EB MEDICINE

PEDIATRIC EMERGENCY MEDICINE PRACTICE

AN EVIDENCE-BASED APPROACH TO PEDIATRIC EMERGENCY MEDICINE ▲ EBMEDICINE.NET

Vascular Access in Pediatric Patients in the Emergency Department: Types of Access, Indications, and Complications

Abstract

Vascular access is a potentially life-saving procedure that is a mainstay of emergency medicine practice. There are a number of challenges associated with obtaining and maintaining vascular access, and the choice of the route of access and equipment used will depend on patient- and provider-specific factors. In this issue, the indications and complications of peripheral intravenous access, intraosseous access, and central venous access are reviewed. Timely and effective assessment and management of difficult-access patients, pain control techniques that can assist vascular access, and contraindications to each type of vascular access are also discussed.

June 2017
Volume 14, Number 6

Authors

Rachel Whitney, MD
Clinical Fellow, Department of Pediatrics, Section of Emergency Medicine, Yale University School of Medicine, New Haven, CT

Melissa Langhan, MD, MHS
Associate Professor of Pediatrics and Emergency Medicine; Fellowship Director, Director of Education, Pediatric Emergency Medicine, Yale University School of Medicine, New Haven, CT

Peer Reviewers

Jennifer Bellis, MD, MPH
Clinical Fellow, Department of Pediatric Emergency Medicine, Icahn School of Medicine at Mount Sinai, New York, NY

Stephanie Leung, MD, FAAP
Director of Pediatric Point-of-Care Ultrasound Fellowship, Assistant Professor, Section of Emergency Medicine, Department of Pediatrics, Baylor College of Medicine & Texas Children's Hospital, Houston, TX

CME Objectives

Upon completion of this article, you should be able to:

1. Discuss the indications for, advantages of, and disadvantages of different vascular access options.
2. Employ device-assisted techniques for access.
3. Utilize appropriate procedural analgesia methods.

Prior to beginning this activity, see "Physician CME Information" on the back page.

Click on the icon for a closer look at tables and figures.

Case Presentations

A 16-year-old adolescent boy with a history of acute lymphoblastic leukemia presents to the ED with fever and a headache. He is undergoing induction chemotherapy with vincristine and doxorubicin. His last medication administration was 2 weeks ago. His vital signs are: temperature, 39°C (102.2°F); heart rate, 160 beats/min; blood pressure, 80/40 mm Hg; and oxygen saturation, 98% on room air. The nursing staff immediately places him in a room. You recognize signs of shock and the need for rapid fluid resuscitation. Given his condition, he is likely to have difficult peripheral access. The nurse asks whether it would it be better to administer fluids by placing a large-bore peripheral IV line or by accessing his Broviac® catheter...

A 9-day-old girl who was born in Mexico and just moved to the United States is brought to the ED with vomiting and lethargy that have been increasing for the past 3 days. Her mother is no longer able to wake the baby. The baby is afebrile and unresponsive to voice. She has cool, mottled extremities with a capillary refill time of 5 seconds. Her heart rate is 180 beats/min and her systolic blood pressure is reported as 60 mm Hg by palpation. The nurses have been unsuccessful in obtaining access after multiple attempts. The resident who is working with you asks if an intraosseous needle can be placed in a 9-day-old baby. If so, can blood samples for laboratory tests be obtained from the site? Are there medications that are contraindicated through an intraosseous line?

A 2-year-old girl presented to her pediatrician's office after 3 days of nonbilious vomiting. She has been unable to eat or drink anything without vomiting. Her parents state that her last urine output was the prior evening. Although her doctor gave her oral ondansetron and attempted to rehydrate her orally in the office, the patient continued to vomit and she was transferred to the ED for further management. At triage, she is afebrile, her heart rate is 130 beats/min, and her blood pressure is 80/50 mm Hg. You discuss intravenous fluid hydration with the family. Her parents are nervous about the pain associated with the procedure and the possible need for multiple attempts. Can you predict whether or not it will be difficult to obtain intravenous access on this patient? How can you address their concerns about pain?

Introduction

Intravenous (IV) access is commonly required in the emergency department (ED) and is a critical life-saving procedure. Since the development of early techniques in the 1830s, there have been significant advancements in obtaining IV access. Advancements in vascular access include devices such as central-line bundles to help decrease infection and technology to assist in difficult IV placement and decrease the pain and anxiety often associated with access procedures.[1]

When choosing the equipment to use, it is important to consider the reason why vascular access is needed for that patient. Fluid flow through an IV catheter is determined by Poiseuille's law, which states that the viscosity of the fluid, the pressure gradient across the tubing, and the length and diameter of the tubing all affect the rate of flow. Therefore, for situations requiring rapid fluid administration, the shortest length and widest diameter equipment should be selected. This includes the catheter as well as the IV tubing.[2]

The ability to obtain vascular access is a paramount skill for the emergency clinician, as it is often a necessity for ill or injured patients. Obtaining vascular access can often be challenging, especially in the pediatric population. This issue of *Pediatric Emergency Medicine Practice* reviews the indications for obtaining vascular access, different types of access procedures, contraindications for each type of access, and methods for troubleshooting difficult cases.

Critical Appraisal of the Literature

The literature on vascular access was reviewed in PubMed using the search terms *pediatric intravenous access*, *successful intravenous placement*, *intraosseous access*, *central venous catheters*, *intravenous catheter complications*, *difficult intravenous access*, and related terms. The date range for the search was from 1950 to 2016. Nearly 10,000 articles were found using these parameters, and 108 were selected for review. Abstracts were reviewed for relevance to the topic, and articles cited within the search results were also considered for inclusion. The primary focus was on articles that involved vascular access in the ED setting. Where applicable, articles that reviewed vascular access techniques and complications from the pediatric and neonatal intensive care units were included. The available literature on the most recent technologies for assisting with difficult access and on techniques and medications for alleviating pain and anxiety around placement of an IV line was also reviewed. Citations ranged from informational review articles to randomized controlled trials, though the majority of articles were observational studies.

Types of Intravenous Access

Peripheral Intravenous Access

Peripheral intravenous (PIV) device placement is the most common method for obtaining vascular access in the emergency setting. Establishing PIV access can be quick, relatively painless, and allows for blood testing and medication or fluid administration. Duration of treatment, indication for treatment, type of solution, vein availability, and age are all factors to be considered when selecting the type and location of PIV access.

While all of these factors need to be considered, a guideline for catheter gauge selection is the following: 24-gauge for infants or patients with fragile veins, 22-gauge for children or elderly patients needing intermittent infusions, 20-gauge for adults or those with continuous infusion needs, and 18-gauge to 14-gauge (or the largest gauge possible in smaller patients) as necessary for trauma management or high-volume fluid resuscitation. In general, choosing the smallest gauge and shortest length catheter for the needs of the patient is the best practice.[3]

Indications for Peripheral Intravenous Access

Administration of Intravenous Fluids

The most common indications for a critically ill patient to receive IV fluids include severe hypovolemia, shock, sepsis, and oliguria.[4] As with all patient assessments, history and physical examination findings can help guide the decision to place an IV catheter for fluid administration.

Hypovolemia can be due to decreased oral intake (eg, nausea, refusal to take oral fluids) or increased loss (eg, vomiting, diarrhea, hemorrhage, third-spacing). IV fluid administration may also be needed without fluid loss if vascular tone is low, such as in the setting of distributive shock. Tachycardia is often the first sign of hypovolemic or distributive shock in children.

Early recognition of hemodynamic instability with tachycardia, especially in the setting of normothermia, should trigger consideration for establishing IV access. In early compensated shock in children, blood pressure is often normal for age.[5] (For normal vital sign values in children, scan the QR code or click the link below.) After recognition of compensated or decompensated shock, the revised Pediatric Advanced Life Support (PALS) guidelines recommend a carefully monitored, rapidly delivered 20-mL/kg bolus of IV crystalloid fluid.[6] IV fluid therapy is the current gold standard to reduce morbidity and mortality in the setting of pediatric septic shock; careful evaluation of the patient should be made between each fluid bolus given.[7] According to the PALS guidelines, subsequent fluid boluses or vasopressor support may be needed according to the category of shock the patient is in and their response to ongoing interventions.[8]

Normal Vital Signs by Age

For normal vital sign values in children, scan the QR code with a smartphone or tablet or click the following link: https://chemm.nlm.nih.gov/pals.htm.

Administration of Medication

PIV access broadens the emergency clinician's options for medication administration. Rapid sequence intubation medications, emergent cardiac medications, and vasopressor support are a few examples of infusions that are commonly used in the emergency setting that require IV access. Similarly, IV contrast may be required for certain diagnostic tests in the ED. If oral medications (eg, analgesics, antiepileptics, or antibiotics) are not tolerated, there is often the option to give these intravenously.

Difficult Peripheral Intravenous Access

Even in nonemergent situations, successful and timely placement of a PIV catheter is important. Multiple attempts at PIV catheter placement can be painful and frightening for a patient, affect ED flow, and give the perception of poor quality of care.[9-11] Studies have attempted to characterize time to PIV catheter placement and methods to improve success rates.[12]

The difficult intravenous access (DIVA) score is a clinical prediction rule that has been validated as a useful tool for predicting which children will have difficult IV access. This score gives proportional weight to 4 separate variables: (1) vein palpability after tourniquet, (2) vein visibility after tourniquet, (3) history of prematurity, and (4) age. **(See Table 1.)** A DIVA score ≥ 4 is useful to identify patients who might have difficult venous access and need extra consideration before IV catheter placement.[9] Subsequent re-evaluation of the DIVA score found a consistent failure rate of > 50% for first attempt at placement in patients with a score ≥ 4.[13] Lininger found similar results among nurses attempting PIV access on patients in a children's hospital, with a

Table 1. Difficult Intravenous Access Prediction Score[10]

Variable	Point Value		Score
Vein visible after tourniquet	Visible	0	
	Not visible	2	
Vein palpable after tourniquet	Palpable	0	
	Not palpable	2	
Age	≥ 3 years	0	
	1-2 years	1	
	< 1 year	3	
History of prematurity	Full-term	0	
	Premature	3	
		Total	

The sum of point values of the variables noted is the DIVA score (range, 0-10).
A DIVA score ≥ 4 indicates that extra consideration may be needed before placing a peripheral intravenous catheter.
Abbreviation: DIVA, difficult intravenous access.

