National
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Peripherally Inserted Central Catheters: Guideline for Practice, 3rd edition

National Association of Neonatal Nurses
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Peripherally Inserted Central Catheters: Guideline for Practice, 3rd edition

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Dedication
This edition is dedicated to Janet Pettit, DNP MSN RNC NNP-BC VA-BC CNS, whose vision for a revolution in vascular access for babies we continue to strive for and are privileged to share.

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Abstract

Peripherally inserted central catheters (PICCs) are being placed routinely in infants to enhance the delivery of care for this vulnerable population. Guidelines for PICC use are indicated to support nursing practice at the bedside and promote infant safety. This guideline defines criteria for educational competencies for nurses inserting and maintaining PICCs and discusses infant selection criteria, techniques for catheter insertion, identification and management of complications, and strategies for daily maintenance.

This is the only guideline that is specific to infants with PICCs. Nurses also should be aware of the *Infusion Nursing Standards of Practice* by the Infusion Nurses Society (INS),[1] the *Position Statement* related to catheter tip location from the National Association of Vascular Access Networks (formerly NAVAN, now the Association for Vascular Access [AVA])[2] and the U.S. Food and Drug Administration (FDA).[3] These remain the only two current tip position statements. Nurses should also be aware of the *Guidelines for the Prevention of Intravascular Catheter Related Infections* from the Centers for Disease Control and Prevention (CDC),[4] guidelines specific to particular patient populations, and state and federal statutes.

This guideline is designed as a description of practices currently accepted and documented by experts in the field of neonatal care. The guideline also identifies gaps in existing scientific knowledge. The guideline does not preclude the use of manufacturers' recommendations or other safe and acceptable methods for inserting and maintaining PICCs. This document provides a foundation for the specific nursing protocols, policies, and procedures developed by individual institutions.

This guideline was developed and revised by the National Association of Neonatal Nurses (NANN).

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Objective

To provide an evidence-based clinical guideline for the use of PICCs in the neonatal population

Users and Setting

Neonatalogists, neonatal nurse practitioners (NNPs), and nurses. Settings include neonatal intensive care units (NICUs) and other settings that include neonates and infants.

Target Population

The guideline's recommendations are intended for all neonates and newborn infants, with an age range from birth while in neonatal intensive care to pediatric or pediatric intensive care settings most appropriate for infants younger than 6 months of age who require vascular access. This guideline may apply to patients up to 2 years of age as appropriate.

Evidence Collection Methods

Evidence was collected via continuous review of electronic databases—the National Center for Biotechnology Information (NCBI) at the U.S. National Library of Medicine (NLM), PubMed, EBSCO, Cochrane, OVID, and CINHAL—to evaluate and research all scientific literature from 2000 to 2015.

Searches included (intensive care units, neonatal OR intensive Care, neonatal OR NICU[tw] OR NICUs[tw] OR infant, newborn OR neonate* OR neonatal nursing OR neonatology) AND (PICC[tw] OR PICCs[tw] OR PCVC*[tw] OR PCVCs[tw] OR "perc line"[tw] OR "perc lines"[tw] OR "long line"[tw] OR "long lines"[tw]) AND English[la] AND 2006 : 2014[dp]) OR (intensive care units, neonatal OR intensive care, neonatal OR NICU[tw] OR NICUs[tw] OR infant, newborn OR neonate* OR neonatal nursing OR neonatology) AND (catheterization, central venous OR cvc*[tw] OR central venous catheters) AND (catheterization, peripheral OR peripher*[tw] OR percutaneous*[tw]) AND English[la] AND 2006 : 2014[dp]) OR (intensive care units, neonatal OR intensive care, neonatal OR NICU[tw] OR NICUs[tw] OR infant, newborn OR neonat* OR neonatal nursing OR neonatology) AND central*[tw] AND (line[tw] OR lines[tw] OR access[tw] OR catheter[tw] OR catheters[tw] OR catheterization[tw]) AND (peripher*[tw] OR percutaneous*[tw] OR perc[tw] OR catheterization, peripheral) AND English[la] AND 2006 : 2014[dp]) OR (intensive care units, neonatal OR intensive care, neonatal OR NICU[tw] OR NICUs[tw] OR infant, newborn OR neonat*[tw] OR neonatal nursing OR neonatology) AND (central venous catheters OR catheterization, central venous OR cvc*[tw] OR PICC[tw] OR PICCs[tw] OR PCVC*[tw] OR PCVCs[tw] OR "perc line"[tw] OR "perc lines"[tw] OR "long line"[tw] OR "long lines"[tw]) AND (ae[sh:noexp] OR cross infection[mh] OR infection control[mh] OR catheter-related infections[mh] OR CLABSI[tw] OR CLA-BSI[tw] OR CLABSIs[tw] OR CLA-BSIs[tw] OR bloodstream[tw] OR microbiology[sh:noexp] OR bacterial infections[mh] OR depsis[mh] OR malposition*[tw] OR reposition*[tw] OR misplac*[tw] OR medical errors[mh] OR equipment failure[mh] OR equipment contamination[mh] OR clinical competence[mh] OR device removal[mh]) AND English[la] AND 2006 : 2014[dp]).

Practice Recommendation	Level of evidence	Reference(s)
1. Maintain the catheter tip in a central tip location in superior vena cava/inferior vena cava. **Rationale:** Placement of the catheter tip in the superior vena cava or inferior vena cava is associated with lower risk of complications.	A1	1,2,3,11,19,20,34
2. Consider noninvasive catheter repositioning strategies to correct catheter tip malposition. **Rationale:** Noninvasive repositioning facilitates central catheter tip location while posing less trauma to the skin and patient associated with catheter withdrawal or replacement and dressing removal.	B3	1,35,36,37,38,39
3. Obtain follow-up imaging subsequent to catheter repositioning. **Rationale:** Catheter tip position should be verified following all repositioning efforts. Accurate information about the catheter tip location supports minimizing complications.	A1	1,3,18,35,40
4. Maintain the extremity where catheter is inserted in a consistent position for accurate radiographic confirmation. **Rationale:** Consistent patient positioning of the extremity of catheter insertion supports accurate and consistent confirmation of the catheter tip location. Changes in patient position impact catheter tip location and depth.	A1	1,18,35,41,42,43,44
5. Perform dressing change as needed per patient or external indications. **Rationale:** The needs, risks and benefits of dressing changes should be considered because the procedure is not without risk and may cause discomfort or trauma to fragile skin.	A3	1,4,18,22,45,46,47,48, 49,50,51,52,53
6. Utilize air embolism preventive measures upon catheter removal. **Rationale:** Air embolism can occur due to air inadvertently entering the venous system upon dislocation of the catheter.	A3	54,55,56,57
7. Consider chlorhexidine gluconate or povidone iodine as disinfectant agents for skin antisepsis. Remove povidone iodine prior to dressing application. **Rationale:** Removing povidone iodine minimizes the risk for tissue damage, absorption, and thyroid suppression.	A1	45,58,59,60,61, 62,63,64,65,66
8. Consider incorporating new technology and equipment to enhance practice as appropriate to specific patient needs. **Rationale:** Evolving technology enables new procedures that may help meet specific patient needs and improve outcomes.	B2	67,68,69,70,71
9. Implement complications prevention strategies, including central line-associated bloodstream infection prevention. **Rationale:** A culture of complications prevention has been successful in central line-associated bloodstream infection prevention.	A1	45,50,51,52,64,72,73,74, 75,76,77,78
10. Provide initial, ongoing, and consistent education for providers who insert and care for PICCs. **Rationale:** Appropriate and timely education for those placing and caring for PICCs has been integral to preventing central line-associated bloodstream infection, and is critical to minimizing risks of other complications.	A1	3,4,8,22,45,72,74,79, 80,81
11. Limit the use of contrast media to situations where the catheter tip cannot be visualized. **Rationale:** Use of contrast does not guarantee precise visualization of the catheter tip in all situations.	B3	42,82,83
12. Consider the right saphenous vein in initial assessment for catheter placement unless gastroschisis is present. **Rationale:** Lower-extremity vessels are associated with lower complications rates. The right saphenous vein is associated with lower malposition rates.	B2	84,85,86,87,88,89,90, 91,92,93,94,95

Recommendations and Grading Criteria

The following grading system was employed to rate the quality and strength of the evidence to support the practice recommendations.

Strength of Recommendation Taxonomy[5]

A Recommendation based on consistent and good-quality patient-oriented evidence

B Recommendation based on inconsistent or limited-quality patient-oriented evidence

C Recommendation based on consensus, usual practice, disease-oriented evidence, case series for studies of treatment or screening and/or opinion

Study Quality

1 Good-quality patient-oriented evidence

2 Limited-quality patient-oriented evidence

3 Consensus guidelines, extrapolations from bench research, usual practice, opinion, disease-oriented evidence or case series

Highlights of the Third Edition

This third edition reflects our growing interest in and emerging evidence for providing the best care of our patients who require PICCs. New evidence is reflected in concise evidence-based and graded practice recommendations. Common complications and their detection and prevention, new management strategies, and evolving technology are addressed.

Introduction

The increasing number of extremely-low-birth-weight, critically and chronically ill neonates heightens the need for parenteral nutrition to support growth and reliable vascular access for the administration of additional intravenous fluids and medications. The number of neonates requiring surgical procedures has continued to increase, including those with significant bowel anomalies, such as gastroschisis, who have long-term, increasing parenteral nutrition requirements. As a result, caregivers are continually challenged to improve the methods by which they provide safe and consistent vascular access to these vulnerable populations.

Peripheral intravenous (PIV) and umbilical catheters have commonly been employed for these purposes, but they have a limited dwell time (i.e., the life of an inserted vascular access device [VAD]). In addition, the PIV catheter has an increased complication profile and infusate limit compared with other central venous catheters. Surgically inserted, tunneled central venous catheters (CVCs) (e.g., Broviac®) have been successfully placed in neonates and infants for decades and have proven to be a reliable but more costly means of providing long-term access. In 1973, Shaw described a novel technique for inserting a silicone catheter into the central veins of neonates.[6] Since then, improvements in catheter material, configuration, sizes, and imaging technology have modernized the practice of inserting PICCs. At the heart of the PICC insertion procedure are the registered nurses (RNs) who offer a cost-effective approach to providing vascular access while yielding outcomes with low infection rates. The institution and development of RN-led PICC teams allows for the consistent management of PICCs.[7,8] According to Pettit,[9] the use of trained nurses in developed vascular access teams has been linked to improved outcomes. Ultrasound technology and echocardiography has shown increased sensitivity and specificity in placement with a decrease in procedure timeframes, ongoing monitoring of tip placement, and radiation exposure.[10-12]

Definitions

A *peripherally inserted central catheter* is a device inserted into a peripheral vein and threaded into the central venous circulation. PICCs can be used for an extended period of time and have been associated with lower infection rates compared with central venous catheters.[13] Although PICC is the proper term for this device, neonatal care providers have historically referred to these catheters as percutaneous central venous catheters (PCVCs), perc lines, and long lines. According to the FDA and other entities, the tip of the PICC should reside in the superior vena cava (lower one-half to one-third) for upper-body insertions and the thoracic inferior vena cava above the level of the diaphragm for lower-extremity insertions or within the vena cava above L2.[1,2,3]

A *midline catheter* is a vascular device that is inserted into a peripheral vein and threaded to an area of greater blood flow in the proximal portion of the extremity, or inserted into a scalp vein and threaded into the jugular vein.[1,14] Catheter tips that remain in the peripheral circulation are referred to as midline catheters. These catheters may be appropriate for the infusion of fluids or medications with osmolalities < 600 mOsm/kg, a pH ranging from 5 to 9, and the noncontinuous infusion of irritant or vesicant properties (similar to those that can safely be administered through a PIV).[1,14-8] Midline catheters are a consideration for anticipated 5- to 7-day dwell times with tip placement at an area of nonflexion.

Noncentral catheters are associated with higher rates of infiltration and mechanical complications when the tip is in a smaller vein in the upper or lower extremity or jugular vein. There is a 28% higher risk of complications with catheters when the tip is not central.[19] A careful risk-benefit analysis is warranted if a catheter cannot be advanced into the central circulation in neonates.[11] Complications related to noncentral venous catheters significantly exceed those associated with catheters in which the tip resides within the superior or inferior vena cava.[11,20]

Early assessment of the infant during hospitalization is imperative to determine the most appropriate VAD for meeting the infant's ongoing needs. The chosen device will allow for uninterrupted therapy, preserve the peripheral vasculature, reduce the cost of delivering therapy, and protect the infant from pain associated with multiple PIV attempts.[21,22] The selection criteria for vascular devices include length and type of anticipated therapies, age and weight of the infant, diagnoses, condition of the vasculature, available sites, and current clinical condition of the infant.[1] One device will not meet the needs of every infant, and some will need multiple devices throughout their hospital stay. Critical review and comparison of devices is warranted.[23] Some infants may need more than one PICC for infusion or withdrawal of laboratory specimens. Special considerations should be taken into account when assessing the length of therapy in infants who have congenital bowel anomalies because of the lengthy treatment regimen generally indicated in this population.

PIVs have been indispensable for providing therapies to infants who require intensive care. Although PIVs historically have served as the vehicle for infusing most IV solutions and medications, the potential for temporary or permanent damage to the peripheral veins has not been sufficiently considered. A patient's length of therapy and type of therapy distinguishes whether the infant is well-suited for peripheral or central catheter placement. An algorithm for determining the optimal device for each infant is a proactive quality initiative that should be implemented to decrease the risk of PIV infiltration events.[24] Although PIVs remain common, the risk of complications is high.[25] Nonelective removal of a PIV due to complications occurs in up to 78% of insertions and can lead to premature removal of up to 95% of devices, though variations in reporting make accurate rates difficult to determine.[25] Inserting and maintaining PIVs in premature infants, especially those weighing less than 1,000 g, can be difficult due to the small size of their veins and the depletion of available sites from repeated venipuncture. Infants may undergo multiple attempts at IV placement before successful cannulation, which has been shown to increase the risk of infection.[25,26] Multiple PIV insertions present a challenge to pain management and the goal of prevening pain in neonates.[27] PICC insertion has demonstrated a 50% reduction in painful PIV insertion attempts in infants weighing less than 1,250 g.[21] Infants receiving PICCs are subject to fewer peripheral sticks.[28] PICCs prevent damage to the peripheral veins (caused by the properties of many IV solutions and medications) and protect infants from the pain and stress of frequent PIV restarts and peripheral infiltration.[18,22]

For neonates who are critically ill at birth, an umbilical catheter may be indicated. If ongoing vascular access is necessary, a PICC should be considered before removing the umbilical device to avoid repeated attempts at PIV access, interruption in therapies, and the potential risk of infection from prolonged umbilical use and multiple IV attempts.[29]

Infants who are not critically ill and do not require umbilical venous access should be evaluated for a midline catheter or PICC as the initial VAD, based on diagnosis, vascular assessment, and therapeutic and nutritional needs. According to the CDC, umbilical venous catheters should be removed as soon as possible when no longer needed but can be used up to 14 days if managed aseptically.[4] In 2012, an evidence-based catheter bundle demonstrated that replacing an umbilical arterial catheter with a PICC when central access is needed beyond 7 days decreases infection risks.[29]

Midline catheters offer an alternative for those infants who do not require a PICC but do need several days of IV therapy. Mean dwell times for midline catheters have been reported to be between 6 and 10 days and up to four times as long as PIVs.[14,15,17,30] Reducing PIV attempts, therapy interruptions, stress to the infant, and the duration make midline catheters an attractive option for vascular access in select infants. To date, no data exist to support a limit to the dwell time of a properly functioning midline catheter.

Tunneled CVCs (e.g., Broviac®) historically have been associated with a higher rate of infection when compared with the reported infection rate of PICCs.[13,31] More recent data support equal infectious risks when comparing PICCs to tunneled CVCs.[32] The risks of pneumothorax and hemothorax, including requisite vein ligation, limit the future use and availability of accessed veins. Increased insertion-related costs, use of anesthesia, and invasiveness of the insertion procedure remain some of the major disadvantages of the tunneled catheter.

Recommendations for PICCs

Although many infants will benefit from central venous access using a PICC, the CDC recommends that patients who require more than 6 days of therapy be considered for more than a PIV.[4] Assertive placement of PICCs has been shown to be safe and effective in infants with anticipated hospital stays of 4 to 7 days with low risk for complications.[33] PICCs offer neonates numerous advantages over other VADs and provide a safe, effective alternative for providing required therapies. Appropriate monitoring of the PICC includes periodic imaging surveillance, which may be performed by ultrasound, echocardiography, or radiograph.[3,11,12]

Infusate Considerations for VAD Selection

Placement of the PICC with the tip residing in the superior or inferior vena cava provides increased blood flow with resulting increased hemodilution of infusates.[1,2,19] This allows the safe delivery of more concentrated parenteral nutrition, increased dextrose-containing solution with higher caloric density, and medications (e.g., vancomycin, phenobarbital) known to damage the peripheral veins with repeated use.

Many substances infused into peripheral veins can cause venous damage, including chemical phlebitis, thrombosis, and infiltration or extravasation injuries.[16,34,96] Trauma to the vein, as well as the potential decrease in dwell time leading to the development of chemical phlebitis, is related to the composition of the infusate (i.e., osmolality, pH, chemical properties).[97] Chemical phlebitis may present clinically with the appearance of erythema within hours of infusing an offending agent. Infiltration and extravasation injuries may present with ecchymosis, blistering, and skin sloughing, including loss of joint function. Intervention and prompt removal of the peripheral device is required to facilitate vein healing and recovery. Occasionally, it may be necessary to infuse medications or solutions that are known to cause venous damage into a peripheral vein. Although this may be tolerated for short periods of time, it is important to ensure that the vein is large enough to enhance hemodilution and decrease the risk of severe damage to the vessel. For repeated administration of these substances, central venous access should be obtained.[1,22] The standard of care has evolved to encompass an availability of PICC placement for the long-term management of central total parenteral nutrition (TPN) for nutrition factors.[98] The following factors should be considered when determining the appropriate route for infusing an IV solution or medication.

Osmolality Factors

Medications and IV solutions with an osmolality less than 450 mOsm/kg rarely cause chemical phlebitis, whereas those with an osmolality between 450 and 600 mOsm/kg run a moderate risk of developing chemical phlebitis. Medications and IV solutions with an osmolality more than 600 mOsm/kg are highly likely to lead to chemical phlebitis, resulting in decreased PIV dwell time.[16] Peripheral veins have been shown to tolerate higher osmolar solutions for shorter periods of time before developing complications.[99] Hyperosmolar solutions routinely given to neonates include dextrose concentrations more than or equal to 10% and parenteral nutrition. Central venous access is recommended for the infusion of solutions with an osmolality higher than 600 mOsm/kg for longer than 6 days.[4,100]

pH Factors

If the pH of the medications or solutions is less than 5 or more than 9, vein damage can occur when the infusate enters a small vein without adequate hemodilution.[101] Gentamicin and vancomycin are examples of acidic drugs and ampicillin and phenobarbital are examples of alkaline drugs routinely given to infants.[102,103] Adults often describe burning and unbearable pain when these medications are infused into the peripheral vein; unfortunately, neonates are unable to verbalize their feelings of discomfort, and crying may be interpreted as being related to multiple factors. Although there is evolving evidence on pH and osmolarity parameters in the adult, there is no recent literature that addresses the neonatal population.[98]

Chemical/Irritant Factors

The chemical properties of some medications irritate the veins, possibly leading to phlebitis and thrombosis. Amphotericin B, vasopressin, dopamine, and calcium are examples of chemical irritants that can promote venous damage, particularly if there is inadequate hemodilution. Other predisposing factors to phlebitis include using veins proximal to joints or surrounding the antecubital fossa.[103]

Cost Considerations for VAD Selection

The cost of a midline catheter is equivalent to that of a PIV after 3 to 4 days of therapy. The cost of inserting a PICC has been favorably compared to that of surgical placement of a CVC.[104] The latter procedure may require an operating room, a skilled surgeon, and, often, general anesthesia, all of which increase the cost of the procedure. Most PICC insertions require less time (i.e., 30 minutes to about 1 hour). Identifying the need for the PICC early in the course of treatment is financially prudent. The total cost of a PICC catheter placed in interventional radiology, including staff time and supplies, is about $1,500, which is 42% higher than the cost of RN or advanced practice nurse placement.[105,106] The hospital's operational cost of multiple attempts of peripheral catheters (more than four) is approximately $156, whereas a PICC insertion is approximately $330.[107]

Candidate Selection and Contraindications

Candidates for PICC insertion may include

- premature infants, specifically low-birth-weight infants, including intrauterine-growth-restricted infants, due to a delay in establishing maintenance quantities of enteral nutrition
- infants requiring more than 6 days of IV therapy,[4] which may include those with
  - infections requiring IV antimicrobial therapy
  - gastrointestinal disorders, such as necrotizing enterocolitis, omphalocele, gastroschisis, and those with short gut who may require multivisceral transplants (specifically for vein preservation and high-caloric nutrition)
  - respiratory insufficiency
  - congenital or acquired renal insufficiency who may or may not require peritoneal dialysis (attempt to spare upper-extremity antecubital veins)
  - congenital cardiac disorders
  - limb anomalies, which may limit the number of vascular access sites available

- infants requiring the infusion of fluids or medications with hyperosmolar (>600 mOsm/kg), nonphysiologic pH (<5 or >9), or irritating properties[1]
- infants with inadequate peripheral venous access; PICC insertion should be considered before the problem occurs
- infants whose medical providers or parents prefer the use of a PICC over other VADs.

Infants should be assessed individually, with attention to the risks and benefits of the procedure. There are few absolute clinical contraindications to the insertion of a PICC (e.g., lack of suitable peripheral veins or need for vascular access). Ultrasound, transillumination, and infrared vein visualization technologies may enhance vessel assessment in situations where suitable veins are not visible.

However, the existence of any of the following conditions will affect the assessment and warrant additional consideration:

- bacteremia or fungemia (Invasive devices could become colonized with organisms, which would impede or prevent adequate treatment. Some recommend as acceptable practice antimicrobial treatment for 24 to 48 hours before an elective PICC placement. However, the infant may require reliable vascular access, and a PICC may be the most appropriate device for antimicrobial treatment.)
- thrombocytopenia or coagulopathy (Delayed clotting mechanisms increase the risk of prolonged bleeding at the PICC insertion site; correctional blood products may be indicated prior to insertion.)
- fracture (The condition of the veins surrounding the fractured bone is uncertain and the presence of the fracture can hinder assessment for PICC-related complications.)
- decreased venous return (Edema that presents due to decreased venous return may be difficult to distinguish from edema resulting from a PICC-related complication. Use of another extremity or the scalp is preferable.)
- cardiac malformations requiring operative procedures (Consult with a surgeon regarding the use of a PICC and the preferred catheter tip location.).

Educational Competency for Nurse Inserters and Caregivers

RNs assuming responsibility for the placement of PICCs should consult with their respective State Board of Registered Nursing to determine whether the procedure is within the scope of nursing practice. PICC placement may be considered an advanced nursing practice and therefore require development of a standardized procedure requiring approval from an interdisciplinary practice committee. Practice restrictions, such as limitations of veins that can be cannulated, vary among states and hospitals.

PICC insertion requires specialized training to improve patient outcomes by reducing device-related complications and decrease the cost of care.[3,4] All PICC insertion nurses should be part of a developed team concept to enhance outcomes.[79] A two-pronged approach to PICC team training consists of a didactic and clinical component.[45] An expert in the field of neonatal vascular access who possesses current expertise in PICC placement in infants should provide the didactic content. A curriculum designed to prepare professionals for placing and maintaining PICCs should be formalized and at a minimum include

- indications and contraindications for placement
- risk-benefit analysis of the procedure
- applicable legal issues
- knowledge of guidelines and standards of infusion therapy published by professional organizations and governmental agencies
- knowledge of the anatomy and physiology of the venous and arterial systems
- application of sterile technique
- patient preparation
- pain management
- use of equipment and supplies for PICC insertion
- insertion technique (traditional and modified Seldinger technique [MST], when appropriate)
- assessment and management of complications
- routine catheter care and maintenance (including troubleshooting)
- institutional quality improvement process for PICCs
- documentation of the procedure, assessment findings, and complications[1]

Each facility is responsible for establishing written criteria for qualifying healthcare PICC team members to perform the procedure and defining guidelines for obtaining competence.[3,108,109] A healthcare professional who is experienced in PICC insertion must observe a new PICC team member to verify and assess clinical competency. A minimum of three supervised successful insertions is suggested as required for independent practice.

