

Ultrasound Guidance for Central Vascular Access in the Pediatric Emergency Department

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Abstract: Central vascular access is sometimes required for hemodynamic monitoring and infusion of fluids and medications in the pediatric emergency department. In many cases, it is attempted after failed peripheral venous and intraosseous access. Some evidence exists demonstrating benefits of ultrasound (US)-guided central vascular cannulation in adults in emergency departments. With appropriate education in its use, US-guided cannulation of central veins in children is likely to be associated with less complications and greater success. In the pediatric emergency department, the femoral vein is the most practical central venous cannulation site. A sound educational and quality assurance program is necessary for US-guided cannulation in the pediatric emergency department.

Key Words: ultrasound, vascular cannulation

INDICATIONS FOR CENTRAL VENOUS ACCESS

Central vascular access in the PED is sometimes required for hemodynamic monitoring and infusion of fluids and medications including vasoactive agents. It is likely to be necessary in infants and young children in whom peripheral venous access is often difficult. Peripheral venous access is even more challenging under emergency situations such as during severe cardiopulmonary compromise. In fact, failure to obtain vascular access is a rate-limiting step in the resuscitation of children. Under these circumstances, if obtaining peripheral venous access is unsuccessful, then the intraosseous route should be attempted.¹ However, there are situations when the intraosseous route is unsuccessful, and hence central vascular access might be the only route available.

CHOICE OF CENTRAL VENOUS ACCESS

Before inserting any central venous vascular device, it is important to first examine the patient for the best suitable site for catheter insertion. The femoral vein is the most common site attempted during pediatric resuscitation.

Because of lower complication rates in an emergency situation, the femoral vein should be the first choice for the PED physician. For pediatric critical care physicians, the jugular and subclavian are reasonable alternatives, with the subclavian vein having the most consistent landmarks but likely to lead to the most severe complications. In addition, they may have difficulty in accessing the subclavian and internal jugular vessels while the airway is being secured and with cervical spine stabilization procedures. Therefore, by default, the femoral vein is most often accessed in an emergency, however, it may be difficult to identify from landmarks in small children and in children with low cardiac output with poor central pulses. Identification may also be difficult because anatomical variations are common in both the jugular and femoral venous sites, ranging from 10% to 20% in both adult and pediatric patients.²⁻⁴ The femoral site is associated with the lowest complication rate compared with the internal jugular or subclavian sites in a hypovolemic patient or in a patient with low cardiac output.

Complication rates depend partly on the experience of the physician performing the procedure.⁵⁻⁷ The femoral site is the most practical for the PED physicians who may be attempting central line placement infrequently. Although not well studied, in our experience, identifying and accessing the femoral vein using a US device is easy to learn and is likely to reduce the time to access the central circulation. Complications may be reduced and success rate increased after appropriate training in the use of US devices in the PED.

CLINICAL EVIDENCE FOR US USE IN CENTRAL VENOUS CANNULATION

There are currently 2 approaches to the insertion of central venous catheters—the traditional landmark approach, whereby known anatomical landmarks are used to guide blind puncture, and more recently, US techniques. Whether routine use of US devices improves the success rate of vessel puncture or reduces the time of insertion of the catheter is unproven. It is also debatable whether US devices would be as beneficial in the anxiety-provoking emergency setting, where time to insertion is critical as opposed to the less stressful elective environment in the operating room or the intensive care unit.

Adult Studies

There are 2 published meta-analyses of studies comparing US-guided central venous access to the use of anatomical landmark techniques.^{8,9} Randolph et al⁸ reviewed