53% first-attempt success rate and an average of 2.35 attempts before successful placement.[14]

An evaluation of PIV catheter placement in pediatric patients in a community hospital found factors that increased the odds of difficult PIV catheter placement to be younger age, non-black/non-white ethnicity, and placement in the hand or lower extremity (as compared with the antecubital fossa).[15] Factors reported by Black et al included patient weight of < 5 kg or patients with prior PIV catheter placement.[16]

Ultrasound assessment of antecubital, saphenous, and hand veins in 60 children aged ≤ 3 years found similar width measurements of the antecubital and saphenous veins, both of which were larger than hand veins, making the saphenous vein another good choice for first-attempt placement. There was a measurable 1-millimeter increase in width over hand veins, making the saphenous vein a target 2.4 times larger, and giving providers the ability to potentially place a 22-gauge rather than a 24-gauge catheter in younger children.[17]

Recognizing a patient with potentially difficult access can enable the provider to intervene at the beginning of the procedure rather than after several failed attempts. In a study by Larsen et al, nurses with > 1 year experience and a self-rated confidence level of "expert" were shown to have a higher success rate and faster time to placement of PIV catheters than those with < 1 year experience, or those who rated themselves as "novice,""competent," or "proficient."[10] While some hospitals may look to a physician after failed attempts by the nursing team, Frey et al reported a 23% first-attempt success rate for physicians compared with a 44% success rate for nurses. However, use of an IV access specialist team had a 98% first-time success rate, as well as benefits of decreased time to placement, fewer IV-related complications, and improved cost-effectiveness.[18] These results are valid throughout general and pediatric populations.[11,19-22]

Given the current evidence, nursing staff with even minimal experience should be allowed to attempt PIV access in patients with a DIVA score < 4. However, recognizing that insertion attempts lasting longer than 1 minute have a > 50% chance of failure, the team should progress quickly to the second attempt, and a more experienced nurse should step in, if available. For patients with known or expected difficult access, an IV nurse-specialist or alternative IV access methods (such as ultrasound-guidance, if available) should be used for the first attempt rather than as a last resort.[11]

Peripheral Infusion Considerations

Caution should be used when giving some medications through a PIV catheter. Solutions with a pH < 5 or > 9 can cause blistering and tissue necrosis if extravasation occurs. Solutions with an osmolarity > 600 mOsm/L, such as some chemotherapy medications or sodium bicarbonate (8.4%, 2000 mOsm/L; 4.2% 1000 mOsm/L), can also cause damage if not contained in a peripheral vein.[23]

Vasopressor administration through a PIV catheter should also be used with caution, due to possible tissue ischemia in the event of extravasation. A systematic review published in 2015 found that complications from PIV catheter use for vasopressor administration were related mainly to placement distal to the antecubital fossa, and the average time of infusion before local tissue injury occurred was 55.9 hours.[24] A 2013 randomized controlled trial of central versus peripheral catheter complications for venous access found that 14% of patients with PIV catheters had extravasation events during vasopressor infusion, though none of these were associated with tissue injury.[25]

The osmolarity of different dextrose infusions given through a PIV catheter should be considered as well. A solution of 50% dextrose (D50) has a concentration of 2523 mOsm/L, well above the recommended limit of 600 mOsm/L for PIV use. Adverse effects of D50 extravasation due to its high osmolarity include thrombophlebitis and local tissue inflammation or necrosis.[26] While D50 can be given in small aliquots and pushed slowly to help reduce the risk of extravasation, lower concentration solutions such as D10 (505 mOsm/L) and D12.5 (625 mOsm/L) can be given through a PIV catheter with a lower risk of local tissue injury and with similar effect in treating hypoglycemia.[27,28]

Calcium chloride (2053 mOsm/L) is often given in situations of severe hypocalcemia, calcium-channel blocker overdose, or hyperkalemia. However, in a nonemergent scenario, and if PIV catheter is the only access, a lower osmolality solution (such as calcium gluconate [697 mOsm/L]) should be considered instead, as calcium chloride can cause skin and soft-tissue necrosis if extravasation occurs.[29]

Hypertonic saline (3%, 1027 mOsm/L) is used for many clinical conditions, including severe hyponatremia, cerebral edema, and intracranial hemorrhage.[30-32] While conventional teaching is to avoid giving hypertonic saline through a PIV catheter, more recent studies have found no episodes of phlebitis or tissue necrosis after peripheral administration.[33,34]

Another debated PIV infusion is contrast media for enhanced imaging, especially with the common use of power injectors. Individual institutions often have gauge and location requirements for PIV catheter placement due to the concern for extravasation of the contrast material, which is often (though not always) very viscous and highly concentrated. However, in a prospective study of 557 children receiving contrast material through a PIV catheter administered by a power injector, there was no significant difference in extravasation rate in any of the subjects, despite 67.5% having a hand IV catheter and 94.2% having small-gauge IV catheters, factors thought to increase adverse events.[35] Jacobs et al also found no correlation between catheter location or size and extravasation rate.[36]

Intraosseous Access

Intraosseous (IO) access has been used in children since the 1940s. However, this method was largely abandoned when IV catheters were invented and it was not often considered during resuscitations.[37] In 1986, IO access was included in recommendations for vascular access in the PALS guidelines, and, as of the 2010 update, it is the preferred method of access over central line placement and PIV access attempts taking > 30 seconds.[29,37]

Indications

IV access may be difficult or time-consuming in a life-threatening emergency, especially if the patient is obese, seizing, burned, or edematous.[38] In these circumstances, obtaining IO access may be the best option. Use of IO access has been proven safe for all ages, and studies in the newborn population suggest faster placement time than umbilical catheters.[39-41] There are several cases of successful IO resuscitation in preterm newborns weighing < 1000 g, though IO access in this population should be used with extreme caution and only in a true emergency.[39,42] Needle size selection should be based on weight, with a 15-gauge, 15-mm needle used for children weighing 3 kg to 39 kg, and a 15-gauge, 25-mm needle used for children weighing ≥ 40 kg.[38] ARROW® EZ-IO® also makes a 15-gauge, 45-mm needle for larger patients. If needed, a cutdown of the overlying skin may be performed in the event of a large soft-tissue mass or difficult skin penetration.

A review by Hansen et al of IO access use in pediatric patients found that cardiac arrest is the most commonly listed diagnosis in children receiving an IO line in the ED, followed by trauma, then respiratory failure.[43] IO access can be used for rapid high-volume fluid infusion, collection of blood for laboratory testing, and medication infusion.

Blood samples can be sent for any laboratory study; however, interpretation of certain laboratory values may vary. Carbon dioxide tension may be slightly lower than IV sampling due to stasis in the marrow as well as some arterial mixing. White blood cell counts will be higher than in a peripheral sample, while platelet counts will likely be lower.[38,44] Given the potentially limited volume of blood that can be drawn from the marrow space, 2 mL waste is sufficient before collecting a specimen for testing.[44]

All blood products, including fresh-frozen plasma, whole blood, and packed red blood cells, can be given through an IO line. Additionally, all medications that are approved for IV infusion may be given intraosseously, including epinephrine, dopamine, calcium, diazepam, phenytoin, insulin, glucose, heparin, antibiotics, and medications needed for intubation, such as neuromuscular blocking agents.[44] Medications should be dosed and administered using the same guidelines as for IV administration, and may be followed by a saline bolus of 10 mL to ensure systemic circulation delivery.[45] For pediatric patients, 0.5 mg/kg of 1% or 2% lidocaine (maximum 3 mg/kg) can be administered over 120 seconds through an IO needle to decrease the pain of any high-volume infusion to the marrow space.[38]

Devices and Insertion

The preferred site of IO insertion is the anteromedial plane of the proximal tibia, 1 to 2 cm below the tibial tuberosity. **(See Figure 1.)** Other options for placement include the distal tibia (medial surface proximal to the medial malleolus), the distal femur (anterior surface 2-3 cm above the lateral condyle), the distal end of radial bone, the proximal metaphysis of the humerus, the sternum, the calcaneus, the iliac crest, the clavicle, and the lateral or medial malleoli.[38,45-46]

After sterile preparation of the skin, the needle should be placed at a 90° angle to the surface. Open growth plates in younger patients should be considered during insertion, and the needle should be angled away from the metaphysis.[38,45] After insertion through the cortex, the needle should feel firm and stand upright. Some devices come with specific stabilizer dressings; however, stabilization with 2 pieces of tape across the plastic skirt, with or without gauze padding, is an acceptable technique. A lack of bone marrow aspirate does not necessarily indicate incorrect placement.[38]

IO needles should be a temporary means of access until more secure IV access is obtained. While

Figure 1. Intraosseous Placement in the Tibia

Robert Schafermeyer, Milton Tenenbein, Ghazala Sharieff, et al. *Strange and Schafermeyer's Pediatric Emergency Medicine*, 4th ed. McGraw-Hill Education. Figure 22-1, p. 116. Copyright 2014. Used with permission from McGraw-Hill Education.

IO lines may be left in place up to 96 hours, ideally, they should be removed within 6 to 12 hours.[38] Although there are several devices that are specifically manufactured for IO access **(see Figure 2)**, any needle can be used, though a needle with a stylet is best. Butterfly needles, spinal needles, standard IV needles and catheters, and bone marrow biopsy needles have been described for IO access. Specialized needles come with a stylet to reduce clogging with bone marrow spicules and are designed to maximize successful placement, with large handles and short needle shafts.[38]

Manual devices such as the Jamshidi™ needle and the Cook® IO needle **(Figure 2A)** are widely available and are approved for pediatric use. Other specialized needle options include semiautomatic devices such as the Arrow® EZ-IO® **(Figure 2B and 2C)** and the Bone Injection Gun (B.I.G.). When used by prehospital providers, successful placement, complication rates, and user satisfaction between the manual and semiautomatic devices are generally equivalent.[46,47] Findings on time to insertion are conflicting, though experts agree IO placement, regardless of the device used, is an easy-to-learn and relatively quick technique for establishing vascular access.[46-48]

Contraindications

There are a few contraindications to IO placement. Bone disorders such as osteogenesis imperfecta, osteopetrosis, and osteopenia will result in a high likelihood of iatrogenic fracture. Overlying infection, burns to the area, and ipsilateral fracture of the intended bone for access are also relative contraindications, but still may be considered if there is no other vascular access in an emergency situation. Use of an uninjured bone on the ipsilateral side of a fracture is allowable. Repeat attempts are discouraged, and previous sites of IO placement should not be used for 1 to 2 days.[38] While not absolutely contraindicated for infusion, hypertonic and alkaline solutions can lead to osteomyelitis and should be diluted before infusion.[38,45]

Central Venous Access

Central venous catheters (CVCs) terminate in the centrally located veins of the thorax and are placed in both emergent and nonemergent situations. There are several devices that serve a variety of IV access needs. In general, CVCs are used for administration of large volumes of IV fluids or blood products, administration of medications that are harmful to peripheral tissues (such as chemotherapy) and for long-term access to allow for frequent blood sampling or scheduled infusions.[49]

With the increasing accessibility and ease of IO access, central line placement is not often the next step in the event of difficult PIV access. However, a CVC is the only device with no absolute contraindications for placement or use, and should therefore still be in the purview of the emergency clinician. The use of ultrasound-guided placement of a CVC is becoming more commonplace.[50-53] While few studies exist evaluating CVC placement in the pediatric

Figure 2. Intraosseous Devices

Image A: Cook® intraosseous infusion needles
Image B: Arrow® EZ-IO® device
Image C: EZ-IO® needles
Images courtesy of Rachel Whitney, MD and Melissa Langhan, MD.

ED, Gallagher et al found a significantly higher success rate of CVC placement by physicians using ultrasound guidance, even after adjusting for level of experience.[54] There is some evidence to support preferential placement of a CVC in the intensive care unit or the operating room to ensure the lowest complication rate and infection risk.[55,56]

Central Venous Catheter Devices

Peripherally Inserted Central Catheters

Peripherally inserted central catheters (PICCs) are most often inserted in the basilic, brachial, or cephalic veins of the arm, and terminate in the superior vena cava.[57] PICC lines are placed for patients who need to receive several weeks to months of parenteral nutrition, IV antibiotics, or other medications or blood transfusions. While PICC lines are not often placed in the ED, an existing PICC line may be used for blood sampling, medication, or fluid administration; if cleaned and flushed properly, this could avoid additional needle sticks for the patient. As is the case with most indwelling catheters, a blood culture should be drawn from a separate venipuncture site rather than an existing line to reduce the rate of false-positive blood cultures via contamination, which could result in unnecessary treatment.[58]

Nontunneled Catheters

A nontunneled CVC is a temporary IV access device that may be placed in the ED during medical or trauma resuscitation. The most common sites for placement include the internal jugular, subclavian, and femoral veins. Clinical landmark techniques can be used at these sites.