Maintaining Competency

Each facility is responsible for establishing criteria for maintaining clinical competence.[1] According to a 2013 survey published in *Advances in Neonatal Care*[110], the successful insertion of a minimum of three PICCs per year was most commonly reported (in raw data) as the minimal annual requirement. NANNP's *Competencies and Orientation Toolkit for Neonatal Nurse Practitioners* recommends the successful insertion of a minimum of three PICCs per year to maintain competency.[111] In addition, a review of relevant literature, NICU procedures for PICC insertion, maintenance, and outcomes, including team improvement efforts, should be performed annually.[1,8,79] Long-term success with PICC utilization is most associated with education regarding all aspects of PICC care, team management, and surveillance.[8] An increase in knowledge and self-efficacy has been demonstrated following targeted educational programs, along with a significant decline in the rate of PICC occlusion.[112] Knowledgeable staff members are able to intervene earlier to identify problems. Every RN caring for a patient with a PICC must demonstrate knowledge of potential complications as well as care and maintenance strategies.[22] RNs with verified competency should perform dressing changes, instill agents for catheter occlusions, and discontinue catheters due to the risk of catheter dislodgement or loss.

Vascular Access Teams

Specially trained neonatal teams have demonstrated effectiveness in reducing catheter-related complications, particularly infections, and have proven to be cost-effective.[4,58,72,113] Using dedicated PICC teams has significantly improved patient safety and reduced costs. The efforts of consistent team members decreases multiple insertion attempts, improves outcomes, and decreases infection rates.[113,114] Early vascular access assessments are a multidisciplinary effort and the identification and initiation should be facilitated by the nursing team. The majority of healthcare providers may be unaware of the multitude of venipunctures infants will experience. Early assessment through a team concept may well decrease the pain and suffering caused by short-term peripheral venous access.[27] Therefore, all healthcare providers responsible for neonates should be educated to identify and triage which neonates would benefit from early PICC access. Notification of the ordering of hyperosmolar medications or other medications or solutions irritating to the vein should be incorporated as part of the pharmacy communication with the PICC team to facilitate early device-appropriate assessment.

The responsibility of these teams may vary but should incorporate performing PICC insertions, conducting daily surveillance of each catheter and dressing, performing dressing changes, troubleshooting catheter problems, providing formal and informal staff education, and conducting outcome monitoring, quality assurance, and ongoing data collection. A team concept further minimizes the use of inappropriate device selection and inappropriate catheter tip location. Neonatal PICC teams implement team strategies, monitor surveillance data, and formulate educational opportunities that have changed their outcomes by decreasing central line infections and reducing multiple venipunctures.[45]

Facilities may choose to have one team responsible for PICC insertion and another team designated for care and maintenance, while following standardized protocols that have minimized complications.[8,72] Advancing the team concept to include full responsibility for all aspects of the PICC program is the ultimate goal. Providing staff education and competency validation, ensuring adequate staff scheduling to perform PICC insertion, and financially supporting the PICC program are responsibilities of the healthcare institution that elects to develop and support a PICC team. Empowering and expanding nursing practice by incorporating a PICC team decreases complications and improves the vascular health of neonates.[115]

Outcome Monitoring

Quality improvement programs are an integral component of a hospital's PICC program.[1,8] Data gathered through this process guide decision making to positively affect patient care. Targeted data collection for outcome monitoring (procedural documentation requires additional information) for each PICC placed should at a minimum include

- patient's weight, day of life, and gestational age at the time of catheter insertion
- indication for placement
- catheter specifics (brand, composition, size, number of lumens, lot number)
- insertion site
- complications occurring during insertion, dwell, or removal
- length of catheter dwell
- reason for removal.

Team data are reviewed on a regular basis to identify trends in usage and outcome measures. Data should be reported per 1,000 catheter days to allow for benchmarking.

Calculation:

$$\frac{\text{Total number of complications}}{\text{Number of catheter days}} \times 1{,}000 = \text{rate of complications per catheter day}$$

The 2015 CDC report *Bloodstream Infection Event (Central Line-Associated Bloodstream Infection and Non-Central Line-Associated Bloodstream Infection)* outlines the definitions and surveillance guidelines for unit of attributions and reporting guidelines.[73]

Equipment and Supplies for PICC Insertion Procedure

Table 1 outlines each step in the process of PICC insertion in an infant.

Potential Insertion-Related Difficulties

A number of problems can occur related to catheter insertion. Those most common are addressed in this section.

Inability to Thread the Catheter Through the Introducer

After the vein is cannulated, blood return is typically, but not always, evident. Although the catheter usually is easily advanced into the vein, obstructions can be encountered. Strategies to facilitate catheter passage are included below.

- Ensure that the introducer and the entire bevel are in the vein. If unsure, redirect the device into the vessel.
- Check the angle of the introducer in the vein and realign or straighten; move the introducer either up or down to prevent the catheter from contacting the vein wall.
- Remove the tourniquet after the catheter has passed into the vein lumen.
- Visualize the location of the catheter using ultrasound or other imaging technologies. Using ultrasound to visualize the catheter in the subclavian or internal jugular veins will provide further information to evaluate whether the catheter is malpositioned in an upward position toward the head.
- Remove the introducer and catheter if these measures fail to correct the problem.

Inability to Thread the Catheter to the Premeasured Distance

Vasospasm, venous valves, bifurcation of the vein, scarring or sclerosis of veins, venous anatomy, and patient positioning have all been linked to difficulty in threading catheters. In addition, the catheter may be taking an aberrant route. If the catheter cannot be threaded more than 2 cm to 3 cm beyond the tip of the introducer, the catheter may not be within the vein. Establish where the catheter is located by determining the length of the catheter in the patient, then follow the appropriate strategies.

Inability to Insert the Catheter Through the Peripheral Circulation

1. Remove the introducer (if needle style) to prevent catheter damage and withdraw the catheter a few centimeters (depending upon the distance it is inserted).
2. Rotate the catheter and gently attempt to reinsert. This can help the catheter to pass valves.
3. If the catheter fails to advance, place a tourniquet high on the extremity above the catheter tip. Venous engorgement may help the catheter advance.
4. If a stylet is present, it can be withdrawn a few centimeters. Partial withdrawal of the stylet adds more flexibility to the catheter tip and can facilitate catheter advancement. The stylet can be completely removed if the catheter still will not thread. Once removed, the stylet should not be reinserted into the catheter.
5. Gentle flushing while threading can help the catheter pass valves or an obstruction.
6. Other strategies:
   - Massaging over the length of the vein has been described as helpful in catheter passage. Forceful massage of the vessel is not recommended due to the risk of irritating the vein, which could result in mechanical phlebitis.[116]
   - Application of warm packs to promote dilatation
   - Waiting several minutes to allow the vein to relax
7. If the catheter cannot be advanced, it should be removed.

Inability to Thread the Catheter from the Peripheral into the Central Circulation

If the catheter is entering the trunk of the body, the following should be considered:

1. Ensure that the patient is correctly positioned. For upper-extremity insertions, the arm should be at a 90° angle and the head turned toward the arm of insertion.
2. If using a needle introducer, remove the introducer.
3. Partially withdraw the catheter and reinsert it following the instructions outlined below.
   a. For insertion in the arm, leveling or elevating the shoulder or moving the arm in different locations may allow the catheter to pass the obstruction.[117]
   b. For insertion in the leg, elevating the pelvis may help a catheter that is stuck at the groin to advance. Abducting or manipulating the leg are other measures that may allow the catheter to thread.[117]
   c. Difficulty in threading catheters from the scalp to the jugular vein may be overcome by gently stretching the skin on the neck down toward the body if the catheter is stuck anterior to the ear. If the catheter is stuck at the neck, rotate the patient's shoulders or gently move the head to midline, extend or flex the neck.[117]
4. Gentle superficial massage over the vein where the catheter does not advance has been described anecdotally as beneficial. Caution: there is potential for mechanical phlebitis.[116]
5. Catheters should be primed with flush solution prior to insertion. Gently flushing with 0.5 ml to 1 ml of flush solution while attempting to advance can be helpful.

6. If you are still unable to thread the catheter, consider repeating strategies in step 3.
7. If the catheter is successfully inserted to the premeasured depth, attempt to aspirate for a blood return. If a blood return is not obtained, the catheter may not be in the vein or may have developed a knot.[276] An X ray or other imaging can help determine the position of the catheter tip.
8. If the catheter remains outside the superior vena (typically in the brachiocephalic or subclavian vein) despite attempts to place it within the vena cava, based upon individualized risks versus benefits analysis, it may be beneficial to withdraw the catheter to an acceptable peripheral position to infuse therapies that can safely be given through a PIV, if doing so will meet the infant's needs or as a temporary measure until a CVC can be placed. Blood return should be present and the catheter should flush easily. The subclavian vein is not considered a central catheter tip position because there is an increased risk of thrombosis, infiltration, occlusion, extravasation.[19,20,34,118]
9. Catheter tips that remain in the peripheral circulation are referred to as midline catheters.
   a. Midline catheters placed in the arm should have the tip located at or below the axillary line not entering the torso and away from areas of flexion.[1,14]
   b. Midline catheters inserted in leg veins should remain below the inguinal crease and away from areas of flexion, with the tip below the groin.[1]
   c. Midline catheters placed in the scalp should have the tip terminate in the external jugular vein above the clavicle and not within the torso.[1]

Table 1. Procedure for PICC Insertion in an Infant

Step	***Considerations***	***Precautions/Comments***
1. **Determine indication for a PICC and obtain an order.**	The nurse inserter should evaluate patients individually to verify the need, risks and benefits, and presence of a suitable vein. Not all infants are appropriate candidates. Use a catheter insertion checklist and a standardized protocol for central venous catheter insertion.[74]	Anticipated duration of therapy is a key factor in the decision for a PICC. If a suitable vein is not identified, the infant may be a better candidate for another VAD. Inability to obtain successful PIV access after two providers have each attempted twice should escalate the vascular access plan.[24]
Verify patient identification.	Follow hospital procedure to ensure compliance with patient identification procedures including two patient identifiers as outlined in the National Patient Safety Goals by the Joint Commission.[74]	Acceptable identifiers may be the individual's name, an assigned identification number, telephone number, or other person-specific identifier.
2. **Review the procedure with parents and obtain informed consent** (per hospital protocol and by appropriate personnel, according to state and federal statutes). Some facilities consider PICC insertion a routine procedure for the NICU and do not require a separate signed consent.	Information should include a description of the procedure, indications, the risks and benefits of the procedure, and alternative options.[119] Sample consent forms and information for parents about the procedure are included in the appendices.	The nurse performing the procedure is responsible for ensuring that informed consent has been obtained (if required and per hospital protocol).
3. **Select the vein to be used for the procedure. Figures 1** and **2** show the major veins that can be used for PICC insertion in neonates. **Figure 2** shows the major veins that can be used for PICC insertion in older infants.	The vein needs to be of sufficient caliber to accommodate the size of the catheter and introducer.	Avoid using previously damaged or sclerotic veins because of the increased risk of complications (i.e., difficulty threading catheter, phlebitis).

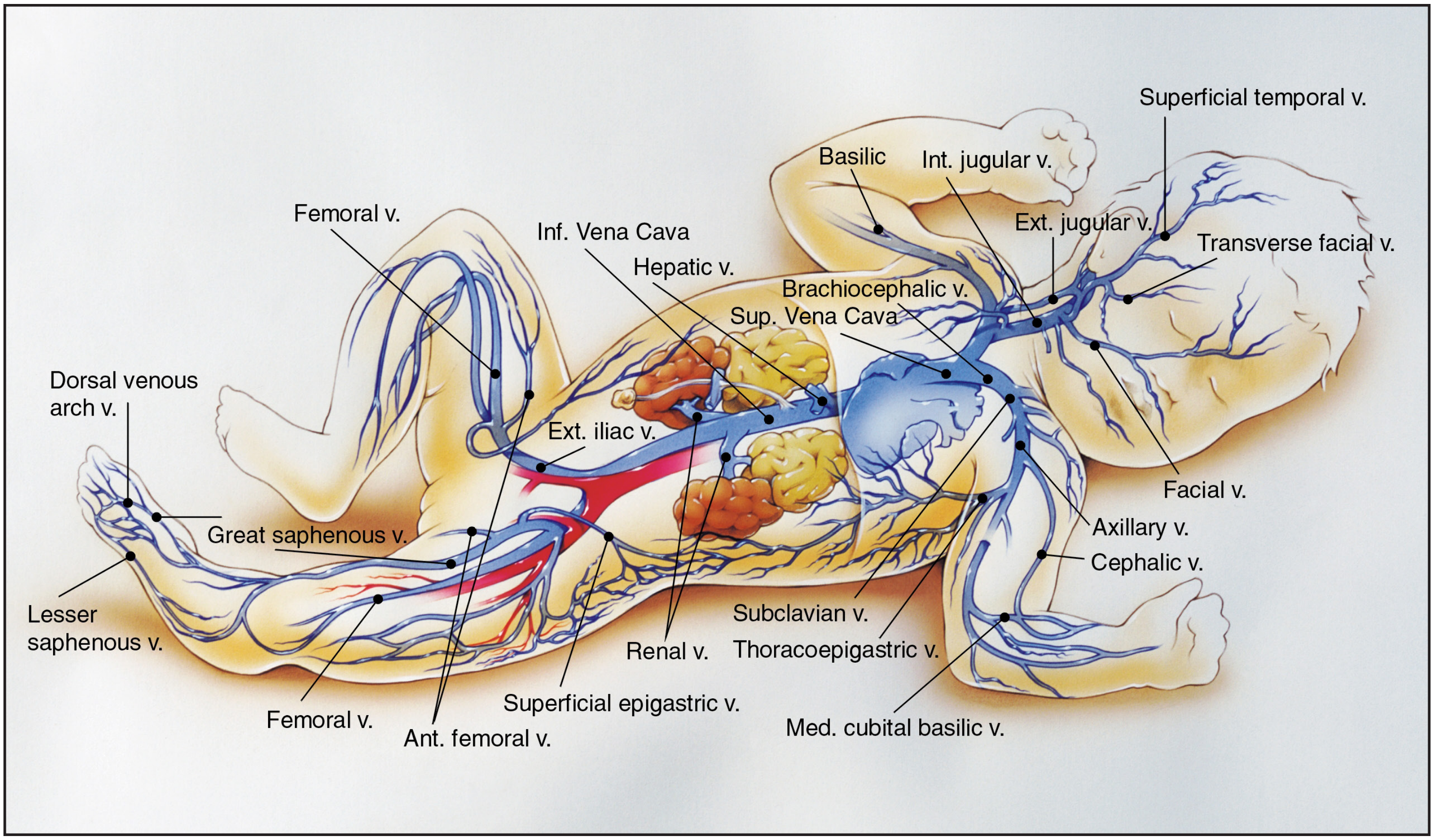

Figure 1. *Vascular anatomy of the neonate*

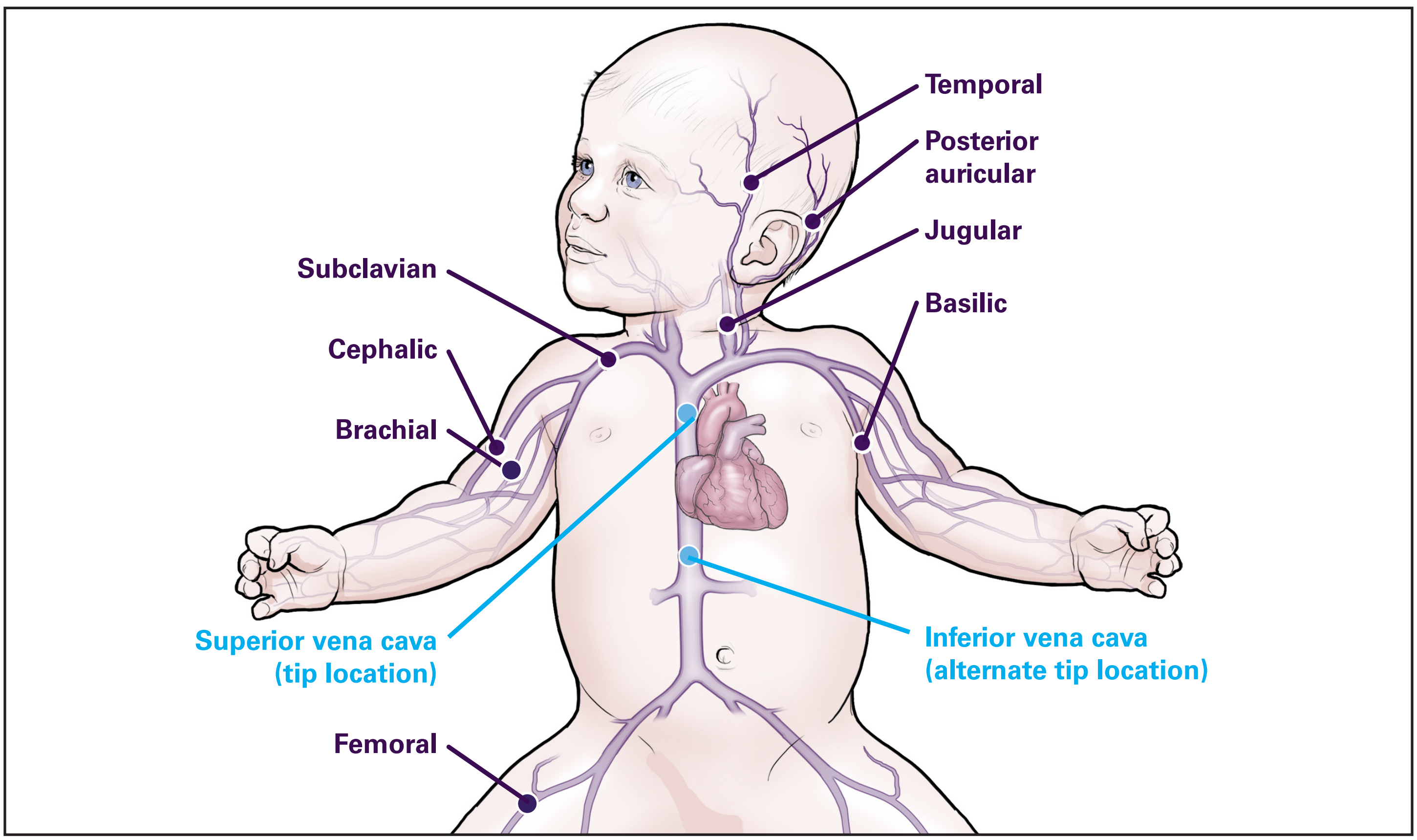

Figure 2. *Pediatric catheter insertion sites*

Figure 1 Courtesy and © Becton, Dickinson and Company. Figure 2 is © Rob Flewell. Used with permission.

Table 1. Procedure for PICC Insertion in an Infant *(continued)*

Step	***Considerations***	***Precautions/Comments***
Some hospitals and states specify the veins that RNs are allowed to cannulate for a PICC. Only a highly skilled inserter should cannulate the external jugular, femoral, and axillary veins.	If the vein is difficult to locate, consider the use of a transilluminator, ultrasound or other imaging devices, application of warm packs, or application of a loose tourniquet. The sole use of anatomical landmarks and palpable veins to insert PICC catheters is rapidly becoming obsolete. Recommendations from the Agency for Healthcare Research and Quality (AHRQ) and the CDC support the use of ultrasound technology for the insertion of PICC catheters.[4] These technological advancements provide enhanced imaging capabilities to facilitate placement of PICC catheters. The advantages incorporate exact vessel location, size, avoidance of arterial puncture and decreased infection.[4] Ultrasound technology further improves the success rate and decreases the complication rate, while diminishing pain for the patient by minimizing attempts.[120,121]	Use of ultrasound requires additional training to achieve proficiency.
The following veins are used for PICC insertion in neonates[22,122,123]:		
Veins of the arm		
• Basilic and median cubital basilic vein (see **Figures 3** and **4**)	The basilic vein is a large vein in the arm that is straighter and less tortuous than the cephalic vein in the arm. The basilic vein is easily accessible to thread the catheter through, requires less time for insertion, and allows a secure dressing to be placed. The basilic vein has a lower incidence of reported phlebitis compared with the cephalic vein.[46]	Disadvantages of using the basilic vein include close proximity to the brachial artery and risk of inadvertent arterial puncture, as well as possible previous venipuncture for lab draws. The most common site of malposition when inserting into the basilic vein is catheter tip placement in the jugular vein.[124]
• Cephalic and median cubital cephalic vein (see Figures 3 and 4)	The cephalic vein is smaller than the basilic and has a sharp angle where it joins the axillary vein. The cephalic or median cubital cephalic vein may bifurcate, with one portion joining the external jugular vein and the other the axillary vein.[124]	The cephalic vein narrows and may be tortuous as it ascends the arm leading to an increased risk of mechanical phlebitis. Threading the catheter past the shoulder may be difficult, and the catheter may become malpositioned into the axillary vein or lateral thoracic vein.[124] Catheters inserted via the cephalic vein carry a higher risk of mechanical complications.[125]

