

AIUM Practice Parameter for the Use of Ultrasound to Guide Vascular Access Procedures

I. Introduction

The clinical aspects of this parameter were developed collaboratively among the AIUM and other organizations whose members use ultrasound for guidance in vascular access procedures (see “Acknowledgments”). Recommendations for practitioner requirements, the written request for the examination, procedure documentation, and quality control vary among the organizations and are addressed by each separately.

This parameter has been developed by and for clinicians from diverse specialties and practitioner levels who perform vascular access. While vascular access may be performed using external landmarks, point-of-care ultrasound is now increasingly available.¹ Appropriately used, ultrasound guidance for vascular access has been shown to improve success rates while reducing iatrogenic injury, the number of needle passes, and infection rates.² Additionally, it may improve patient comfort and satisfaction.

This parameter is intended to be evidence based when possible and to include selected references of importance, but it is not meant to be a comprehensive or rigorous literature review, as this has been accomplished elsewhere.³ The intent of this document is to highlight appropriate evidence while also providing a practical, real-world expert consensus from clinicians with diverse backgrounds on the best use and techniques for incorporating ultrasound into vascular access procedures with the ultimate goal of improving the care of our patients.

II. Indications/Contraindications

Ultrasound should be used to aid in central venous, peripheral venous, and arterial access procedures.⁴ When used appropriately by qualified personnel, there are no absolute contraindications to using ultrasound as a procedural adjunct for vascular guidance. Based on evidence and the consensus opinion of the collaborating organizations, ultrasound should be used whenever feasible in all central vascular access procedures. While ultrasound guidance may not be required for peripheral venous or arterial access, it can aid in the safety and success of these procedures, particularly if they are not

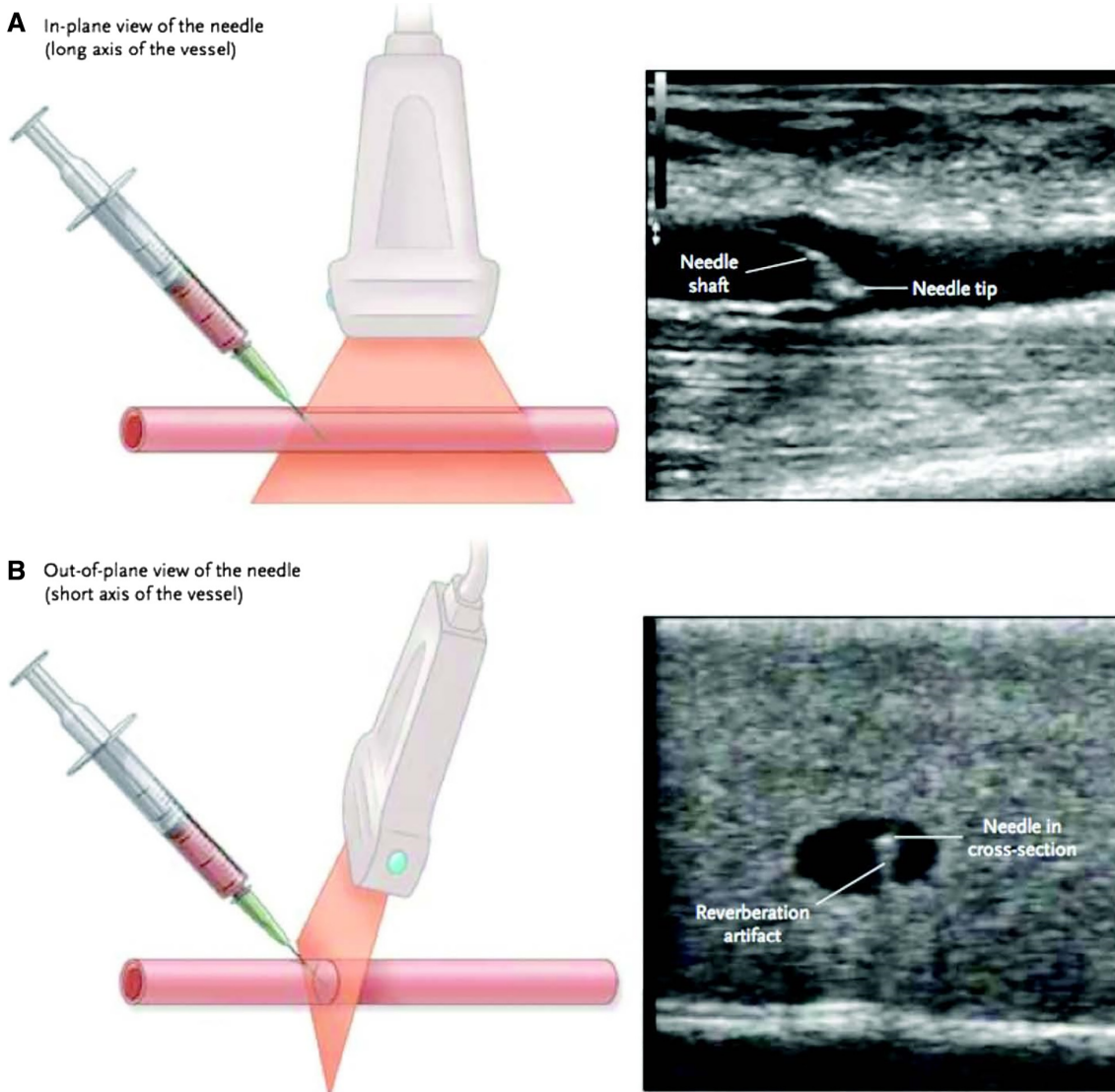
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successful on a first pass. Clinicians routinely performing vascular access procedures should have access to appropriate ultrasound equipment, should be adequately trained in the use of ultrasound for procedural guidance, and should understand the benefits and limitations of using ultrasound to guide vascular access procedures.