The internal jugular vein is often estimated to lie between the medial and lateral heads of the sternocleidomastoid muscle just above its insertion at the clavicle. The carotid artery can be palpated medially to the internal jugular vein in most cases; however, it may be aberrant in 8.5% of patients.[59] When obtaining internal jugular vein access, the head of the patient should be rotated away from the side of insertion. The subclavian vessels typically run beneath the medial third of the clavicle and are approached in an infraclavicular manner. The needle should be directed toward the sternal notch. Placing the patient in the Trendelenburg position or having the patient perform the Valsalva maneuver may help to fill the internal jugular and subclavian veins, thus easing visualization. For both internal jugular and subclavian catheter access attempts, the right side of the patient is often preferable, with a lower complication rate due to a lower-lying lung apex on this side and the position of the thoracic duct on the left. The frequency of complications (such as pneumothorax and carotid artery puncture) are reduced when using ultrasound guidance as opposed to landmarks alone.[52]

In the femoral bundle, the femoral vein is located medial to the femoral artery, which can be palpated below the inguinal ligament. Femoral veins are often the site of choice due to easily identifiable landmarks, the ability to perform the procedure away from the head of the patient, and the ability to apply direct pressure in the event of excessive bleeding.[59] However, there is evidence to suggest that, despite sterile technique and central-line bundles, the risk of infection is highest when a femoral line is placed.[50,55,60]

A study by Parienti et al compared catheterization at these 3 sites and found that catheterization of the subclavian vein resulted in a lower risk of catheter-associated bloodstream infections and symptomatic deep-vein thrombosis when compared with internal jugular or femoral vein placement.[60] This is hypothesized to be because of the longer subcutaneous course before vein entry and a lower skin bacterial burden of the subclavian insertion site when compared with the femoral or internal jugular placement sites. However, subclavian veins are subject to a higher risk of mechanical complications (including pneumothorax requiring a chest tube) during placement when compared to the other sites.[49,60]

Nontunneled catheters should be for short-term use of 5 to 7 days if sterile technique is ensured, but no longer than 48 hours if sterility is not certain.[49,50] See **Table 2** for nontunneled central line selection based on patient age and weight.[61]

Skin-tunneled Catheters

Skin-tunneled CVCs, such as the Hickman® or Broviac® catheter **(See Figure 3, page 8),** are typically placed in patients requiring long-term and frequent access, and they have a lower infection rate than PICC lines due to the increased distance between skin insertion and IV insertion (hence "tunneled"). Similar to PICC line use, patients

Table 2. Central Venous Catheter Size Recommendations by Patient Age and Body Weight

Age (years)	Weight (kg)	Catheter Gauge	French Gauge	Length (cm)
< 1, newborn	4-8	24	3.0	5-12
< 1	5-10	22	3.0-3.5	5-12
1-3	10-15	20	4.0	5-15
3-8	15-30	18-20	4.0-5.0	5-25
> 8	30-70	16-20	5.0-8.0	5-30

Table reprinted with permission from Medscape Drugs & Diseases (http://emedicine.medscape.com/), 2017, available at: http://emedicine.medscape.com/article/940865-overview requiring frequent blood draws or infusions may have a tunneled catheter placed.[49] When a patient with a tunneled CVC presents for evaluation of fever or concern for serious infection, palpation at the site of insertion and along the subcutaneous length of the catheter is important to help locate the potential source of fever.[50]

Implantable Ports

An implantable port (also known as a port-a-cath) has a subcutaneous reservoir that is attached to the chest wall with a connecting IV catheter.[49] These lines are surgically placed and are used for long-term, but infrequent, blood draws, as access requires puncturing the skin. While implantable ports have a low infection rate compared to other catheters that are open and outside the skin, other complications include extravasation and thrombosis.[62] These CVCs can be evaluated for infection by examination of the overlying skin.

Umbilical Catheters

If peripheral or IO cannulation is not obtainable in a newborn who requires IV access, the umbilical vein offers an alternate option, as it is viable for up to 7 days.[63] In these cases, a loose tourniquet should be placed around the umbilical stump and the dried umbilical cord should be cut with a scalpel at the level of the umbilical stump. An umbilical vein and 2 umbilical arteries are typically visualized. The umbilical vein has a thinner wall and lies superior to the arteries. Small forceps may be required to stent the vessel open while the umbilical catheter is being inserted. When placed in the ED, umbilical vein catheters should be inserted only to the point of blood return, usually 4 to 5 cm. This "low-lying" position can be used for emergency medication administration and blood draws, and should be removed or replaced with more stable IV access as soon as possible.[64]

Given the high rate of complications, an umbilical vein catheter should be used only after other methods have failed. Chest radiography is neither sensitive nor specific in correctly identifying the location of the tip of the catheter after placement, and incorrect placement has been linked to serious adverse events.[65,66] A study published by Lloreda-Garcia et al in 2016 found that umbilical vein catheters placed in the neonatal intensive care unit were placed correctly only 48% of the time, and that incorrectly placed catheters were much more likely to be associated with problems such as dislodgement, extravasation, hepatic hematoma, obstruction, and ascites.[67]

Arterial Access

Arterial lines, or A-lines, have been traditionally used for continuous and more accurate blood pressure readings than those obtained by sphygmomanometer, especially when the mean arterial pressure is extremely low (such as in cases of resuscitation). Arterial lines can also be helpful when frequent arterial gas measurements are needed. However, placement can be difficult and time-consuming, and it is often not practical during an emergency situation unless the emergency clinician is comfortable with the procedure. Similar to venous access, ultrasound can be used to assist in placement of arterial catheters.

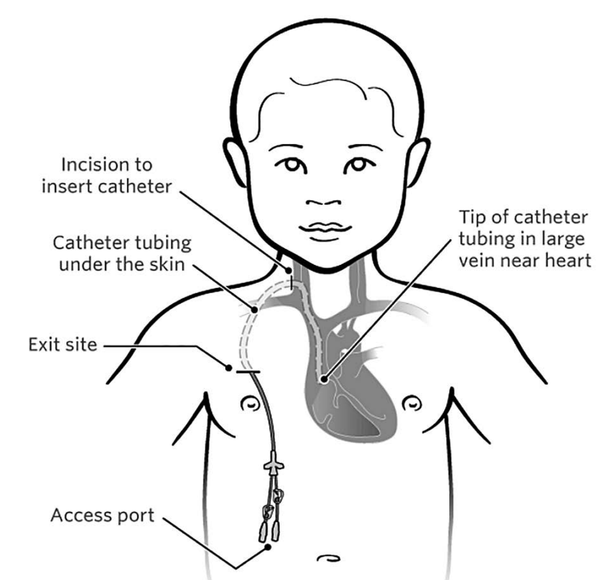
Device-Assisted Access

Most emergency clinicians needing to establish IV access on a child will have a number of techniques that can be used in cases of difficult access. Many of these techniques include direct manipulation of the vein or skin using readily available materials in any standard room, such as alcohol swabs, heat packs, or tourniquets. In addition, ultrasound guidance may be used for placement of IV access. For more information on ultrasound-guided line placement, see the June 2016 issue of *Pediatric Emergency Medicine Practice* titled "Procedural Ultrasound In Pediatric Patients: Techniques And Tips For Accuracy And Safety," available at: www.ebmedicine.net/POCUS. Troubleshooting devices that not all emergency clinicians may be familiar with are infrared technology and transillumination.

Infrared Technology

The VeinViewer® and AccuVein® are examples of devices that use near-infrared light to penetrate the skin and subcutaneous fat. While skin and fat do not absorb the frequency of this light well, blood and

Figure 3. Skin-tunneled Central Venous Catheter



Reused with permission from the Children's Hospital of Philadelphia. Available at: http://www.chop.edu/treatments/tunneled-catheter-placement.

blood vessels do, which creates a darkened, 2-dimensional outline of the underlying vessels on the patient's skin. **(See Figure 4.)** These devices do not produce heat or radiation. While evidence does not seem to support an increase in first-attempt success rate with these devices, a survey of nurses found that 90% of respondents found them helpful in patients with difficult access.[68,69]

Transillumination

Transillumination uses a light source to show the deeper veins of the hands and extremities of younger patients, with the hope that visualization will decrease failure of placement. **(See Figure 5.)** Light sources ranging from a simple otoscope or flashlight to specifically manufactured devices (eg, Veinlite® and Venoscope®) have shown higher success rates of first-attempt IV placement when transillumination is used.[70,71]

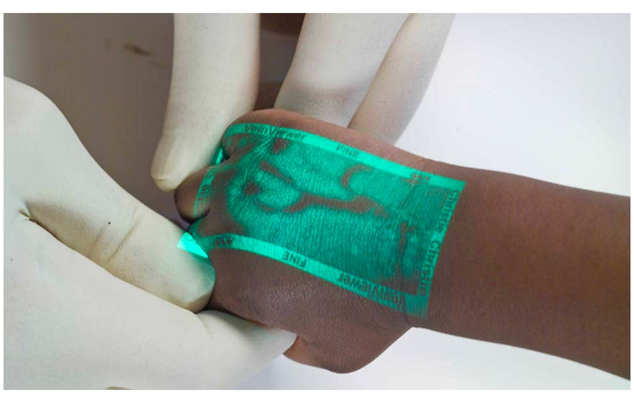
Pain Control

Pain control strategies are appealing to patients and their parents when IV access is needed, and they also serve to increase the likelihood of success of first-attempt placement.[72]

Topical Creams

A eutectic mixture of local anesthetics (EMLA® cream, 2.5% lidocaine, 2.5% prilocaine) is a topical anesthetic for use on intact skin that is widely available in most pediatric EDs. While there is evidence that patient comfort and successful IV placement are increased with the use of EMLA®, the time to appropriate analgesia ranges from 45 to 60 minutes.[72,73] LMX® (formerly ELA-Max®), is a 4% lidocaine cream delivered via a liposomal vehicle that results in effective pain control for minor procedures in 30 minutes.[73,74] While an occlusive dressing is often needed for EMLA® cream; this is not a requirement for LMX®.

Figure 4. VeinViewer® Imaging of Blood Vessels



Used with permission from Christie Medical Holdings, Inc.

Needle-free Lidocaine Injection

The Jet, or J-tip™ is a needle-free drug delivery system that rapidly injects lidocaine to the intradermal area overlying intended IV catheter placement. Time to onset is reported to range from 3 to 5 minutes.[75,76] In a study comparing saline, 1% lidocaine, and 2% lidocaine, Lysakowski et al found that 2% lidocaine reduced pain scores by > 50%. However, problems reported with the J-tip™ included 20% of patients experiencing moderate pain from the device itself, device failure, and difficulty with IV placement due to subsequent edema and bleeding.[77] A study published in 2015 evaluated nearly 1000 children receiving PIV catheters, half of whom received anesthesia with the J-tip™; the other half received no intervention. There was no difference in first-attempt success of PIV catheter placement.[78] Cooper et al found similarly conflicting evidence; while the J-tip™ with 1% lidocaine was less painful than traditional injection with a 25-gauge needle, subsequent cannulation was more painful after J-tip™ use.[75]