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8 randomized controlled trials evaluating the effect of real-time US guidance for internal jugular or subclavian vein cannulations. Compared with standard techniques, the use of US reduced placement failure in both the internal jugular and subclavian veins (relative risk [RR], 0.32; 95% confidence interval [CI], 0.18–0.55), decreased complications (RR, 0.22; 95% CI, 0.1–0.45), and decreased the need for multiple attempts (RR, 0.6; 95% CI, 0.45–0.79). In 2003, the British National Institute for Clinical Excellence published a meta-analysis of 18 randomized clinical trials involving US guidance for central vascular access.⁹ They concluded that there is evidence supporting the use of US devices to access the internal jugular vein in adults, with a lower failure rate (RR, 0.14; 95% CI, 0.06–0.33) and greater success with the first attempt (RR, 0.59; 95% CI, 0.39–0.88). There was limited evidence in their meta-analysis favoring US guidance over landmark techniques for either the femoral vein or the subclavian vein approach. Most of the patients in these studies were adults; therefore, the conclusions may not be generalizable to children. A randomized study of femoral vein access in adults during cardiopulmonary resuscitation showed a higher success rate (99% vs 65%, $P = 0.058$), a lower number of attempts (2.3 ± 3 vs 5 ± 5 , $P = 0.006$) and fewer arterial punctures (0% vs 20%, $P = 0.025$). Two nonrandomized studies in adults requiring hemodialysis reported a benefit of US over landmark techniques at the femoral site.^{10,11}

Despite increasing support for the use of US techniques, support however is not universal.¹² There are several reasons for these disparate opinions on the benefit of US-guided catheter placement. It is likely that US guidance may be chosen only in the more difficult cases or after failed landmark techniques. In addition, success with US guidance seems to depend on the skills of the operator and the US technique used, specifically whether real-time use rather than spot localization of the vessel is used.

There are 5 publications^{13–17} in the emergency medicine literature on the use of US in the emergency department. The report by Miller et al¹³ is the only publication comparing real-time US insertion with landmark techniques in an adult emergency department. In a variety of vessels and varying experience of operators, time from skin puncture to blood flash was reduced (mean, 115 seconds vs 512 seconds) and number of attempts was reduced from a mean \pm SD of 1.6 (± 1) versus 3.5 (± 2.7), although complications were comparable in both groups. All studies supported the use of US devices in the emergency department for adults.

Based on the adult data, some organizations are recommending US-guided techniques over the traditional techniques as the standard of care in both elective and emergency clinical situations.^{18,19} Recently, the American College of Emergency Physicians published a revised policy statement on the use of US imaging for emergency physicians that specifically included this technique in the list of primary applications for US in the emergency department.²⁰ After publication of these recommendations, there have been dissenting opinions expressed.^{21,22} These opinions outlined deficiencies in the studies that preclude a

clear understanding of the role of US guidance in emergency departments. Deficiencies included failure to stratify patients according to anticipated difficulty, lack of studies that include children, lack of studies involving the femoral vein or subclavian vein, cost of widespread implementation, and failure to account for experience levels of operators.

Pediatric Studies

Reports on the use of real-time US guidance for central vessel cannulation in children has been limited to 4 randomized trials and small case series.^{5,23–26} The study by Alderson et al² used the US device to locate the vein but did not use real-time technique for vessel cannulation.⁵ The 2 small studies by Vergheze et al^{23,24} supported the use of real-time US techniques for internal jugular vessel cannulation. A meta-analysis of pediatric studies by Hind et al⁹ confirmed a higher success rate with 2-dimensional US compared with landmark for the internal jugular vein (RR, 0.15; 95% CI, 0.03–0.64). These studies were performed in elective patients under general anesthesia and compared US guidance with landmark techniques at only the internal jugular vein. The study by Grebenik et al,²⁵ also in elective anesthetized children, failed to demonstrate superiority of the US guidance over landmark techniques for the internal jugular vein. As can be seen, the data are less clear in pediatric patients compared with adult patients.

Regardless of the success of US guidance techniques in an elective and controlled environment, it remains to be seen whether similar success will be demonstrated in emergencies in children. Skepticism of its successful use in the PED is warranted because it is likely to be used by physicians who may be using the technique infrequently. In addition, cannulation will be done in the critically ill child under stressful conditions rather than the controlled anesthetic suite.

COST-EFFECTIVENESS

The only economic evaluation of cost-effectiveness published used the National Health System to model incremental costs per complication avoided with the use of US central venous cannulation. Using conservative modeling assumptions, they found a cost saving with the use of US in that health care system.²⁷ A recent editorial²¹ suggested that the savings could be even greater. The findings of this cost analysis may not be relevant to children. One could argue that because complication rates in the critically ill child may be higher than in the adult, the successful use of US may result in greater cost savings in children. However, data to support this assertion are not available.