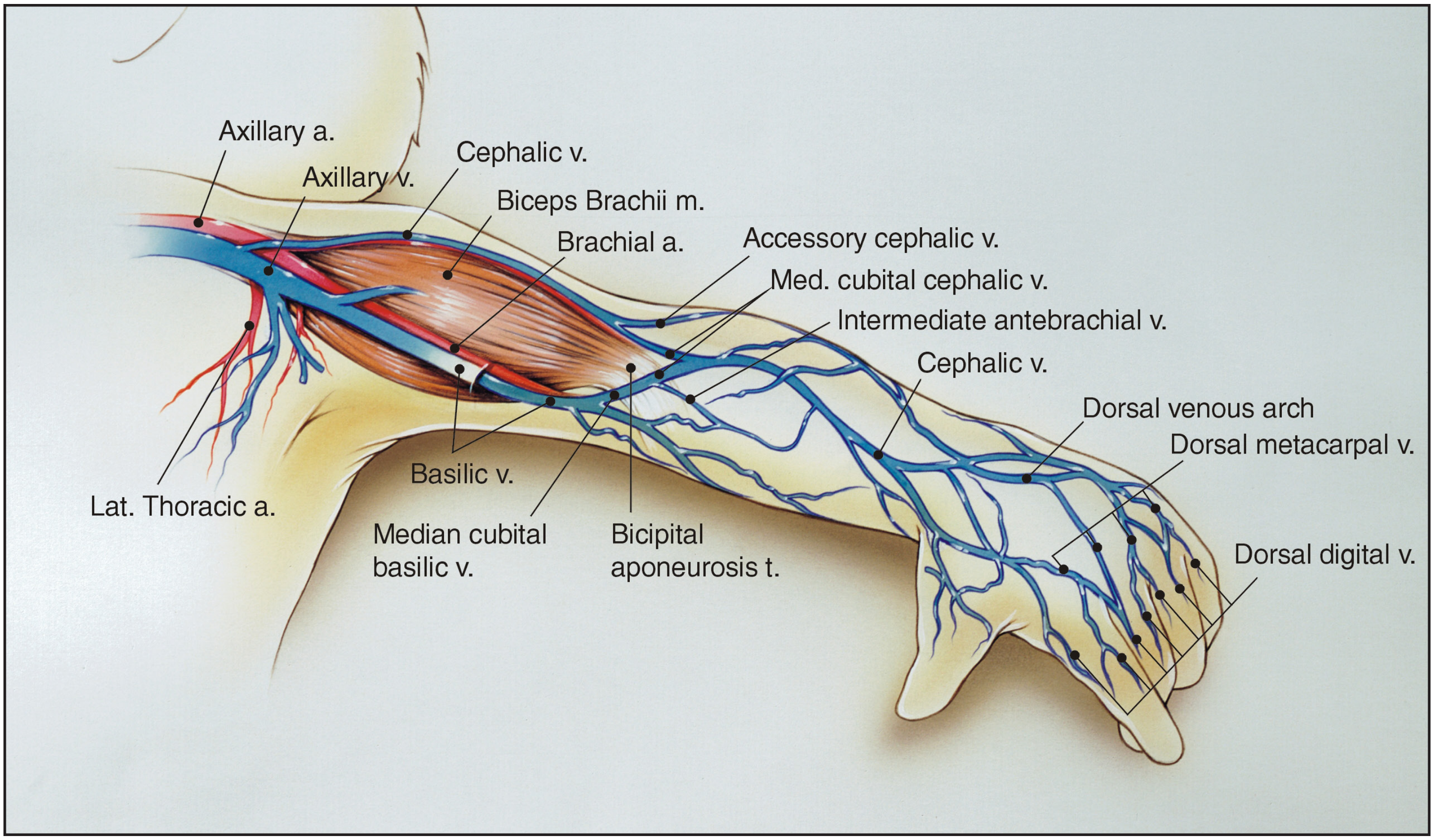

Figure 3. *The major veins of the arm*

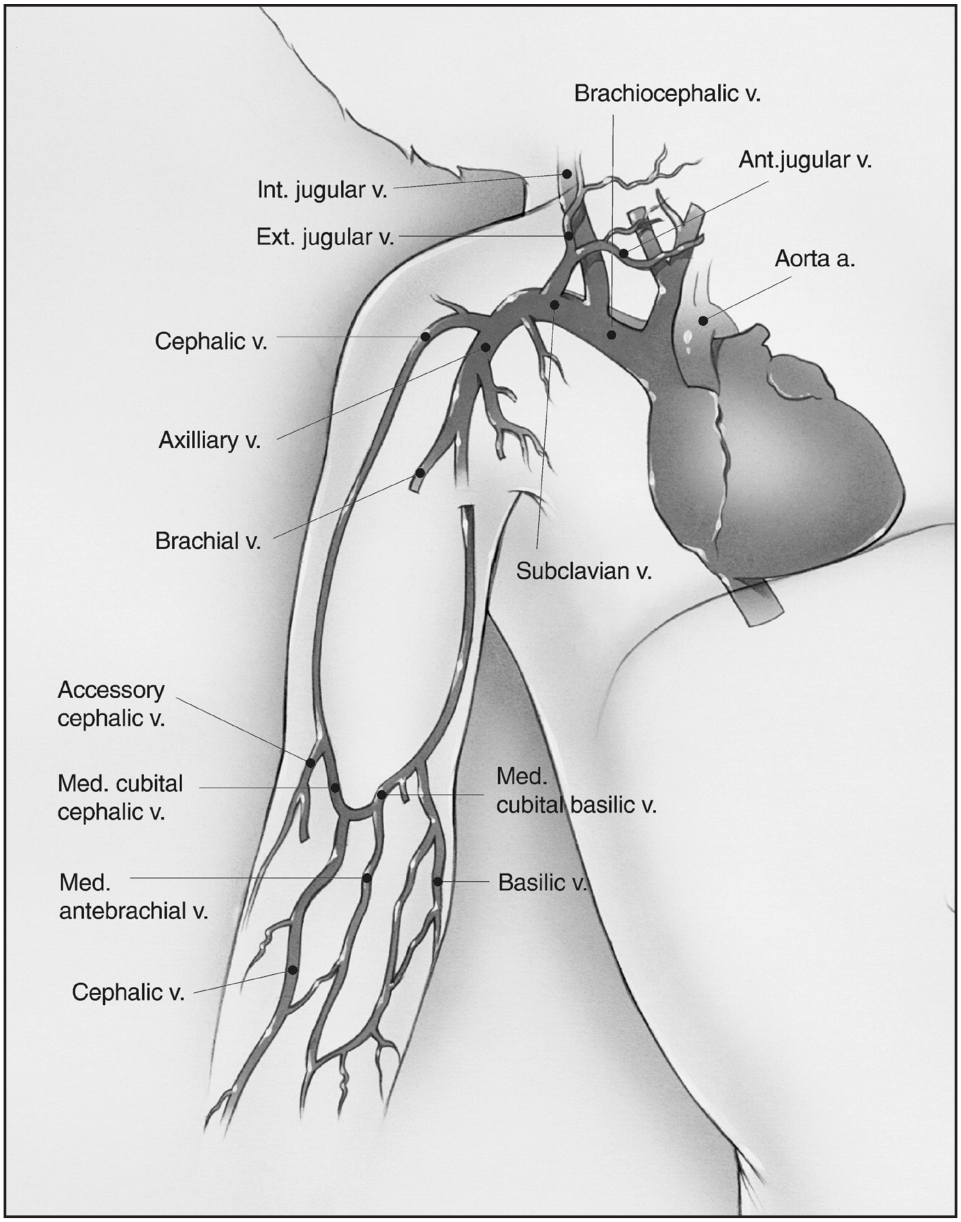

Figure 4. *The major veins in the upper arm*

Figure 4 Courtesy and © Becton, Dickinson and Company. Used with permission.

Table 1. Procedure for PICC Insertion in an Infant *(continued)*

Step	***Considerations***	***Precautions/Comments***
• Axillary vein (see Figure 3)	Benefits of using the axillary vein include its large size, which makes it easy to cannulate and thread the catheter through, and its short distance to the superior vena cava. The size of this vein allows the use of larger-size and dual-lumen catheters in many infants. Evidence demonstrates infants with catheters inserted via the axillary vein are 12 times less likely to have catheter-related complications and 7 times more likely to have the catheter removed due to the achievement of full enteral nutrition.[126]	Many clinicians consider unsuccessful attempts at more distal sites a prerequisite to consideration for axillary vein insertion. The axillary vein may be difficult to visualize in larger infants due to subcutaneous fat. The close proximity of the axillary vein to the axillary artery necessitates clear identification of the vein to avoid the risk of arterial cannulation; therefore, ultrasound or other vein-enhancement technology may be beneficial in this situation. Insertion technique should ensure the introducer remains out of the thorax.
Veins of the scalp and neck (A right-sided approach is preferred because it provides a near straight entry into the superior vena cava. A neck roll can facilitate catheter entry into the subclavian vein.)		
• External jugular vein (see **Figures 5** and **6**)	The external jugular is a large, superficial vein that is easily palpable and visible. The vessel usually has not been cannulated for other purposes. To facilitate entry, place a towel roll under the shoulders to slightly hyperextend the neck, then turn the head to the side.[127] Ultrasound use is recommended. Use of the external jugular vein is contraindicated in patients who may become candidates for extracorporeal membrane oxygenation.	Positioning patients for catheter placement and stabilizing the catheter after insertion can be difficult. There also can be increased risk of catheter dislodgment, and it is difficult to maintain a dry, intact dressing. Leaving a few centimeters of catheter external and bringing the hub onto the upper chest for securement keeps the catheter away from formula and secretions, promotes increased stability and comfort, and allows for easier access into the catheter.[127]
• Temporal vein (see Figure 5)	The branch of the temporal vein just in front of the ear is large and easily visualized.[123]	Carefully distinguish the temporal vein from the adjacent temporal artery. Resistance to threading can occur where the catheter traverses the area in front of the ear and where it enters the subclavian vein.
• Posterior auricular vein (see Figures 5 and **7**)	The posterior auricular vein is best cannulated behind the ear and has a low rate of complication.[125]	The posterior auricular vein is variable in size and may be tortuous. Resistance to threading can occur where the catheter enters the subclavian vein.

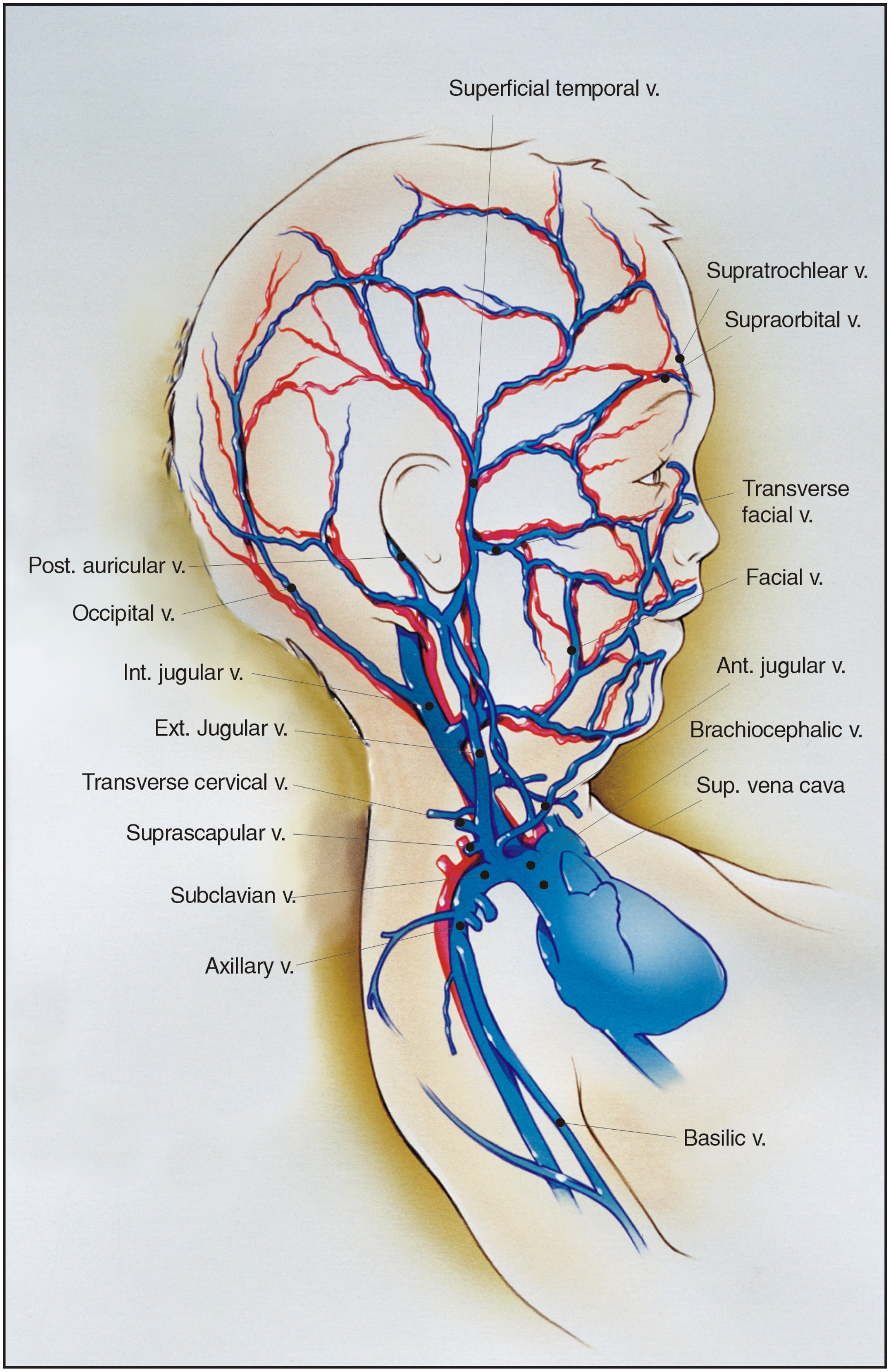

Figure 5. *The path from the temporal and posterior auricular and external jugular veins into the central circulation*

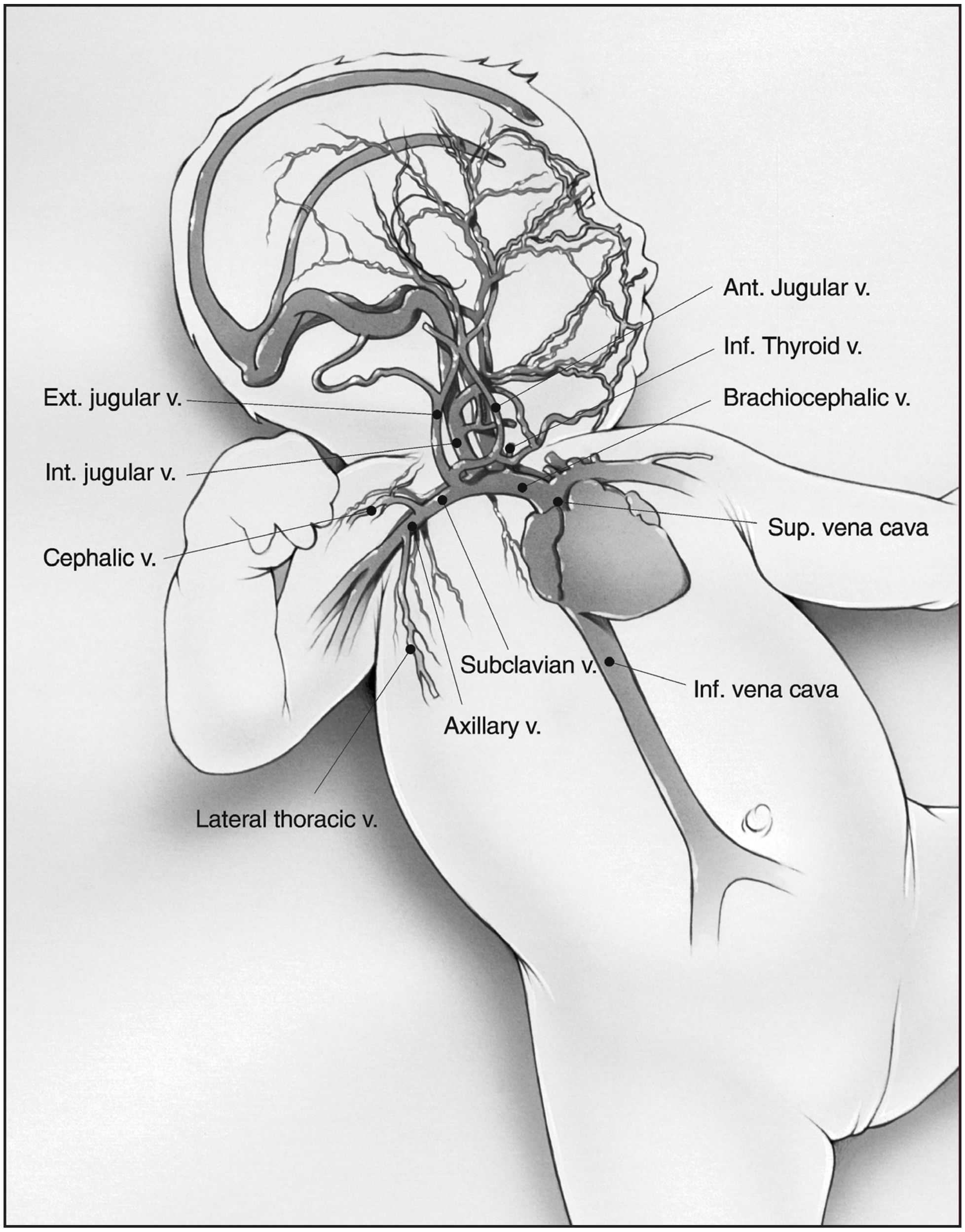

Figure 6. *The major veins in the neck*

Figure 6 Courtesy and © Becton, Dickinson and Company Used with permission.

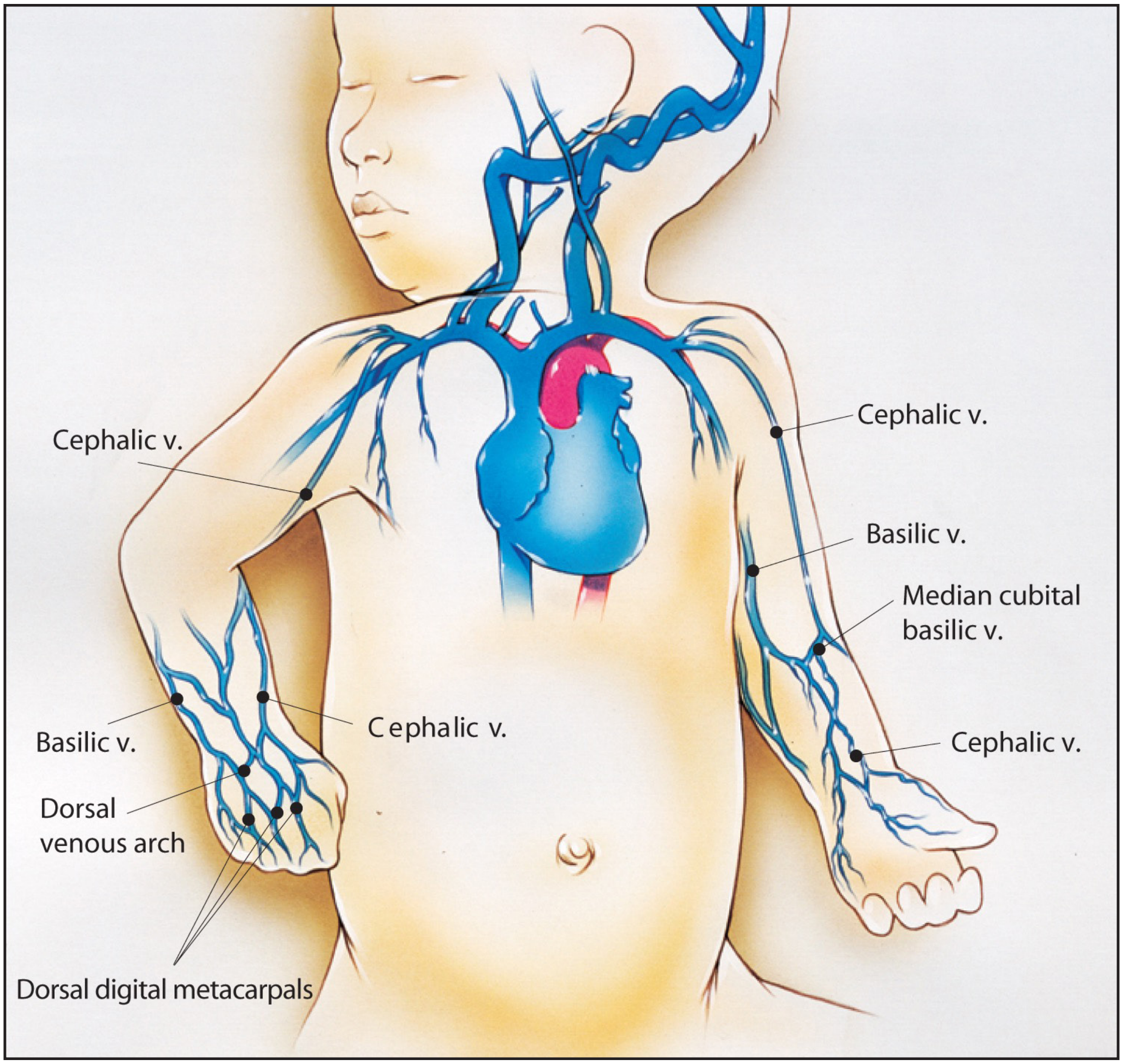

Figure 7. *The major veins in the head and upper torso*

Table 1. Procedure for PICC Insertion in an Infant *(continued)*

Step	***Considerations***	***Precautions/Comments***
Veins of the legs	Lower extremity PICCs have lower rates of catheter-related bloodstream infection, longer time to first complication, and lower cholestasis despite longer duration of TPN.[84,85,95] When possible, lower extremity–inserted catheters should be considered for the administration of TPN unless a gastroschisis is present.[84,85] Lower-extremity PICCs are associated with increased risks in neonates with gastroschisis during silo reduction and after abdominal closure.[85] In a retrospective review of PICC records in a level III NICU, there was no difference in complications necessitating removal between catheters inserted in the upper and lower extremities.[86]	When inserting PICCs into veins in the lower extremities, consider the right lower extremity as preferred because of the shorter distance to the inferior vena cava.
• Femoral vein (see **Figures 8** and **9**)	Catheterization of the femoral vein can be accomplished by inserting the needle at a 30° angle 1 cm below the inguinal ligament and 5 mm medial to the femoral pulse.[87] A larger or dual-lumen catheter can be placed into this vein due to its large size. Imaging technology is recommended while cannulating the femoral vein.[88]	The close proximity to the femoral artery poses the risk of arterial puncture. The femoral vein may be needed for cardiac catheterization, so it may not be an appropriate choice. Maintaining the integrity of the insertion site and dressing may be challenging due to the proximity to the perineum. The risk of leg swelling has been reported to be as high as 15.6%.[32]
• Greater saphenous vein (see Figures 8 and 9)	The greater saphenous vein is a large, easily visible vein on the medial aspect of the leg beginning near the ankle and extending up the leg. Cannulation may be performed at multiple sites along the vein. Some report a higher incidence (9%) of phlebitis.[89] Use of the right saphenous vein is associated with a lower risk of ascending lumbar vein catheter malposition.[90] Use of the greater saphenous vein was not associated with insertion-related mechanical or infectious complications and may be preferred to preserve future venous access sites in the upper extremities.[91]	The greater saphenous vein is the longest vein in the body, containing 7–15 valves that must be traversed. It is not an appropriate choice for infants requiring cardiac catheterization via the femoral vein. Edema of the leg may occur due to placement of the PICC. This edema is related to the relatively larger size of the catheter.

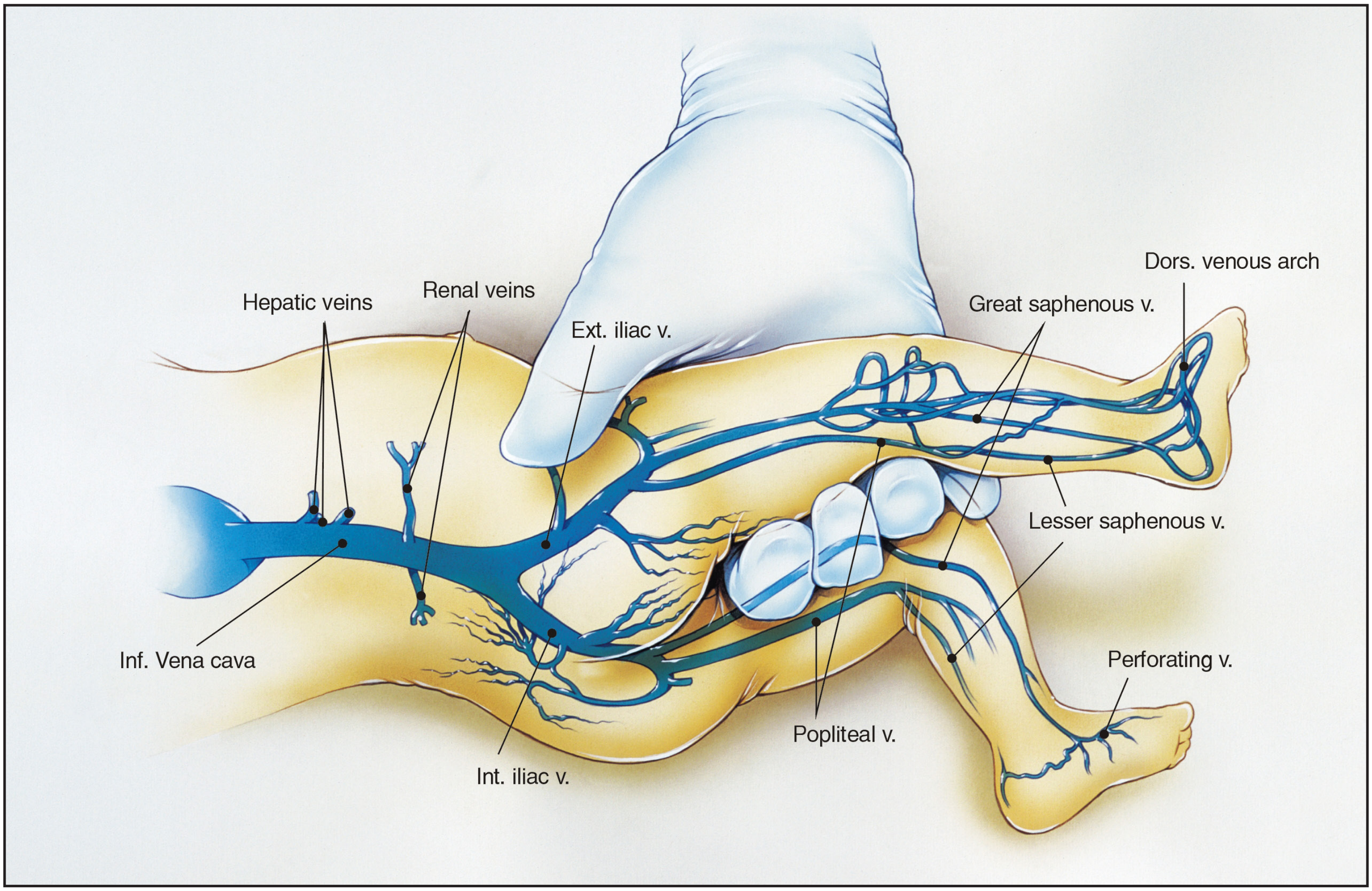

Figure 8. *Access sites for entering the leg veins and venous pathway into the central circulation*