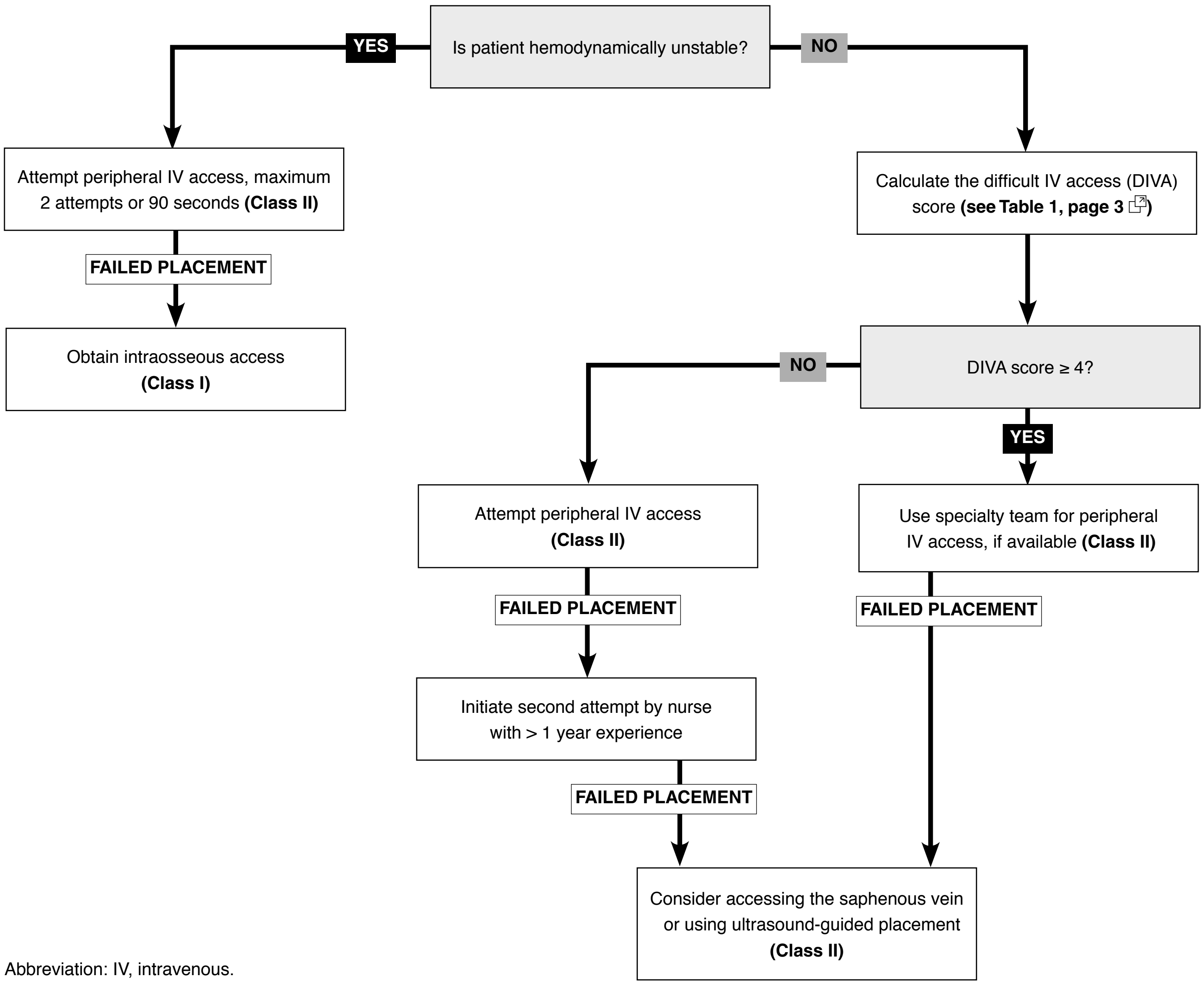
Vapocoolant

Vapocoolant (eg, ethyl vinyl chloride) is a noninvasive and quick-acting cryoanalgesic topical spray intended to decrease pain associated with minor procedures such as vaccine injection or venipuncture. Evidence from the pediatric population does not seem to support significant pain reduction specifically for IV cannulation, and its use does not seem to significantly increase the rate of successful IV placement.[79-82] While the device itself produces a sudden popping noise with deployment, there were no reported differences in patient anxiety with and without the device.[76] In a study examining the difference in pain during PIV catheter place-

Figure 5. Transillumination to Identify Blood Vessels

Image courtesy of Rachel Whitney, MD and Melissa Langhan, MD.

Clinical Pathway for Vascular Access in Pediatric Patients



Abbreviation: IV, intravenous.

Class Of Evidence Definitions

Each action in the clinical pathways section of *Pediatric Emergency Medicine Practice* receives a score based on the following definitions.

Class I
- Always acceptable, safe
- Definitely useful
- Proven in both efficacy and effectiveness

Level of Evidence:
- One or more large prospective studies are present (with rare exceptions)
- High-quality meta-analyses
- Study results consistently positive and compelling

Class II
- Safe, acceptable
- Probably useful

Level of Evidence:
- Generally higher levels of evidence
- Nonrandomized or retrospective studies: historic, cohort, or case control studies
- Less robust randomized controlled trials
- Results consistently positive

Class III
- May be acceptable
- Possibly useful
- Considered optional or alternative treatments

Level of Evidence:
- Generally lower or intermediate levels of evidence
- Case series, animal studies, consensus panels
- Occasionally positive results

Indeterminate
- Continuing area of research
- No recommendations until further research

Level of Evidence:
- Evidence not available
- Higher studies in progress
- Results inconsistent, contradictory
- Results not compelling

This clinical pathway is intended to supplement, rather than substitute for, professional judgment and may be changed depending upon a patient's individual needs. Failure to comply with this pathway does not represent a breach of the standard of care.

ment using ice versus vapocoolant, nurses felt the vasoconstriction caused by vapocoolant made the vein more difficult to see, despite an above-average success rate for PIV catheter placement.[82] Vapocoolant spray is inexpensive and safe, did not increase pain or distress in any patients, and, when combined with other distraction techniques, may provide some benefit to the patient.[79]

Nonpharmacologic Options

Techniques to lessen the pain and anxiety of cannulation without the use of medications should be tailored to the patient's age. Distraction techniques such as movies, counting, singing, playing games or listening to a story are best for younger patients. Patients aged ≥ 8 years may be able to participate in guided imagery, where the parent or child-life specialist helps patients use their imagination to describe a pleasant scene. Techniques that are effective for all ages include music and massage.[83-85] The use of a Buzzy®, a vibrating device placed on the skin near the site of cannulation, has also been shown to reduce pain and increase patient compliance.[86]

Complications

Peripheral Intravenous Access

Common complications with placement of a PIV catheter include pain, failure to access the vein or get blood return, difficulty advancing the catheter over the needle and into the vein, and difficulty infusing fluids after the catheter is placed in a vein.[23] Often, these complications require no intervention beyond removal of the catheter and making another attempt. Less common but more serious complications can include arterial puncture, peripheral nerve palsy, compartment syndrome, and skin and soft-tissue necrosis, which require more intensive intervention.[23,50] Thrombophlebitis is a more common serious complication of IV cannulation; recommendations to help avoid this include replacing and alternating sites every 72 to 96 hours, avoiding wrist and scalp vein use, and selecting a 24-gauge catheter.[87] Thrombus formation can be mitigated by using heparin flushes and splinting the cannulated area. This should be done for all PIV catheters to help ensure longevity.[87,88]

Intraosseous Access

The most common cause of complication from IO needle insertion is operator error and technical complications such as dislodgement leading to extravasation and tissue damage or compartment syndrome.[38,44] Theories for extravasation include not fully puncturing the cortex; going through the bone; excessive rocking of the needle during placement, creating a hole larger than the needle; and leakage of fluids from prior IO sites or fractures if using the same bone for placement.[89,90] If significant force is needed for placement or an inexperienced operator is performing the procedure, these complications leading to extravasation and possible compartment syndrome are more likely to occur. Care should be taken to monitor for extravasation, and the IO needle should be used only if the needle feels firmly secure after placement, with minimal movement.[91] More serious complications with IO needle placement include iatrogenic fracture, osteomyelitis, growth plate injury resulting in leg length discrepancy, and fat embolism.[38] Local cellulitis, abscess, and skin necrosis can also result from improper cleaning and securing; removal after 72 hours is recommended to decrease these complications.[38,45] With proper technique, Hansen et al described no complications after IO needle insertion in 291 pediatric patients.[43]

Central Venous Catheter Access

Central venous catheters are more invasive and are therefore subject to more complications than PIV catheters or IO needles. Thrombosis, hematoma, arterial puncture, and creation of associated bloodstream infection have all been extensively documented in the literature.[55,59,60,92] When considering the location for placement of a nontunneled CVC, emergency clinicians must balance the low infection risk with the possibility of mechanical complication with subclavian line placement.[49,60] Reports of organ puncture and venous extravasation leading to an acute abdomen are reminders of the care that must be taken during this procedure.[59,60,93] In the event of creation of an associated bloodstream infection, risks and benefits of catheter removal should be weighed, often with the guidance of an infectious disease specialist.[50]

Special Circumstances

Venous Cutdown

Because of the wide availability of IO placement, venous cutdown has become an infrequent method of emergency vascular access if percutaneous methods fail. However, this procedure remains within the purview of the emergency clinician.

The saphenous vein is a well-described and fairly safe access point; it is described as the "classic" pediatric cutdown.[94,95] The saphenous vein is the longest vein in the body, originating from the medial marginal vein of the foot and crossing 1 to 2 centimeters anterior and 1 to 2 centimeters superior to the medial malleolus as it continues superficially along the anteromedial aspect of the leg before joining the femoral vein.[96] Other common sites for cutdown include the greater saphenous vein nearer the groin, and the basilica vein above the elbow.[96]

To perform venous cutdown of the saphenous vein, a transverse incision is made through the skin about 2 fingers-breadth cephalad to the medial malleolus. The subcutaneous tissue around the vessel is first dissected, then the vein is isolated with a hemostat. The distal end of the vein is tied off, and after access is gained via incision or needle insertion, the cannula is secured with a proximal tie. **(See Figure 6.)**

Absolute contraindications to venous cutdown include significant trauma or vascular injury proximal to the chosen site. Bleeding diathesis, venous thrombosis, and overlying cellulitis are complications to consider, but are relative contraindications.

Complications include those previously listed for any IV catheter; the additional risk of artery or nerve injury exists with this method. Should significant bleeding or hematoma result, pack the area and attempt access on the opposite side, and have the area explored in the operating room for proper repair of any large-vessel injury.[96] Even with sterile procedure, the risk of infection is significantly higher than if using a percutaneous method.[97]

Hemodialysis

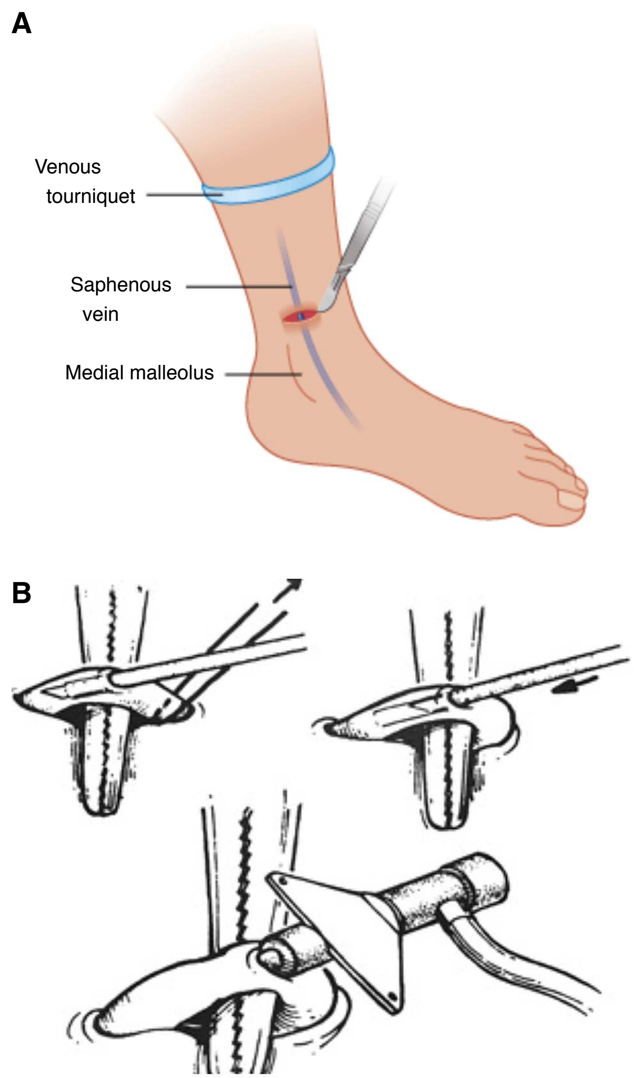
While approximately 80% of pediatric patients requiring hemodialysis will have a CVC for vascular access, arteriovenous fistulas and arteriovenous grafts may still be seen in patients needing care in the ED.[98] It is important for the emergency clinician to be able to assess and manage common vascular access problems in this population.