III. Qualifications and Responsibilities of the Ultrasound User for Vascular Access

Vascular access, with or without ultrasound, should be performed by practitioners whose scope of practice encompasses these procedures. Training and

Figure 1. Planes of ultrasound visualization for vascular access procedures. Panel **A** shows an in-plane view of the needle, long axis to the vessel. The in-plane view has the advantage of showing the entire needle, including the tip (ultrasound image at right), although it can be challenging to obtain and maintain this view of the needle. Panel **B** shows an out-of-plane approach (short axis to the vessel), with the characteristic “target sign” of the needle in the vessel lumen. The ultrasound image also shows a reverberation artifact, which occurred in this case when the ultrasound beam struck a metallic object. The artifact appears as closely spaced, tapering lines below the needle. Although the visualized portion of the needle is centered in the lumen, the disadvantage of an out-of-plane approach is that the plane of the ultrasound may cut through the needle shaft proximally, underestimating the depth of the tip (figure and legend used with permission from the *New England Journal of Medicine*¹).



determination of competency for the use of ultrasound in procedural guidance will be defined by the practitioner's respective specialty but should include basic didactic training in principles and instrumentation of ultrasound equipment to include basic Doppler techniques, practice of ultrasound imaging techniques and orientation, instruction in the techniques of ultrasound guidance for vascular access, instruction in the proper transducer and sterilization techniques, instruction in the required documentation of the procedure, and proctored assessment of competency in a simulated or actual patient care setting.^{3,5,6}

IV. Written Request for the Examination

A written request is not required in these examination settings when qualified providers determine that these ultrasound applications are appropriate to incorporate into patient care.

V. General Considerations for Ultrasound-Guided Vascular Access

As with all procedures, the clinician should perform a sufficient history and physical examination to determine the appropriate procedure and anatomic site. Known anatomic issues, prior procedures, and the potential for complications (particularly the presence of an underlying coagulopathy) should be evaluated. For central access (and other procedures per institutional protocol), written informed consent should be obtained unless the procedure is emergent. The following sections delineate procedures and practices that are relatively constant across different ultrasound-guided vascular access procedures.