AVAILABLE US DEVICES

Currently there are 2 available devices used for US guidance during vascular access. The Site-Rite device (Dymax Corporation, Pittsburgh, Pa) uses a 7.5-MHz mechanical sector transducer, with a cathode ray tube screen displaying the US image. SonoSite (SonoSite Inc., Bothell, Wash) offers a range of diagnostic equipment and a range of lightweight broadband 10 to 15 MHz frequency transducers that also allows pulsed and continuous wave Doppler.

TECHNICAL ASPECTS OF US-GUIDED CENTRAL VASCULAR ACCESS

Every effort should be made to use full barrier precautions during central vessel cannulations under all conditions. A sterile field can be maintained using a sterile transducer sheath filled with transmission gel, in addition to applying sterile gel directly onto the sterile skin surface over the vessel (Fig. 1). This process ensures sterility while maximizing the chances of visualizing the vessel using the US device; however, this process may take extra time a luxury not available in the child experiencing cardiac arrest. Therefore, during emergency cannulation such as in the PED, timely resuscitation may not allow the implementation of full barrier precautions.

Identifying the vessels for cannulation using US guidance is done by first identifying the vessel position in relation to surrounding structures and determining whether the vessel is an artery or a vein. This is achieved by observing for presence or absence of pulsatility, compressibility of the vein in comparison with the artery, and an increase in vein lumen size with a Valsalva maneuver (Fig. 2).

Ultrasound devices may be used in several ways to assist during vascular access. Various proprietary mechanical guides are available that can also be used, although they tend to be cumbersome and limit the angle of needle entry.

Real-Time Method

This is the preferred and recommended approach. Real-time ultrasonography generates a 2-dimensional gray-scale image of the vessels and surrounding tissues. Vessel puncture with the needle is performed using continuous direct visualization of the vessel with the US device. The best technique involves a single operator who simultaneously manipulates the transducer while inserting and guiding the needle into the vessel. The needle can be visualized as an echogenic line advancing through the tissues and can be seen to impinge on the vessel wall, compressing the anterior and posterior vessel surfaces. A blood flash confirms penetration

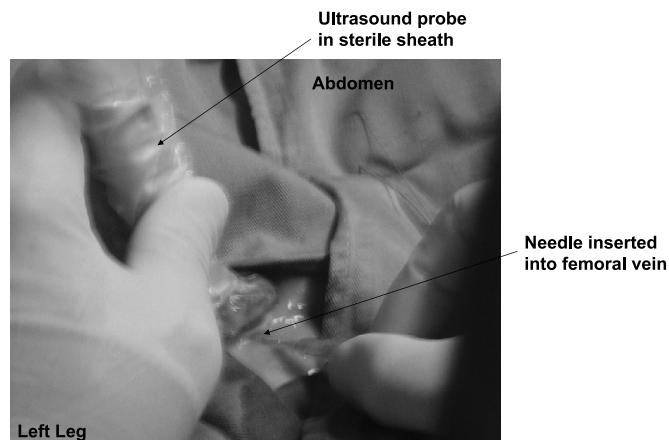


FIGURE 1. Ultrasound probe applied to skin after it was placed in sterile sheath with sterile gel. Needle is advanced after vessel was identified.

of the vessel, after which the transducer is taken away from the field, and the usual Seldinger technique is used for insertion of the cannula into the vessel.

Indirect Method

The indirect method simply uses the image obtained using 2-dimensional US to identify the location and size of the vessel on the skin surface (dimension, depth below the skin surface), allowing the operator to make a surface mark for subsequent blind vessel puncture. This approach has not been demonstrated to have any benefit over the traditional landmark technique.

Continuous Wave Doppler

This technique is rarely used alone. Doppler US generates an audible sound with blood flow in the localized blood vessel but gives no information on the depth or size of the vessel. It can be helpful in identifying actual blood flow in vessels, confirming the vascular structures and differentiating the artery from the vein.