Both arteriovenous fistulas and arteriovenous grafts are internal structures that join an artery and vein together by either surgical anastomosis (fistula) or via a synthetic tube (graft). Fistulas are most commonly placed in the nondominant arm, but grafts can also be found in the femoral region of smaller children, though this area is generally avoided due to higher infection rates than noted in the upper extremity.[99,100]

Complications of arteriovenous fistulas and arteriovenous grafts include thrombosis and, occasionally, hemorrhage. Loss of thrill or bruit over the anastomosis site indicates a likely thrombus, which can be verified with ultrasound, and warrants an emergent vascular surgery consult. Bleeding around the site should first be managed with direct pressure. Excessive bleeding soon after dialysis is likely related to heparin administration, in which case, 1 mg of protamine IV/100 units of heparin used should be administered, or 10 to 20 mg of protamine IV if the heparin dose is unknown.[101,102]

Catheters for dialysis may be either a temporary nontunneled CVC, such as a Quinton™ catheter, or a more permanent tunneled CVC such as a Hickman® catheter. Catheters should have a minimum of 2 large lumens to sustain a blood flow rate of 300 mL/min, with one lumen used for arterial flow and another for venous flow. Potential complications are similar to those for all CVCs; however, because of the large lumens, catheters used for dialysis are especially at risk for thrombosis. Rapid flow causes turbulence at the catheter tip, leading to endothelial proliferation.[103] Frequent cannulation or areas chafed by the catheter are also at risk for thrombus formation.[104] Catheter-directed tissue plasminogen activator should be used for a suspected thrombus. For patients weighing < 30 kg, a tissue plasminogen activator dose equivalent to 110% of the internal lumen volume of the catheter (but not to exceed

Figure 6. Venous Cutdown



A: The saphenous vein lies in proximity to the medial malleolus. A shallow incision can be made directly over the vessel.
Judith Tintinalli, Ronald L. Krome, Ernest Ruiz, et al. *Emergency Medicine: A Comprehensive Study Guide.* 4th ed. McGraw-Hill Education. Figure 18-4, p. 89. Copyright 1996. Used with permission from McGraw-Hill Education.
B: After visualization of the saphenous vein, a clamp can be placed underneath the vessel to facilitate catheter placement.
Judith E. Tintinalli, J. Stephan Stapczynski, O. John Ma, et al. *Tintinalli's Emergency Medicine: A Comprehensive Study Guide.* 7th ed. McGraw-Hill Education. Figure 33-16, p. 231. Copyright 2010. Used with permission from McGraw-Hill Education.

2 mg/mL) can be used. In patients weighing ≥ 30 kg, 2 mg/2 mL of tissue plasminogen activator can be instilled. The tissue plasminogen activator should remain in the catheter for 30 minutes to 2 hours; a second dose can be instilled if the occlusion is still present. In a meta-analysis, a bolus of 1 to 2 mg of tissue plasminogen activator per lumen appeared to be a safe and effective method of restoring patency to the line.[105]

Disposition

Prior to discharge from the ED, PIV catheters and IO needles are removed from the patient and a bandage applied to the area. There are very few circumstances that might require a patient to be discharged with a CVC that was placed in the ED. Prolonged parental antibiotic use is the most likely reason for discharge with a CVC (for infections such as chronic osteomyelitis, soft-tissue infections, or pneumonia).[106] Discharge and management of a home catheter should be coordinated with an infectious disease or antimicrobial stewardship team, as well as the home care or visiting nurse providers.[107]

Time- And Cost-Effective Strategies

- Abandon PIV access placement after 2 failed attempts that last more than a total of 90 seconds.[108] This is especially important in cases of critical need for vascular access. IO access is generally fast and easy to place, and can be used for administration of any fluids or medications that can be given intravenously.
- Ensure the entire pediatric ED staff is up to date on procedural line placement and troubleshooting. Good teamwork is a tenet of emergency care, and having all team members aware of current procedural techniques can help make the vascular access process smoother. Likewise, any ancillary techniques needed to troubleshoot difficult line placement (such as ultrasound guidance) work best if everyone involved can anticipate the course of the procedure.
- Appropriate use of pain control and distraction techniques during IV catheter placement can improve success. Taking these steps at the beginning of the procedure, rather than after a failed attempt, can save time and reduce anxiety for the patient and family.

Summary

The ability to obtain and manage vascular access is a life-saving staple of emergency medical care. PIV access is the most common form of access; however, when peripheral access is difficult to obtain, IO needles, CVCs, and venous cutdown may be necessary in patients who are critically ill. The ease by which PIV access is obtained may be predicted by both patient and staff factors. New technology is available to help assist emergency clinicians in locating vessels that may be suitable for access. Nonetheless, all forms of venous and arterial access are painful and invasive procedures. Pain control and nonpharmacologic assistance should be considered to improve the comfort of patients during these procedures. All forms of access should be monitored for rare—but serious—complications including extravasation of caustic medications and thrombophlebitis. The information in this article should familiarize the emergency clinician with the various types of vascular access, including methods, complications and, trouble-shooting.

Case Conclusions

Although the likely source of infection in this young cancer patient is his existing CVC, you attempted to access the line and draw blood to send off for initial laboratory testing. However, while the line could flush, the nurse was not able to draw blood back. You administered 1 mg of tissue plasminogen activator into the catheter for 30 min, but there was still no blood return. In the meantime, your resident spoke with the patient's oncologist, who felt strongly that you should not use the CVC to administer fluid. Given your suspicion that the patient was in septic shock, you needed to gain vascular access quickly. You considered the volume of fluid and how quickly you needed to give it, as well as the potential need for vasopressors if fluid resuscitation was not adequate. The patient told you he is "a difficult stick" in both of his arms due to his long medical history and the need for blood sampling, so you opted to place a 20-gauge PIV catheter in his saphenous vein, which drew blood back easily and did not extravasate after 20 mL/kg IV fluid was given with a pressure bag. Luckily, the patient defervesced after acetaminophen, and his blood pressure stabilized after only 1 fluid bolus.

For your lethargic neonate patient, your nurse, who recently recertified in PALS, reminded you that an IO needle can be placed in young infants, especially when they are critically ill. She further stated that it can be used for both laboratory tests and the administration of medications that would go through an IV catheter. You immediately recognized the severity of illness of this neonate, and proceeded directly to IO placement for fluid resuscitation. You chose to place a 15-gauge, 15-mm needle in the proximal tibia and felt confident in its placement due to blood return and stability of the needle in the bone. A blood sample was sent off for culture, complete blood cell count, and electrolytes. After 0.5 mg/kg of 1% lidocaine was administered over 120 seconds through the IO needle, you began aggressive IV fluid resuscitation with 20-mL/kg crystalloid boluses. The infant's examination revealed ambiguous genitalia, and the electrolytes confirmed your

Risk Management Pitfalls in Pediatric Patients Who Need Vascular Access

1. **"I need to place an IV catheter in a 13-year-old boy; he's old enough to handle the pain."**
   Age-appropriate relaxation techniques and analgesia should be provided for every patient undergoing a vascular access procedure. Guided imagery, watching a movie, or listening to music, as well as the use of a Buzzy® or needle-free injection of lidocaine would be appropriate for this patient. These techniques may improve patient and family satisfaction with the experience.

2. **"My patient has lost a lot of blood, and I only have access to an IO line placed in the field. I need to place a central line in order to give her blood products."**
   If the IO line is infusing well, blood products for the patient may be given through the established IO line without need for separate venipuncture. Any fluid, blood product, or medication that can be given intravenously may also be given intraosseously.

3. **"I placed a 24-gauge PIV catheter in a 4-day-old patient's hand; I taped it well, so it shouldn't cause any problems."**
   Both 24-gauge PIV catheters and placement in the wrist area are risk factors for thrombosis. The patient's arm should be splinted to avoid bending the wrist.

4. **"My patient needs a CT scan with contrast, but the radiologist will not administer contrast through the 24-gauge catheter in the patient's antecubital fossa. Even the most experienced staff are unable to place a larger-gauged PIV catheter, so I guess I need to place a central line."**
   Despite evidence showing that location and small catheter size are not related to the risk of contrast extravasation, hospital protocol can still dictate the placement of specific PIV catheters before contrast is given. Even in younger children, the saphenous vein is often overlooked, and is consequently pristine, allowing for more successful placement of a larger catheter.

5. **"My 5-year-old patient needs a central line. Since we're in the pediatric ED, I don't need to worry about catheter size, as all of the catheters should be child-sized."**
   CVC selection requires careful consideration, not only for the type of catheter for the needs of the patient, but also the length and diameter of the catheter based on the patient's age and weight. **(See Table 2, page 7.)** Correct catheter size should always be double-checked before preparing for placement.

6. **"The CBC drawn from an IO needle from my septic patient shows a WBC count of 25 x 10^9/L and platelets at 75 x 10^9/L. I'm worried about impending disseminated intravascular coagulation."**
   Abnormal blood test results can be alarming, but before making decisions about treatment, the source of the sample should always be questioned. Blood tested from the marrow, such as blood from an IO aspirate (as in this case) will have leukocytosis and thrombocytopenia as compared with a venous sample. Blood from a venous or arterial sample should be sent off for the most accurate interpretation of a complete blood cell count.

7. **"The patient has a DIVA score of 1, but I keep missing the vein. I know I can get it on the next try."**
   Even if a patient is not identified as having potentially difficult IV access, the first provider should relinquish attempts to a more experienced provider after a failed first or second attempt. If available and appropriate, techniques such as transillumination, an infrared device, or ultrasound should be used.

8. **"The chest x-ray of my patient with an umbilical catheter confirms my placement, so I can't understand why I'm not able to aspirate blood or infuse saline."**
   Chest x-ray is neither sensitive nor specific for umbilical catheter line placement; difficulty with infusion through the catheter could indicate incorrect placement or even creation of a false tract during placement. The catheter should be removed and alternate access should be obtained.

9. **"My patient has a DIVA score of 5, but I could really use the practice."**
   The chances of first-attempt success are much higher with an experienced provider. If available, an IV nurse-specialist should attempt first access on a patient like this.

10. **"My patient is coding, and I have no vascular access. Since it's an emergency, I can just drill an IO line anywhere in the leg."**
    Taking the time to review correct IO placement, even in a stressful emergency, is best for the patient and the care team. Finding the correct spot 2 cm below and 2 cm medial from the tibial tuberosity, avoiding the epiphysis, will increase the chance of fast, successful access and will minimize complications.

suspected diagnosis of congenital adrenal hyperplasia. The patient's blood pressure stabilized after administration of 60 mL/kg of crystalloid fluids. You gave her a dose of 1 mg/kg methylprednisolone through the IO line as you prepared to admit her to the PICU.

The nurse for your 2-year-old vomiting patient was a recent graduate, and he correctly identified a DIVA score of 4, as he could not palpate any veins for PIV catheter placement. Luckily, there was an IV nurse-specialist available in the department. Because of the likelihood of difficult placement, given the child's age and her state of dehydration, you asked the more experienced nurse-specialist to attempt placement as the first attempt. You also asked your child-life specialist for age-appropriate toys for the patient, and with a soothing environment and the presence of the parents, the patient's PIV catheter was successfully placed on the first try. She was then given IV crystalloid fluids and 0.1 mg/kg ondansetron through her peripheral line, and was soon able to tolerate fluids orally. Her PIV catheter was removed, and she was discharged home to continue oral rehydration.

References

Evidence-based medicine requires a critical appraisal of the literature based upon study methodology and number of subjects. Not all references are equally robust. The findings of a large, prospective, randomized, and blinded trial should carry more weight than a case report.

To help the reader judge the strength of each reference, pertinent information about the study, such as the type of study and the number of patients in the study is included in bold type following the references, where available. The most informative references cited in this paper, as determined by the authors, are noted by an asterisk (*) next to the number of the reference.

