VIDEOS IN CLINICAL MEDICINE

Intraosseous Catheter Placement in Children

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OVERVIEW

Obtaining vascular access in acutely ill or injured children can be challenging. Intraosseous access provides a means for delivery of medications, crystalloid fluids, colloids, and blood products during pediatric resuscitation. In addition, when intraosseous access is achieved, blood samples can be obtained for laboratory analysis. Numerous studies show that an intraosseous catheter can be placed more rapidly than a central venous catheter and that this technique is more reliable than venous cutdown.[1-3]

INDICATIONS

Intraosseous cannulation is indicated when peripheral vascular access cannot be rapidly obtained in an infant or child in shock, respiratory failure, or respiratory or cardiac arrest. The most recent guidelines on pediatric advanced life support state that intraosseous access "is useful as the initial vascular access in cases of cardiac arrest."[4]

CONTRAINDICATIONS

Intraosseous access should not be attempted in any bone with a suspected or known fracture near or proximal to the insertion site or in a bone in which a previous attempt was unsuccessful. In these circumstances, infused medications or fluids may not reach the central circulation and extravasation during fluid administration may lead to compartment syndrome.

Indwelling hardware from a previous orthopedic procedure is a relative contraindication, since it may prevent successful cannulation in that bone. The presence of infection in the skin or soft tissue overlying the insertion site is also a relative contraindication, since passing a needle through the infected area may introduce bacteria into the bone or the systemic circulation.

Avoid intraosseous cannulation in patients with underlying bone diseases, such as osteogenesis imperfecta or osteopenia, whose bone may not tolerate or support cannulation. In patients with osteopetrosis, a condition characterized by very dense bone, penetration through the thickened bony cortex may not be possible.

ANATOMY

It is possible to introduce fluid and medications through the bones because of the connections between the marrow cavity and the systemic venous circulation (Fig. 1). The cortex overlying the metaphysis of long bones is relatively thin and easy to penetrate. The administered substance passes through the underlying cancellous bone by means of venous sinusoids, which in turn drain into nutrient vessels and emissary veins that connect with systemic venous circulation. Cannulation anywhere within the noncollapsible medullary cavity provides a reliable means of infusing fluids or medications into the systemic venous circulation.

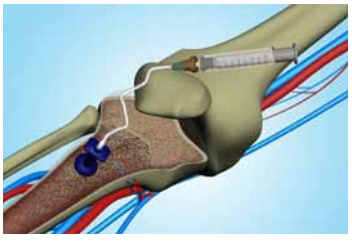

Figure 1. Infusion of Fluid or Medication through the Marrow Cavity and Emissary Veins to the Systemic Venous Circulation.

Figure 2. The Preferred Site for Intraosseous Cannulation in Children — The Flat Surface Medial and Inferior to the Tibial Tuberosity.

SITE SELECTION

Several anatomical sites may be used for intraosseous cannulation. The most commonly used include the proximal tibia, the distal tibia, the proximal humerus, and the distal femur. The anterior superior iliac spine is used less commonly. The sternum and distal radius have been identified for use in adults but not in children.

The proximal tibia is the preferred site in children because palpation and identification of underlying bony landmarks are less likely to be obscured by large amounts of soft tissue (Fig. 2). In addition, this location is remote from the head and chest, where airway management and chest compressions may be ongoing in an emergency situation. The prominence immediately below the lower pole of the patella is the tibial tuberosity. The broad, flat surface of tibia that is 1 to 2 cm inferior and medial to the tuberosity serves as the targeted insertion site.

The distal tibia has easily palpable landmarks in most children. It has less cortical thickening than the proximal tibia and is therefore preferred in older children. Identify the medial malleolus. The intraosseous insertion site spans the flat portion of the tibia, 1 to 2 cm proximal to the superior margin of the malleolus.

When tibial sites are not available or when previous attempts at intraosseous cannulation at these sites have been unsuccessful, the proximal humerus can be used.[5] Begin by palpating the midportion of the humerus in the upper arm. Follow the bone proximally until the greater tubercle is appreciated, just anterior to the midline of the lateral shoulder and distal to the shoulder joint. This bony prominence is the insertion site.

The distal femur can be cannulated for intraosseous infusion, although abundant overlying soft tissue and muscle often make identification of bony landmarks challenging. Therefore, this site should be considered only when the use of tibial and humeral sites is contraindicated. The distal femoral insertion site is in the midline, 1 to 3 cm proximal to the palpable epicondyles of the distal femur.