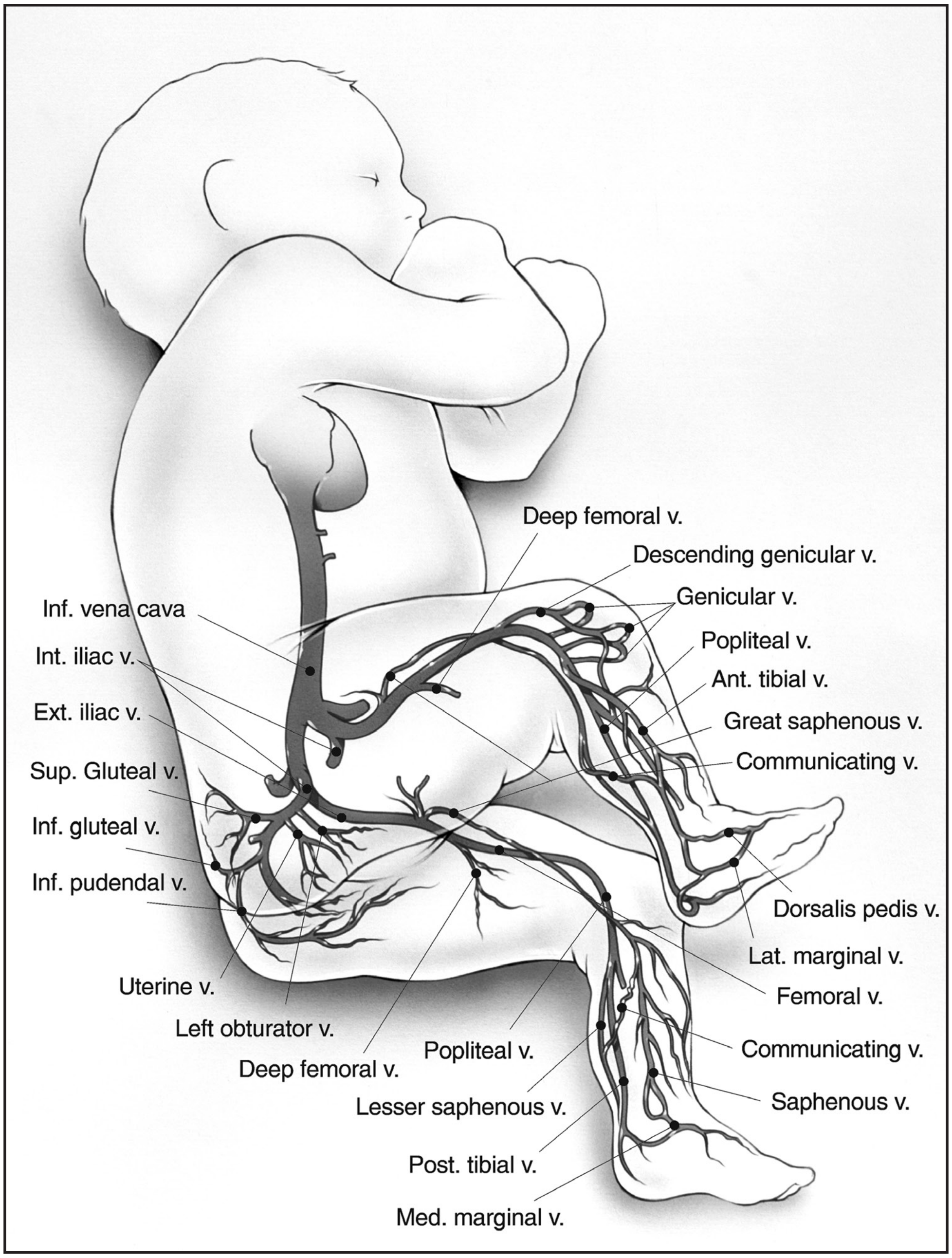

Figure 9. *The major veins in the lower extremity*

Table 1. Procedure for PICC Insertion in an Infant *(continued)*

Step	***Considerations***	***Precautions/Comments***
• Lesser saphenous vein (see Figures 8 and 9)	The lesser saphenous vein is a small, tortuous vein best reached from the lateral aspect of the leg.	Positioning the infant may be awkward. This vein joins the popliteal vein at the back of the knee. The lesser saphenous vein is not an appropriate choice for infants requiring cardiac catheterization via the femoral vein.
• Popliteal vein (see Figures 8 and 9)	The popliteal vein is easily visualized in the premature infant, but may be less visible in the full-term and older infant. Ultrasound can be useful for imaging this vein when it is not visible.	Access may be difficult with the increase in muscle tone seen with advancing gestational age. Stabilizing the catheter after insertion may be difficult due to flexion at the popliteal fossa. The popliteal vein is not an appropriate choice for infants requiring cardiac catheterization via the femoral vein.
4. **Measure the length of the catheter to be inserted.** For upper-body insertion, measure from the insertion site along the course of the vein, to the right of the sternal border, to the third intercostal space. If insertion is through an arm vein, extend the arm at a 90° angle for measuring or along the natural vein path with the extremity in the most frequent position of rest. For lower-extremity insertion, measure from the insertion site along the course of the vein, to the right of the umbilicus and up to the xiphoid.[128]	Measuring, determining the insertion distance, and inserting the catheter to a premeasured depth helps to achieve the desired placement within the superior vena cava or inferior vena cava and prevents complications associated with malpositioning of the catheter.	There is variability in venous pathways among individuals, and external measurement will not exactly predict internal placement.[129] Referring to any prior radiographs can aid in assessing the anatomy to determine more accurate measurement.
5. **Assemble the following equipment and supplies before the procedure.** Many of the supplies are available packaged as commercially prepared kits.	Use of a standardized supply cart or kit that contains all necessary components for CVCs is an element of performance for National Patient Safety Goal 07.04.01.[74]	Efforts should be made to provide latex-free, powder-free, and di-(2-ethylhexyl) phthalate (DEHP)-free products to minimize the risk to healthcare providers of an allergic reaction and the risk of such an allergy developing in infants.
General equipment and supplies • Sterile gown • Hair cover • Face mask • Protective eyewear • Sterile gloves (two pairs), powder and latex-free • Developmental positioning aids or swaddling device (optional) • Imaging devices, such as a transilluminator, infrared technology, or ultrasound and sterile sleeve or sterile glove (if applicable)	Maximum sterile barrier precautions include the use of a sterile gown, sterile gloves, hair covering, and a full-body drape. Developmentally appropriate support should be provided to promote flexion, containment, alignment, and comfort.	

Table 1. Procedure for PICC Insertion in an Infant *(continued)*

Step	***Considerations***	***Precautions/Comments***
Catheter equipment and supplies		
• 1.1 to 3 Fr (28- to 20-gauge) catheter, depending on vessel size at intended insertion site, with sufficient length to achieve appropriate catheter tip placement	Use the appropriate size catheter that accommodates the therapy.[1]	The most commonly used catheters in neonates are sized 1.1 to 2 Fr.
• Introducer needle or cannula, in a size appropriate for the catheter, use safety-engineered introducers, if available[108]	Use active or passive safety technology to prevent needlestick injury.[1]	
• Modified Seldinger technique supplies (if applicable) in addition to the previously listed supplies:		
• 24-gauge peripheral intravenous device • Flexible guidewire, size 0.08–0.15, approximately 15 cm–20 cm in length • #11 surgical blade • Sheath dilator	Use short peripheral catheters equipped with a passive or active safety mechanism to provide sharps injury protection. [1]	
These items may be available in a manufacturer-supplied kit: • Tape measure • Sterile tourniquet • Antiseptic solution (e.g., chlorhexidine gluconate or povidone iodine) • Sterile water or saline wipes • Sterile 4″ x 4″ and 2″ x 2″ lint-free gauze sponges • Sterile tape measure for trimming catheter (optional) • Sterile tape or skin-closure tape strips • Semipermeable transparent dressing • Two or three surgical drapes (one may be fenestrated) • Flush solution, which may include a heparinized saline solution, concentration per unit protocol (usually 0.5–1.0 units heparin/ml) or sodium chloride. (Throughout the document, "flush solution" is the term used to indicate either solution.) • One or two 5-ml to 10-ml syringes (per manufacturer's recommendation) • Sterile labels • Needles or needleless supplies for drawing flush solution into syringes or prefilled syringes that are sterile on the outer surface and labeled.	The addition of heparin to the infusate has been shown to decrease catheter occlusion and lengthen catheter dwell time in neonates.[130] In neonates requiring short-term intravenous access, heparin may be safely omitted from continuous infusions without compromising catheter usability.[125] If adding an extension set, use the minimum number of ports to accommodate the infant's needs. This decreases weight and direct tension on the catheter. Consider securing an extension set to the extremity to enhance stabilization. Indications for use of contrast media: • Catheters containing lower amounts of radio-opaque materials • Smaller catheters if unable to visualize the tip • Infants with extensive cardiopulmonary or abdominal pathology preventing visualization of the catheter tip • Whenever unable to visualize the tip of the catheter on radiograph	

Table 1. Procedure for PICC Insertion in an Infant *(continued)*

Step	***Considerations***	***Precautions/Comments***
• Nontoothed or sleeved iris forceps • Scissors • Catheter-trimming device (per manufacturer's recommendations) • Extension set (T-connector, straight connector, or multilumen device) with luer-lock and closed-end adapter. The extension set should be lipid resistant and free of DEHP. Some catheters are manufactured with an integrated extension set and do not require a separate extension set. • Water-soluble radiocontrast media (optional)		
6. **Select a catheter.** Select the size catheter appropriate to the infant's weight and vein size. Using inappropriate catheter size to accommodate the vein size may decrease the life of the catheter and cause vein trauma and clotting.	Infants with multiple infusion needs may be candidates for a double-lumen catheter, more than one PICC or a PICC and a midline catheter. An infant w,ith more than one PICC may have the tip of one catheter located in the superior vena cava and the other in the infeerior vena cava. The clinician should select the catheter that best meets the infant's therapeutic needs.	Bilaterally inserted catheters with tip terminations within the same vessel can become entangled and be difficult to remove.
	Catheter material • PICCs are currently made of silicone or polyurethane. • Catheters made of both materials have been successfully used in infants. • The choice of catheter material is personal because little current data support the superiority of either.	Both materials have been used successfully for many years, and both are biocompatible. Catheter materials are judged by their structural integrity, resistance to kinking, structural rigidity for easy insertion, low thrombogenicity, low bacterial adhesion, long-term stability, inertness to surrounding cells and tissues, and chemical inertness to infusate and mechanical irritation.[131] The major significant difference lies in the tensile strength of the catheter material. Polyurethane has high tensile strength, allowing thinner catheter wall design and a larger internal lumen. Silicone requires thicker walls with resultant smaller inner lumen diameter.[131]

Table 1. Procedure for PICC Insertion in an Infant *(continued)*

Step	***Considerations***	***Precautions/Comments***
	Number of lumens • Single- or dual-lumen devices are available. • A dual-lumen device is appropriate for an infant receiving total parenteral nutrition, multiple incompatible medications, or volume resuscitation. Size • Determining factors include the infant's weight, size of the vein, type of fluids to be infused, rate of infusion, and need for blood sampling or administration. • Place the smallest size catheter that will meet the infant's needs.[1] • Larger catheters have increased incidence of edema and phlebitis.[46,67] • The external diameter of the catheter should not exceed one-third of the internal diameter of the vein if measured using ultrasound.[68,132-134]	Use of dual-lumen catheters is associated with increased risk for central line–associated bloodstream infection, thrombosis, occlusion and costs.[125,135,136] A meta-analysis of 15 published studies concluded that multilumen CVCs may be associated with a slightly higher risk of infection when compared with single-lumen catheters; however, this relationship diminishes when only high-quality studies that control for patient differences are considered. The slight increase in infectious risk when using multilumen catheters is likely offset by their improved convenience, thereby justifying the continued use of multilumen vascular catheters.[137]
	Presence of stylet • Stylets provide stiffness to the catheter to facilitate insertion. • Stylets are increasingly available in polyurethane and silicone catheters.[131,138]	Stylets have been used in neonatal PICCs for more than 20 years and are standard in pediatric and adult PICCs without substantiated risk of an increase in morbidity or mortality.[139] Catheters with stylets have been used in infants as small as 700 g.[140]
7. **Select the preferred style of introducer according to the catheter size.** • Current choices from manufacturers include peel-away cannulas, break-away needles, or butterfly needles. • Safety-engineered introducers should be used to prevent needlestick injuries and exposure to blood-borne pathogens if offered by the manufacturer.[1,108]	Break-away needles may be smaller than over-the-needle sheath cannula-style devices and may facilitate entry into smaller vessels with less trauma.	The insertion technique for a break-away needle is similar to that for a butterfly needle. There is a risk of catheter shearing if used inappropriately. A peel-away cannula is similar in design to a conventional intravenous catheter and may provide a shorter learning curve in the insertion technique. There may be less risk of catheter shearing with this device.
8. **Manage pain.** Provide developmentally supportive care and comfort measures prior to and throughout the procedure. Use swaddling, pacifiers, and visual stimulation. Use containment, positioning, gentle technique, non-nutritive sucking, and sucrose or breast milk as appropriate.[27] Consider premedicating the infant with opioids or apply a topical anesthetic. Topical anesthesia (e.g., EMLA or LMX4 creams) may be appropriate for full-term infants.[27]	PICC insertion causes pain. Infants requiring a PICC often are unstable and easily agitated. Movement of the infant during the cannulation procedure can lead to unsuccessful venipuncture or catheter damage. Incorporating family-centered care allows a parent or caregiver to provide comfort during the procedure.	Medication should be administered and the effectiveness ensured before the procedure begins. Monitor for respiratory depression and other side effects. Document procedural sedation per hospital policy. Topical anesthetics can cause vasoconstriction in a small percentage of patients.

Table 1. Procedure for PICC Insertion in an Infant *(continued)*		
Step	***Considerations***	***Precautions/Comments***
9. **Apply hair covering and mask.**		
10. **Perform hand hygiene, using an alcohol-based waterless cleanser or antimicrobial soap and water.**	Perform hand hygiene procedures, either by washing hands with conventional soap and water or with alcohol-based hand rubs. Hand hygiene should be performed before and after palpating catheter insertion sites as well as before and after inserting, replacing, accessing, or dressing an intravascular catheter. Palpation of the insertion site should not be performed after the application of an antiseptic, unless aseptic technique is maintained. [4]	
11. **Open equipment and prepare a sterile field.**	Creating a large sterile field reduces the risk of contamination of supplies and allows the inserter adequate space to work.	Restrict traffic near the sterile field to reduce the risk of contamination.
12. **Perform hand hygiene, then don sterile gown and gloves.**	Maximal sterile barrier precautions include the use of hair covering, face mask, sterile gown, gloves, and large full-body drape.[4]	Use latex-free gloves. Exposure to latex in the healthcare environment should be minimized.
Use protective eyewear.	Standard precautions protect the caregiver against infectious exposure from the patient.	There is a minimal risk of splashing blood when breaking the introducer needle or sheath.
13. **Prepare the catheter.**		
Flush the catheter. • Attach a 5-ml to 10-ml syringe, per the manufacturer's recommendation, to the catheter and flush. • Flushing is required for catheters containing a hydrophilic-coated stylet to easily retract and remove the stylet. • This step cannot be performed with all catheters, depending on their configuration.	Flushing the catheter displaces air from the internal lumen and promotes assessment of the integrity of the catheter prior to insertion into the patient.	Assess the catheter for breaks or signs of leakage.
Trim the catheter • Excess catheter length can be trimmed to the premeasured intended insertion length. Modifications to the catheter should be consistent with the specific manufacturer's instructions for use. • Follow the manufacturer's directions for trimming.	Benefits of trimming excess catheter include • facilitating assessment of the external portion of catheter to ensure the same amount is present as was left external upon insertion • decreasing the risk of catheter migration • decreasing resistance to flow within the catheter and decreasing risk of occlusion[141] • decreasing potential damage to the external portion of the catheter • creating a smoother catheter tip on some catheters, dependent upon method.	Trimming should be performed in accordance with each manufacturer's directions for use. FDA guidelines state that the trimmed tip should be squarely (not bevel) cut and should closely approximate the original tip.[142] Manufacturers fashion the catheter tip by cutting with a blade. This may result in a straight or slightly irregular cut surface.[9]

Table 1. Procedure for PICC Insertion in an Infant *(continued)*		
Step	***Considerations***	***Precautions/Comments***
	Potential risks of trimming the catheter include • trimming too short • creating an irregular catheter tip depending upon catheter and trimming method • presence of fragments remaining on trimmed end.[143]	The method of trimming (scissors, scalpel blade, or trimming tool) may alter the smoothness of catheter tip differently, though data linking this to a patient complication, such as phlebitis or thrombosis, remain lacking.[9,143]
Stylet management: • If a stylet is used, it should be retracted 0.5 cm–1 cm from the catheter tip and secured to ensure that it remains within the lumen of the catheter. • Stylets should never be trimmed or allowed to extend beyond the catheter tip.	Flexible stylets facilitate threading of the catheter; can increase success in threading into the vena cava; and reduce the risk of coiling, reversing direction or doubling back onto itself, or catheter shearing with a break-away needle.[139]	The concern that stylets may increase the risk of phlebitis or vascular perforation is not supported by available data.[139] If the stylet has been trimmed in error, catheter damage can occur and a new catheter should be used. In one study, a higher rate of complications was attributable to the larger introducer sheath rather than the stylet.[140]
14. **Position the patient and restrain as needed.**		
Arm insertion: Abduct the arm to a position of comfort, with the patient's head turned toward the intended arm for PICC insertion.	Abducting the arm makes the venous course straighter and facilitates entry into the axillary and subclavian veins. Turning the head narrows the angle between the jugular and subclavian veins, making it difficult for the catheter to enter the jugular vein.	For upper-extremity insertion, the infant should be positioned chin to shoulder to ease threading.
Axillary vein insertion: Abduct the arm 100°–130° or place the infant's hand by the head and puncture parallel and inferior to the artery.	Using a small roll beneath the shoulder for positioning may facilitate prominence and ease of puncture of the axillary vein.	In a 2014 clinical trial, the use of the axillary vein as a site of insertion of a PICC line was correlated with significantly fewer complications in premature newborns than other sites of insertion. However, the use of this site requires specialized training and is best accomplished with ultrasound technology.[126]
Femoral vein insertion: Position the infant "frog-legged" at a 60° angle; insert the introducer at a 30° angle 1 cm–2 cm below the inguinal ligament and 5 mm medial to the femoral pulse.[87]	For femoral placement, the puncture should be close to the inguinal ligament at the level of the common femoral artery. Low abdominal compression and ultrasound guidance can facilitate successful insertion.[88,119,120]	

Table 1. Procedure for PICC Insertion in an Infant *(continued)*

Step	***Considerations***	***Precautions/Comments***
15. **Prep the insertion site and surrounding skin with chlorhexidine gluconate (CHG) or povidone iodine (PI) per facility protocol.**[4,58,59,65]	The CDC recommends preparation of the skin with > 0.5% chlorhexidine with alcohol before CVC insertion and during dressing changes. If there is a contraindication to chlorhexidine, tincture of iodine, an iodophor, or 70% alcohol can be used as alternatives. Though no recommendation can be made for the safety or efficacy of chlorhexidine in infants younger than 2 months, chlorhexidine has demonstrated significant effects in decreasing infant mortality and infection.[4,66] There is no specific antiseptic that can be recommended for all infants at this time. A large prepped area reduces the risk of contamination. The hand or foot may be wrapped in sterile gauze or glove and a large portion of the extremity prepped. This method of prepping provides access to a larger portion of the extremity, reducing the incidence of contamination, and allows entry into alternate sites without repeating disinfection if the original insertion attempt is unsuccessful.	PI and CHG have been shown to cause local skin reactions in some neonates and PI has been linked to thyroid dysfunction.[60] CHG (alcoholic and aqueous formulations) should be used with caution in very-low-birth-weight infants due to reports of skin erythema and breakdown.[144] In one study, 11% of infants who weighed less than 1,000 g and were younger than 48 hours of age and were receiving 2% aqueous chlorhexidine for disinfection developed skin irritation.[145] In another study, 20 preterm infants (gestational age 24 to 31 weeks or more) receiving 2% aqueous chlorhexidine had no incidence of skin irritation.[146]
PI: Begin at the insertion site and prep in a circular motion for 30 seconds. Allow at least 2 minutes to dry.	Drying time is required for maximal effectiveness of the antiseptic. There is evidence that neonatal exposure to iodine-containing disinfectants causes thyroid dysfunction in infants born at < 32 weeks.[60]	PI should be removed from the skin after the procedure to prevent tissue damage, absorption, and thyroid suppression.[61,62]
CHG: Apply the solution by moving the applicator using a back-and-forth and side-to-side motion for 30 seconds and allow at least 30 seconds to dry.[147,148] Change gloves if contamination occurs.	There are many products containing CHG available with aqueous or alcohol bases and containing different concentrations of CHG. An early neonatal study compared 0.5% CHG in 70% alcohol with 10% PI on peripheral intravenous sites and noted less skin colonization with use of CHG.[149] Numerous facilities have reduced central line–associated bloodstream infections through bundled approaches including CHG antisepsis.[45,58,59] CHG bathing has been associated with a reduction in CLABSI rates from 4.92 to 1.28 per 1,000 catheter days and shows promise as a tool for CLABSI prevention in pediatric patients.[63,64]	There is no evidence of sustained toxicity with CHG remaining on the skin, although the aqueous formulation needs to be removed due to its soapy consistency to allow the dressing to adhere.[61,150] Trace serum levels have been detected following bathing and umbilical cord care with 1% or 2% chlorhexidine, particularly in preterm newborns. Absorption potentially may be reduced with aqueous formulation.[150] Studies have used a variety of concentrations for multiple interventions, and numerous neonates worldwide have received CHG for umbilical cord care, bathing, and maternal vaginal lavage prior to birth without reported adverse effects.[150] In one study, half of the preterm infants showed detectable levels of chlorhexidine 2 to 3 days after exposure.[146]

Table 1. Procedure for PICC Insertion in an Infant *(continued)*		
Step	***Considerations***	***Precautions/Comments***
16. **Place a sterile drape underneath and above the insertion area.** Cover as much of the infant as can be safely done while ensuring the ability of adequate observation.	This step provides a large sterile field to minimize the risk of contamination of the catheter and supplies and is a recommended component of maximum sterile barrier precautions.[4]	
17. **Apply a sterile tourniquet (for an extremity insertion).** For insertion into a scalp or axillary vein, apply digital pressure proximal to the insertion site. If using the modified Seldinger technique, place ultrasound gel on probe, ensheath in sterile probe cover, and the locate vein for cannulation. Consider using an echogenic needle to cannulate the vein. Insert guidewire and use a blade to make a small nick at the insertion site if necessary. Thread the dilator sheath over the guidewire into the vein. Remove the guidewire and insert the catheter. Proceed to step 22.	This step is performed to dilate the vessel to enhance insertion. Large veins may not require a tourniquet for insertion.	If the tourniquet is placed on an unprepped area of the extremity, ask an assistant to remove or maintain sterility by changing sterile gloves. Monitor the extremity to prevent arterial occlusion from a restrictive tourniquet.
18. **Insert the introducer bevel at a 15°–30° angle into the skin a few millimeters before anticipated entry into the vein.** Hold the skin taut below the level of insertion to stabilize the vein and prevent the vein from rolling. A 30° angle is recommended for insertion into the femoral vein.[87] Consider utilizing ultrasound guidance if available.	Blood return may not be visible with some introducers. If you think you have cannulated the vein, try advancing the catheter.	
19. **Observe for blood return.** When the vessel is cannulated, a blood return may be observed or a "pop" may be felt. When the blood returns, lower the introducer until it is parallel with the skin, and gently advance a few millimeters farther to ensure that the entire needle bevel is within the vein.	A blood return usually is obtained due to the large size of the introducer, but it may be absent in some infants and in low perfusion states. Sometimes it is not evident until the catheter is advanced.	A vein can be cannulated without blood return. Observe the color, speed of flow, and pulsation of blood to detect arterial cannulation. If in doubt, obtaining a blood gas specimen through the catheter or attaching to a transducer may be helpful. In addition, contrast injection or ultrasound may be definitive.
20. **Remove the tourniquet after the introducer is well within the vein and blood return is evident.**	Tourniquets distend the vein and when removed the vein contracts. If the introducer tip is not entirely within the lumen or close to the wall it may retract with tourniquet removal leading to extravascular placement.	Removal of the tourniquet may cause some infants to move and may cause the introducer to become dislodged.