1. McMullan R, Gordon A. Impact of a central line infection pevention bundle in newborn infants. *Infect Control Hosp Epidemiol*. 2016:1-8. **(Retrospective cohort analysis; 353 CVCs placed in 214 neonates during baseline period, 260 CVCs in 162 neonates during intervention period)**
2. Wilson W. *Trauma: Emergency Resuscitation, Perioperative Anesthesia, Surgical Management*. Vol 1. New York: Informa Healthcare USA, Inc.; 2007. **(Textbook)**
3. PIV catheter gauge selection. Available at: https://infusionnurse.org/2013/03/27/piv-catheter-gauge-selection/. Accessed May 15, 2017. **(Online review)**
4. Hoste EA, Maitland K, Brudney CS, et al. Four phases of intravenous fluid therapy: a conceptual model. *Br J Anaesth.* 2014;113(5):740-747. **(Review article)**
5. Silverman A, Wang V. Shock: a common pathway for life-threatening pediatric illnesses and injuries. *Pediatr Emerg Med Pract*. 2005;2(10):1-22. **(Review article)**
6. de Caen AR, Berg MD, Chameides L, et al. Part 12: Pediatric Advanced Life Support: 2015 American Heart Association guidelines update for cardiopulmonary resuscitation and emergency cardiovascular care. *Circulation*. 2015;132(18 Suppl 2):S526-S542. **(Guidelines)**
7. Carcillo JA, Davis AL, Zaritsky A. Role of early fluid resuscitation in pediatric septic shock. *JAMA*. 1991;266(9):1242-1245. **(Prospective cohort study; 34 patients analyzed together and in 3 groups)**
8. Kleinman ME, Chameides L, Schexnayder SM, et al. Pediatric Advanced Life Support: 2010 American Heart Association guidelines for cardiopulmonary resuscitation and emergency cardiovascular care. *Pediatrics*. 2010;126(5):e1361-e1399. **(Guidelines)**

9.* Yen K, Riegert A, Gorelick MH. Derivation of the DIVA score: a clinical prediction rule for the identification of children with difficult intravenous access. *Pediatr Emerg Care*. 2008;24(3):143-147. **(Prospective cohort study; 615 patients age 0-21 years)**

10. Larsen P, Eldridge D, Brinkley J, et al. Pediatric peripheral intravenous access: does nursing experience and competence really make a difference? *J Infus Nurs.* 2010;33(4):226-235. **(Prospective observational study; 1135 venipunctures in 592 pediatric patients)**

11.* Jacobson AF, Winslow EH. Variables influencing intravenous catheter insertion difficulty and failure: an analysis of 339 intravenous catheter insertions. *Heart Lung*. 2005;34(5):345-359. **(Retrospective study; 339 IV insertions by 34 nurses)**

12. Brunette DD, Fischer R. Intravascular access in pediatric cardiac arrest. *Am J Emerg Med*. 1988;6(6):577-579. **(Retrospective review; 33 cases)**
13. Riker MW, Kennedy C, Winfrey BS, et al. Validation and refinement of the difficult intravenous access score: a clinical prediction rule for identifying children with difficult intravenous access. *Acad Emerg Med*. 2011;18(11):1129-1134. **(Prospective observational study; 366 patients undergoing IV placement)**
14. Lininger RA. Pediatric peripheral I.V. insertion success rates. *Pediatr Nurs*. 2003;29(5):351-354. **(Prospective study; 249 IV placements)**
15. Petroski A, Frisch A, Joseph N, et al. Predictors of difficult pediatric intravenous access in a community emergency department. *J Vasc Access*. 2015;16(6):521-526. **(Retrospective cohort; 652 pediatric patients)**
16. Black KJ, Pusic MV, Harmidy D, et al. Pediatric intravenous insertion in the emergency department: bevel up or bevel down? *Pediatr Emerg Care*. 2005;21(11):707-711. **(Randomized crossover study; 396 IV attempts from 63 nurses)**
17. Riera A, Langhan M, Northrup V, et al. Remember the saphenous: ultrasound evaluation and intravenous site selection of peripheral veins in young children. *Pediatr Emerg Care*. 2011;27(12):1121-1125. **(Prospective observational study; 60 children aged 0-3 years)**

18.* Frey AM. Success rates for peripheral I.V. insertion in a children's hospital. Financial implications. *J Intraven Nurs.* 1998;21(3):160-165. **(Retrospective cohort study and cost-effectiveness analysis)**

19. Costantino TG, Parikh AK, Satz WA, et al. Ultrasonography-guided peripheral intravenous access versus traditional approaches in patients with difficult intravenous access. *Ann Emerg Med*. 2005;46(5):456-461. **(Randomized study; 60 patients with IV placement failure > 3 attempts)**
20. Miller JM, Goetz AM, Squier C, et al. Reduction in nosocomial intravenous device-related bacteremias after institution of an intravenous therapy team. *J Intraven Nurs*. 1996;19(2):103-106. **(Retrospective cohort study and cost-effectiveness analysis)**
21. Scalley RD, Van CS, Cochran RS. The impact of an I.V. team on the occurrence of intravenous-related phlebitis. A 30-month study. *J Intraven Nurs*. 1992;15(2):100-109. **(Prospective observational study)**
22. Meier PA, Fredrickson M, Catney M, et al. Impact of a dedicated intravenous therapy team on nosocomial bloodstream infection rates. *Am J Infect Control*. 1998;26(4):388-392. **(Retro-**

spective cohort study; pre- and post- specialized IV team)**

23. Kumar RJ, Pegg SP, Kimble RM. Management of extravasation injuries. *ANZ J of Surg*. 2001;71(5):285-289. **(Retrospective case review; 9 patients)**
24. Loubani OM, Green RS. A systematic review of extravasation and local tissue injury from administration of vasopressors through peripheral intravenous catheters and central venous catheters. *J Crit Care*. 2015;30(3):653.e659-617. **(Systematic review; 270 patients with 325 injuries)**
25. Ricard JD, Salomon L, Boyer A, et al. Central or peripheral catheters for initial venous access of ICU patients: a randomized controlled trial. *Crit Care Med.* 2013;41(9):2108-2115. **(Randomized controlled trial; 135 patients with CVC, 128 patients with PIV)**
26. Kuwahara T, Asanami S, Kubo S. Experimental infusion phlebitis: tolerance osmolality of peripheral venous endothelial cells. *Nutrition*. 1998;14(6):496-501. **(Animal study; veins examined histopathologically at 8, 12, and 24 hours)**
27. Hern HG, Kiefer M, Louie D, et al. D10 in the treatment of prehospital hypoglycemia: a 24 month observational cohort study. *Prehosp Emerg Care*. 2017;21(1):63-67. **(Observational cohort; 1323 patients)**
28. Moore C, Woollard M. Dextrose 10% or 50% in the treatment of hypoglycaemia out of hospital? A randomised controlled trial. *Emerg Med J*. 2005;22(7):512-515. **(Randomized controlled trial; 51 patients)**
29. Kleinman ME, Chameides L, Schexnayder SM, et al. Part 14: Pediatric Advanced Life Support: 2010 American Heart Association guidelines for cardiopulmonary resuscitation and emergency cardiovascular care. *Circulation*. 2010;122(18 Suppl 3):S876-S908. **(Guidelines)**
30. Fisher B, Thomas D, Peterson B. Hypertonic saline lowers raised intracranial pressure in children after head trauma. *J Neurosurg Anesthesiol*. 1992;4(1):4-10. **(Double-blind cross-over study; 18 pediatric patients with head trauma)**
31. Kamat P, Vats A, Gross M, et al. Use of hypertonic saline for the treatment of altered mental status associated with diabetic ketoacidosis. *Pediatr Crit Care Med*. 2003;4(2):239-242. **(Case reports and literature review)**
32. Khanna S, Davis D, Peterson B, et al. Use of hypertonic saline in the treatment of severe refractory posttraumatic intracranial hypertension in pediatric traumatic brain injury. *Crit Care Med*. 2000;28(4):1144-1151. **(Prospective cohort; 10 pediatric patients with increased ICP)**
33. Ayus JC, Caputo D, Bazerque F, et al. Treatment of hyponatremic encephalopathy with a 3% sodium chloride protocol: a case series. *Am J Kidney Dis*. 2015;65(3):435-442. **(Case series; 71 cases in 64 patients)**
34. Luu JL, Wendtland CL, Gross MF, et al. Three-percent saline administration during pediatric critical care transport. *Pediatr Emerg Care*. 2011;27(12):1113-1117. **(Retrospective study; 101 pediatric patients)**
35. Amaral JG, Traubici J, BenDavid G, et al. Safety of power injector use in children as measured by incidence of extravasation. *AJR Am J Roentgenol*. 2006;187(2):580-583. **(Prospective observational study; 557 patients receiving contrast through PIV access)**
36. Jacobs JE, Birnbaum BA, Langlotz CP. Contrast media reactions and extravasation: relationship to intravenous injection rates. *Radiology*. 1998;209(2):411-416. **(Prospective observational study; complications of 6660 contrast injections)**
37.* Reuter-Rice K, Patrick D, Kantor E, et al. Characteristics of children who undergo intraosseous needle placement. *Adv Emerg Nurs J*. 2015;37(4):301-307. **(Retrospective descriptive analysis; 143 patients)**
38. Tobias JD, Ross AK. Intraosseous infusions: a review for the anesthesiologist with a focus on pediatric use. *Anesth Analg.* 2010;110(2):391-401. **(Review article)**
39. Ellemunter H, Simma B, Trawoger R, et al. Intraosseous lines in preterm and full-term neonates. *Arch Dis Child Fetal Neonatal Ed*. 1999;80(1):F74-F75. **(Prospective cohort; 30 IO lines placed in 27 patients--20 preterm, 7 full-term)**
40. Leidel BA, Kirchhoff C, Bogner V, et al. Comparison of intraosseous versus central venous vascular access in adults under resuscitation in the emergency department with inaccessible peripheral veins. *Resuscitation.* 2012;83(1):40-45. **(Prospective observational study; 40 adult patients receiving IO and CVC simulataneously)**
41.* Smith R, Davis N, Bouamra O, et al. The utilisation of intraosseous infusion in the resuscitation of paediatric major trauma patients. *Injury.* 2005;36(9):1034-1038. **(Retrospective review)**
42. Ramet J, Clybouw C, Benatar A, et al. Successful use of an intraosseous infusion in an 800 grams preterm infant. *Eur J Emerg Med*. 1998;5(3):327-328. **(Case report)**
43. Hansen M, Meckler G, Spiro D, et al. Intraosseous line use, complications, and outcomes among a population-based cohort of children presenting to California hospitals. *Pediatr Emerg Care*. 2011;27(10):928-932. **(Retrospective cohort study; 291 pediatric patients with IO placement)**
44. Miller LJ, Philbeck TE, Montez D, et al. A new study of intraosseous blood for laboratory analysis. *Arch Pathol Lab Med*. 2010;134(9):1253-1260. **(Cross-sectional study; 10 samples of IO and peripheral blood)**
45. Evans RJ, Jewkes F, Owen G, et al. Intraosseous infusion--a technique available for intravascular administration of drugs and fluids in the child with burns. *Burns*. 1995;21(7):552-553. **(Case reports)**
46. Hartholt KA, van Lieshout EM, Thies WC, et al. Intraosseous devices: a randomized controlled trial comparing three intraosseous devices. *Prehosp Emerg Care.* 2010;14(1):6-13. **(Single-blind randomized trial; 65 adult and 22 pediatric patients)**
47. Myers LA, Russi CS, Arteaga GM. Semiautomatic intraosseous devices in pediatric prehospital care. *Prehosp Emerg Care*. 2011;15(4):473-476. **(Retrospective review; semiautomatic vs conventional devices)**
48. Spriggs NM, White LJ, Martin SW, et al. Comparison of two intraosseous infusion techniques in an EMT training program. *Acad Emerg Med.* 2000;7(10):1168. **(Prospective cross-over study; 28 EMT students and 10 paramedics)**
49. Cheung E, Baerlocher MO, Asch M, et al. Venous access: a practical review for 2009. *Can Fam Physician*. 2009;55(5):494-496. **(Review article)**
50. O'Grady NP, Chertow DS. Managing bloodstream infections in patients who have short-term central venous catheters. *Cleve Clin J Med*. 2011;78(1):10-17. **(Review article based on 2009 Infectious Diseases Society of America guidelines)**
51. Miller AH, Roth BA, Mills TJ, et al. Ultrasound guidance versus the landmark technique for the placement of central venous catheters in the emergency department. *Acad Emerg Med.* 2002;9(8):800-805. **(Prospective cohort study; 122 patients with CVC placement)**
52. Leung J, Duffy M, Finckh A. Real-time ultrasonographically guided internal jugular vein catheterization in the emergency department increases success rates and reduces complications: a randomized, prospective study. *Ann Emerg Med*. 2006;48(5):540-547. **(Prospective randomized study; 130 patients)**
53. Ballard DW, Reed ME, Rauchwerger AS, et al. Emergency physician perspectives on central venous catheterization in the emergency department: a survey-based study. *Acad Emerg Med*. 2014;21(6):623-630. **(Survey study; 365 emergency medicine physicians)**
54. Gallagher RA, Levy J, Vieira RL, et al. Ultrasound assistance

for central venous catheter placement in a pediatric emergency department improves placement success rates. *Acad Emerg Med*. 2014;21(9):981-986. **(Retrospective cohort study; 168 patients)**