EQUIPMENT

Figure 3. Use of a Spring-Loaded Device to Facilitate Intraosseous Cannulation.

Manual needles designed specifically for intraosseous access are available for use in children of all ages. These needles have cutting stylets to prevent soft tissue or bony spicules from obstructing the cannula, ergonomic handles to facilitate placement, and depth markings or an adjustable flange to guide depth of insertion. Large-bore spinal and butterfly needles may be used in infants if an intraosseous needle is not available.

Power-assisted devices have been shown to provide a rapid and safe means of achieving intraosseous access.[5] Currently, two such devices have been approved for pediatric use. A spring-loaded device allows the single deployment of a needle to a preset depth of insertion, which is calculated on the basis of the patient's age (Fig. 3). Drill-assisted devices allow placement of needles of varying lengths suitable for children or adults (Fig. 4). The battery-powered driver and cutting needle facilitate penetration of the bony cortex, and the operator can control the depth of insertion by increasing or decreasing the pressure applied and by changing the length of time the drill trigger is depressed. The video demonstrates the use of the drill-assisted device.

Figure 4. Use of a Drill-Assisted Device to Facilitate Intraosseous Cannulation.

PROCEDURE

Preparation

Place all equipment on an open surface that is readily accessible. Make sure that approved biohazard sharps receptacles have been placed nearby, since intraosseous cannulae are not equipped with retractable safety needles. Follow standard precautions. Whenever possible, identify the patient with the use of two identifiers before beginning the procedure and whenever a procedural time-out is initiated.

Explain the procedure to the conscious patient and to any family members who are present. When no surrogate adult is available, this urgent lifesaving procedure can be performed without informed consent.

Position the patient so that the selected insertion site is easily accessible. When using the proximal tibia or distal femoral sites, placement of a rolled towel under the popliteal fossa may help to flex the knee and maintain stability of the leg. Wear protective eyewear and sterile gloves. Using aseptic technique, clean the chosen insertion site with chlorhexidine or povidone–iodine solution. In patients who are awake and alert, infiltrate the area with lidocaine to provide local anesthesia.

Manual Technique

When using manual insertion, remove the safety cap from the needle. Ensure that the stylet is appropriately placed within the needle and that the bevels are aligned. Using your nondominant hand, stabilize the limb distal to the insertion site. This allows for counterpressure against the advancing needle and prevents unexpected patient movement. To decrease the risk of needlestick injury, make sure that no portion of your hand is behind the insertion site.

Place the needle handle in the palm of your dominant hand, with your thumb and forefinger positioned along the shaft of the needle for stabilization. Place the needle against the skin overlying the site.

Puncture the skin and continue through the soft tissue. Use firm, steady pressure and a rotating or coring motion to penetrate the bony cortex. You will note a sudden "give," with loss of resistance, as you enter the medullary cavity. Avoid continued pressure at this point, which could push the needle through the opposite side of the bone. Remove the needle cap and stylet. If the device has a supporting flange, adjust it so the surface is flush with the skin to stabilize the needle and to avoid inadvertent deeper insertion. Take care to avoid disrupting the needle while adjusting the flange.

Drill-Assisted Technique

For drill-assisted insertion, select the appropriate needle size on the basis of the patient's weight. The pediatric needle is designed for use in children weighing less than 40 kg, unless large amounts of overlying soft tissue indicate the need for a longer needle.

Remove the needle from its protective container. Attach the needle set to the driver, allowing the magnetic pull to hold it in place. Turn the safety cap clockwise to remove it and pull it off the needle. Place the needle against the skin overlying the site. Be careful to insert the needle 1 to 2 cm away from the adjacent physis. To allow the needle to penetrate the soft tissue and then the bony cortex, apply gentle, steady pressure while engaging the trigger. Once resistance decreases, marking the entrance into the medullary cavity, release the trigger and allow the driver to stop spinning before pulling back or disconnecting the needle. Gently hold the needle and pull the drill directly backward and off the needle to disconnect. Turn the stylet counterclockwise to unscrew it, and gently remove it from the needle set.

Spring-Loaded Technique

For spring-assisted insertion, select the appropriate depth of penetration in accordance with the patient's age. Firmly position the device perpendicular to the insertion site, holding the device with the dominant hand. Pull out the safety latch with your nondominant hand. Trigger the device by pushing down with the palm of your hand while continuing to hold the bottom firmly against the skin. Slowly pull up the casing around the inserted needle. Remove the stylet and secure the needle with the safety latch. Place the stylet in a biohazard sharps receptacle.

