr>
<tr>
<td>Vascular access device (VAD) type and location</td>
<td></td>
</tr>
<tr>
<td>Administration date/time</td>
<td></td>
</tr>
<tr>
<td>PN ingredients (should match PN label)</td>
<td></td>
</tr>
<tr>
<td>Amino acids</td>
<td></td>
</tr>
<tr>
<td>Dextrose</td>
<td></td>
</tr>
<tr>
<td>Lipid injectable emulsion (ILE)</td>
<td></td>
</tr>
<tr>
<td>Sodium phosphate</td>
<td></td>
</tr>
<tr>
<td>Sodium chloride</td>
<td></td>
</tr>
<tr>
<td>Sodium acetate</td>
<td></td>
</tr>
<tr>
<td>Potassium phosphate</td>
<td></td>
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<tr>
<td>Potassium chloride</td>
<td></td>
</tr>
<tr>
<td>Potassium acetate</td>
<td></td>
</tr>
<tr>
<td>Magnesium sulfate or magnesium chloride</td>
<td></td>
</tr>
<tr>
<td>Calcium gluconate</td>
<td></td>
</tr>
<tr>
<td>Multivitamins</td>
<td></td>
</tr>
<tr>
<td>Trace elements</td>
<td></td>
</tr>
<tr>
<td>Additives (e.g., cysteine, regular insulin) as clinically appropriate and compatible</td>
<td></td>
</tr>
<tr>
<td>PN Instructions</td>
<td></td>
</tr>
<tr>
<td>Total volume, infusion rate, start and stop times, cycle information</td>
<td></td>
</tr>
<tr>
<td>Prescriber and contact information</td>
<td></td>
</tr>
</tbody>
</table>

preferable to PICCs due to the higher risk of thrombosis with PICCs as well as more difficulty with self-administration (Pironi et al., 2016). The VAD should be the smallest gauge device with the fewest number of lumens necessary to meet the patient's needs (Gorski et al., 2016, p. S51; Worthington et al., 2017). PPN is administered via a short peripheral catheter or a midline peripheral catheter.

Care of peripheral IV catheters is addressed in Chapter 6, and care of CVADs is discussed in Chapter 8.

**PN Administration**

*Multilumen VADs*

When a patient has a multilumen VAD, A.S.P.E.N. recommends dedicating one of the lumens exclusively to PN administration (Worthington et al., 2017). While A.S.P.E.N. acknowledges that the research supporting this practice is based on a single study, the frequency of manipulation (i.e., accessing the lumen) is limited, which reduces the risk for intraluminal entry of microorganisms. Furthermore, the risk of infusing potentially incompatible medications with the PN is eliminated with this practice.

*Filtration*

PN solutions are always filtered during administration. Use of a 0.22-micron filter for PN administration can remove microorganisms, but this practice is limited to use with lipid-free formulas. PN formulas with lipids (i.e., TNAs) require the use of a 1.2-micron filter (see also Chapter 5 for a discussion and illustrations of filters). If a ILE is administered as a separate infusion, it is also filtered with a 1.2-micron filter in accordance with the manufacturer's directions.

**NURSING FAST FACT!**

PN formulations are considered high-risk admixtures and can become contaminated during compounding or administration setup.

*Catheter Locking*

Because patients receiving PN are at increased risk for bloodstream infection (BSI), antiseptic or antimicrobial drug locking may be considered for both therapeutic (i.e., to treat infection) and prophylactic reasons. Ethanol, sodium citrate, taurolidine, and ethylenediaminetetraacetate (EDTA) have been used (Gorski et al., 2016). Such solutions must be made by a compounding pharmacy because they are not commercially available at this time in single-dose syringes. The use of an antimicrobial lock may be used in patients with long-term CVADs, with a history of multiple BSIs, and in high-risk patients (Gorski et al., 2016, p. S79). Based upon a meta-analysis, the use of ethanol to lock the CVAD rather
than heparin (or saline) was associated with a decreased rate of BSIs (Oliveira, Nasr, Brindle, & Wales, 2012). Ethanol is an antiseptic with bactericidal and fungicidal activity against a broad range of microorganisms. Because there are conflicting data about the effect ethanol may have on polyurethane CVADs, recommendations are for use with silicone catheters. In accordance with recommendations by the INS, such locking solutions should be aspirated at the end of the locking period, rather than flushed into the patient’s bloodstream (Gorski et al., 2016, p. S79).

**Administration Sets and Infusion Pumps**

Specific recommendations guide the use of administration sets for PN. If any add-on devices (e.g., extension sets) are used, they are changed with each administration set change. Recommendations from A.S.P.E.N for administration set changes are as follows:

- All PN solutions with/without lipids: Administration set including the filter (and solution container) is changed every 24 hours (Ayers et al., 2014a).
- Separate infusions of ILE: The time limit for the container of ILE and the administration set is 12 hours due to concerns about microbial growth in the solution. If ILE is infused for longer than 12 hours, a new ILE container and administration set are used (Ayers et al., 2017; Gorski et al., 2016).

Another important issue related to administration sets and containers used with lipid-based infusions is that they should be DEHP free. DEHP is a toxin, is lipophilic, and is extracted into the solution with commonly used PVC administration sets and containers (Gorski et al., 2016). This issue is also discussed in Chapter 5.

PN is always administered using an electronic infusion device (EID) with free-flow protection (Gorski et al., 2016). Infusion pumps are addressed in Chapter 5.