Table 1. Procedure for PICC Insertion in an Infant *(continued)*

Step	***Considerations***	***Precautions/Comments***
21. **If using a breakaway needle, using nontoothed or sleeved forceps, thread the catheter through the introducer needle in 0.5 cm–1 cm increments to the premeasured length. If using a peel-away sheath introducer, remove the needle, then thread the catheter as above.**	Slow, controlled insertion can prevent venous irritation and the development of phlebitis.[151] It also allows the catheter to float into the central circulation with the flow of blood. To minimize trauma to the vessel, threading the catheter should take at least 30–60 seconds.	
22. **If resistance is encountered, consider flushing with flush solution while attempting to advance the catheter in small increments.**	Flushing may help the catheter advance past obstructions and valves in veins.	There is little benefit to flushing a catheter containing a stylet because only minimal flow can be achieved.
23. **Remove the introducer.** Consider applying gentle digital pressure to the insertion vein a few centimeters above the tip of the introducer to stabilize the catheter and slowly remove the introducer until it is several centimeters outside of the skin. Alternatively, hold the catheter in place with smooth or sleeved forceps while withdrawing the introducer. Initially, hold behind the introducer and then switch to close the skin as soon as the introducer is removed.	Stabilizing the catheter and vein minimizes the risk of catheter dislodgement while the introducer is being withdrawn. The introducer needs to be away from the insertion site to be removed from the catheter and completely external to the skin at the insertion site to prevent inadvertent enlargement of the puncture site and increased bleeding.	Applying pressure too close to the tip of the introducer may cause catheter damage. Keep the introducer parallel to the catheter to prevent catheter damage.
24. **Release the break-away needle or peel-away cannula per the manufacturer's guidelines.**	This step removes the introducer from the catheter and allows the required length of catheter to be inserted.	Prevent catheter damage by keeping the introducer and catheter parallel.
25. **Apply pressure to the puncture site until the bleeding stops.**	Bleeding can persist for several minutes.	Persistent, difficult-to-control bleeding is unusual. In such cases, coagulopathy or arterial puncture should be considered.
26. **Ensure that the catheter is at the premeasured length. Adjust as necessary.**	The catheter may slip out slightly during removal of the introducer. Reinsert it as needed.	
27. **If a catheter with a stylet is used, remove the stylet slowly over a period of 30–60 seconds.** Do not hold the catheter with forceps during stylet removal. If the stylet cannot be removed (possibly due to a curve in the vein), the catheter can be pulled back 1 cm and removal attempted. If a hydrophilic-coated stylet is in place, the catheter must be flushed to activate the lubricant before the stylet is removed.	Rapid removal can lead to catheter damage. Follow the manufacturer's directions for use.	If the catheter bunches or ripples near the insertion site, it is necessary to slow down.

Table 1. Procedure for PICC Insertion in an Infant *(continued)*		
Step	***Considerations***	***Precautions/Comments***
28. **Aspirate for a blood return and flush the catheter.** If blood return is not present, withdraw the catheter slightly and aspirate. Continue this maneuver until a blood return is present or the catheter is pulled back to the extremity or scalp. Attempt to reinsert the catheter to the premeasured depth.	Blood return indicates vascular placement. A lack of blood return or inability to flush may indicate malposition.	Radiographic verification may assist in identifying tip location, which may provide guidance for repositioning efforts.
29. **Attach the luer-lock extension set, if an integrated extension set is not part of the catheter design.**	Extension sets applied at the time of insertion may be considered part of the catheter and not routinely changed unless clinically indicated or according to manufacturer's recommendations.[152]	All connections should contain luer locks to prevent inadvertent disconnection, with the potential for embolus, occlusion, or exsanguination. Extension sets allow additional tubing length, which is useful in stabilization. This can minimize direct stress to the catheter hub from repeated disconnection or IV tubing changes and can be instrumental in mimizing dislodgement.
30. **Temporarily secure the catheter to the skin with sterile tape or skin-closure tape.**	The catheter is lightly and temporarily secured until verification of the tip position is accomplished via radiography or other imaging techniques. Temporary taping prevents needing to remove the dressing (and risk for skin damage) to reposition the catheter, if necessary. Allowing tape or skin-closure tape to remain on the catheter over time has been linked to catheter damage and is not recommended by many manufacturers. The infant and the catheter should be carefully monitored until the catheter tip is confirmed and the catheter is secured and dressed.	If possible, maintain the sterile field while waiting for verification of tip location. If an X ray cannot be performed in a timely fashion, consider clinical status and a risks vs. benefits analysis before applying the dressing.
31. **Maintain catheter patency by flushing intermittently with 0.5 ml flush solution in a 5-ml to 10-ml syringe; or attach a positive or neutral displacement device until the position is verified.** Flush using a pulsatile (short bursts or start-stop) technique.	Catheters with small internal lumens (27 and 28 gauge) are more prone to develop occlusion without frequent flushing or require the use of a needleless connector device prior to the infusion of fluids. Refer to the manufacturer's directions for use for recommended minimum syringe size.	Maintain sterility during flushing. Pulsatile flushing has been anecdotally described as a method of enhancing catheter patency.

Table 1. Procedure for PICC Insertion in an Infant *(continued)*

Step	***Considerations***	***Precautions/Comments***
32. **Verify the location of the catheter tip with radiography or other imaging modality.** If the insertion site is in the upper extremity, include a portion of the upper arm and neck. If the insertion site is in a lower extremity, include the abdomen and a portion of the lower extremity and consider obtaining a lateral view on initial placement or if maposition is suspected.[41] For scalp insertion, include the skull. The catheter must be adequately visualized and tip location confirmed before the catheter is used.	Radiographic or another imaging modality is required for verification of the catheter-tip location[2,3] Tips for enhancing tip visualization • Positioning the infant for a lateral oblique view of the chest (right side elevated at a 10°–15° angle) can enhance visualization of the catheter because the PICC is not superimposed over the mediastinal structures. This technique has been credited with enhancing agreement among healthcare providers on catheter tip location when compared with the anterior-posterior view in adults.[153] • Overpenetrating the radiograph can enhance visualization of the catheter. Digital radiography allows adjustment of the degree of contrast and inversion and magnification features. • Consider a radiographic assessment of the insertion site to rule out coiling of the catheter if unable to advance the catheter to the inferior vena cava or superior vena cava. • A lateral X ray may be beneficial in locating the catheter tip, particularly if malpositioning is suspected based on the anterior-posterior view or clinical findings.[41]	Infant positioning for the insertion and subsequent X rays to verify catheter tip location should be consistent to support accurate evaluation of the catheter tip location and prevent the misconception that catheter migration has occurred due to change of extremity positioning in sequential surveillance imaging. Staff education has been associated with utilizing consistent positioning techniques to support consistent monitoring.[80] There is little data to suggest the optimal position to place the infant in for the X ray. Suggestions for infant and catheter tip positioning include the following: • Position the infant for the postinsertion radiograph and subsequent monitoring in a manner that would place the catheter at its deepest tip location, minimizing the risk of the catheter moving further inward, or place the infant in the position that is most likely to be maintained during the infant's day.[35] • Maintaining the catheter tip 1 cm outside of the cardiac reflection in a premature infant and 2 cm in a term infant has been suggested; however, there is an increased risk of thrombosis with catheters in the upper and middle superior vena cava.[154,155]
PICC catheters are radiopaque, but some, depending on the manufacturer and size, may be difficult to see on radiograph and require the instillation of contrast media.[42] Catheters may be difficult to visualize in infants with certain respiratory or abdominal pathology. When unable to visualize the catheter tip, water-soluble, isotonic nonionic contrast media may be used to enhance catheter visualization and confirm tip location. Digital viewing systems can minimize occasions when contrast may be indicated.	Many catheters contain enough barium for visualization without additional contrast enhancement. Contrast media can be instilled if the catheter tip cannot be adequately visualized. Certain water-soluble, nonionic contrast solutions may not cause tissue damage if the catheter tip is extravascular. Consider the use of contrast agents carefully, using only water-soluble, nonionic isotonic media when needed to visualize the catheter tip.	The contrast medium should be injected slowly, instilling enough to slightly overfill the catheter. The X ray can be taken after 3–5 seconds. This allows time for the bloodstream to wash excess contrast away from the catheter tip so that the tip can be accurately identified. Withdraw the contrast after the X ray. There is a lack of agreement to support the use of contrast as a routine measure and the use of contrast does not guarantee precise localization of a catheter tip in all situations.[42,82] Additional considerations for use of contrast include hypertonicity and increased risk for extravasation.[156]

Table 1. Procedure for PICC Insertion in an Infant *(continued)*

Step	***Considerations***	***Precautions/Comments***
33. **Place the catheter tip in the superior vena cava or thoracic inferior vena cava.**[1-3] This position for the superior vena cava has been described as the T3–T5 level, but it varies depending on radiographic technique and infant anatomy. Both the INS and NAVAN (now AVA) recommend the lower one-half to one-third of the superior vena cava as the ideal tip location for upper body insertions. Difficulty defining this location and the risk for complications related to the catheter migrating in the right atrium in infants have led to the more general superior vena cava location. The catheter should lie parallel to the vessel wall. Current data suggest that appropriate catheter tip placement in the inferior vena cava is between the right atrium and the diaphragm, described as T8–T10.[19] (see Figures 1 and 7)	A catheter tip in the lower one-third of the superior vena cava lies parallel to the vessel wall, so the risk of thrombosis and infection is reduced.[154] The superior vena cava is much shorter in neonates than in adults, so identifying the lower one-third is challenging. Outside the vena cava, the catheter tip is subjected to smaller diameter vessels, curvature of the vein, and venous valves; these features increase the likelihood of the catheter contacting and damaging the vessel wall. Chemical irritation (caused by the infused fluid or medication) is more likely in these smaller diameter veins. Exposure of the subendothelial layer of the vein due to mechanical or chemical irritation can lead to thrombosis, thrombophlebitis, and infection.[19] A 60% rate of subclinical thrombosis of the axillary, subclavian, and brachiocephalic veins has been seen with catheter tips residing in these veins in adults.[34]	Placement in the right atrium is contrary to current recommendations. The FDA stated in 1989 that only pulmonary artery catheters should be left in the heart due to the risk of dysrhythmias, perforation, tamponade, and death. Catheter tip locations in the brachiocephalic and subclavian veins are not considered central, due to the decreased diameter and lack of laminar blood flow in these veins and increased risk of complications.[1,3,11,20] More than half of the catheters with tips located in the subclavian vein required removal for nonelective reasons.[157]
34. **Reposition the catheter, if necessary.**	If sterile technique has been maintained and repositioning can be accomplished in an efficient manner, the catheter can be advanced if necessary. Otherwise, the catheter may only be withdrawn to reposition it.	Verify the new catheter tip location by radiographic means after repositioning efforts.
35. **Remove PI with sterile water or saline.** If desired, remove CHG skin prep with sterile saline.	PI can be absorbed through the skin, leading to elevation of iodine levels and hypothyroidism.[60] The formulation of aqueous CHG prevents adherence of dressings if not removed. There is currently no data to support the removal of CHG contained in an alcohol base. Removal of CHG may not be possible due to its ability to bind to the skin.[158] Removal of CHG eradicates its residual antimicrobial benefits.	Attempts to remove CHG may reduce its residual antimicrobial effects on minimizing colonization.

Table 1. Procedure for PICC Insertion in an Infant *(continued)*

Step	***Considerations***	***Precautions/Comments***
36. **Secure the catheter to the skin.** Any external length of catheter should be arranged with a slight curve as it exits the skin. This minimizes the risk of tension causing outward migration or allowing inward migration with movement.	The dressing is intended to secure the catheter to the skin and reduce the potential for infection. Transparent semipermeable membrane dressings promote optimal visibility of the catheter and insertion site.[47] Trimming the catheter to an appropriate length according to the manufacturer's recommendations minimizes risks of migration and occlusion.[141]	Attempt to stop bleeding before dressing to decrease blood remaining on the skin, which serves as a medium for bacterial growth. Consider a hemostatic agent to minimize bleeding if indicated. Dress in a manner that promotes visualization of the catheter and insertion site to facilitate assessment and promote catheter security. Follow the manufacturer's recommendations. Avoid placing skin-closure tape or strips directly on the catheter tubing, because these have been reported to cause catheter damage and fracture.[159]
Secure to allow visualization of amount of catheter external to infant and the insertion site.[22] If several centimeters of catheter are external, place the curve as directed above and coil the catheter while preventing kinks or bends in it Avoid laying the catheter over itself. A stabilization device should be used if one is available.[1]	Stabilization devices are available for specific catheters. These can minimize catheter movement and prevent dislodgement.	Document the length (amount in centimeters) of external catheter at insertion and at each subsequent dressing change.
Sterile, padded foam tape or hydrocolloid skin barriers may be placed under the catheter hub to prevent skin breakdown from contact with a rigid catheter hub or T-connector.	Maintaining skin integrity is critical to avoid infection.	
The catheter hub should be secured to the infant using the method described by the manufacturer. If not specified, adhere hub or disk to the skin with sterile tape or skin-closure strips. Extension sets (i.e., T-connector) should be attached to the skin with tape to prevent catheter dislodgement.	Do not place skin-closure strips over the catheter tubing due to risk of catheter damage.[159]	

Table 1. Procedure for PICC Insertion in an Infant *(continued)*		
Step	***Considerations***	***Precautions/Comments***
Apply the dressing to the catheter and hub. The choice of dressings includes transparent semipermeable or gauze and tape. The dressing should cover the insertion site and catheter.	Transparent semipermeable membrane dressings are comfortable and allow optimal visualization of the insertion site. Gauze and tape are not optimal dressings for neonates because they require manipulation for ongoing monitoring of the catheter and site. When circumstances require their use, these should be changed every 48 hours. Antimicrobial ointments should not be applied to the insertion site because these may promote fungal infections and antibiotic resistance.[4]	The dressing should not overlap itself or be completely wrapped around the extremity, because this may lead to venous stasis and edema. Accumulation of moisture or blood on the skin may provide a medium for bacterial growth. Infants who have oozing of tissue fluid or persistent bleeding are at risk for catheter migration. For persistent bleeding, a topical hemostatic agent may be placed under the dressing.
37. **Document the procedure on the medical record. The following should be recorded:** • indication • consent and parent education (see Appendix) • patient identification • skin preparation solution • vein of insertion • brand, type, size, number of lumens, and lot number • initial length of catheter (i.e., length trimmed, inserted, and external) • style and size of introducer • presence of stylet • radiographic location of catheter tip • type of dressing used • infant's tolerance of procedure • number of attempts at cannulation • complications encountered • procedural medications administered with therapeutic response • MST specifics (i.e., size of guidewire and size and type of introducer and dilator sheath) • imaging technology used for insertion, including vein measurements • catheter tip location verified radiographically • name of clinician performing procedure	A formal procedure note should be prepared. The bedside caregivers should have immediate access to this information to support ongoing assessment of catheter tip placement and monitoring for complications. If adjustments are indicated following the initial X ray, document the length of catheter withdrawn and the amount of external length. Document use of a catheter checklist and adherence to central venous catheter protocols per institutional policies.	Data should be collected for outcome monitoring following each insertion. Each shift, the catheter should be evaluated for signs of malfunction, integrity of the dressing, and cleanliness of the site.

Use of Modified Seldinger Technique

Some infants have veins that are difficult to cannulate, making the traditional methods of insertion challenging. MST is an acceptable option in the neonatal and pediatric population.[69] MST can be cost effective and reduce CLABSI when used appropriately.[70] As with all CVC insertions, MST requires specialized training and adherence to practice protocols, and in some states it requires approval of the facility and state boards of nursing.

Using MST, also referred to as micropuncture, allows a smaller introducer to be used.[71,160] A small-gauge, short PIV catheter is initiated following strict sterile technique as set up for the PICC placement. Following cannulation, the needle is removed and a short floppy tip guidewire is inserted a few centimeters beyond the tip of the PIV while remaining in the peripheral circulation. The peripheral catheter is removed over the wire.

After the skin is anesthetized, a small nick is made to allow the introducer to be inserted. The PICC introducer sheath or dilator is advanced over the guidewire. Once in place, the guidewire and dilator (if used) are removed. The PICC is placed through the introducer sheath and advanced into the proper position. The introducer sheath is separated and removed. Using ultrasound technology in combination with the MST can enhance identification of suitable veins, minimize painful events, and improve success.

Malposition of Catheter

When the PICC does not terminate in the appropriate location within the vena cava it is considered to be malpositioned.

Etiology

- Vein selected for catheter insertion
- Rapid advancement of catheter
- Venous anatomy

Location of Malposition

- Catheters inserted into the basilic vein most commonly are malpositioned into the internal jugular vein.
- Catheters inserted into the cephalic vein most commonly are malpositioned into the axillary and basilic veins. Catheters inserted via vessels in the upper extremity may malposition in other non-central vessels such as the intercostal, mammary veins and lateral thoracic vessels[161]
- Catheters inserted through the saphenous or other lower-extremity veins (particularly on the left side) may enter the ascending lumbar vein.[92,93] Oliguria and other sequelae have been associated with catheters placed below L2.[94,162]
- Catheters inserted into the scalp can enter intracranial or facial veins or tissue and thoracic veins.[163]

Identification

Suspect malposition if

- the catheter is difficult to thread or will not thread to the premeasured depth[161]
- a blood return is not easily obtained
- the catheter flushes with resistance
- the stylet is difficult to remove or is bent upon removal.

An X ray may provide definitive evidence that a catheter is malpositioned. A lateral view may provide additional information.

Management

Techniques for repositioning a malpositioned catheter include

- partially withdrawing the catheter and attempting to reinsert it (done only at the time of insertion and requires sterile technique to have been maintained). To prevent catheter shearing, the catheter must not be withdrawn until the needle introducer is removed.
- performing catheter exchange using MST for guidewire or a cannula-style introducer for a through-the-sheath exchange.[71]
- using noninvasive repositioning maneuvers[35]
  - For basilic vein insertions with the catheter tip in the jugular vein, abduct the arm at the shoulder and extend the elbow fully to pull the catheter into a more peripheral location. Follow these maneuvers by adducting the arm and flexing the elbow to reinsert the catheter.
  - For cephalic vein insertions with the catheter tip in the axillary vein, adduct the arm and extend the elbow fully to withdraw the catheter into a more peripheral location. Abducting the arm and flexing the elbow will reinsert the catheter.
- repositioning the patient to promote gravity and blood flow directing the catheter to the superior vena cava[36]
  - Raise the head of the bed if the catheter is in the internal jugular vein.[36]
  - Place the infant on the ipsilateral side with the head of the bed elevated if the catheter has entered the contralateral brachiocephalic vein.[36]
  - Catheters that are curled back into the axillary vein can flow to the superior vena cava if the infant is placed on the contralateral side with the head of the bed elevated and the extremity extended[36]

- if the PICC is looped back on itself and is in a deep vein (e.g., subclavian, jugular), or is in a large vein such as the internal jugular vein, it may spontaneously reposition into the superior vena cava with fluid infusion, gravity, and the aid of venous return to the heart.[36,37]
- gentle flushing through the catheter may also facilitate repositioning. Forceful flushing may cause displacement.

Alternate options include

- infusing peripherally accepted fluids at a maintenance rate or maintaining the catheter as heparin locked until proper position is achieved to avoid vascular injury.[37] Repeat X rays within 24 hours following insertion to reassess catheter position.[38] This strategy does not prevent malposition but supports detection of malposition at the time of the surveillance film.
- withdrawing the catheter to a midline position and adjusting the infusion not to exceed peripheral limitations until desired central placement is achieved.
- discontinuing the catheter if its position is not appropriate to the patient's infusion needs.[37]

Prevention

- Perform vessel assessment and selection, considering the risks of malposition.
- Position the infant to facilitate successful insertion. (Refer to positioning the infant in "Insertion Procedure.")
- Insert the catheter slowly, allowing the catheter to be carried with blood flow toward the heart.

Bleeding

Oozing from the insertion site is common during the 24 hours after insertion because of the relatively larger size of the insertion device and patient activity.

- Apply pressure on the puncture site for at least 5 minutes following insertion and until bleeding has stopped.
- A sterile piece of gauze can be applied under the dressing to the side of the catheter to wick blood away from the site temporarily. Placing gauze under the dressing can contribute to moisture accumulation and requires a dressing change within 48 hours.[4]
- If there is persistent oozing, a sterile hemostatic agent can be applied under the dressing to promote adherence and to prevent catheter migration. If a hemostatic agent is used, the dressing should be changed according to the manufacturer's recommendation for the specific agent or if visible blood that obscures the insertion site is present at 24 hours.

Prevention

- Use the smallest introducer available to minimize the size of the puncture site.[1]
- Excessive bleeding can be caused by an inadvertent arterial puncture. Perform careful assessment to differentiate the vein from the artery before attempting the insertion. Ultrasound technology is useful for differentiating a vein versus an artery.
- If oozing or bleeding persists, investigate the cause with a high index of suspicion for inadvertent arterial puncture. Other causes include infant activity, vessel shearing, and coagulopathy.

Air Embolism

Etiology

Air embolism is an air or gas bubble that occurs when air enters the venous system (VAE) and travels to the right ventricle and pulmonary system. Positive intrathoracic pressure becomes negative, allowing air to enter the vein tract.[54] Air embolism can occur during insertion, after insertion, or upon catheter removal if the infant takes a breath while the catheter is not connected.[55]

Identification

The following are symptoms of air embolism:

- cyanosis
- respiratory distress
- tachycardia
- elevated central venous pressure
- shock
- cardiac arrest
- millwheel murmur.

Risk Factors

- Catheter fracture, tubing disconnection, deep inspiration during catheter insertion or removal
- Inadvertent infusion of air into the IV administration set

Prevention

- Position the infant in a supine position.
- Use only luer-lock devices, including needleless access devices.
- Monitor frequently to ensure IV tubing connection junctions are secure.
- Ensure the catheter is clamped during tubing and needleless device changes.[164]

Management

- Place the infant in a left lateral Trendelenburg position to move air away from the pulmonic valve.
- Administer 100% oxygen to decrease air embolism.[56,57]

Postinsertion Complications

The incidence of major complications associated with PICC use is low. The majority of catheters are removed electively at the conclusion of therapy.[8,22,157,165] A variety of complications have been associated with PICCs; the risk of complications is increased in facilities where the procedure is performed infrequently.[75,166] A reduction in complications was noted when the procedures for insertion and catheter care were standardized and nurses became more experienced in inserting and maintaining the catheters.[75,76] Compliance with a central line policy and care regimen was positively linked to a specialized program offering routine education and updates. [167]

Although most complications are minor and easily treated, some can be life threatening and require prompt action. Mechanical problems, including occlusion, leaking, and dislodgment, along with infection are the most commonly identified complications. Complications can be related to insertion technique, routine care and maintenance procedures, or patient-specific problems.[18,22] Serious complications often are related to improper catheter tip location.[93,155,165] The complications encountered most commonly or associated with serious sequelae are addressed in this guideline.