55. Freeman JJ, Gadepalli SK, Siddiqui SM, et al. Improving central line infection rates in the neonatal intensive care unit: Effect of hospital location, site of insertion, and implementation of catheter-associated bloodstream infection protocols. *J Pediatr Surg*. 2015;50(5):860-863. **(Retrospective chart review; 368 catheters in 285 NICU patients)**
56. Froehlich CD, Rigby MR, Rosenberg ES, et al. Ultrasound-guided central venous catheter placement decreases complications and decreases placement attempts compared with the landmark technique in patients in a pediatric intensive care unit. *Crit Care Med*. 2009;37(3):1090-1096. **(Prospective observational cohort study; 93 patients)**
57. Dougherty L. Central venous access devices. *Nurs Stand*. 2000;14(43):45-50. **(Review article)**
58. Weddle G, Jackson MA, Selvarangan R. Reducing blood culture contamination in a pediatric emergency department. *Pediatr Emerg Care*. 2011;27(3):179-181. **(Retrospective cohort study; pre- and post-phlebotomy policy)**
59. Chiang VW, Baskin MN. Uses and complications of central venous catheters inserted in a pediatric emergency department. *Pediatr Emerg Care*. 2000;16(4):230-232. **(Retrospective chart review; 121 patients)**
60. Parienti JJ, Mongardon N, Megarbane B, et al. Intravascular complications of central venous catheterization by insertion site. *N Engl J Med*. 2015;373(13):1220-1229. **(Multicenter randomized trial; 3471 catheters in 3027 adult patients)**
61. Andropoulos DB, Bent ST, Skjonsby B, et al. The optimal length of insertion of central venous catheters for pediatric patients. *Anesth Analg*. 2001;93(4):883-886. **(Prospective observational study; 452 internal jugular and subclavian line placements in pediatric patients)**
62. Galloway S, Bodenham A. Long-term central venous access. *Br J Anaesth*. 2004;92(5):722-734. **(Review article)**
63. Keir A, Giesinger R, Dunn M. How long should umbilical venous catheters remain in place in neonates who require long-term (≥5–7 days) central venous access? *J Paediatr Child Health*. 2014;50(8):649-652. **(Evidence-based review)**
64. Hollingsworth C, Clarke P, Sharma A, et al. National survey of umbilical venous catheterisation practices in the wake of two deaths. *Arch Dis Child Fetal Neonatal Ed*. 2015;100(4):F371-F372. **(Survey study)**
65. Guimarães AF, Souza AA, Bouzada MC, et al. Accuracy of chest radiography for positioning of the umbilical venous catheter. *J Pediatr (Rio J)*. 2017;93(2):172-178. **(Cross-sectional observational study; 162 newborns with umbilical venous catheter placement)**
66. Jain A, Deshpande P, Shah P. Peripherally inserted central catheter tip position and risk of associated complications in neonates. *J Perinatol*. 2013;33(4):307-312. **(Retrospective cohort study; 336 infants)**
67. Lloreda-Garcia JM, Lorente-Nicolás A, Bermejo-Costa F, et al. [Catheter tip position and risk of mechanical complications in a neonatal unit]. *An Pediatr (Barc)*. 2016;85(2):77-85. **(Prospective cohort study; 604 CVCs in NICU patients)**
68. Perry AM, Caviness AC, Hsu DC. Efficacy of a near-infrared light device in pediatric intravenous cannulation: a randomized controlled trial. *Pediatr Emerg Care*. 2011;27(1):5-10. **(Randomized controlled trial; 123 patients)**
69. Rothbart A, Yu P, Muller-Lobeck L, et al. Peripheral intravenous cannulation with support of infrared laser vein viewing system in a pre-operation setting in pediatric patients. *BMC Res Notes*. 2015;8:463. **(Retrospective case-control; 238 pediatric patients)**
70. Katsogridakis YL, Seshadri R, Sullivan C, et al. Veinlite transillumination in the pediatric emergency department: a therapeutic interventional trial. *Pediatr Emerg Care*. 2008;24(2):83-88. **(Randomized trial; 240 pediatric patients with nonemergent PIV placement)**
71. Goren A, Laufer J, Yativ N, et al. Transillumination of the palm for venipuncture in infants. *Pediatr Emerg Care*. 2001;17(2):130-131. **(Prospective cohort study; 100 infants aged 2-36 months)**
72. Cordoni A, Cordoni LE. Eutectic mixture of local anesthetics reduces pain during intravenous catheter insertion in the pediatric patient. *Clin J Pain*. 2001;17(2):115-118. **(Double-blind placebo-controlled trial; 57 patients aged 4-12 years)**
73. Koh JL, Harrison D, Myers R, et al. A randomized, double-blind comparison study of EMLA and ELA-Max for topical anesthesia in children undergoing intravenous insertion. *Paediatr Anaesth*. 2004;14(12):977-982. **(Double-blind randomized trial; 60 patients aged 8-17 years)**
74. Smith DP, Gjellum M. The efficacy of LMX versus EMLA for pain relief in boys undergoing office meatotomy. *J Urol*. 2004;172(4 Pt 2):1760-1761. **(Prospective randomized study; 52 patients aged 1-10 years)**
75. Cooper JA, Bromley LM, Baranowski AP, et al. Evaluation of a needle-free injection system for local anaesthesia prior to venous cannulation. *Anaesthesia*. 2000;55(3):247-250. **(Randomized cross-sectional study; 72 patients with large-bore IV placement)**
76. Spanos S, Booth R, Koenig H, et al. Jet injection of 1% buffered lidocaine versus topical ELA-Max for anesthesia before peripheral intravenous catheterization in children: a randomized controlled trial. *Pediatr Emerg Care*. 2008;24(8):511-515. **(Randomized controlled trial; 70 pediatric patients)**
77. Lysakowski C, Dumont L, Tramer MR, et al. A needle-free jet-injection system with lidocaine for peripheral intravenous cannula insertion: a randomized controlled trial with cost-effectiveness analysis. *Anesth Analg*. 2003;96(1):215-219. **(Randomized controlled trial; 400 patients)**
78. Lunoe MM, Drendel AL, Brousseau DC. The use of the needle-free jet injection system with buffered lidocaine device does not change intravenous placement success in children in the emergency department. *Acad Emerg Med*. 2015;22(4):447-451. **(Retrospective cohort study; 300 patients)**
79. Costello M, Ramundo M, Christopher NC, et al. Ethyl vinyl chloride vapocoolant spray fails to decrease pain associated with intravenous cannulation in children. *Clin Pediatr (Phila)*. 2006;45(7):628-632. **(Double-blind randomized controlled trial; 127 patients aged 9-18 years)**
80. Soueid A, Richard B. Ethyl chloride as a cryoanalgesic in pediatrics for venipuncture. *Pediatr Emerg Care*. 2007;23(6):380-383. **(Randomized cross-sectional study; 55 pediatric patients)**
81. Ramsook C, Kozinetz CA, Moro-Sutherland D. Efficacy of ethyl chloride as a local anesthetic for venipuncture and intravenous cannula insertion in a pediatric emergency department. *Pediatr Emerg Care*. 2001;17(5):341-343. **(Randomized cross-sectional study; 222 patients aged 3-18 years)**
82. Waterhouse MR, Liu DR, Wang VJ. Cryotherapeutic topical analgesics for pediatric intravenous catheter placement: ice versus vapocoolant spray. *Pediatr Emerg Care*. 2013;29(1):8-12. **(Cross-sectional cross-over study)**

83.* Doellman D. Pharmacological versus nonpharmacological techniques in reducing venipuncture psychological trauma in pediatric patients. *J Infus Nurs*. 2003;26(2):103-109. **(Review article)**

84. Sahiner NC, Bal MD. The effects of three different distraction methods on pain and anxiety in children. *J Child Health Care*. 2016;20(3):277-285. **(Prospective randomized controlled trial; 120 patients aged 6-12 years)**

85. Bagnasco A, Pezzi E, Rosa F, et al. Distraction techniques in children during venipuncture: an Italian experience. *J Prev Med Hyg*. 2012;53(1):44-48. **(Prospective cross-sectional study; 203 patients aged 2-15 years)**

86. Moadad N, Kozman K, Shahine R, et al. Distraction using the BUZZY for children during an IV insertion. *J Pediatr Nurs*. 2016;31(1):64-72. **(Randomized controlled trial; 48 patients aged 4-12 years)**

87. Smith B. Peripheral intravenous catheter dwell times: a comparison of 3 securement methods for implementation of a 96-hour scheduled change protocol. *J Infus Nurs*. 2006;29(1):14-17. **(Prospective block-randomized cohort study; 73 adult patients)**

88.* Tripathi S, Kaushik V, Singh V. Peripheral IVs: factors affecting complications and patency--a randomized controlled trial. *J Infus Nurs*. 2008;31(3):182-188. **(Randomized controlled trial; 377 catheters in 88 patients aged 0-12 years)**

89. Galpin RD, Kronick JB, Willis RB, et al. Bilateral lower extremity compartment syndromes secondary to intraosseous fluid resuscitation. *J Pediatr Orthop*. 1991;11(6):773-776. **(Case report)**

90. Simmons CM, Johnson NE, Perkin RM, et al. Intraosseous extravasation complication reports. *Ann Emerg Med*. 1994;23(2):363-366. **(Case reports)**

91. LaSpada J, Kissoon N, Melker R, et al. Extravasation rates and complications of intraosseous needles during gravity and pressure infusion. *Crit Care Med*. 1995;23(12):2023-2028. **(Prospective randomized study; animal study)**

92. Theodoro D, Olsen MA, Warren DK, et al. Emergency department central line-associated bloodstream infections (CLABSI) incidence in the era of prevention practices. *Acad Emerg Med*. 2015;22(9):1048-1055. **(Prospective observational study; 994 CVCs in 940 patients)**

93. Venkataraman ST, Thompson AE, Orr RA. Femoral vascular catheterization in critically ill infants and children. *Clin Pediatr (Phila)*. 1997;36(6):311-319. **(Meta-analysis)**

94. Adelman S. An emergency intravenous route for the pediatric patient. *JACEP*. 1976;5(8):596-598. **(Review article)**

95. Gauderer MW. Vascular access techniques and devices in the pediatric patient. *Surg Clin North Am*. 1992;72(6):1267-1284. **(Review article)**

96. Chappell S, Vilke GM, Chan TC, et al. Peripheral venous cutdown. *J Emerg Med*. 2006;31(4):411-416. **(Review article)**

97. Zimmerman JJ, Strauss RH. History and current application of intravenous therapy in children. *Pediatr Emerg Care*. 1989;5(2):120-127. **(Review article)**

98. Chand DH, Valentini RP, Kamil ES. Hemodialysis vascular access options in pediatrics: considerations for patients and practitioners. *Pediatr Nephrol*. 2009;24(6):1121-1128. **(Review article)**

99. Brittinger WD, Walker G, Twittenhoff WD, et al. Vascular access for hemodialysis in children. *Pediatr Nephrol*. 1997;11(1):87-95. **(Review article)**