**Blood Sampling for Laboratory Testing**

Blood sampling from the CVAD is not recommended unless there is no available peripheral access due to increased risk for catheter-related BSI (Ayers et al., 2014a; Buchman, Opilla, Kwasny, Diamantidis, & Okamoto, 2014). Laboratory sampling should be via venipuncture.

**Practice Criteria for Administration of Parenteral Nutrition**

**Establish Goals**

Once it is determined that the individual will receive PN, goals for nutritional support should be set with specific markers and outcomes to be measured (Ukleja et al., 2010). Goals should address energy and nutrient requirements and intake goals, route for nutritional support, and short- and long-term measurable goals.
Examples of patient goals include:

1. Normalization of laboratory values
2. Increase, or decrease, in weight (amount specified)
3. Wound healing
4. Improvement in functional status

**Monitoring**

The monitoring of patients receiving PN consists of assessment of the clinical and therapeutic response to the PN regimen. Assessment focuses on nutritional status, progress toward nutritional goals as discussed above, and anticipating and monitoring for potential complications as discussed in the next section. Specific areas for monitoring identified by A.S.P.E.N. (Ukleja et al., 2010) are physical assessment, functional status, vital signs, actual intake (oral, IV, enteral), weight, medication reviews, and changes in GI function. Monitoring of laboratory data is also important. Laboratory testing is more frequent when PN is initiated and then is decreased in frequency as clinically indicated. Also, regular assessment and meticulous care of the VAD and infusion system are essential aspects of care.

A.S.P.E.N. provides a PN administration checklist that addresses aseptic technique, PN container inspection, confirmation of patient identity and correct formula, and key steps in administration and monitoring. This is a helpful tool for nurses who administer PN in any health-care setting (see Table 12-4).

**NURSING POINTS OF CARE**

**ADMINISTRATION OF PARENTERAL NUTRITION**

**Focus Assessment**

- History of weight changes
- Dietary intake
- History of diseases/surgeries
- Identification of allergies
- Medications including over-the-counter and herbal products
- Vital signs
- Neurological status, including level of consciousness
- Assessment of skin, hair, nails, and oral cavity
- Intake and output
- Baseline laboratory findings: serum glucose, albumin, total protein, electrolyte, and chemistry profile
- Assessment for most appropriate VAD based on PN formula
Key Nursing Interventions

1. Assist with insertion of central line, or insert if competent, as appropriate for therapy.
2. Insert short peripheral or midline catheter per agency protocol for PPN.
3. Ascertain correct tip placement of CVAD before beginning PN.
4. Follow key steps in PN administration (Table 12-4).
5. Maintain VAD patency. Provide site care/dressing changes per agency protocol (at least every 7 days when using a transparent dressing; every 2 days when using gauze dressings) and prn if dressing loosened/dislodged or if drainage is present.
6. Monitor
   a. Patient response
   b. VAD-related complications: Pay particular attention to phlebitis/infiltration with peripheral IV catheters; risk for bloodstream infection with all VADs
   c. Serial weights
   d. Intake and output
   e. Laboratory results: Serum albumin, total protein, electrolyte, glucose, and chemistry profile
   f. Vital signs
   g. Blood glucose
      - Adult hospitalized patients: Serum glucose should be maintained between 140 and 180 mg/dL (McMahon et al., 2013).
      - Home-care patients: Attempt to keep serum glucose under 180 mg/dL with cyclic infusions (Pironi et al., 2016).
7. Check the label of the PN solution and ensure that it matches the orders before hanging each solution container.
8. The hang time of a PN solution container should never exceed 24 hours.
9. Use an EID to administer PN solutions.
10. Change the PN solution container and administration sets/filters every 24 hours. For ILE administered separately, the time limit for the container of ILE and the administration set is limited to 12 hours.
11. Use a 0.22-micron filter for fat-free PN solutions, a 1.2-micron filter for TNAs and separately administered ILEs.
12. Administer insulin as ordered to maintain BG in the ordered range.
13. Report abnormal signs and symptoms associated with PN to the physician and modify care accordingly.
14. Observe for signs and symptoms of electrolyte imbalance (see Chapter 3 for a review of signs and symptoms).
Table 12-4

PN Administration CHECKLIST

The American Society for Parenteral and Enteral Nutrition (A.S.P.E.N.) champions the best evidence-based practices that support parenteral nutrition therapy in varying age populations and disease states. The appropriate use of this complex therapy aims to maximize clinical benefit while minimizing the potential risks for adverse events.

The purpose of this checklist is to promote safe practices by nurses administering parenteral nutrition.

☐ Perform hand hygiene

☐ Use sterile technique when manipulating vascular access device

☐ Inspect PN container, check for:
  - Integrity of container: no defects or leaks present
  - No visible particles or precipitates
  - No oiling, streaking, clumping, or separation

☐ Confirm correct formulation, check for:
  - Patient's name on label
  - Match all components listed on the label against the PN order
  - Route of administration (central vs peripheral)
  - Documentation of proper VAD tip placement
  - Start time
  - Infusion rate with taper if appropriate
  - Beyond use date and time

☐ Verify patient identification
  - Confirm patient identity using two identifiers
  - Inspect armband (not applicable in home care)

☐ Initiate PN infusion
  - Use appropriate size filter on distal end of tubing
  - Spike container
  - Prime tubing
  - Set infusion pump settings using double check
  - Trace catheter system to point of origin
  - Disinfect needleless adapter on VAD hub
  - Connect PN to patient
  - Initiate PN infusion at prescribed rate