A. In-Plane (Long-Axis) Versus Out-of-Plane (Short-Axis) Visualization (Figure 1)

Using basic B-mode imaging, the orientation of the plane of the ultrasound image may be described relative to the needle or to the vessel. Relative to the needle, when the ultrasound plane is parallel to the needle, it is referred to as "in-plane," whereas when the ultrasound plane is perpendicular to the needle, it is considered "out-of-plane." With in-plane

visualization of the needle, the plane of the ultrasound will be longitudinal or long axis to the vessel, whereas when the needle is out-of-plane, the ultrasound plane will be perpendicular to the vessel, which will then be seen in the transverse or short axis. While the terms "out-of-plane" and short axis or transverse (and "in-plane" and long-axis or longitudinal) are often used synonymously when describing vascular access, in- and out-of-plane are the preferred terms for describing the relationship of the ultrasound plane to the needle in ultrasound-guided procedures, as there are times (such as in performing nerve blocks) when an in-plane approach may visualize the structure of interest in a short axis. For vascular access using an out-of-plane approach, the vessel should appear in the short axis as an anechoic circle on the screen, with the needle visualized as a hyperechoic point in cross section. In an in-plane view, the image plane is parallel to the course of the vessel, which will be seen in the long axis. The image should show the course of the vessel across the screen and the shaft and point of the needle as it is advanced.

The out-of-plane (short-axis) view allows the needle approach to be over the center of the vein. However, care must be taken to "fan" the plane of the image along the needle as it advances to track the tip and avoid underestimating the depth of the tip. A helpful way to ensure that the tip of the needle terminates in the center of the vessel is to fan the ultrasound plane distally and see the target sign disappear, known as the "vanishing target" sign.⁷ While the in-plane (long-axis) view has the advantage of allowing visualization of the entire needle shaft and tip,⁸ it may be more difficult to keep the plane of the ultrasound in line with the vessel, as the plane of the image may "slip off" to the side of the plane of the needle and/or the center of the vessel.⁹ The in-plane approach may be easier and more appropriate to use in larger vessels such as central veins when knowing the tip location is crucial, although with experience and care, the out-of-plane approach is adequate and sufficient to follow the needle tip location. The out-of-plane, short-axis approach may also be used when the space available for the transducer footprint does not allow for the in-plane, long-axis view: ie, in patients with a short neck or when devices or structures are in the way of the beam. It may be helpful to start a procedure with an out-of-plane, short-axis view to ensure that the needle

is centered over the middle of the vessel and then rotate the transducer to a long-axis, in-plane view as the needle is advanced.

B. Differentiating Arteries and Veins

As tubular fluid-filled vessels, arteries and veins have a similar appearance on a grayscale ultrasound image. Both typically have an anechoic (black) lumen. However, arteries have thicker walls that are slightly more hyperechoic (brighter) than the walls of veins. Arteries are less compressible than veins, but both are compressible with enough pressure. Peripheral arteries are more easily compressible than central arteries, but central arteries may be fairly easily compressed in a hypotensive patient. The ability to compress and collapse the venous walls with relatively minimal pressure is a useful way to distinguish a vein from an artery. If there is any doubt that a vessel may be arterial, the vessel should be imaged in the short axis and enough pressure applied to slightly deform the vessel, and it should be observed for several seconds to determine whether arterial pulsations are present or absent. A noncompressible venous lumen indicates a thrombus. Color Doppler imaging may also be used to identify blood flow and to help differentiate arterial from venous flow. The Doppler scale should be lowered sufficiently (by lowering the pulse repetition frequency) and the color gain increased sufficiently to detect flow if it is not initially seen. Pulsed wave Doppler imaging may also be used and differentiates a biphasic venous waveform from an arterial triphasic waveform, which can show typical high-velocity arterial waveforms that differ from lower-velocity venous waveforms with respihasic variation.