There are 2 approaches (the short- and long-axis) for visualization of the vessel. The short-axis approach gives a transverse view of the vessel. This approach is better if the goal is to minimize access time and minimize arterial puncture. Care needs to be taken that the US plane is positioned close to the needle tip. By placing the midpoint of the transducer directly over the vessel and inserting the needle beneath the midpoint, the needle can be guided and visualized entering the vessel. Because the needle only passes through the plane of the US at 1 point, the effect of the needle passing into the vessel (compression of the anterior wall) is most often seen rather than the actual needle. Acute angulation of needle entry allows the needle to be more reliably kept in the plane of the US. Blood flashback confirms entry into the vessel but is uncommon. The long axis involves holding the transducer longitudinally over the vessel. This approach is better if the goal is to avoid posterior vessel puncture. Guiding the needle through the subcutaneous tissues and entering the vessel is performed as with the short-axis view, although in our experience, the long-axis view is more technically challenging for nonradiologists.

QUALITY ASSURANCE AND CENTRAL VENOUS CATHETER INSERTION USING US

Complications are relatively common after placement of central vascular catheters. Moreover, complication rates have not been clearly demonstrated to be reduced by the use of US.⁹ Although not fully accepted by all PED or critical care physicians, it is likely that US-guided placement of CVLs both electively and emergently will become the standard of care. Identifying and accessing the femoral vein using a US device is easy to learn and likely to reduce the time to access the central circulation and the complication rates.

In an effort to improve patient safety and ensure best practice, a quality assurance program should be developed in any institution that chooses to use this technique. These

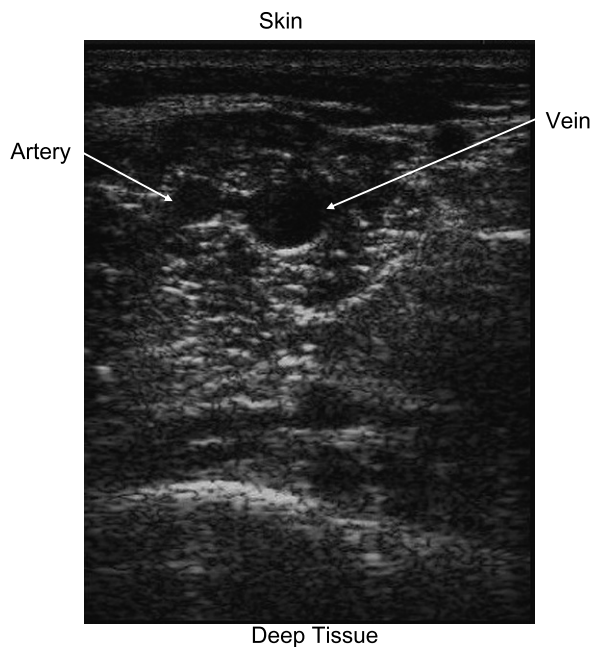


FIGURE 2. Screen showing artery and vein as seen by operator. Note smaller caliber of artery and larger caliber of vein.

programs will vary between institutions, but some or all of the following principles should be included:

- an educational module
- credentialing of operators in the use of US for vascular access
- best evidence infection control practices applied during all cannulations
- collection of data on compliance with infection control practices, success rate of cannulation including number of attempts at insertion, experience and training of the operator, and complication rates.
- regular review and audit of practices
- annual review of credentialing of the operator

The educational module should not only address the educational aspects surrounding vascular access insertion and infection control policy for both nursing and medical practitioners, but should also include formalized instruction in the techniques of US applicable to the insertion of vascular catheters. In our program, this training is undertaken in cooperation with radiologists who are skilled in this technique. It is unclear how long it takes to develop the skills in the use of US techniques, or how many central venous catheter insertions using US guidance are required annually to maintain those acquired skills. In our program, we recommend annual recertification, unless the operator has successfully performed a minimum of 10 US-guided cannulations.

Data collection and data entry can be facilitated by ensuring that someone completes a checklist during every

catheter insertion. The entered data, reflecting success rates and complications, should be reviewed on a regular basis (eg, every 6 months) and changes to practice made based on identified problems.

SUMMARY

Some evidence exists demonstrating benefits of US central vessel guided cannulation in adults in emergency departments. Evidence supporting its use in pediatric emergency departments is lacking. However, with appropriate education in its use, US guided cannulation of central veins in children is likely to be associated with less complication rates and greater success than landmark techniques. A sound educational and quality assurance program and critical evaluation is necessary to further our knowledge of the role of US guided central vessel cannulation in the Pediatric Emergency Department.

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