Initiate monitoring protocol which includes:
  - Patient response
  - Glucose monitoring
  - Serial weights
  - Intake and Output
  - Bloodwork
  - Vital signs

PN Administration Checklist. Part of the A.S.P.E.N. Parenteral Care Pathway. (https://www.nutritioncare.org/SmartPN_Pathway.aspx)
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Complications Associated With Parenteral Nutrition

Complications associated with PN are divided into three categories: (1) VAD-related complications, (2) metabolic, and (3) nutritional (Table 12-5) (see Chapter 9 for a thorough discussion of VAD-related complications). When administering PPN, there is risk for phlebitis and infiltration. As with any CVAD, risks include pneumothorax, air embolism (during insertion and during maintenance of the device), venous thrombosis, catheter occlusion, malposition, and BSI. This chapter focuses on metabolic and nutritional complications associated with nutritional support.
Table 12-5  Complications Associated With PN

<table>
<thead>
<tr>
<th>Complications/ Etiology</th>
<th>Symptoms</th>
<th>Treatment</th>
<th>Prevention</th>
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</thead>
<tbody>
<tr>
<td><strong>Infection</strong></td>
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<tr>
<td>Cause: Microbial</td>
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<tr>
<td>contamination at the</td>
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<tr>
<td>catheter insertion</td>
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<tr>
<td>site, microbial</td>
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<td></td>
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<tr>
<td>contamination</td>
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<tr>
<td>via the catheter hub,</td>
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<tr>
<td>homogeneous seeding</td>
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<tr>
<td>from other sources,</td>
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<tr>
<td>contaminated infusate</td>
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<tr>
<td>(rare)</td>
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<tr>
<td></td>
<td>Chills, fever, malaise, elevated white blood cell (WBC) count, tachycardia, tachypnea, flushing, hypotension</td>
<td>Blood cultures Catheter removal (catheter tip culture) and replacement may be required Antibiotics</td>
<td>Hand hygiene Maintain aseptic technique with all aspects of infusion-related care Use 0.22-micron filter with nonlipid PN formulas; use 1.2-micron filter with lipid-containing formulas Avoid blood sampling from VAD</td>
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<tr>
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<tr>
<td><strong>Metabolic Complications</strong></td>
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<tr>
<td>(Most Common; Other Electrolyte Imbalances Possible; See Chapter 3)</td>
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<tr>
<td><strong>Hyperglycemia</strong></td>
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<tr>
<td>Cause: Carbohydrate</td>
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<tr>
<td>intolerance, insulin</td>
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<tr>
<td>resistance, rapid</td>
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<tr>
<td>PN delivery, diabetes,</td>
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<td></td>
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<tr>
<td>infection/sepsis,</td>
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<tr>
<td>traumatic stress</td>
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<tr>
<td></td>
<td>Increased serum glucose, acetone breath, anxiety, confusion, dehydration, polydipsia, polyuria, malaise</td>
<td>Administer insulin</td>
<td>Decreased dextrose concentration or decreased rate Increase calories with lipids Monitor blood glucose</td>
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<tr>
<td><strong>Hyperkalemia</strong></td>
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<tr>
<td>Cause: Renal impairment,</td>
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<tr>
<td>iatrogenic-induced,</td>
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<tr>
<td>metabolic and respiratory acidosis, tissue damage</td>
<td>Serum K elevated &gt;5.5 mEq/L, electrocardiographic (ECG) changes, cardiac arrest, muscular weakness, flaccid muscles, intestinal colic, diarrhea</td>
<td>Adjust PN formula, dialysis</td>
<td>Monitor serum potassium, intake and output</td>
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<tr>
<td><strong>Hypocalcemia</strong></td>
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<tr>
<td>Cause: Vitamin D</td>
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<tr>
<td>deficiency, insufficient</td>
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<td></td>
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<tr>
<td>calcium or magnesium</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>intake, malabsorption,</td>
<td></td>
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<tr>
<td>pancreatitis</td>
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<tr>
<td></td>
<td>Central nervous system (CNS) irritability, confusion, muscle cramps in extremities, muscle spasms, laryngeal spasms, seizures, tetany</td>
<td>Adjust PN formula</td>
<td>Monitor serum calcium levels, avoid calcium-depleting medications, maintain adequate calcium intake</td>
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<tr>
<td><strong>Hypoglycemia: Rebound</strong></td>
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</tr>
<tr>
<td>Cause: Abrupt cessation</td>
<td>Diaphoresis, irritability, nervousness, shakiness, decreased level of consciousness</td>
<td>Administer dextrose or decrease insulin</td>
<td>Maintain steady rate of infusion; wean gradually Taper rate down for last 1–2 hours of cyclic infusions</td>
</tr>
<tr>
<td>of PN</td>
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</tbody>
</table>

Continued
# Table 12-5 Complications Associated With PN—cont’d

<table>
<thead>
<tr>
<th>Complications/ Etiology</th>
<th>Symptoms</th>
<th>Treatment</th>
<th>Prevention</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hypokalemia</strong>&lt;br&gt;Caused by: Shift of potassium into cells, gastrointestinal (GI) losses, diuretic therapy, steroid administration, anorexia</td>
<td>Serum K &lt;3.5 mEq/L, anorexia, fatigue, muscle weakness, decreased gastric motility, postural hypotension, ECG changes</td>
<td>Adjust PN formula</td>
<td>Monitor serum potassium, intake and output</td>
</tr>
<tr>
<td><strong>Hypomagnesemia</strong>&lt;br&gt;Caused by: GI losses, refeeding after starvation, renal disease</td>
<td>Apprehension, depression, apathy, neuromuscular hyperexcitability, tremors, premature ventricular contractions (premature ventricular contractions, tachycardia, ventricular fibrillation)</td>
<td>Adjust PN formula</td>
<td>Monitor serum magnesium, assess for neuromuscular changes</td>
</tr>
<tr>
<td><strong>Hypophosphatemia</strong>&lt;br&gt;Caused by: Inadequate phosphorus in PN formula, burns, malabsorption, starvation</td>
<td>Apprehension, irritability, seizures, decreased red blood cells (RBCs), muscle weakness, insulin resistance</td>
<td>Adjust PN formula</td>
<td>Monitor serum phosphorus levels</td>
</tr>
</tbody>
</table>