Each unit should review and evaluate its complications profile to continue to improve care. Using an improvement science methodology such as TeamSTEPPS can help the unit take crucial strides toward better outcomes.[115]

Catheter-Related Bloodstream Infection (CRBSI) or Central Line-Associated Bloodstream Infection (CLABSI)

The terms used to describe intravascular catheter–related infections also can be confusing because catheter-related bloodstream infection (CRBSI) and central line–associated bloodstream infection (CLABSI) are often used interchangeably even though the meanings differ.[4]

CRBSI "is a clinical definition, used when diagnosing and treating patients, that requires specific laboratory testing that more thoroughly identifies the catheter as the source of the BSI."[4] A CRBSI is defined as bacteremia or fungemia in a patient who has an intravascular device and ≥1 positive result of culture of blood samples obtained from the peripheral vein, clinical manifestations of infection (e.g., fever, chills, hypotension), and no apparent source for bloodstream infection (with the exception of the catheter).[168]

A CLABSI is a primary BSI in a patient that had a central line within the 48-hour period before the development of the BSI and is not bloodstream related to an infection at another site. The CLABSI surveillance definition may overestimate the true incidence of CRBSI. The CDC defines a CLABSI as "a laboratory-confirmed bloodstream infection (LCBI) where central line (CL) or umbilical catheter (UC) was in place for > 2 calendar days on the date of event, with day of device placement being Day 1, and a CL or UC was in place on the date of event or the day before. If a CL or UC was in place for > 2 calendar days and then removed, the date of event of the LCBI must be the day of discontinuation or the next day. If the patient is admitted or transferred into a facility with an implanted central line in place, and that is the patient's only central line, day of first access in an inpatient location is considered Day 1. *Access* is defined as line placement, infusion, or withdrawal through the line. Such lines continue to be eligible for CLABSI once they are accessed until they are either discontinued or the day after patient discharged. Note that the "deaccess" does not result in the patient's removal from CLABSI surveillance".[73]

If using catheter cultures, one of the following would occur: a positive result of semiquantitative (≥15 cfu per catheter segment) or quantitative (≥ 10^2 cfu per catheter segment) catheter culture, when the same organism (species and antibiogram) is isolated from a catheter segment and a peripheral blood sample; simultaneous quantitative cultures of blood samples with a ratio of greater than 5:1 (CVC vs. peripheral); and/or differential time to positivity (i.e., a positive result of culture from a CVC is obtained at least 2 hours earlier than a positive result of culture from peripheral blood).[48,169]

The term catheter-associated bloodstream infection (CABSI) is intended as a surveillance definition for use in benchmarking performance and directing quality improvement activities.[170]

Sepsis appears to be the most consistently reported serious problem associated with PICCs. The incidence data of CRBSI reported in the literature vary due to inconsistent use of diagnostic criteria and reporting. Comparing rates is difficult because of inconsistencies in the definition of CRBSI; the insertion, care, and maintenance procedures; and the population of infants included.[115]

A retrospective study of infants matched by birth weight and admission date concluded that PICCs do not lead to a greater number of CRBSIs than PIVs.[171] These data have been confirmed in a randomized, comparative trial of very-low-birth-weight infants.[21] Equal numbers of infants developed bacteremia in the group with a PICC and the group with a PIV. More recently, infants weighing less than 1,000 g were matched by weight, gestational age, gender, and Clinical Risk Index for Babies (CRIB) scores to evaluate success during insertion and short- and long-term catheter complications. [21] Infants in the treatment group received IV fluids and medications via a PICC while the control group was managed with PIVs. Placement of a PICC was successful in the majority of cases and carried a significantly lower risk of infection than those infants in the control group managed with PIVs. In a 2011 study by Taylor and colleagues, CRBIs in extremely-low-birth-weight infants requiring long-term central venous access was reduced by nearly half after the implementation of a dedicated PICC team in the NICU. Standardizing PICC line placement is important, but standardizing line maintenance is essential to the improvement of CRBSI rates.[75]

The additional cost to treat a neonate who experiences a CLABSI over one who does not has been estimated at $90,221, with an approximate increased length of stay of 31 days.[172]

Etiology

CRBSI is an inherent risk with the use of any VAD. This multifactorial nature of infection can be due to the migration of skin flora from the insertion site along the catheter tract and colonization of the catheter.[48] Other mechanisms of catheter colonization include contamination of the catheter hub, contamination of the catheter at the time of insertion, administration of contaminated infusates, and hematogenous seeding of the catheter from a distant site of infection.[4,73]

Risk Factors

Premature infants, especially those with a birth weight lower than 1,000 g, are at higher risk of infection because of deficiencies in their host defense mechanisms and the number of invasive procedures to which they typically are subjected. Additional risks for CRBSI may include

- PICC insertion or care by relatively inexperienced staff[75,76]
- multiple entries to catheter
- contamination of the catheter hub
- long catheter dwell time (i.e., more than 3–6 weeks)[72]
- multilumen catheters.[173,174]

Treatment

There are no controlled clinical trials to provide data about the appropriate management of CRBSI in infants.[168] Therapeutic treatment regimens are discussed from a risk-benefit perspective for infants who require VADs to survive. Based on a retrospective review of infants who had a variety of CVCs and developed bacteremia without an identified source, removing the PICC with a CRBSI of gram-negative rods, *Staphylococcus aureus*, or *Candida* could improve a patient's outcome.[168,175-177] Successfully treating infants who have four or more positive blood cultures for coagulase-negative *Staphylococcus* without removing the CVC is unlikely.[178]

For patients with CRBSI for whom catheter salvage is attempted, additional blood cultures should be obtained, and the catheter should be removed if blood culture results remain positive when blood samples are obtained 72 hours after the initiation of appropriate therapy.[168] Two sets of blood cultures should be obtained on a given day; one set is acceptable for neonates.

In critically ill neonates, the incidence of CRBSI can be as high as 18 cases per 1,000 catheter days.[179] Consider the high risk of pan-resistant bacteria in this immunosuppressed population and use clinical stewardship and resource antibiograms to identify the best empiric regimen in these situations.

The literature reports that the following are alternatives to be used based on a case-by-case assessment of each infant:

- Treat the infection with antimicrobials through the catheter and repeat a blood culture after 48 hours. If it is positive, consider removing the catheter.[168,180]
- Discontinue the catheter without attempting to clear the infection (there is the potential for ineffective treatment when attempting in situ therapy, especially with systemic fungal infections).[175,180] A new catheter often can be placed, if necessary, after 24–48 hours of antibiotic therapy has been administered.

Prevention

Recommended strategies for preventing CLABSI and CRBSI include

- using a central line bundle, such as that recommended by the Institute for Healthcare Improvement (IHI) that includes five key components: hand hygiene, maximal barrier precautions upon insertion, chlorhexidine skin antisepsis, optimal catheter site selection, and daily review of line necessity with prompt removal of unnecessary lines[181]
- ensuring staff competency in inserting and maintaining a catheter[8]
- limiting the number of staff members who insert catheters
- using standardized protocols for maintaining PICCs[8,72,182]
- using maximum sterile barrier precautions for catheter insertion and sterile technique for dressing changes[4]
- practicing appropriate hand hygiene before the catheter is inserted and when accessing the PICC
- using PI or CHG for skin disinfection prior to catheter insertion and with dressing change.[4,61,145] Prepare clean skin with a >0.5% chlorhexidine preparation with alcohol before CVC and peripheral arterial catheter insertion and during dressing changes. If there is a contraindication to chlorhexidine, tincture of iodine, an iodophor, or 70% alcohol can be used as alternatives. Chlorhexidine/alcohol antiseptics may be used in neonates younger than 2 months of age with caution in accordance with the latest recommendations from the FDA.[4,65]
- dressing the insertion site with a sterile, occlusive material. If dressing integrity is lost, change the dressing.[48,49] A multidimensional strategy to

decrease blood stream infection that included weekly dressing changes showed a statistically significant decrease in blood stream infection; however, it is difficult to quantify the role the weekly dressing change played in the outcome.[50]

- eliminating stopcocks from tubing and instead using capped injection ports that must be vigorously cleaned with alcohol prior to entry[22,183-85]
- exercising meticulous care to prevent contamination when using the catheter or changing IV tubing. Change administration sets for solutions containing dextrose or parenteral nutrition without lipids every 72–96 hours.[4,78]
- minimizing entry into the line. A closed medication system (entry restricted to once every 24 hours) used as a component of a multidimensional strategy to decrease blood stream infection was found to significantly decrease the incidence of blood stream infection[50]
- minimizing contamination risk by disinfecting the needleless access site and scrubbing the device each time the needleless access site is entered with an appropriate antiseptic (chlorhexidine/alcohol, povidone iodine, an iodophor, or 70% alcohol) and accessing the needleless access site only with sterile devices. Appropriate disinfectants must be used to prevent transmission of microbes through connectors. Multiple studies have shown that disinfection of the devices with chlorhexidine/alcohol solutions appears to be most effective in reducing colonization.[4]
- providing continuing education and monitoring staff compliance with hand hygiene and care regimes. Following up with subsequent reporting and feedback to staff.
- using antibiotic lock strategies, which have demonstrated a reduction in CRBSI in a small clinical trial[179]
- removing the PICC as soon as a vascular access device is not required. The risk of CLABSI increased in the 2 weeks following insertion with greater incidence of gram-negative CLABSI in PICCs with dwell times greater than 50 days.[277]

Catheter Migration

Catheter migration occurs when the catheter tip location changes from a satisfactory documented postinsertion location to either a more central or different location after from initial placement.

Etiology

- In vivo and ex vivo reports commonly document movement or migration of the catheter at any time while in situ.
- The movement of PICCs within the body may occur spontaneously or as the result of patient movement, as outlined in **Table 2.** Movement may cause a catheter shift to a more peripheral or central location.[35]
- A catheter can migrate further inside or outside the body if the dressing is not secure.
- Difficulty in securing external jugular insertions has led to increased migration.[35]

Risk Factors

Patients at higher risk for migration (based on reports primarily from adults) include those who experience the following:

- increased thoracic pressure
- high-frequency ventilation
- frequent vomiting
- coughing
- rapid infusion of fluid or forceful flushing.

Signs and Symptoms

Catheter migration may be asymptomatic although reported symptoms can include

- pain and irritability based on the catheter location and infusate
- erythema or edema of shoulder, neck, or arm (for arm-inserted catheters)
- change in catheter function (difficulty flushing or withdrawing)

Table 2. Relationship Between Patient Position and Catheter Tip Location

Catheter Insertion Site	*Infant Position*	*Resultant Tip Movement*
Cephalic vein[35,190]	Abduction of arm	Inward migration
	Adduction of arm	Outward migration
Basilic and axillary veins[35]	Abduction of arm	Outward migration
	Adduction of arm	Inward migration
Preantecubital insertion[35]	Flexion of arm	Inward migration
	Extension of arm	Outward migration
External jugular and catheters traversing neck[191,192]	Neck flexion	Inward migration
Leg vein insertion[94]	Leg flexion	Inward migration
	Leg extension	Outward migration

- change in visible measurable length of external catheter segment[18]
- symptoms specific to a particular complication (i.e., dysrhythmias due to catheter migration into the heart or pericardial or pleural effusion, which are described under "Complications").

Treatment

- Obtain radiographic verification of the catheter tip location.[18]
- Refer to strategies identified in "Malposition."
- Patient repositioning maneuvers have been shown to successfully adjust PICCs in some instances.[36]
  - For basilic vein insertions with catheter tip in the jugular vein, abduct the arm at the shoulder and extend the elbow as far as possible to withdraw the catheter tip into a more peripheral location. Follow these maneuvers by adducting the arm and flexing the upper extremity to re-advance the catheter.
  - For cephalic vein insertions with catheter tip in the axillary vein, adduct the arm and extend or straighten the upper extremity as far as possible to withdraw the catheter into a more peripheral location. Abducting the arm and flexing the upper extremity will reinsert the catheter.
- Determine whether it is safe to leave the catheter in its current position; doing so may not be acceptable, especially if the patient is symptomatic or if there is tip location/infusion property mismatch.
- Consider removing the catheter or performing a catheter exchange if the tip is outside the appropriate location in the vena cava. Pulling the tip back into an acceptable midline location may also be an option. If the catheter is withdrawn to a midline tip location, only solutions and medications that can safely be infused into a peripheral vein should be used. This includes solutions with dextrose 12.5% and less. See midline catheters for further considerations.

Complications

Complications that can arise from catheter migration include the following:

- thrombosis[19]
- dysrhythmias
- vascular perforation or extravasation[186]
- myocardial perforation, effusion, tamponade[187]
- pleural effusion[43]
- neurologic abnormalities (Refer to discussion of neurologic complication for symptomatology.) Adults and children have reported hearing water-like sounds when catheters migrate into the jugular vein. The infusate may be directed against the flow of blood and can allow infusion into smaller veins or into the intracranial venous sinuses and create neurological problems.[90,188]
- catheter looping, knotting[189]
- signs of discomfort or pain.

Prevention

Migration may not be preventable due to dynamic forces within the body. Strategies that minimize the risk of migration and enhance accurate assessment include

- maintaining the security of the catheter with intact dressing and/or securement device
- verifying the catheter tip location upon insertion, following repositioning, and on an ongoing basis[3]
- verifying the position of the extremity or head on radiograph. This can alter the catheter tip position.[35]

Catheter Dislodgement

Inadvertent partial or complete removal of the catheter from the body is termed catheter dislodgement.

Etiology

- Loss of secure dressing[188]
- Catheters are inadvertently withdrawn during dressing removal[188]
- Excessive bleeding or drainage at the insertion site prevents catheter securement.[18] Catheter tubing is not fixated through adherence to dressing.
- Tension placed on catheter and dressing,[18] particularly excess catheter remaining external

Treatment

- Radiographically verify the tip location to determine risks versus benefits of leaving catheter indwelling.[18]
- Remove catheter or perform a catheter exchange if a new tip location is unsatisfactory.[18,71]

Prevention

- Maintain the security of the catheter with an intact dressing.
- Consider using catheter securement devices.[1,47]
- Do not use ointment under the dressing.[4]
- Promote dressing duration by applying to skin after antiseptic agent has completely dried.
- When performing a dressing change, remove the old dressing by gently stretching the distal corner of the dressing to break adherence and lifting the dressing in the direction of the insertion site.
- Secure extension tubing to the infant at a different location, not overlying or obscuring the catheter insertion site.

Dysrhythmias

Atrial and ventricular dysrhythmias can occur if the catheter enters either chamber of the heart. Pacing tissue may also be present in the lower segment of the superior vena cava.

Identification

- Monitor the heart rhythm during insertion, and slightly withdraw the catheter if dysrhythmias occur.
- If dysrhythmias occur without an identified etiology, verify the catheter tip placement by radiograph or another imaging technique.
- If dysrhythmias occur without an identified etiology, verify the catheter tip placement by radiograph or another imaging technique.

Prevention

- Measure the patient to determine the correct length of the catheter to be inserted.
- Monitor the patient during insertion, observing any changes in electrocardiographic patterns.
- Verify and maintain the catheter tip location in the vena cava and outside the heart.
- Maintain a secure dressing to prevent catheter migration.

Myocardial Perforation, Effusion, or Tamponade

Myocardial perforation occurs anytime during catheter dwell—the median time of occurrence is 3 days after insertion. Based on retrospective data, however, effusion may occur at any time during catheter dwell.[155] This review also identified catheter tips to be predominantly within the pericardial silhouette at the time the effusion was identified. Pericardial effusion, tamponade, and death can result if the symptoms are not readily identified and the pericardial effusion drained.[165,166] Heightened awareness of this potential complication may decrease mortality[193] (see **Figure 10**).

Proposed Etiologies

More data are required to determine the precise etiologies, but those reported include

- myocardial damage as the catheter tip contacts the cardiac muscle with each contraction, becoming fixed with resultant thrombus or causing a direct myocardial perforation[155]
- endocardial damage due to osmotic injury with infusion of hyperosmolar fluid into the interstitium, leading to diffusion injury of the myocardium[155,187]
- rapid injection of fluid[155]
- erosion of catheter through the lower portion of the superior vena cava just outside the heart and egress of fluid into the pericardial space.[187,194]

Risk Factors

Factors that can increase the risk include

- catheter tip residing within heart[155]
- catheter angulation, curvature, or looping allowing contact with myocardium when catheters reside in the heart[165,195,196]
- displacement of the catheter into the heart due to movement of the extremity, head, or neck[35,94,192]
- inadequate catheter securement allowing migration.[18]

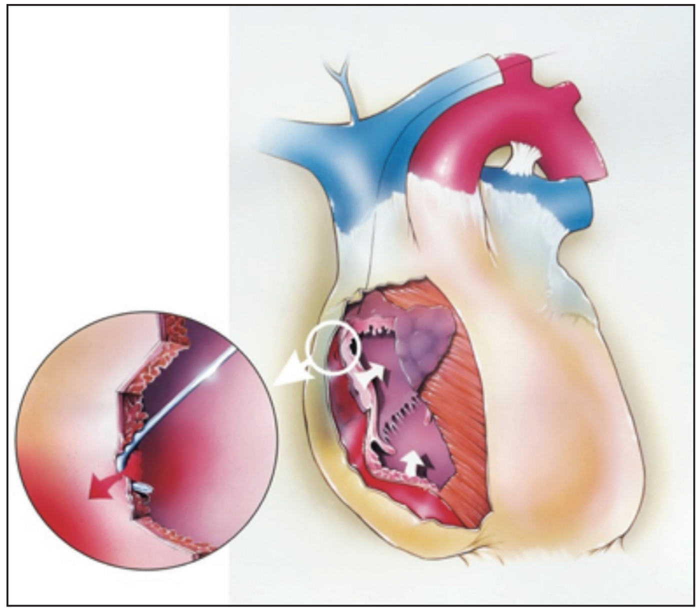

Figure 10. *Catheter erosion through the myocardium, leading to pericardial effusion*

Figure 10 Courtesy and © Becton, Dickinson and Company. Used with permission.

Signs and Symptoms

Signs and symptoms can vary in severity, with some infants being asymptomatic, and may be due to the rate and volume of infusion and the size of the infant. Symptoms may include the following[40,155,193,197,198]

- tachycardia or bradycardia
- narrow pulse pressure
- hypotension
- muffled heart tones
- dysrhythmias
- weak peripheral pulses
- respiratory distress
- poor color or extreme pallor
- poor response to resuscitation
- resistance to external cardiac compressions
- sudden cardiovascular or respiratory compromise
- cardiomegaly on radiograph and/or distancing of the catheter withdrawing from the pericardium on radiograph
- pulseless electrical activity.

Identification and Treatment

Rapid identification and treatment are critical for survival.[198] If myocardial perforation, effusion, or tamponade are suspected or occur the following management strategies should be used:

1. Stop the infusion of fluid and notify the medical care provider.[18]
2. Immediately obtain a chest X ray. The X ray may show a widened mediastinum or enlarged heart. (The pericardial effusion would be difficult to visualize on X

ray because it is a similar density to that of the heart). An echocardiogram is the preferred method because it facilitates viewing the effusion and visualizing the catheter tip within or near the heart, but it may not be readily available.[40]
3. Attempt to aspirate blood from the catheter while awaiting the imaging study.[40,155,199] If the aspirate appears consistent with the infusate, continue to aspirate until as much fluid as possible is removed.[40] If the fluid cannot be retrieved by direct aspiration from the catheter, pericardiocentesis may be necessary. The infant's condition may require life-saving intervention such as a pericardiocentesis prior to the radiologic procedure being accomplished.
4. Withdraw the catheter to the appropriate position in the vena cava; removal of the PICC is not required.[155,199]
5. Follow up with an X ray or ultrasound because effusion can reoccur.[40]

Prevention

To help prevent myocardial perforation, effusion, or tamponade the following steps should be taken:

- Maintain the catheter tip in the appropriate location in the vena cava.[3,35]
- Trim the catheter to the specific length required for the infant to facilitate assessment.[90]
- Dress and stabilize the catheter securely to prevent possible migration and trim the catheter to the length required for the infant to facilitate assessment.[9,47]
- Visually assess hourly that the correct length of catheter is outside the body.[22]
- Obtain an X ray or other imaging at periodic intervals to detect migration.[3] Ensure that the extremity containing the PICC or the head is in a consistent position with each X ray.[35,190]

Suggested, but unproven, strategies to consider:

- Position the infant for the postinsertion X ray to allow the maximal inward movement of the catheter.[35] Maintain the catheter tip outside pericardial reflection, above T2.[193] Refer to the radiographic assessment of tip location located in the insertion procedure for these strategies.
- Maintain the catheter tip 1 cm outside the cardiac reflection in a premature infant and 2 cm in a term infant.[155] Positioning the catheter tip outside the heart does not entirely prevent pericardial effusion and may cause other serious complications.[195,200]

Pleural Effusion/Hydrothorax

Pleural effusion has been reported when catheter tips reside in the right atrium, inferior or superior vena cava, braciocephalic and subclavian veins, and a small branch of the pulmonary artery. This complication occurs infrequently, is typically unilateral, and has been reported to occur due to a variety of factors (see **Figure 11**).

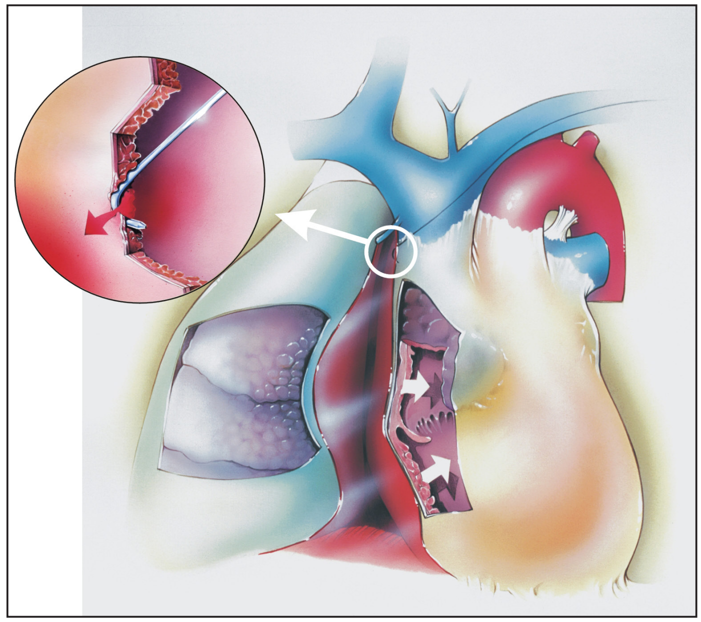

Figure 11. *Catheter erosion at the junction of the brachiocephalic vein and the superior vena cava, which may lead to pleural effusion*

Figure 11 Courtesy and © Becton, Dickinson and Company. Used with permission.

Etiology

- Perforation of a central vein during or after catheter insertion[200,201]
- Catheter tip or thrombus blocking the opening of the thoracic duct or migrating into the lymphatic vessels, leading to retrograde flow[202]
- Catheter tip against the vessel wall or malpositioned or migrated into a small vessel and not into the vena cava[43,203]
- Erosion of the vessel due to contact with the catheter can result in pleural effusion or hydrothorax[204]
- Mechanical and chemical irritation, which can act synergistically to erode the vessel[204]
- Infusion of hyperosmolar solutions leads to osmotic injury and vascular leakage without catheter perforation of the vein.[202,205]
- Superior vena cava thrombosis leading to chylothorax[194,206]

Risk Factors

- The left brachiocephalic vein joins the superior vena cava at an acute angle. Left-sided insertions in the upper body may place the infant at increased risk if the catheter does not complete the curve from the brachiocephalic vein to the superior vena cava and is left with the tip at this junction. If left in the brachiocephalic vein, the catheter's movement may allow contact with the vein wall or the infusate may be directed at the vein wall without the benefit of adequate hemodilution, leading to erosion and subsequent effusion.[207]

- A large catheter placed in a small vessel allows the catheter to remain in contact with the vessel wall and can lead to erosion of the vessel's inner layer and infiltration into the mediastinal or pleural space. Placement outside the vena cava increases this risk.[208]
- Thrombus formation at the catheter tip can result in catheter dysfunction, necrosis of the vessel wall, and leakage of fluid. The leakage of concentrated solutions draws large amounts of fluid into the pleural space.[202]

Signs and Symptoms

The signs and symptoms can vary with the size of the effusion, rate of fluid accumulation, size of the infant, and degree of venous damage. Some effusions occur slowly or they can be obscured with preexisting cardiorespiratory disease. Signs and symptoms include

- respiratory distress with decreased breath sounds over the affected lung[43,208]
- soft-tissue swelling[205]
- absence of blood return from the catheter (this may also be due to other causes).

Identification

- Radiologic imaging studies confirm the diagnosis of pleural effusion and hydrothorax. Chest X rays reveal opacification of an affected lung with the ultrasound demonstrating pleural fluid. The injection of a contrast agent may demonstrate entry into the lymphatic system.
- Blood may not be aspirated from the catheter.

Management

- Stop the infusion of fluid through the catheter.
- Notify the medical care provider.
- Obtain imaging studies (e.g., chest X ray, ultrasound).
- Attempt to withdraw infiltrated fluid back through the catheter.[201]
- Thoracentesis to remove effusion fluid may be required.[208]
- Some pleural effusion and hydrothorax resolve themselves spontaneously without catheter removal.[209]
- Monitor for reaccumulation with radiologic imaging studies.

Prevention

- Maintain the catheter tip in the appropriate position within the superior or inferior vena cava.
- Ensure the catheter lies parallel with the vein wall.[2,210,211]

Phrenic Nerve Injury/Diaphragmatic Paralysis

This infrequently reported complication has been seen with catheter tips that reside in the subclavian vein or brachiocephalic vein.[212,213] The right phrenic nerve lies in close proximity to the right brachiocephalic vein and the left phrenic nerve lies close to the left subclavian artery, left brachiocephalic vein, and aortic arch.