A syringe can be attached directly to the needle hub. Alternatively, attach extension tubing to the hub to avoid further needle movement. Use wide-bore tubing when available. The marrow specimen obtained on aspiration can be used for bedside glucose testing and sent for culture and determination of blood type, electrolyte concentrations, drug levels, and pH and partial pressure of carbon dioxide ($PaCO_2$).[6] Samples should not be sent for a complete blood count because immature cell forms from the marrow space will not accurately represent findings from the peripheral circulation. If fluids or medications have been previously infused, samples should not be sent for laboratory analysis after more than 5 minutes of resuscitation.[7] Once blood samples have been sent, a 10-ml saline flush is recommended to open venous sinusoids for further infusion of crystalloid, colloid, or medications.

In conscious children, pretreatment with a single dose of lidocaine (0.5 mg per kilogram of body weight) through the intraosseous catheter can be effective in preventing the visceral pain that results from the increased intramedullary pressure caused by the infusion of fluids. Take care in dosing — numerous concentrations of lidocaine are available.

Substantial pressure may be required during the administration of medication or fluid to overcome the intrinsic resistance of the marrow cavity, particularly during the initial flush. When a rapid infusion rate is crucial, a bolus infused manually with syringes is the most efficient way to quickly deliver a considerable volume of fluid. Pressure bags and infusion pumps may also be used.

Confirmation of Proper Placement

A number of methods can be used to confirm correct catheter placement. First, the needle should stand on its own, because of the lateral support provided by the bony cortex. Aspiration of bone marrow contents also signifies that the catheter is in the appropriate cavity. However, it is important to note that blood return may not occur even when an intraosseous catheter is placed properly. Absence of local swelling at the insertion site on infusion with a saline flush also indicates correct placement. Because the bone marrow cavity is not distensible, it is normal to sense resistance during manual infusion into the intraosseous cannula. Fluoroscopy and ultrasonography have been used to confirm placement, but their use is not routine.[6,7]

Stabilization of the Catheter

You may place tape or sterile gauze around the catheter, but avoid the use of dressings that will prevent you from monitoring the site for infiltration, infection, or limb swelling. Use an arm board to provide additional stabilization. Secure the intravenous tubing away from the insertion site to avoid inadvertent movement of the catheter, which can widen the cortical entry site and may lead to extravasation. Record the time and date of placement either near the insertion site or on an identifying wristband.

Removal of the Catheter

The intraosseous catheter should be removed as soon as more definitive access is obtained. To remove an intraosseous needle, loosen and remove any tape or dressing securing the cannula and extension tubing to the skin. Stabilize the extremity. Firmly grasp the needle flange, or connect a sterile Luer-Lok syringe to the hub. Rotate the syringe and catheter clockwise while gently pulling the needle from the extremity. Place a sterile occlusive dressing over the insertion site.

COMPLICATIONS

Serious complications associated with intraosseous cannulation are rare. The most common complications are related to incorrect catheter placement. Extravasation can occur after inadvertent infusion of fluid into the soft tissue surrounding the targeted bone or beneath the periosteum. Movement of the needle or multiple attempts at insertion at a single site may create openings for infused fluid to extravasate from within the marrow cavity into the surrounding soft tissue. When left unrecognized, prolonged extravasation of fluid can lead to compartment syndrome.[8] To decrease this risk, check for swelling periodically, and remove intraosseous catheters once further vascular access is obtained, ideally within 24 hours.

As with any needle insertion, the introduction of skin flora or other pathogens can lead to infection at the insertion site, within the soft tissue, or in the bone. Using proper aseptic technique and limiting the time the intraosseous catheter is in place minimize this risk. Substantial force may be required to penetrate the bony cortex, particularly when using a manual placement technique. Fractures can occur, especially in young infants or patients with osteopenia. Although not reported in the pediatric literature, growth-plate injuries can occur if an intraosseous catheter is inadvertently directed into a physis. Microscopical fat emboli have been detected in studies in animals,[9] but pediatric case series have not reported adverse outcomes related to embolic events.

SUMMARY

Appropriate placement of an intraosseous catheter is a reliable means of obtaining urgent vascular access in children and is associated with low rates of reported complications. Both manual and power-assisted placement techniques can be used to deliver fluids and medications rapidly during pediatric resuscitation.

No potential conflict of interest relevant to this article was reported.
Disclosure forms provided by the authors are available with the full text of this article at NEJM.org.

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