## Nutritional Alterations

| Altered Mineral Balance<br>Caused by: Result of deficiencies caused by malnourishment or starvation | Chromium: Elevated serum lipid levels, insulin resistance, glucose tolerance<br>Copper: Hypochromic microcytic anemia, neutropenia<br>Iron: Fatigue, glossitis, hypochromic microcytic anemia<br>Manganese: CNS changes<br>Selenium: Cardiomyopathies<br>Zinc: Alopecia, apathy, confusion, poor wound healing | Supply adequate supplementation in PN | Monitor for abnormal laboratory values |
Table 12-5 Complications Associated With PN—cont’d

<table>
<thead>
<tr>
<th>Complications/Etiology</th>
<th>Symptoms</th>
<th>Treatment</th>
<th>Prevention</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Altered Vitamin Balance</strong></td>
<td>Vitamin A: Dry, scaly, rough, cracked skin; decreased saliva; impaired digestion; diarrhea</td>
<td>Provide vitamin supplements in PN</td>
<td>Monitor for symptoms and assess for deficits</td>
</tr>
<tr>
<td>Cause: Disease processes can alter vitamin requirements PN must supply the needed fat- and water-soluble vitamin supplements</td>
<td>Vitamin D: Decreased serum calcium or phosphorus levels</td>
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</tr>
<tr>
<td>Vitamin E: red blood cell (RBC) hemolysis</td>
<td>Vitamin K: Delayed clotting</td>
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</tr>
<tr>
<td>Vitamin B1: Increased serum and urine lactate or pyruvate levels, anorexia, confusion, fatigue, painful calf muscle</td>
<td>Vitamin B2: Glossitis, stomatitis, dermatitis, photophobia</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vitamin B3 (niacin): Dermatitis, glossitis, diarrhea, dementia</td>
<td>Vitamin B12: Anorexia, depression, dyspnea, memory lapses, delirium, hallucinations</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Folic acid: Macrocytic anemia, diarrhea, glossitis</td>
<td>Vitamin C: Bleeding gums, petechiae, depression</td>
<td></td>
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</tr>
</tbody>
</table>

**Essential Fatty Acid Deficiency (EFAD)**
Cause: Deficient intake
Desquamating dermatitis, alopecia, brittle nails, delayed wound healing, thrombocytopenia, decreased immunity, increased capillary fragility
Intravenous fat emulsion (ILE)
Accurate calculation of protein, fat, and carbohydrate ratios to maintain a positive nitrogen balance

Continued
Table 12-5 Complications Associated With PN—cont’d

<table>
<thead>
<tr>
<th>Complications/Etiology</th>
<th>Symptoms</th>
<th>Treatment</th>
<th>Prevention</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Refeeding Syndrome</strong></td>
<td>Cardiorespiratory complications (dyspnea, tachycardia advancing to heart failure and cardiac arrest)</td>
<td>Monitor serum electrolytes, especially phosphorus and potassium</td>
<td>Can be averted by starting PN gradually and then gradually increasing rate</td>
</tr>
<tr>
<td><strong>Metabolic Complications</strong></td>
<td></td>
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<tr>
<td><strong>Altered Glucose Metabolism: Rebound Hypoglycemia</strong></td>
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<tr>
<td>Rebound hypoglycemia may occur when cyclic PN is discontinued or when continuous PN is interrupted because of continued secretion of insulin by the pancreas in response to the high-dextrose solution. Hypoglycemia is defined as BG less than 70 mg/dL (McMahon et al., 2013). Symptoms include diaphoresis, irritability, nervousness, and shaking and may result in a decrease in level of consciousness. Rebound hypoglycemia is prevented by ensuring that there are no interruptions in the infusion. For some patients on cyclic infusions, the infusion rate may be tapered down over the last 1 to 2 hours.</td>
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<tr>
<td><strong>Altered Glucose Metabolism: Hyperglycemia</strong></td>
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<tr>
<td>Hyperglycemia is a common and significant complication associated with PN and is caused by poor tolerance of the high-dextrose concentrations. Factors that put the patient at risk for hyperglycemia are the presence of overt or latent diabetes mellitus, older age, sepsis, hypokalemia, and hypophosphatemia. Hyperglycemia is associated with increased risk for complications such as pneumonia and acute renal failure and with an increased mortality rate (McMahon et al., 2013). Close attention to BG monitoring and management is critical. Current guidelines from A.S.P.E.N. state that the target BG range is between 140 and 180 mg/dL (McMahon et al., 2013). For home-care patients receiving cyclic PN, BG should be below 180 during the infusion with a normal hemoglobin A1C level (patients with diabetes) (Pironi et al., 2016). Conditions of stress result in impaired glucose tolerance and hyperglycemia in as many as 25% of patients on PN (Krzywda &amp; Meyer, 2014). Infusion of large amounts of glucose can also unmask latent diabetes, making hyperglycemia one of the most common complications encountered with</td>
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</table>
PN. Another consideration when infusing formulas containing high concentrations of glucose is the potential effect of carbohydrate metabolism on respiration. Metabolism of carbohydrates results in increased production of carbon dioxide. Increased carbon dioxide is compensated by increased minute ventilation. This could precipitate respiratory failure in patients with preexisting respiratory disease or interfere with weaning from mechanical ventilation.