Etiology

The specific mechanisms and factors contributing to vessel damage include

- catheter tip location in a noncentral vein and vascular erosion[212,214]
- extravasated fluid from the catheter tip residing in the subclavian vein causes irritation of the underlying phrenic nerve[215]
- thrombosis, engorgement of the subclavian vein, which may compress the phrenic nerve.[213,216]

Symptoms

- Respiratory distress
- Persistent, often asymmetrical elevation of the diaphragm on X ray will be demonstrated in hemidiaphragmatic palsy.[212,213]

Diagnosis

Radiologic imaging (e.g., X ray, ultrasound, fluoroscopy) can be used to diagnose phrenic nerve injury and diaphragmatic paralysis.[213]

Prevention

To minimize the risk of phrenic nerve injury and diaphragmatic paralysis, the catheter tip should be located in the superior or inferior vena cava.[2,19,34,108]

Catheter Fracture and Embolism

Etiology

This multifactorial complication has several proposed etiologies, with fracture being identified on the internal or external portion of the PICC:

- Shearing of the catheter can occur during insertion if the catheter is withdrawn while the insertion needle is in place.[43,217]
- Catheter can fracture from high pressure created by using small-volume syringes for infusion or flushing against resistance.[218,219]
- Removal of the catheter using force[220]
- Disconnection of the catheter from the hub[221,222]
- Pinch-off phenomena caused by compression of the catheter between the clavicle and the first rib at the costoclavicular space has resulted in catheter fracture requiring retrieval of the fragment from the coronary sinus.[223]

Signs and Symptoms

Symptomatology varies depending upon the location of the fracture and the presence of embolus. Some infants remain asymptomatic with the fracture or catheter embolus being identified radiographically or clinically based on the assessment of the length of the external catheter segment.[43]

Other symptoms include

- fluid leaking from the insertion site[188,219]
- inflammation or swelling along the catheter pathway[188]
- difficulty flushing or withdrawing blood[218,219]
- respiratory distress
- cardiac dysrhythmias.

Treatment

If the catheter fractures during withdrawal

- Apply digital pressure over the vein or apply a loose tourniquet to the involved extremity proximal to the insertion site to prevent further migration into the central circulation.[224] The tourniquet should not occlude arterial flow.
- Keep the patient immobile.
- Obtain radiographic verification of the location of the catheter fragment.

Catheters kept in the peripheral circulation may be removed by venotomy. Catheters embolizing to the central circulation may require removal by percutaneous transvenous retrieval through interventional radiology, cardiology, cardiothoracic, or vascular procedures.[219,223]

Prevention

- Assess the need for analgesia or sedation for the insertion procedure.
- If catheter repositioning is needed at the time of insertion, do not retract the PICC through the introducer needle to prevent catheter shearing.
- Maintain the catheter securely under the dressing, while preventing tension to the catheter. Ensure extension tubing is also secured to patient.
- Avoid forceful infusion through the catheter using smaller syringes that produce higher pressures. Routinely use a 10-ml barrel pressure.
- Do not flush if resistance is encountered.
- Only healthcare professionals with demonstrated clinical competency should remove PICCs.
- Remove the catheter gently, while holding the catheter at the point of insertion rather than the hub, and *never place tension* on the catheter material or use force.

Thrombosis

Etiology

The inside layer or venous endothelium, is nonthrombogenic. Damage to the intimal layer of the vessel exposes the subendothelial layer of the vein, allowing adherence of platelets and activation of the extrinsic and intrinsic coagulation cascade. Vascular trauma, inflammation of the vessel wall, alteration in coagulation, and stasis of blood flow can cause the endothelial injury.[225] Left-sided arm and scalp insertion catheters may fail to make the transition from the brachiocephalic vein to the superior vena cava, leading to vessel damage.[207] Catheter tips residing outside the vena cava can lead to an increased risk of thrombosis.[19] The incidence of thrombosis varies due to the lack of a standardized method of diagnosis, but is higher in younger children. Clinical diagnosis of thrombosis is made in approximately 1% of patients with all CVCs, but diagnosis by ultrasound and venography shows an overall risk of thrombosis in 20% of patients with CVCs.[166]

Signs and Symptoms

Most of the signs and symptoms are silent, but may include the following[225]:

- prominent superficial or collateral vessels
- edema or discoloration of the extremity in which the catheter is located[226]
- unexplained fever[225]
- unexplained thrombocytopenia[225]
- chylothorax, which may be the only sign of a Superior vena cava thrombosis[166]
- unexplained cardiorespiratory decompensation, particularly with hypoxia, which is suggestive of pulmonary embolus or pericardial effusion[166,225]
- discoloration or pain in affected limb.[166,226]

Prevention

- The catheter tip should be maintained in the vena cava.[19]
- The catheter size should be appropriate for the size of the vessel to be cannulated. An appropriately sized catheter facilitates blood flow around the catheter and prevents irritation of the venous wall.[225]
- Secure the catheter to prevent vessel damage, stimulation of the coagulation cascade, and thrombosis secondary to migration.

Vena Cava Thrombosis

Superior and inferior vena cava thrombosis is subclinical in most instances. This condition can be diagnosed using ultrasound or a venogram. Many of the etiologies are inclusive of those outlined under "Thrombosis."

Signs and Symptoms

Signs and symptoms can include the following[227]:

- edema of the upper extremity, neck, and head (superior vena cava thrombus)
- edema of the lower body and limbs (inferior vena cava thrombus)[228]
- dilation of veins on the skin (collateral circulation)
- respiratory distress
- cardiac murmur
- central nervous system disturbances (superior vena cava thrombus)
- full fontanel (superior vena cava thrombus).

Treatment

The treatment of superior vena cava thrombosis varies depending on its severity. A variety of treatment options have been proposed though there is no consensus about which is the preferred method. Treatment options may include the infusion of a thrombolytic agent via the PICC or an alternative VAD, anticoagulation, surgical removal of the thrombus, transcatheter recanalization, or catheter removal with supportive care.[226,229]

Mechanical Phlebitis

Etiology

Mechanical phlebitis is an inflammatory reaction of the vein associated with placement and the ongoing dwell of a catheter within the vein. Symptoms vary and may include pain at the insertion site or along the track of the vein, edema, erythema, palpable venous cord, and purulent drainage. Mechanical phlebitis is most commonly reported during the first 72 hours to 1 week following catheterization, but it may occur at any time during the catheter dwell time.[46,230] The incidence, clinical symptomatology, treatment, and outcomes are not well defined in neonates. No differences in incidence were noted between catheters placed in the upper and lower extremities.[86]

Risk Factors

Risk factors for mechanical phlebitis include the following:

- rapid or traumatic insertion, which can damage the intima of the vein[151]
- use of a large-gauge catheter in relation to the size of the vein[164]
- catheter tip outside of the vena cava[19]
- cephalic vein insertion[46,89]
- saphenous vein insertion[89]
- inadequately secured catheter[46]
- manipulation of the PICC during insertion.[46]

Inexperienced clinicians placing the catheter have been anecdotally associated with a more rapid insertion, which may cause irritation to the vein intima.

Treatment

The need for and type of treatment for phlebitis remain unclear. Some consider this a benign condition with spontaneous resolution.[116,122] Treatment options include

- applying warm, moist compresses over the vein every 4 hours until the phlebitis is resolved[18,159]
- elevating the involved extremity and administering a gentle range-of-motion exercise, if the infant has little spontaneous activity.

With early identification and treatment, phlebitis usually resolves itself within 24 to 72 hours.[18,46,159] If there is no improvement or if the phlebitis advances after 24 hours of therapy (as indicated by a red streak, palpable cord, or purulent drainage), discontinuing the catheter should be considered.[231]

Prevention

- Maintain the catheter tip within the vena cava.[2,19]
- Monitor the vein of catheter insertion every hour to promote early detection and management.[232]
- Slowly and gently insert the catheter.[151]
- Use the smallest catheter capable of delivering the required therapies.[1,159]
- Avoid using the cephalic vein if other sites are available.[46,89]
- Saphenous vein insertions may carry an increased risk for phlebitis.[89]
- Secure the catheter to prevent movement, using a stabilization device if one is available.[1,18,46]
- Catheters should be inserted by trained personnel to minimize the risk of irritation to the vein intima associated with rapid insertion procedures.[81]

Chemical Phlebitis

Chemical phlebitis is most commonly associated with PIVs and midline catheters, but it also can be associated with a PICC that is positioned in a non-central vein. Chemical phlebitis results from inflammation of the vein intima in response to chemicals infused or catheter material.

- With a peripheral catheter tip (i.e., in the extremity or scalp), this form of phlebitis has a rapid onset.
- Erythema is seen within hours of infusing medications or solutions that are irritating to the vessel, were improperly mixed or diluted, were rapidly administered, or contain particulate matter.
- Formation of a fibrin sheath surrounding the catheter may allow fluid to exit into a vein smaller than the vena cava, which can lead to chemical phlebitis.

Risk Factors

- The properties of the infusate may lack adequate hemodilution if the catheter tip is located in a small vein, which leads to venous damage. In a study of 121 infants with hypoglycemia, more than half of the infants receiving 15% and 20% dextrose developed phlebitis.[233]
- A fibrin sheath forms around the tip and propagates along the length of the catheter. Infused fluid follows the path of least resistance and exits into the sheath. If the sheath covers part of the catheter, the fluid path retrogrades and symptoms are seen at the end of the sheath. If the sheath covers the entire catheter, the fluid exits around the catheter insertion site. The diverted fluid pathway can lead to localized irritation to the vein intima.
- Placing the catheter tip in a location with inadequate hemodilution can lead to chemically induced vessel irritation and erosion.[214,234]

Signs and Symptoms

The symptoms are similar to those of mechanical phlebitis.

- Pain during and after infusion can indicate chemical phlebitis.

- Chemical phlebitis due to a fibrin sheath can be diagnosed by means of a contrast injection into the catheter, venogram, or ultrasound.

Treatment

- Chemical phlebitis due to noncentral tip location warrants catheter removal to avoid more serious complications.
- If chemical phlebitis is caused by a fibrin sheath, the catheter should be removed.

Prevention

Appropriate device and catheter tip location in combination with evaluation of the chemical properties (i.e., pH, osmolarity, irritant/vesicant features) minimizes the risk of chemically induced phlebitis.

Infiltration and Extravasation

Infiltration and extravasation occur due to inadvertent administration of an infusate into surrounding tissues. *Infiltration* refers to inadvertent administration of a nonvesicant solution or medication into surrounding tissues. *Extravasation* refers to inadvertent administration of a vesicant solution into surrounding tissues.[164]

Catheter Occlusion

Most cases of catheter occlusion are due to improper flushing or catheter-locking protocols, but they may also be due to infusate incompatibilities, fibrin sheath formation, catheter tip location, and possibly low flow rates through the catheter.[19,188] Catheter occlusions can be described as partial occlusion (i.e., the catheter can be flushed but blood cannot be aspirated) or total occlusion (i.e., the catheter cannot be flushed or aspirated through). Thrombotic occlusions represent the most common etiology.

Etiology

Thrombotic occlusions are due to

- fibrin or clot formation inside or outside the lumen
- venous thrombosis from injury to the vessel wall
- large catheters with insufficient venous flow around them, which creates turbulence and increases the risk of thrombus.[225]

Risk Factors

- Improper flushing technique, which leads to an inability to create positive pressure within the catheter with heparin lock, or blood refluxing into the catheter[235]
- Failure to adequately flush routinely or before and after medication administration

Nonthrombotic or Mechanical Occlusions

Etiology

- Incorrectly set pump occlusion alarm
- Closed clamps on tubing
- Kinks or bends in catheter tubing
- Infant's position (i.e., flexion of extremity with PICC)
- Medication precipitation

Risk Factors

- Failure to adequately flush before and after medication administration or incompatible solutions
- Calcium-phosphate imbalance of TPN
- Lipid residue
- Fungus infection (e.g., *Malassezia furfur*)[44]

Signs and Symptoms for All Types of Catheter Occlusion

Signs and symptoms include

- sounding of pump occlusion alarms
- visible clots, particulate matter, or lipid residue in the catheter
- change in ability to aspirate or flush the catheter
- pain during infusion and fluid leaking at the catheter insertion site (due to a fibrin sheath).[151]

Identification

The cause of catheter occlusion should be evaluated by assessing the catheter site, equipment and tubing, and medication history and recent infusates.[22,225,236,237]

- The catheter should be inspected under the dressing for kinks and bends and secured to prevent bends or movement.[22]
- The hub and the external portion of the catheter should be checked for leaks and assessed for malpositioning and migration.[22] An X ray may be necessary to determine malposition and migration.
- Contrast injections through the catheter, venogram, or ultrasound can be used to detect fibrin sheaths or mural thrombosis.[225]

Management

The etiology determines the course of treatment.

- Repositioning may be required if the catheter is lodged against a vessel wall.
  - The infant can be moved from side to side or from prone or supine.
  - If the catheter is in an extremity, the arm or leg can be repositioned. Abducting or extending the arm can alleviate a catheter bend.
- Catheter salvage is preferred over catheter replacement. Although rare, catheter removal is necessary when a fungal occlusion occurs.[169]
- Use a clearing agent for medication precipitation. Instill an appropriate clearing agent to return the precipitate into a solution by creating a favorable pH balance. Most reports of success have been anecdotal. The volume of the clearing agent instilled should be the priming volume of the catheter (or be slightly more in the case of a thrombolytic); the volume should be adequate to provide interaction with the occlusion, but not excessive to minimize entry into the bloodstream.[1]

- A protocol should be in place and staff trained in the procedure. The risks and benefits of the procedure must be examined to determine whether the catheter is essential for care.
- Catheter-clearing agents can be instilled into the catheter using one of these techniques:
  - Gentle flush: Use for catheters with partial occlusion or sluggish lumen.
  - Negative pressure using a three-way stopcock for total occlusion:
    1. Attach the stopcock to the hub of the catheter.
    2. Using a 10-ml syringe, aspirate until enough resistance is felt to indicate the presence of a vacuum within the catheter.
    3. Attach a 1-ml or 3-ml syringe containing the clearing agent.
    4. Open the stopcock to the syringe containing the clearing agent, and the agent will be gently drawn into the catheter.
    5. Close the stopcock to the patient to allow the cleaning agent to dwell within the catheter for the prescribed time.
    6. Verify the catheter patency by assessing for blood return.
    7. If patency is achieved, aspirate the clearing agent and blood from the catheter, flush the catheter well with saline, and begin infusion of prescribed fluids.

Thrombolytics and Clearing Agents

In the event of thrombotic occlusion, thrombolytic agents are instilled into the catheter according to the manufacturer's recommendations.[237] Tissue plasminogen activators (tPA), also known as alteplase, have been used in neonates and are the approved thrombolytic agent for catheter clearance in children and adults. The use of tPA has been frequently described for the treatment of vascular thrombus in neonates, but less so for catheter-related thrombus.[237] For occlusions related to calcium-phosphate precipitate, parenteral nutrition, and acidic drugs, 0.1 *N* hydrochloric acid (HCl) may clear the blockage.[238] An amount equal to the catheter volume is instilled into the catheter. After 20 minutes, the HCl is withdrawn. If patency has not been restored, the procedure can be repeated once or twice. If HCl is not available, L-cysteine has shown effectiveness in clearing occlusions caused by drugs with acidic pH.[239]

Sodium bicarbonate (1 mEq/ml) has been reported to clear alkaline drug-related occlusions by restoring the alkaline environment and allowing the precipitate to regain solubility. An amount equal to the catheter volume is instilled into the catheter. After 20 minutes, the sodium bicarbonate is withdrawn. If patency has not been restored, the procedure can be repeated once.[237,240]

For lipid occlusions, 70% ethanol, which breaks down lipid, is instilled in an amount equal to but not exceeding the catheter volume and is allowed to dwell for 1 to 2 hours. The ethanol then is withdrawn. If patency has not been restored, the procedure can be repeated once.[238]

Prevention

- Heparinization of continuous infusion fluids reduces the risk of thrombotic occlusions.[241] (See "Infusion of Fluids" for more information.)
- Consider the minimum infusion rate orders based on the NICU outcome data reporting rate of thrombotic catheter occlusion.[122]
- The flushing method must be monitored. Use pulsatile movements (i.e., short bursts) when flushing.
- Ensure compatibility of medications and coinfusing solutions.
- Create a positive or neutral pressure within the catheter when heparin locking (refer to the heparin-locking procedure).
- Flush before and after giving medications or changing solutions to prevent drug incompatibility and precipitate formation.[242]
- Promptly respond to occlusion alarms on the infusion pump.
- Confer with a pharmacist to ensure TPN components are balanced to minimize precipitate formation.

Assessment after clearing

Possible complications related to the clearing agent and the procedure include catheter damage and leakage.

Catheters that Resist Removal

Catheters infrequently resist removal at the conclusion of therapy. Most catheters can be removed over time (some take a few days to remove) and do not require surgical intervention. Aggressive traction ***should never*** be applied during removal due to the risk of catheter breakage, catheter embolism, and venous damage.

Etiology

- Venous spasm caused by mechanical irritation of the vein by catheter movement or patient anxiety accounts for the majority of cases. The catheter may be partially removed with the tip being in the peripheral circulation before resistance is encountered.[230,243]
- Thrombus may trap part or all of the catheter within the vein during the removal process.[230,244,245] Thrombus may be associated with infection (e.g., *Staphylococcus epidermidis, Malassezia furfur*) and the catheter may become adherent to the vein wall.[44,245]
- Phlebitis and thrombophlebitis may contribute to resistance.[243]
- The presence of a fibrin sheath can cause resistance. The catheter may be partially removed before the sheath assumes an accordion appearance and is seen in the peripheral portion

of the vein, or a lump is visible or palpated and resistance is encountered.[246]
- Fibers (e.g., lint) attached to the fibrin may contribute to resistance to removal.[220,246]

Procedure

- Apply warm compresses along the entire length of the vein track for 20–30 minutes, then attempt removal.[245] If the PICC still cannot be removed, one to two additional attempts to remove the catheter during the following 12 to 24 hours are reasonable. Continue to apply intermittent warm compresses along the vein track, then reattempt removal. Avoid tension or stretching of the catheter as this may lead to catheter breakage,[220] which may require a venotomy. In between catheter removal attempts, perform skin antisepsis and apply a sterile dressing to the site.
- Avoid applying traction to the catheter, due to the risk of unmonitored catheter breakage and subsequent embolism.[220]
- If the catheter is not easily removed on first occaison of attempted removal, evaluate catheter location radiographically or with ultrasound to determine etiology and further strategies for removal.
- Other measures that can be considered, based on suspected cause, include
  - placing a tourniquet on the extremity above the catheter tip to dilate the vein
  - flushing through the catheter[243]
  - rotating and repositioning the extremity[243]
  - massaging the skin overlying the vein[230]
  - using relaxation techniques[220]
  - obtaining a radiograph to rule out knots in the catheter and an ultrasound to rule out thrombus as etiology for resistance[44,247]
  - seeking interventional or surgical consult for catheter removal.[220,246,247]
- If catheter breakage occurs, grasp the external segment of the catheter to prevent embolism.
  - If embolism occurs, apply proximal compression overlying the vein containing the catheter with your hand or a tourniquet to trap the catheter within the peripheral circulation. Place the infant on the right side to trap the catheter within the right heart.[230]

Prevention

- Identify proper PICC tip location within the vena cava.
- Use infusates that are appropriate for tip location.
- Use a no-touch technique when manipulating the catheter.
- Remove the catheter slowly without visibly stretching it.

Drainage from Catheter or Insertion Site

Drainage at the insertion site may be a normal serous fluid or represent a leak in the catheter due to catheter damage or a fibrin sheath surrounding the catheter.

Etiology

- Leaks can be caused by excessive pressure created by syringes, sharp objects (e.g., clamps, introducers) piercing the catheter, and the catheter having been flushed against resistance.
- Leaks can signify a catheter obstruction.[18]
- Leaks can be seen at the catheter hub or external portion of the catheter, usually due to damage.
- Fibrin sheath formation along the catheter allows fluid to follow the path of least resistance back down the catheter. Fibrin sheaths can cover the tip of the catheter or travel part or all of the way down the catheter to the entrance site. Ultrasound or contrast injection can diagnose fibrin sheaths.

Prevention

To prevent leaks,

- use techniques to minimize catheter damage (i.e., do not apply clamps or sharp objects to the catheter or hub, use the appropriate syringe size and pressure when infusing, do not flush when resistance is encountered)
- do not pull the catheter back through the needle introducer
- cautiously remove break-away needles
- secure the catheter and extension tubing to the patient to prevent stretching and breakage.

Management

If a leak occurs because of a catheter fracture, prevent embolization of the catheter (see "Catheter Embolism"). Determine whether the catheter can be exchanged for a new catheter[230] or whether removal is necessary.

Extremity Edema

Throughout the catheter dwell, mild to gross edema surrounding the insertion site or in the extremity may be identified.

Etiology

This condition can be caused by the following factors:

- restrictive dressing
- bend in the extremity
- dependent positioning
- decreased movement
- thrombus
- catheter that is so large for the size of the vein that it restricts adequate venous return
- extravasation of infusate.

Treatment

The treatment is based on the cause.

- Redress and straighten the extremity, then elevate.

- Measure the circumference of the proximal portion of the extremity and compare with the opposing extremity until the edema improves.
- Obtain a venogram or ultrasound if thrombus is suspected.
- If the edema is mild and stable without compromising the health of the extremity, the catheter may be left in place if it is monitored vigilantly.
- If the edema is progressive or if the extremity is compromised, consider removing the catheter.

Neurologic Complications

The most commonly reported neurologic symptoms stem from catheters placed via veins in the lower extremities. For catheters inserted via upper extremity veins, see "Phrenic Nerve Injury." PICCs inserted via a lower-extremity or femoral vein pose a risk of entering the ascending lumbar veins rather than the inferior vena cava. The ascending lumbar veins drain the vertebral venous plexus into the common iliac vein. Infusion through a catheter in this location can result in venous stasis and pressure and fluid transmitted to the spinal cord, thereby leading to a variety of neurologic complications, including paralysis.[92,248] Migration of the central venous catheter or redistribution of the infusate into the ascending lumbar vein is thought to occur in infants who are experiencing an increase in intra-abdominal pressure (i.e., abdominal distention, necrotizing enterocolitis, repaired congenital diaphragmatic hernia)[249,250]

Risk Factors

- Left-sided insertions pose a higher risk of entering the ascending lumbar vein because of the angle of entry from the common iliac vein.[251,252]
- Difficulty advancing the catheter to a premeasured depth also represents a risk for malposition and neurologic complications.[251,252]
- The rapid insertion technique has been anecdotally linked to catheter malposition.
- Catheters allowed to reside in the femoral, iliac, or lower portion of the inferior vena cave have migrated into or near the ascending lumbar vein or produce venous thrombus and lead to retrograde flow into the ascending lumbar vein.[249,253,254]

Signs and Symptoms

- The infant may be asymptomatic, particularly if the malposition is identified on initial postinsertion radiographs.[255]
- Lack of blood return has been noted from some catheters, particularly upon insertion.[256]
- Resistance when the catheter is inserted[251]
- Sepsis-like symptoms such as unexplained respiratory distress and lethargy[92,252,257]
- Cerebrospinal fluid on lumbar puncture may appear milky with abnormal levels of glucose, protein, or lipids on analysis.
- Seizures, flaccid quadriplegia, or neurologic deficits[252,256,257]
- Death[256]
- Radiographic findings
  - left-sided insertion that fails to cross the midline to enter the inferior vena cava and appears to overlay the spine[251,252]
  - a bend or hump in the catheter at the L4-5, or L5-S1 level on AP view, particularly on left-sided insertions and when the catheter is threaded to or beyond the level of L3[251,252,258]
  - a marked posterior deviation of the catheter at L4-5 on a lateral view[248,252]
  - a 360° curl or loop in the catheter in the inguinal region prior to advancement up the ascending lumbar vein[255,259]
  - on lateral view, posterior deviation of the catheter crossing over the spine[259,260]

Prevention

- Maintain a high index of suspicion throughout treatment. Experienced personnel should meticulously assess the radiograph for the catheter location. Observe the length of the catheter from the leg to the tip for subtle clues of malposition.[248,252,255]
- If malposition is suspected, obtain a lateral view radiograph. The catheter presenting anterior to the spinal column is typically in the inferior vena cava, while the catheter deviating posteriorly may be in the ascending lumbar vein or epidural space[41,252,259,260]
- If a plain radiograph does not demonstrate malposition, a contrast injection through the catheter may provide additional information, however, there is some concern that this may lead to irritation or damage.[252]

Medical Device Reporting and MedWatch

MedWatch is the FDA's Safety Information and Adverse Event Reporting Program to provide postmarket surveillance to protect public health. When a medical device causes or contributes to the death of a patient, federal law requires that user facilities report the incident to the FDA and manufacturer within 10 working days.[261]

Other device complications that must be reported to the manufacturer within 10 working days include

- serious injury caused by the device
- life-threatening event
- permanent impairment of a body function or permanent damage to a body structure
- necessary medical or surgical intervention to preclude permanent damage or impairment.