100. Nghiem DD, Schulak JA, Corry RJ. Management of the infected hemodialysis access grafts. *Trans Am Soc Artif Intern Organs*. 1983;29:360-362. **(Review article)**

101. Hodde LA, Sandroni S. Emergency department evaluation and management of dialysis patient complications. *J Emerg Med*. 1992;10(3):317-334. **(Review article)**

102. Larsen C, Weathers B, Schwartzwald M, et al. Focus on: dialysis access emergencies. *Clinical & Practice Management*. 2010. Available at: https://www.acep.org/Clinical---Practice-Management/Focus-On--Dialysis-Access-Emergencies/. Accessed May 15, 2017. **(Practice guidelines)**

103. Schwab SJ, Quarles LD, Middleton JP, et al. Hemodialysis-associated subclavian vein stenosis. *Kidney Int*. 1988;33(6):1156-1159. **(Prospective interventional study; 12 patients with stenosis receiving angioplasty)**

104. Cimochowski GE, Worley E, Rutherford WE, et al. Superiority of the internal jugular over the subclavian access for temporary dialysis. *Nephron*. 1990;54(2):154-161. **(Retrospective observational study; 52 patients)**

105. Clase CM, Crowther MA, Ingram AJ, et al. Thrombolysis for restoration of patency to haemodialysis central venous catheters: a systematic review. *J Thromb Thrombolysis*. 2001;11(2):127-136. **(Systematic review)**

106. Kovacich A, Tamma PD, Advani S, et al. Peripherally inserted central venous catheter complications in children receiving outpatient parenteral antibiotic therapy (OPAT). *Infect Control Hosp Epidemiol*. 2016;37(4):420-424. **(Retrospective cohort study; 1465 PICCs in 955 pediatric patients)**

107. Shrestha NK, Bhaskaran A, Scalera NM, et al. Antimicrobial stewardship at transition of care from hospital to community. *Infect Control Hosp Epidemiol*. 2012;33(4):401-404. **(Retrospective cohort study; 244 infectious disease consult requests)**

108.* Vukovic AA, Frey M, Byczkowski T, et al. Video-based assessment of peripheral intravenous catheter insertion in the resuscitation area of a pediatric emergency department. *Acad Emerg Med*. 2016;23(5):637-644. **(Retrospective observational study; 151 nontrauma patients undergoing PIV placement)**

CME Questions

Take This Test Online!

Current subscribers receive CME credit absolutely free by completing the following test. Each issue includes *4 AMA PRA Category 1 Credits™*, 4 ACEP Category I credits, 4 AAP Prescribed credits, or 4 AOA Category 2A or 2B credits. Monthly online testing is now available for current and archived issues. To receive your free CME credits for this issue, scan the QR code below with your smartphone or visit www.ebmedicine.net/P0617.

1. In which of the following cases should immediate vascular access be established in order to provide IV fluids?

a. A 5-year-old with urticaria after peanut ingestion, with a heart rate of 100 beats/min and blood pressure of 100/65 mm Hg

b. A 10-year-old with first-degree burns to the back from sun exposure, with a heart rate of 90 beats/min and a blood pressure of 120/75 mm Hg

c. A 3-year-old with 4 days of vomiting, with a heart rate of 160 beats/min and a blood pressure of 70/40 mm Hg

d. A 4-year-old who was a restrained passenger in a motor vehicle crash, with a heart rate of 110 beats/min and a blood pressure of 110/65 mm Hg

2. **In your evaluation of a patient, you decide to use the difficult intravenous access (DIVA) score to predict the success of IV placement. Based on their DIVA scores, which of the following patients has a predicted first attempt failure rate > 50%?**
   a. A 3-year-old boy with a history of prematurity who has a visible and palpable hand vein
   b. A 6-month-old girl who has a palpable but not visible antecubital vein
   c. An 8-year-old boy who has a palpable but not visible hand vein
   d. A 1-year-old girl who has a visible but not palpable saphenous vein

3. **Which of the following factors is associated with decreased first-attempt success?**
   a. A nurse with > 2 years of nursing experience
   b. An IV placed in a hand vein
   c. A nurse who has a lot of confidence in her ability to place an IV
   d. A patient who weighs < 5 kg

4. **A 6-year-old girl in your ED is awaiting admission when she develops swelling of her arm proximal to the site of her peripheral IV and complains of severe pain. Infusion of which of the following medications would be most concerning?**
   a. Calcium gluconate
   b. Calcium chloride
   c. 10% dextrose solution
   d. 12.5% dextrose solution

5. **Compared to venipuncture results, IO samples will have:**
   a. Lower carbon dioxide tension
   b. Higher platelet counts
   c. Higher creatinine concentration
   d. Lower white blood cell counts

6. **You placed an emergent femoral line in a 13-year-old who was rapidly decompensating. During sign-out, you tell the PICU that, despite your best efforts, the line may not be completely sterile. The line should be removed:**
   a. Immediately
   b. Within 48 hours
   c. In 3 to 5 days
   d. In 5 to 7 days

7. **Based on available evidence, success rates of first-attempt IV catheter placement are improved when using:**
   a. Transillumination
   b. A VeinViewer®
   c. An AccuVein®
   d. A Buzzy®

8. **You are speaking to the parents of a 4-year-old boy who has displaced radius and ulnar fractures after falling from the monkey bars. In order to better control his pain, you would like to place a PIV catheter and administer morphine. The method with the fastest onset of local pain relief prior to IV catheter placement is:**
   a. EMLA® (2.5% lidocaine, 2.5% prilocaine)
   b. LMX® (4% lidocaine)
   c. Needle-free lidocaine injection
   d. Vapocoolant

9. **A 9-year-old patient who was recently discharged from the hospital presents with pain at her former IV catheter site. On examination, there is a knotty palpation over the vein but no signs of erythema or swelling. You are concerned about thrombophlebitis and discuss appropriate care. This may have been prevented by:**
   a. Alternating IV catheter sites every 5 days
   b. Avoiding PIV catheter placement in the lower extremities
   c. Placing a 24-gauge catheter
   d. Infusing lidocaine through the IV catheter

10. **A 15-year-old adolescent was an unrestrained passenger in a high-speed motor vehicle crash. The surgical team is attempting venous cutdown to establish vascular access. An absolute contraindication to this procedure would be:**
    a. A history of bleeding diathesis
    b. Venous thrombosis of the ipsilateral leg
    c. An open femur fracture of the ipsilateral leg
    d. A second-degree burn to the thigh

PEDIATRIC EMERGENCY MEDICINE PRACTICE
AN EVIDENCE-BASED APPROACH TO PEDIATRIC EMERGENCY MEDICINE ▲ EBMEDICINE.NET

THANK YOU!

EB Medicine, publisher of *Pediatric Emergency Medicine Practice,* thanks Vincent J. Wang, MD, MHA, for serving as Associate Editor-in-Chief since 2012. Dr. Wang has contributed to the journal by recommending topics and recruiting authors and peer reviewers. He has reviewed articles as well as authored them, most recently the Altered Level of Consciousness issue. Dr. Wang will continue to support *PEMP* as a member of our Editorial Board. In addition to Dr. Wang's clinical and faculty responsibilities and his work for EB Medicine, he is lead editor of the *Pediatric Emergency Medicine Question Review Book* and co-editor of *Fleisher and Ludwig's 5-Minute Pediatric Emergency Medicine Consult*. Thank you for your years of service, Dr. Wang!

Physician CME Information

Date of Original Release: June 1, 2017. Date of most recent review: May 15, 2017. Termination date: June 1, 2020.

Accreditation: EB Medicine is accredited by the Accreditation Council for Continuing Medical Education (ACCME) to provide continuing medical education for physicians. This activity has been planned and implemented in accordance with the accreditation requirements and policies of the ACCME.

Credit Designation: EB Medicine designates this enduring material for a maximum of *4 AMA PRA Category 1 Credits™*. Physicians should claim only the credit commensurate with the extent of their participation in the activity.

ACEP Accreditation: *Pediatric Emergency Medicine Practice* is also approved by the American College of Emergency Physicians for 48 hours of ACEP Category I credit per annual subscription.

AAP Accreditation: This continuing medical education activity has been reviewed by the American Academy of Pediatrics and is acceptable for a maximum of 48 AAP credits per year. These credits can be applied toward the AAP CME/CPD Award available to Fellows and Candidate Fellows of the American Academy of Pediatrics.

AOA Accreditation: *Pediatric Emergency Medicine Practice* is eligible for up to 48 American Osteopathic Association Category 2A or 2B credit hours per year.

Needs Assessment: The need for this educational activity was determined by a survey of medical staff, including the editorial board of this publication; review of morbidity and mortality data from the CDC, AHA, NCHS, and ACEP; and evaluation of prior activities for emergency physicians.

Target Audience: This enduring material is designed for emergency medicine physicians, physician assistants, nurse practitioners, and residents.

Goals: Upon completion of this activity, you should be able to: (1) demonstrate medical decision-making based on the strongest clinical evidence; (2) cost-effectively diagnose and treat the most critical ED presentations; and (3) describe the most common medicolegal pitfalls for each topic covered.

Discussion of Investigational Information: As part of the journal, faculty may be presenting investigational information about pharmaceutical products that is outside Food and Drug Administration approved labeling. Information presented as part of this activity is intended solely as continuing medical education and is not intended to promote off-label use of any pharmaceutical product.

Faculty Disclosure: It is the policy of EB Medicine to ensure objectivity, balance, independence, transparency, and scientific rigor in all CME-sponsored educational activities. All faculty participating in the planning or implementation of a sponsored activity are expected to disclose to the audience any relevant financial relationships and to assist in resolving any conflict of interest that may arise from the relationship. Presenters must also make a meaningful disclosure to the audience of their discussions of unlabeled or unapproved drugs or devices. In compliance with all ACCME Essentials, Standards, and Guidelines, all faculty for this CME activity were asked to complete a full disclosure statement. The information received is as follows: **Dr. Whitney, Dr. Bellis, Dr. Leung, Dr. Vella, Dr. Wang, Dr. Mishler, and their related parties report no significant financial interest or other relationship with the manufacturer(s) of any commercial product(s) discussed in this educational presentation. Dr. Langhan reported: research grant, Covidien; honorarium, American Academy of Pediatrics. Dr. Jagoda made the following disclosures: Consultant, Daiichi Sankyo Inc; Consultant, Pfizer Inc; Consultant, Banyan Biomarkers Inc; Consulting fees, EB Medicine.**

Commercial Support: This issue of *Pediatric Emergency Medicine Practice* did not receive any commercial support.

Earning Credit: Two Convenient Methods: (1) Go online to www.ebmedicine.net/CME and click on the title of this article. (2) Mail or fax the CME Answer And Evaluation Form with your June and December issues to *Pediatric Emergency Medicine Practice.*

Hardware/Software Requirements: You will need a Macintosh or PC with internet capabilities to access the website.

Additional Policies: For additional policies, including our statement of conflict of interest, source of funding, statement of informed consent, and statement of human and animal rights, visit http://www.ebmedicine.net/policies.

Direct all inquiries to:
EB Medicine
Phone: 1-800-249-5770 or 678-366-7933
Fax: 1-770-500-1316
5550 Triangle Parkway, Suite 150
Norcross, GA 30092
E-mail: **ebm@ebmedicine.net**
Website: **ebmedicine.net**
To write a letter to the editor, please email: vellaadam@gmail.com

Subscription Information
Full annual subscription: $319 (includes 12 monthly evidence-based print issues; 48 *AMA PRA Category 1 Credits™,* 48 ACEP Category I credits, 48 AAP Prescribed credits, and 48 AOA Category 2A or 2B CME credits; and full online access to searchable archives and additional CME). Call 1-800- 249-5770 or go to www.ebmedicine.net/subscribe to subscribe.
Individual issues: $39 (includes 4 CME credits). Call 1-800-249-5770 or go to www.ebmedicine.net/PEMPissues to order.
Group subscriptions at heavily discounted rates are also available. Contact groups@ebmedicine.net for more information.