Factors that predispose a patient to glucose intolerance include:

- Presence of overt or latent diabetes mellitus
- Older age
- Pancreatitis
- Hypokalemia
- Hypophosphatemia
- Thiamine or vitamin B₆ deficiency
- Some antibiotics
- Steroids
- Conditions of stress, such as sepsis or surgery (Krzywda & Meyer, 2014)

**Alterations in Hepatic Function**

Abnormalities in hepatic function are common in patients receiving PN. They include steatosis, cholestasis, and gallbladder stones (Kumpf & Gervasio, 2012). Although the causes are not clear, factors may include continuous dextrose infusion, EFAD, excessive lipid infusion, amino acid imbalance, toxic effects of PN degradation products, and overgrowth of intestinal flora (Krzywda & Meyer, 2014). There is increasing concern that ILE administration may be a factor in PN-associated liver disease, and this has been identified by A.S.P.E.N. as a topic for further research (Worthington et al., 2017).

**NURSING FAST FACT!**

In adults, laboratory findings indicative of hepatic function alterations include elevations in alkaline phosphatase and transaminase levels. Cholestasis and gallbladder disease are potential complications of long-term PN.

**Electrolyte Imbalances**

Major electrolyte imbalances associated with PN can occur if excessive or deficient amounts of electrolytes are supplied in the daily fluid allowance. Electrolyte balance is addressed in Chapter 3. The most common imbalances associated with PN include imbalances of potassium, magnesium, and phosphate (Krzywda & Meyer, 2014). Interventions include frequent monitoring of serum electrolytes and adjustments in the PN solution. In acute care settings, monitoring is recommended 1 to 2 times per week or as clinically
indicated; for long-term PN, monitoring should be monthly (Worthington et al., 2017).

- **Potassium: Hypokalemia.** Potassium is also driven into the intracellular space during PN. Serum potassium can become depleted with an inadequate supply of this electrolyte. Insulin administration further intensifies intracellular potassium.

- **Potassium: Hyperkalemia.** A high potassium blood level can occur with renal impairment, can be iatrogenic induced, or can occur with metabolic and respiratory acidosis when potassium shifts out of the cells. Interventions include reducing the amount of potassium ion in the PN solution.

- **Magnesium: Hypomagnesemia.** The magnesium electrolyte also is driven into the intracellular space during PN administration.

- **Phosphate: Hypophosphatemia.** Adenosine triphosphate (ATP) is required for all cell energy production. Protein synthesis begins when PN is administered and phosphate is driven into the intracellular space as a component of ATP. Therefore, a deficiency of phosphate can occur.

**Nutritional Complications**

**Refeeding Syndrome**

Cardiac and pulmonary failure can occur when aggressive nutritional support is initiated in a severely malnourished patient. **Refeeding syndrome** is a rare complication. This occurs when the body, during its bout with starvation, adapts to nutritional deprivation and compensates by decreasing basal energy requirements and diminishing cardiac reserves. This initiation of nutritional support, especially if it is undertaken too aggressively, can lead to an electrolyte shift from the plasma to the intracellular fluid and can result in hypophosphatemia in particular. Cardiorespiratory complications can occur. The result of refeeding syndrome is manifested by dyspnea, tachycardia advancing to heart failure, and cardiac arrest (Krzywda & Meyer, 2014).

**Essential Fatty Acid Deficiency**

Essential fatty acid deficiency is a risk when the PN formula is lipid free. Clinical signs and symptoms include:

- Alopecia
- Impaired wound healing
- Thrombocytopenia
- Dry and scaly skin

The condition is corrected when an ILE is added to the formula. Fats may be administered in amounts that supply 30% to 50% of the calories.

**Altered Vitamin and Trace Element Balance**

Because of the addition of vitamins and trace elements to the formula, deficiencies are not common. Serum levels are recommended every 3 to 6 months.
for long-term PN, and patients should be monitored for signs and symptoms of deficiencies (Worthington et al., 2017). It is important that multivitamins be added to the solution just prior to infusion because vitamin degradation can occur when vitamins are present in the PN admixture for extended periods of time.

Discontinuation of Nutritional Support

PN should not be discontinued until nutrient requirements can be met by enteral or oral nutrients based on consistently consuming 50% to 75% of energy and protein needs with signs of continuing improvement (Worthington et al., 2017).

AGE-RELATED CONSIDERATIONS

The Pediatric Patient

Pediatric PN differs from the adult PN in nutritional requirements and formulas, monitoring parameters, and administration methods. PN is indicated in infants and children who are unable to tolerate adequate enteral feedings to sustain their nutritional requirements. Patients who require PN fall into two main categories: those with congenital or acquired abnormalities of the GI tract (e.g., severe inflammatory bowel disease, paralytic ileus, intestinal atresia) and those with intractable diarrhea syndromes (Krzywda & Meyer, 2010). PN may be required also in children who are premature, who suffer from chronic malnutrition (failure to thrive), or who are at high risk for developing malnutrition as a result of acute medical illness or prolonged postoperative recovery.