Healthcare professionals, patients, caregivers, and consumers may also submit voluntary reports of significant adverse events or issues with medical products to the FDA via the Medwatch program (www.fda.gov/Safety/MedWatch/default.htm).

The goal of reporting is to improve patient care by identifying problems unforeseen at the time of the initial FDA product review. The facility is responsible for adhering to reporting requirements and faces substantial penalties for failing to report qualified incidents. User facilities should make these reports to the FDA Center for Devices and Radiological Health.

Catheter Care and Maintenance

All providers who care for infants with PICCs must be knowledgeable about effective management to prolong the catheter's duration while minimizing complications and injury to the infant. Maintaining a team of caregivers to change dressings and provide expertise in the early detection of complications has been found to reduce complications and enhance success with PICCs.[58,72,77] Each patient care unit should have protocols to address the following areas.

Assessment and Documentation

The following factors related to the PICC should be monitored and documented in the medical record every hour and more frequently as necessary:

- site (i.e., color, appearance, temperature, presence of drainage, bleeding, edema, erythema). The area along the course of the vein should be palpated for pain or venous cord.
- catheter (i.e., the amount outside the body, configuration of the catheter, presence of kinks or bends, leaking of fluid from catheter tubing, precipitate in catheter or tubing)
- patency (i.e., the ability to infuse fluid or flush, the presence of a blood return if evaluated)
- dressing (should be intact around edges and hold the catheter in place in the center of the dressing; no part of the catheter, except the hub, should protrude from the dressing)
- infusion pump occlusion alarm setting
- infusion tubing (i.e., security of connections, precipitate in tubing)
- complications specific to the known location of the catheter tip (i.e., a tip in the subclavian vein near the shoulder or midline catheter can lead to development of edema and erythema over the site).

Hourly assessment and documentation should cover visual inspection of the site, from the insertion site and dressing along the course of the vein to the tip location and include the quantity of fluid infused by the infusion pump.[18,22]

The use of blood pressure cuffs or tourniquets should be avoided on an extremity with a PICC because of the risk of vessel or catheter damage.

Infusion Tubing Configuration

The configuration of the infusion tubing is integral to the efficient and safe use of the PICC. Infants may require a continuous infusion of one or more fluids along with continuous or intermittent medication administration. When assembling the infusion tubing, requirements for all infusates must be considered to ensure the appropriate number of needleless access devices are available for set-up and to prevent unnecessary access to the catheter.

- Infusion tubing should be assembled using clean technique, however, using sterile technique is a part of the successful multidimensional efforts to decrease CRBSI.[51]
- All infusion tubing connected to the PICC should be luer-locked.
- To minimize entry into the PICC and decrease the risk of contamination, intermittent injection tubing (used for medication administration) should remain attached to the primary administration set and not removed after each injection.[50] A closed medication system (i.e., entry restricted to once every 24 hours) used as a component of a multidimensional strategy to decrease CRBSI was found to significantly decrease the incidence of CRBSI.[45,50]
- Eliminate stopcocks from tubing and instead use needleless access devices, which must be vigorously cleaned with alcohol, povidone, or chlorhexidine/alcohol before entry.[45,51,262,263] A minimum of 10 to 15 seconds of vigorous friction with alcohol or chlorhexidine/alcohol followed by adequate drying has been shown effective in preventing transfer of micro-organisms.[263,264] For disinfection of needleless connectors, follow the specific manufacturer's recommendations for the antiseptic solution or passive disinfection device selected.

Medication Administration

Providing medications through the PICC is an expected function of the device. Safety with this process is integral to the successful dwell of the catheter. The long, narrow catheter configuration provides an opportunity for mixing of incompatible infusates. Care must be exercised when following the established principles of medication administration.

- Flush thoroughly before and after the administration of medications with normal saline (if this is not contraindicated based on infusate).
- Ensure medication is compatible with other infusates.
- If a PICC is heparin locked, flush the PICC before injecting medication, and flush with normal saline

before instilling heparin back into the catheter to prevent precipitation.
- Consider using a closed medication delivery system as described by Aly and colleagues. [50]

Infusion of Fluids

- Fluids should be heparinized to prevent thrombotic catheter occlusion and prolong catheter survival. [241] No increase in heparin-induced thrombocytopenia or hemorrhage was identified with the addition of 0.5 units/kg/hr of heparin.
- Catheter lumens smaller than 26 gauge are difficult to maintain patency without a continuous infusion of fluid.
- Fluids should be administered by an infusion pump.
- There are no data to suggest a minimum amount of hourly flow is required to maintain catheter patency, although 1 ml/hour is the most frequently reported minimum hourly rate. [110] This may differ depending on the infusion characteristics of individual pumps, length of catheter dwell, flushing protocols, and the size of the catheter. Hospitals should monitor the occlusion risk as defined in their outcome data to determine the effect of infusion flow rate on occlusion.

Flushing

Maintaining patency of these small-bore catheters requires meticulous care to prevent occlusion due to thrombus or precipitate.

Frequency

- Flush before and after administering potentially incompatible solutions and medications.
- If routine blood sampling is desired, consider flushing with 1 ml twice a day to enhance patency.
- Flush as needed to assess catheter patency.

Flush Solution

- Both sodium chloride and diluted heparinized saline solutions (dextrose solutions may be used if medication is incompatible with saline) have anecdotally been described. The preferred use will be facility specific.
- Solutions should be obtained from a single-use vial or syringe.[48,265] Multiuse containers as well as flush syringes manually filled by nurses have been associated with an increased risk of contamination. The syringe should be used one time and discarded.[266,267]

Volume of Flush

- Data are not available to suggest the appropriate volume to instill with each flushing action.
- At least twice the catheter volume and any add-on devices, such as extension tubing, has been suggested as reasonable.[108] Depending on specific equipment, this may be approximately 1 ml.

Syringe Size

For safe practice, do not rely on syringe size alone when delivering medications or solutions; consider all of the factors mentioned below.

Syringe size dynamics:

- Follow the catheter manufacturer's recommendations for the minimum syringe size for manual infusion (most specify a 5- or 10-ml syringe).
- Use a technique to infuse that will be within the maximum pressure limits (i.e., pounds per square inch [psi]) for the catheter and does not create catheter damage.
- The smaller the syringe, the greater the pressure that is exerted. Using normal manual pressure to deliver a solution from a full 1-ml syringe can generate more than 300 psi and a full 10-ml syringe will generate less than 40 psi.[268,269]
- The greater the force applied on the syringe plunger, the greater the pressure delivered to the catheter. Even the largest syringe can deliver excessive pressure if great force is applied.[268]
- Applying too much pressure on the catheter and flushing when resistance is felt can lead to the fracture or embolization of the catheter.[43,218] A PICC should never be forcefully flushed if resistance is felt.
- Syringe pumps also can exceed the catheter's burst strength when small-volume syringes are used. Check with the syringe pump's manufacturer.

Catheter Material

PICCs made of polyurethane have greater tensile strength than those made of silicone. This makes them more resistant to damage due to applied pressure and may allow for use of syringes smaller than 10 ml.[131]

Cathether Patency

- Completely patent catheters outside of the body offer no resistance to flow. Fluid will exit without increasing pressure inside the catheter.
- Once a catheter is inserted into the body, complete patency cannot be ensured, especially when resistance to flushing is encountered, is sluggish, or no blood return is appreciated.
- The smallest neonatal catheters may offer some resistance to flushing due to the small size of the internal lumen.

Management of Heparin Locks

Catheter lumens larger than 28 gauge or 1.9 F may allow intermittent heparin locking. Saline locks for PICCs have not been studied in the small-size catheters used in infants and are not a recommended option for maintaining patency at this time. Anecdotal reports suggest limited success maintaining catheter patency with heparin lock, given that most PICCs are used for continuous infusion in the NICU.[122]

Heparin Concentration

The concentration of heparin reported to be effective varies from 1 units/ml to 10 units/ml. Greater success has been found using the 10 units/ml concentration. [122,235]

Flush Volume

- There are no data to suggest the most appropriate volume to instill with each flushing action.
- At least twice the catheter volume and any add-on devices, such as extension tubing, has been suggested as reasonable. Depending on the specific equipment, this may be approximately 1 ml.
- Do not completely depress the plunger when flushing to prevent reflux into the catheter at the conclusion of the procedure.[235]

Frequency

- Heparin locks should be flushed every 6 hours.[108]
- Flush with flush solution before and after giving medications and incompatible solutions to prevent reactions leading to precipitation and lock with heparinized saline (10 units heparin/ml).[242]
- Using a pulsatile method (i.e., short bursts or start-stop technique) creates turbulence within the catheter and has been anecdotally linked to enhanced clearing of substances and blood residing within the catheter.[22]
- Prevent blood reflux into the catheter following flushing or locking by using one of the following methods:
  - Withdraw the syringe from the injection port or clamp the extension set as you infuse the last 0.5 ml.
  - For valve-style injection ports, clamp the tubing while injecting the last 0.5 ml of flush.
  - Use a positive or neutral displacement device attached to the hub of the catheter or extension set to create positive pressure.

Blood Sampling and Administration

Withdrawal of blood specimens through a PICC carries a theoretical risk of catheter occlusion. Anecdotal reports of success in reliably using catheters of 24 or 26 gauge or 1.9 F size for blood sampling and blood administration are slowly increasing. Further research is needed.

- Catheter lumens smaller than 26 gauge have been considered too restrictive to allow this practice. Evidence supports this practice through a 3 F PICC without a significant increase in occlusion or other catheter-related complications.[270]
- Using a push-pull method to decrease iatrogenic anemia has demonstrated accurate values in pediatric oncology patients.[271] The value of some tests may not be accurate when the blood has been drawn through the PICC (i.e., blood glucose when dextrose-containing solutions are infusing, coagulation studies due to heparin in the catheter, therapeutic drug levels due to residual drugs present in the catheter).
- A second PICC may be considered to be strictly used for blood sampling.

Drawing Blood Specimens

1. Perform good hand hygiene and apply clean gloves.
2. Pause the infusion pump.
3. Place a sterile 4 x 4 gauze pad under the needleless access device and disinfect with alcohol, chlorhexidine/alcohol, or PI for 10 to 15 seconds using vigorous friction prior to each entry. Allow sufficient drying time for the disinfectant.
4. Flush with at least 0.5 ml of flush solution.
5. Withdraw at least two times the catheter and extension set volume to clear the catheter of infusates. (For most neonatal PICCs this averages 1 ml.) A push-pull method may be considered, but there is an increased risk for hemolysis due to agitation of the blood. Place cap on syringe.
6. Attach the specimen collection syringe and obtain specimen.
7. Reinfuse the withdrawn blood to clear the catheter if the infusate contains heparin (otherwise microclots may be present in this syringe.[272]
8. Flush the catheter well with flush solution using at least twice the volume of the catheter and extension set. This is approximately 1 ml. Change needleless access device after blood draw.[108]
9. Resume infusion.
10. Perform hand hygiene.
11. Document the amount of blood drawn and the test obtained.

Troubleshooting Techniques

If difficulty is encountered when obtaining the specimen, consider the following techniques:

- Use a small-volume syringe for aspiration. This exerts less negative pressure on the catheter during the withdrawal of blood and facilitates sampling by making the catheter less likely to collapse.
- Reposition the infant's extremity to alter the position of the catheter.
- Flush with a small amount of normal saline.

Tranfusion of Blood Products

Some NICUs use catheters 26 gauge or 1.9 F for administration of blood products. No hemolysis has been noted using 1.9 F catheters.[273] Success has been reported for packed red blood cell transfusions in extremely-low-birth-weight infants using 27-gauge catheters.[274] Consider the effects of interruption of maintenance infusion, such as hypoglycemia, increased frequency of entry into the catheter, and the potential for occlusion in a benefits versus risks analysis.

Catheter Repair

Catheter repair is no longer recommended. Catheter repair more than doubled the incidence of CLASBI in pediatric patients.[275] When catheter damage has occurred, consider these alternative options:

- Evaluate the duration and type of therapy for continued vascular access needs.
- Evaluate the type of therapy needed and alternate administration routes (oral).
- Evaluate the type and duration of therapy and alternate device solutions (PIV, midline, CVL).
- Exchange the catheter at the same site.
- Initiate a new PICC at another site.

Dressing Changes

A secure dressing holds the catheter in place and is intended to minimize catheter migration. Dressing-change practices have been subjected to little formal evaluation in neonates. One small study using transparent, semipermeable polyurethane dressing showed that dressings could be left in place as long as 17 days until they demonstrated signs requiring a dressing change without increased risk for infection.[49] Most NICUs change dressings only when dressing integrity is lost, which is supported by low rates of infection.[45,51] Reports of routine, weekly dressing changes are surfacing as components of bundles designed to decrease the incidence of CRBSI, although there have been no randomized clinical trials to support this practice.[50] NICUs that have implemented central line–bundles, including changing the dressing when nonocclusive, have reported significant decreases in CLABSI.[45,51] Reducing dressing disruption is associated with a lower CLABSI rate.[52] Premature neonates have fewer layers of stratum corneum, which should be considered when developing protocols in dressing change frequency. Repeated removal of transparent dressings can contribute to compromised skin and barrier development.[53] In light of the potential for damage to the stratum corneum and risk for inadvertent dislodgement of the catheter when the dressing is removed, a dressing change is recommended in the following situations:

- Transparent dressings should be changed when they become nonocclusive, no longer adhere to the catheter or skin, or are damp or soiled.[4,47,49]
- Dressings with gauze and tape, a transparent dressing with gauze placed underneath, or an occlusive tape on top require changing every 48 hours.[1,4]
- When there is bleeding at the insertion site, consider the use of a hemostatic agent, which can be applied under the dressing to promote adherence and prevent catheter migration.[1] If a sterile hemostatic agent is used, the dressing should be changed according to the manufacturer's recommendation for the specific agent or if visible blood obscuring the insertion site is present at 24 hours.
- If a chemically impregnated product is incorporated into the dressing, without patient-related indications, follow manufacturer's recommendations for maximum effective duration.

Dressing changes should be performed using sterile technique. Consider a two-person procedure to minimize the risk of contamination. At a minimum, those making contact with the area of skin or the catheter under dressing and those assisting with the procedure should wear face masks and sterile gloves. If contamination of the catheter is possible or a long segment of the catheter is external, consider using sterile drapes, hair covering, and a sterile gown. Assistants should wear a face mask. Securement devices under the dressing should be removed and replaced per the manufacturer's recommendation, and skin antisepsis performed prior to placing a new dressing.

Catheter Removal

Personnel removing PICCs should be educated on the appropriate techniques for removing catheters without ensuing complications. The infant should be calm both before and during the process. To remove a catheter:

1. Gently remove the dressing by grasping the edge of the most distal corner and gently stretching the dressing in a distal direction. This breaks the adhesion, allowing the transparent material to lift away from the skin.
2. Remove the catheter using a slow, steady motion. Grasp the catheter, not the hub, as the removal progresses. Hold the catheter close to the insertion site (this allows better control and earlier identification of tension). Rapid removal and application of pressure to the vein over the site can allow the catheter to contact the vein wall and stimulate vasoconstriction.
3. Measure the length of the catheter removed and compare with the documented inserted length. If the removed length of the catheter is less than the length that was inserted, notify the medical care provider immediately. This discrepancy warrants investigation as embolization may have occurred.
4. Document the length removed, the appearance of the site, the patient's tolerance of the procedure, and any complications encountered during removal.
5. Cover the insertion site with petroleum-based ointment and apply a sterile occlusive dressing for 24–48 hours to decrease the risk of air embolism.[1,54,55]
6. If resistance to removal is encountered, do not proceed. Do not attempt to remove a catheter by applying tension to the device. Redress the site using a sterile technique and refer to strategies outlined

under "Catheters that Resist Removal." Pulling against resistance can damage the vein wall and weaken the integrity of the catheter, leading to catheter fracture and possible embolism.

New Technology

Neonatal PICC practices continue to evolve, enabled by emerging technology and more recently available miniaturization of equipment. The increasing adoption of MST provides a needed solution for some neonates.[67,69] The importance of accurate knowledge of catheter tip location remains in the forefront as healthcare providers strive to establish and maintain these invaluable lifelines for the most vulnerable of patient populations. New strategies for catheter tip confirmation include intravascular electrocardiographic coordination with cardiac rhythm and intravascular ultrasound.

Conclusion

Maintaining vascular access is critical for the survival of extremely-low-birth-weight neonates and infants. New technological advances and a collaborative team approach by educated providers enable the use of PICCs as a life-saving device for infants. PICCs offer a cost-effective approach to care and minimize pain, stress, and risk of infection associated with multiple PIV insertions. PICCs not only can be used during hospitalization, but also facilitate early discharge by allowing for home-based infusion therapy. The use of PICCs should be considered a standard of care for infants who require long-term IV therapy to minimize stress and pain and to promote the delivery of medications and solutions into the most appropriate vessel. PICCs should be used as a first-line choice rather than a last resort. Education and training for healthcare providers form the cornerstone of the future of neonatal PICC practice. NANN endorses appropriate training in the insertion and maintenance of PICCs for healthcare providers as a means of ensuring optimal outcomes for our tiny patients.

Appendix A. Clinical Competencies for the Nurse

COMPETENCIES			
	Step	***Verbalize***	***Demonstrate Competency***
Clinical Competencies for PICC Inserter			
1.	Identify the indications for use of a PICC.		
2.	Identify possible contraindications or special considerations for use.		
3.	Explain to the family the procedure, risks, benefits, and potential complications.		
4.	Perform physical assessment to select the best accessible vein based on the infant's diagnosis and therapy needs.		
5.	Demonstrate and correctly measure the length of catheter to use for the selected insertion site and desired catheter tip location.		
6.	Assess the need for pharmacologic agents and obtain order as indicated.		
7.	Use developmental positioning to facilitate stabilization and comfort.		
8.	Select catheter of appropriate size and number of lumens for the size of the selected vein and the infant's identified infusion needs.		
9.	Gather materials, kit, and catheter. Use hair covering and mask.		
10.	Prepare catheter.		
	a. Prime the catheter with flush solution.		
	b. Trim the catheter based on required measured insertion length.		
	c. Demonstrate care of stylet during trimming process.		
11.	Select an appropriate catheter introducer and demonstrate insertion and removal technique.		
12.	Discuss and demonstrate PICC insertion per procedure including the rationale for decisions.		
13.	Flush the catheter using a pulsatile technique.		
14.	Identify catheter tip placement on radiograph.		
15.	Demonstrate sterile technique during insertion.		
16.	Demonstrate dressing stabilization of the catheter and added tubing during the initial application of the dressing.		
17.	Document the procedure and placement according to facility guidelines.		
Clinical Competencies for the RN Caring for the Infant with a PICC			
1.	Demonstrate how to assess and maintain catheter placement.		
2.	Maintain strict aseptic technique for all catheter management, including tubing changes, medication delivery and blood sampling.		
3.	Demonstrate how to flush and heparin lock the catheter.		
4.	Use sterile technique during a dressing change.		
5.	Demonstrate technique for obtaining blood specimens via PICC.		
6.	Discuss the complications that can occur while a PICC is in place.		
7.	Demonstrate sterile technique and stabilization of the catheter during the application of the dressing including stabilization of the extension tubing.		

Appendix A. Clinical Competencies for the Nurse *(continued)*

COMPETENCIES			
	Step	***Verbalize***	***Demonstrate Competency***
8.	Describe how to instill a thrombolytic or clearing agent into an occluded catheter.		
9.	Describe and demonstrate catheter removal.		
10.	Discuss the management to remove a retained catheter.	.	
11.	Identify the complications that can occur as a result of PICC placement or while the catheter is indwelling along with possible intervention and prevention strategies.		
	a. Phlebitis		
	b. Bleeding		
	c. Migration/dislodgement		
	d. Infiltration (peripheral, pleural, pericardial, peritoneal leakage)		
	e. Occlusion		
	f. Catheter-related bloodstream infection		
12.	Document all interventions and assessment for PICC lines according to facility guidelines.		

Appendix B. Troubleshooting Guide

Problem	Assessment Considerations/Possible Solutions
Sounding of pump occlusion alarm	• Is infusion tubing clamped or pinched? • Reposition patient or extremity of insertion. • Catheter kinked, either externally or internally.
Catheter cannot be flushed	• Assess external catheter for kinks/bends. • Check the minimum infusion rate. • Determine if needleless access device is occluded.
Vein at insertion site is red and hard	• Evaluate for and treat if mechanical phlebitis.
Extremity with catheter is edematous	• Is dressing constricting? • Potential for vascular thrombus within extremity • Reposition extremity if dependent positioning.
Catheter cannot be removed	• Refer to strategies for catheters resistant to removal.

Appendix C. Education Resources for Parents

These are examples of resources that can inform parents, help them to better understand the PICC procedure and their child's needs, and facilitate family-centered care.

PICC or Midline Placement: Part of the Way to Grow Health Information from Children's Hospital of the King's Daughters, this webpage is at www.chkd.org/Patients-and-Families/Health-Library/Way-to-Grow/PICC-or-Midline-Placement.

An Introduction to Your Child's Peripherally Inserted Central Catheter (PICC): The English version of this colorful seven-page PDF from UC Davis Children's Hospital in Sacramento, CA, can be accessed directly at www.ucdmc.ucdavis.edu/children/patients_family_resources/Patient_and_Family_Education_A_to_Z/PDFs/PICC_Catheter_2015.pdf. (For other languages, scroll down to PICC and Port at www.ucdmc.ucdavis.edu/children/patients_family_resources/Patient_and_Family_Education_A_to_Z/index.html.)

Appendix D. Sample PICC Insertion Form

MRN ______________________________

Baby ______________________________

DOB ______________________________

PICC PROCEDURE NOTE

Note started: ______________ Date of service: ______________ LOS: ______________

Preprocedure diagnosis: ______________________________

Postprocedure diagnosis: ______________________________

Patient's specific hospital location during procedure: ______________________________

License of inserter: ______________________________

Ordering MD/NP: ______________ Service: ______________

PI #: ______________ Contact number: ______________

Was inserter a member of PICC team: ☐ YES ☐ NO

Reason for insertion Indication: ______________________________

PICC Use: ______________________________

Appropriate procedural pause ☐ WAS ☐ WAS NOT taken.

Inserter performed hand hygiene prior to central line insertion: ☐ YES ☐ NO

Maximal sterile barriers used: ______________________________

Skin Prep:

*Sterility: ______________________________

*Skin Prep: ______________________________

Skin prep completely dry at time of first skin puncture: ☐ YES ☐ NO

Modified Seldinger insertion technique ☐ WAS ☐ WAS NOT utilized.

Ultrasound guidance ______________________________

*Insertion site: ☐ RIGHT ☐ LEFT

PICC VEINS: ______________________________

VEIN: ______________________________

______________ CM ☐ ABOVE ☐ BELOW the ACF

Measurements:

Internal length (IL): ______________ CM External length (EL): ______________ CM

MAC mid-arm circumference (MAC): CM measured @ CM above ACF.

PICC catheter:

Type of PICC: ______________________________

*Lumen: ______________________________ *Size: ______________________________

Lot #: ______________________________

Vein accessed using: ______________________________

Blood return: ☐ YES ☐ NO Saline lock: ☐ YES ☐ NO Heparin lock: ☐ YES ☐ NO

Postprocedure:

Estimated blood loss: ______________________________

Complications: ______________________________

Comments: ______________________________

Postprocedure CXR: ______________________________

Did this insertion attempt result in a successful central line placement? ☐ YES ☐ NO

**Data needed by Infection Control for Central Line Insertion Practices (CLIP) reporting*

CLIP notification required for each line note (PICC) Inserted by ______________________________

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