C. Static Versus Dynamic Ultrasound Guidance

The static approach uses ultrasound to determine the vessel location and patency, assess surrounding structures, and mark the location to provide optimum placement for needle introduction. After this location is determined, the procedure is performed without real-time ultrasound. In a dynamic approach, the procedure is performed using real-time ultrasound observation of needle entry and placement. The static approach has advantages over a completely landmark-guided procedure. However, the dynamic approach allows for real-time visualization of needle tip

placement and has been shown to be superior to the static approach in most situations.¹⁰

D. One-Person Versus Two-Person Technique

Using dynamic visualization, it is possible for one person to perform the ultrasound imaging while another person performs the procedure (“two-person dynamic approach”). This provides the potential advantage of allowing the person performing the procedure to use two hands for the procedure itself and does not require the dual hand-eye coordination of directing the ultrasound transducer as well as performing the procedure.¹¹ However, the two-person approach has the disadvantage of requiring additional personnel, and it may be more difficult for the practitioner doing the procedure to optimize the image positioning relative to the needle. In a one-person dynamic approach, the person performing the procedure holds the transducer with one hand while directing the needle with the other hand. While a one-person dynamic approach requires more experience, it is preferred by most advanced practitioners, as it allows for real-time hand-eye coordination.¹²

E. Site Selection and Preparation

Site selection is a clinical decision. Guidelines such as the Michigan Appropriateness Guidelines for Intravenous Catheters or other institutionally developed recommendations may be consulted.¹³ Before site preparation for puncture, ultrasound should be used to choose the optimal site for access. The choice of site should include factors such as vessel size, depth, course, surrounding structures, and adjacent pathology (such as overlying cellulitis). The vessel should be assessed for patency, course, and other anatomic issues such as vein valves. Optimizing the anatomy before the procedure is extremely important. In venous access, it is extremely important to choose an angle of needle approach that will avoid the artery if the needle penetrates the posterior wall. This can be aided by appropriate patient positioning.¹⁴

Once a site has been chosen, topical anesthesia may be applied. The chosen site for central venous or arterial access should be prepared using maximal sterile barrier precautions.¹⁵ Maximal sterile barrier precautions are not required when using ultrasound guidance to perform peripheral venous access, although some recent standards recommend use of

sterile gloves when a peripheral catheter may remain in place for a longer time.^{15–17}

In addition to skin preparation and barrier precautions, a sterile sheath is required for the ultrasound transducer. There are commercially available transducer cover kits that include both a sterile cover (sheath) for the transducer and sterile gel. Typically, the transducer is “dropped” into a sheath, which then extends up the cord of the transducer to an adequate length to avoid inadvertent contamination. It is very helpful for the practitioner to have assistance with the equipment to ensure that sterility is maintained. Ultrasound gel must be placed both inside and outside the sheath (except for transducer covers that adhere to the transducer with adhesive, with sterile gel used on the outside). Avoid air bubbles between the face of the transducer and the inner surface of the sterile sheath, as they will lead to suboptimal visualization.

F. Performing the Procedure

Adequate anesthesia will ensure both patient comfort and patient cooperation, reducing the risk of unwanted complications caused by unexpected patient movement. While injection of a small amount of anesthetic in the skin should provide adequate pain control, excessive subcutaneous injection may obscure the ultrasound image without much additional benefit to the patient.

Before needle or catheter insertion, the axis of the vessel should be noted, and the expected direction of the needle path should be in line with this axis. The depth of the center of the intended vessel should be estimated from the ultrasound image, with the point of skin entry for the needle then being about the same distance from the transducer, assuming an approximately 45° angle, set back from the transducer a distance approximately equivalent to the depth of the vessel (“triangulating” the path of the needle toward the vessel lumen). A steeper angle of approach may require a site of entry closer to the transducer, whereas an angle more parallel to the skin would be farther away. The needle should be directed toward the middle of the vessel, typically more easily determined initially using out-of-plane, short-axis ultrasound visualization and centering the vessel on the screen, then using the center of the transducer as a guide for where the needle should enter. Whether

using in-plane or out-of-plane needle visualization with ultrasound, the tip of the needle must be identified throughout the procedure.

The needle should be advanced in small increments. Between each needle depth adjustment, the operator can check the ultrasound screen to ensure that the proper needle trajectory has been maintained. If the needle tip is angled lateral or medial to the vessel, withdraw the needle to just below the skin surface, and then adjust the needle’s orientation. If the needle tip is not clearly seen, very slight movement of the needle may help visualize the tip by showing adjacent tissue movement. Once the needle is passed in the correct plane, the needle tip will be noted on the ultrasound screen to “indent” the wall of the vein. While keeping part of the needle in view is easier in a short-axis view (out-of-plane imaging), ensuring the tip location may be more challenging in this plane and requires “fanning” the plane of the transducer to ensure that the plane of the ultrasound beam is intersecting the needle at or near the tip, rather than more proximally along the shaft (leading to underestimation of tip depth).