Assessment

- Nutritional assessment of pediatric patients includes use of standard growth curves. Calculation of the ratio of weight to height indicates wasting and calculation of the ratio of height to age indicates stunting of growth. Anthropometric measurements are used as gauges of somatic protein and fat stores. Visceral protein stores are evaluated by determining serum albumin, transferrin, prealbumin, and retinol-binding protein levels.
- There are specific recommendations for pediatric patients for energy, protein, and fluid requirements based on age and kilogram of body weight (Ayers et al., 2014b).
- Children have a high basal metabolic rate per unit of body weight, an increased evaporative fluid loss, and immature kidneys. Fluid requirements must be carefully assessed to prevent dehydration or overhydration. There are many factors affecting fluid needs, such as thermal blankets, phototherapy, and radiant warmers (Doellman, 2014).
- The protein needs of pediatric patients are higher than those of adults in proportion to body weight (Gargasz, 2012). Furthermore, certain amino acids that are nonessential for adults may be essential for pediatric patients, including histidine, tyrosine, and cysteine.
- Preterm neonates are especially prone to developing EFAD due to low body fat stores (Ayers et al., 2014b).
• Another area of assessment includes psychological support. Many pediatric patients on PN are infants who are acutely ill and deprived of maternal warmth and comfort. Cuddling and holding the child should be encouraged, along with allowing the parents to participate in their child’s care. Allowing “breaks” from PN may be beneficial to a child who is able to enjoy regular activities. Some patients receiving PN are not acutely ill and have the energy of any other child.

Monitoring
PN must be monitored in the pediatric patient to meet the demands of growth and development.

• The nurse must monitor the child’s physical status and report abnormal findings of temperature spikes, hyper-/hypoglycemia, chills, rashes, irritability, and changes in level of consciousness. Serum levels of various chemistry and hematology tests are checked daily for the first week and then decreased to a weekly schedule for the stable hospitalized or HPN patient.
• Many children require long-term support at home. Monitoring includes many of the same parameters as for adults. Monitoring during initiation of PN includes daily weight, intake and output, daily serum electrolytes until stable, serum glucose measurements every 8 to 12 hours, serum triglycerides and free fatty acid levels weekly, and serum hepatic function test biweekly.
• Children require evaluation of growth determinations, including weight, height, and head circumference for the duration of therapy.
• Cyclic PN should be considered in patients such as those on long-term PN or those with cholestasis.

Practice Guidelines to Prevent Complications in the Pediatric Patient
• Hepatobiliary dysfunction is a common complication in pediatric patients who receive long-term PN, affecting 50% to 66% of patients (Israelite, 2017). Liver function is monitored, and preventative strategies include avoidance of overfeeding, cyclic PN, limiting soybean-based fat to less than 1 gram per day, and preventing and managing sepsis (Pironi et al., 2016).
• Hyperglycemia is of particular concern in neonatal patients. It can cause complications including retinopathy, bronchopulmonary dysplasia, necrotizing enterocolitis, infections, longer hospital stays, and death. Insulin administration by continuous infusion is safe and effective in controlling PN-associated hyperglycemia in infants (Gargasz, 2012). Management of hyperglycemia includes avoiding excess dextrose concentrations, providing fat emulsions, and using insulin for persistent hyperglycemia.

The Older Adult
The physiological changes that occur with advancing age affect nutritional requirements, independent of disease or rehabilitation demands. Physiological changes that decrease caloric requirements include a reduction in lean body mass and redistribution of fat around internal organs (DiMaria-Ghalili, 2012). Furthermore, changes in taste, whether caused by atrophy, medications, or nutrient deficiency, may contribute to an altered nutritional status.

Inadequate dietary intake in elderly people is multifaceted. Causes of malnutrition in older adults include presence of chronic illnesses, poor oral health, polypharmacy, social isolation, dementia, obesity, frailty, and changes in functional status affecting their ability to obtain, prepare, and eat food (Mueller & Zelig, 2012).
Data related to use of PN in the older adult are very limited; however, PN may be an option when nutritional requirements cannot be met orally or via the enteral route. The use of PN via a peripheral IV is discouraged because of the fragility of veins (Mueller & Zelig, 2012). Because of the presence of the normal changes of aging (e.g., diminished renal function) and the presence of chronic illnesses, metabolic problems including fluid and electrolyte disturbances are more common. Older adults are more likely to have vitamin and trace-element deficiencies.

Practice Guidelines
1. Older adult patients should undergo nutrition screening to identify those who require formal nutrition assessment.
2. Age and lifestyle parameters should be used to assess the nutrition status of elderly persons.
3. Potential drug–nutrient interactions should be assessed in all elderly patients receiving medications.
4. Diet and specialized nutritional support for elderly persons should take into consideration altered nutrient requirements observed in this age group.

Home Care Issues
Provision of PN in the home setting dates back to the 1970s. HPN may be a long-term or even lifetime infusion therapy for certain patients. HPN may be administered as a 24-hour/day infusion or, more commonly, as a cyclic infusion. Cyclic HPN is most often administered overnight, allowing the patient freedom from the infusion pump during the daytime.

Advantages of home treatment for nutritional support include lower cost and the ability of the patient to remain in familiar, comfortable surroundings, thereby decreasing the age-related confusion associated with environment changes. In many cases, home treatment allows the patient to return to normal activities and is associated with a lower risk of acquiring a health-care–associated infection, although PN is specifically identified as a risk factor for BSI in patients receiving home infusion therapy (Gorski, 2017). In addition, a person's control over his or her body and the self-care responsibility increase self-esteem.

Patient Selection
Candidates for PN within the home-care environment include patients who have long-term disease in which oral and enteral nutrition have been demonstrated as ineffective in providing nutritional support. Typical diagnoses associated with HPN include intestinal failure, short bowel syndrome, malabsorption, chronic bowel obstruction, Crohn’s disease, radiation enteritis, intestinal/pancreatic fistulas, pancreatitis, and severe, life-threatening malnutrition (Ayers et al., 2014b).

Continued
Before initiating the discharge planning process, reimbursement for home care must be verified. Private third-party payers vary in coverage. Certain diagnoses and PN infusions may be covered under the durable medical equipment benefit under Part B of the Medicare program. Patients must meet criteria that include “permanence,” interpreted as requiring PN for at least 3 months.

Issues to address during discharge planning include the patient’s ability to participate in care, stability of the clinical condition, caregiver/family support, and home environmental safety. Because the goal for most patients on HPN is complete patient and/or caregiver independence in administration and monitoring of the infusion, the ability to participate in care is a necessary aspect of assessment. Intellectual and functional abilities should be carefully assessed. The ability to adhere to aseptic technique and manage an EID, adequacy of eyesight, and manual dexterity are important attributes. Ideally, a formal teaching program should be initiated in the hospital prior to discharge. Before sending a patient home on HPN, the patient must be clinically stable before going home on PN as defined by:

- Weight maintained or increased per goals of PN
- Stable blood chemistry levels
- Stable nutritional laboratory indicators
- No evidence of rebound hypoglycemia with discontinuation of cyclic infusions
- No adverse reactions to HPN infusion

Home safety must be determined before discharge from the hospital. The home environment should be reasonably clean and safe for storage of supplies and preparation for infusion. Electricity, telephone access, and refrigeration are necessary. Ambulatory infusion pumps used in the home setting can be powered by disposable batteries, but for cost-effectiveness, most use rechargeable batteries. The HPN solution is usually delivered weekly, and a reliable refrigerator is required for storage.

### NOTE:
In some cases, the home infusion pharmacy may provide a small refrigerator dedicated to PN storage.

### Preparing for Home Parenteral Nutrition
The home education process should include but is not limited to:

- Verbal and written instructions on appropriate procedures based on an assessment of how the patient best learns with attention to age, cognition, developmental level, health literacy, culture, and language preference (Gorski et al., 2016, p. S25)
Home Care Issues—cont’d

- Demonstration and return demonstration of procedures by the primary caregiver
  - Inspection of HPN containers and contents
  - Aseptic technique required for adding multivitamins to the HPN and for all interventions related to administration via the VAD
  - Proper storage
  - Evaluation and documentation of competency
  - Self-monitoring
  - Limitations of physical activity
  - Emergency intervention and problem-solving
  - Care of infusion equipment, solutions, and supplies
  - Disposal of supplies
  - Expectations of home care and medical and nursing follow-up
  - Statement of whom and when to contact when complications occur

Practice criteria for delivery of PN in the home and hospital are the same.

NOTE: Ambulatory pumps have features specific for HPN administration.

Monitoring

Complications have been previously addressed. Of note, the most common complication for patients receiving HPN is catheter-related bloodstream infection (Ayers et al., 2014b). Monitoring for signs and symptoms of infection and providing patients and families with thorough education aimed at risk reduction are important aspects of home-care nursing. Patients should be instructed on monitoring BG and weights daily, intake and output, and signs of infection (e.g., fever, VAD site redness, swelling) as well as on being attentive to changes (e.g., increased or decreased urine/ostomy output).

BG levels should be checked during PN infusions and then compared with levels when the patient is off the cyclic PN. As a general guideline, glucose levels should be less than 150 mg/dL (Krzywda & Meyer, 2014). During the peak of the cyclic PN infusion, some physicians may allow BG levels as high as 180 mg/dL. It is important to collaborate with the referring nutritional support program/prescribing physician when obtaining reporting parameters. It is important to recognize that a sudden increase in BG may be an early sign of infection and that further evaluation is necessary.

Psychosocial Issues

Psychosocial concerns are often considerable for the patient who is unable to eat “normally” and who requires long-term or lifelong PN. Yet, studies show that little attention is paid to these issues (Huisman-de Waal, van Achterberg, Continued
Home Care Issues—cont’d

Jansen, Wanten, & Schoonhoven, 2011). In a recent qualitative study exploring the experience of adults dependent on HPN, the concept of “normalization” was a repeating and strong theme (Winkler & Smith, 2015). Issues include fear and anxiety related to HPN, loss of ability to eat, changes in family life/roles, depression, caregiver stress, body image alterations, and financial concerns. Lack of sleep due to nighttime infusions, limitations on freedom and social activities, and dependency on others are additional issues these patients face. It is important for the nurse to assess for psychosocial issues and to provide the opportunity for patients and their families to discuss them. Referrals to behavioral health professionals may be appropriate.

An excellent resource and support for patients is the Oley Foundation. It is a nonprofit support organization, established in 1983, that provides education, self-help, and research for persons who are on PN or enteral nutrition. Membership is free. There are excellent patient educational tools, a newsletter, and other resources available on the site.

Website
The Oley Foundation: www.Oley.org

Patient Education
The patient receiving PN will require education, periodic assessment, and retraining as needed. Many of the points listed in patient education for home-care issues apply to patients in all settings. Teaching points include:

- Purpose and duration of the PN
- Hang time of the product with the composition, intended use, and expected outcomes
- VAD management
- Complications, prevention and management
  - Metabolic complications such as hypoglycemia and electrolyte imbalances
  - Mechanical or procedural problems (catheter or tube occlusion, leakage, breakage, or dislodgement)
  - Equipment malfunction or breakage
- Signs and symptoms of localized or systemic infectious process
- Provide 24-hour phone numbers for home-care agency or physician so that patient or caregiver can access professional help.
Nursing Process

The nursing process is a six-step process for problem-solving to guide nursing action (see Chapter 1 for details on the steps of the nursing process). The following table focuses on nursing diagnoses, nursing outcomes classification (NOC), and nursing interventions classification (NIC) for patients receiving nutritional support. Nursing diagnoses should be patient-specific and outcomes and interventions individualized. The NOC and NIC presented here are suggested directions for development of specific outcomes and interventions.

### Nursing Diagnoses Related to Nutritional Support

<table>
<thead>
<tr>
<th>Nursing Diagnoses Related to Nutritional Support</th>
<th>Nursing Outcomes Classification (NOC)</th>
<th>Nursing Interventions Classification (NIC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excess fluid volume, risk for: Excessive fluid intake</td>
<td>Fluid balance, hydration</td>
<td>Fluid management, fluid monitoring</td>
</tr>
<tr>
<td>Health maintenance, ineffective: poor dietary habits with alteration in cognitive functioning</td>
<td>Health beliefs: perceived resources, health-promoting behavior, health-seeking behavior</td>
<td>Health education; support system enhancement</td>
</tr>
<tr>
<td>Infection, risk for related to: Alteration in skin integrity (VAD), receiving PN</td>
<td>Immune status, knowledge of infection management, risk control, risk detection</td>
<td>Infection control, infection protection</td>
</tr>
<tr>
<td>Nutrition, less than body requirements, related to: inability to ingest/absorb nutrients</td>
<td>Nutritional status, nutrient intake; food and fluid intake; weight control</td>
<td>Feeding, nutrition management, nutrition therapy, nutrition counseling</td>
</tr>
<tr>
<td>Skin integrity, impaired and risk for, related to: presence of VAD, inadequate nutrition</td>
<td>Tissue integrity: skin and mucous membranes</td>
<td>Skin care, skin surveillance, incisional (VAD) site care</td>
</tr>
<tr>
<td>Self-care deficit related to: impaired ability to chew/swallow food; inability to ingest food</td>
<td>Activities of daily living, eating</td>
<td>Self-care assistance, feeding</td>
</tr>
</tbody>
</table>

Source: Ackley, Ladwig, & Makic, 2017.

### Chapter Highlights

- Candidates for nutritional support include those with:
  - Altered catabolic states
  - Chronic weight loss
  - Conditions requiring bowel rest
  - Excessive nitrogen loss
  - Hepatic or renal failure
  - Hypermetabolic states
  - Malabsorptive states
  - Malnutrition
  - Multiple trauma
There are three broad classifications of malnutrition: marasmus, kwashiorkor, and mixed malnutrition.

Effects of malnutrition include a decrease in protein stores, albumin depletion, and impaired immune status.

Nutritional assessment includes:
- History (medical, social, dietary, medications)
- Anthropometric measurements (height, weight, skinfold tests, mid-arm circumference)
- Laboratory testing (serum albumin, transferrin, prealbumin and retinol-binding protein, total lymphocyte counts, electrolytes)
- Determination of energy requirements
- Physical examination

PN is an IV solution that includes carbohydrates, amino acids, lipids, electrolytes, multivitamins, and minerals formulated to meet an individual patient’s needs.

Modalities for delivery of nutritional support include:
- Enteral nutrition
- PN, which may be administered via a peripheral vein or a central vein
- PPN, delivered into a peripheral vein, is indicated for short-term nutritional support for patients who are malnourished or at risk for malnutrition, and are not candidates for enteral nutrition.
- PN delivered via a CVAD is the IV administration of hypertonic glucose (20%–70%) and amino acids (3.5%–15%), along with all additional components required for complete support.
- PN and PPN solutions must be filtered with a 0.22-micron filter, except when lipids are added to TNAs, which requires a 1.2-micron filter. Separate infusions of ILE also require a 1.2 micron filter.

Complications of PN include:
- VAD-related complications
- Metabolic complications
- Nutritional complications

**Thinking Critically: Case Study**

A 45-year-old man is admitted with severe exacerbation of his Crohn’s disease. He is 6 feet 1 inches tall, weighs 132 pounds (60 kg), and has experienced a 45-pound weight loss in the past 3 months (25%). He is weak and pale and has dry mucous membranes, a red beefy tongue, and cracks at the sides of his mouth. He has an ileostomy and has developed a draining enterocutaneous fistula. Because of severe malabsorption as a result of the Crohn’s disease, PN is ordered. He is to receive a solution of 20% dextrose, 50 g of protein/L with standard electrolytes, and daily multiple vitamins/trace elements. The goal is 2 L of this solution per day. With lipids, this will provide an average of 2260 calories per day and 100 g of protein. The solution is initiated at 1 L/day and is increased according to
patient tolerance. The PN will be infused through a peripherally inserted central catheter.

Case Study Questions

1. What are the points of care in monitoring this patient?
2. Why is the presence of the enterocutaneous fistula significant in terms of this patient’s nutritional needs (considering increased fluid requirements and wound healing)?
3. What potential complications related to PN is this patient at risk for?

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Note: Page numbers followed by f refer to figures; page numbers followed by t refer to tables; pages numbers followed by p refer to procedures.

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