When the needle enters the vessel, a “target sign” is seen in an out-of-plane or short-axis view (see Figure 1). Typically, a flash of blood will be seen in the needle hub or syringe attached to the needle, although caution should be used in relying on a flash to determine the intraluminal tip position, as a flash often occurs just as the needle penetrates the posterior vessel wall (“back-walling”). The needle may need to be advanced slightly farther, as the endothelium of the vessel may tent into the lumen. Care should be taken not to penetrate the posterior wall of the vein. In some cases (particularly with states such as dehydration), posterior wall puncture may occur. If posterior wall puncture occurs, it should be recognized and the needle withdrawn until the target sign is seen. Using the vanishing target sign (target sign disappears as the ultrasound plane is fanned distally) can ensure that the needle tip terminates in the center of the vessel.⁷

Once the needle has entered the vessel, ultrasound should be used to confirm that the needle and/or guide wire is in the target vessel and is not visible in adjacent vessels not intended for cannulation. Placement of the guide wire, dilator, and line may then proceed. Direct visualization of the guide wire/dilator within the vein ensures proper placement.¹⁸

G. Use of Ultrasound After the Procedure

Ultrasound may be used after cannulation to ensure appropriate placement and to assess for complications. For venous access procedures, a “postprocedure flush” using agitated normal saline may be performed and recorded. This involves injecting a small amount (<10 mL) of saline that has been agitated with air and then had large air bubbles removed from the syringe.¹⁹ When the catheter is properly placed, injection of agitated saline produces hyperechoic contrast within the lumen of the vessel, verifying the proper position. For central catheters, this can be performed while visualizing the right atrium of the heart, which may be improved by using a low-frequency transducer such as a curvilinear or phased array transducer. Ultrasound is faster than a chest x-ray, does not involve radiation, and may confirm that an infusion is entering the right side of the heart; however, current evidence suggests that ultrasound cannot replace the chest x-ray in determining appropriate tip position of the catheter.^{20–22} Intraprocedural methods such as electrocardiographic monitoring may also provide timely, accurate, and cost-effective options for tip confirmation.²³

Lung sliding may also be assessed using ultrasound to help show the absence of pneumothorax, particularly after placement in subclavian or internal jugular (IJ) sites.²⁴

H. Adjunctive Equipment and Aids

While commercial needle guides exist for vascular guidance, most experienced users find that they are cumbersome and do not add value to a freehand technique. Needle guides have been shown to increase first-pass success, although the rate of arterial puncture was not decreased.²⁵ Using needles with “echogenic” needle tips as well as ultrasound machine algorithms that enhance visualization of the needle may be very helpful.²⁶

VI. Specifications of Specific Ultrasound-Guided Access Procedures

A. Ultrasound-Guided Central Venous Catheterization

It is estimated that approximately 5 million central venous catheters are inserted annually in the United

States.¹⁶ Central venous catheters are often used when peripheral access fails, or when large volumes of fluid or medications are required, including vasoactive medications that may be dangerous if given peripherally. There are 4 major sites for accomplishing central venous catheter access: IJ, subclavian, axillary, and femoral veins. Factors such as infection rates, compressibility in the event of arterial laceration, interference from other medical devices, and operator experience may influence site selection. A full consideration of site selection is outside the scope of this document. While ultrasound may be used to provide procedural guidance for all 4 sites, the subclavian vein may be more challenging to visualize with ultrasound due to interference from the clavicle. Access to the subclavian vein via the axillary vein or via a supraclavicular approach may be more amenable to ultrasound. A preprocedure scan should be performed before sterile precautions are secured to identify thrombi, occlusion, and unfavorable anatomy. Measurement of the vessel diameter should be assessed before catheter selection to ensure that the vessel is wide enough to accommodate the catheter. Current standards recommend a catheter-to-vein ratio of 45% or less for the placement of a peripherally inserted central catheter (PICC) as a strategy to reduce the risk of deep venous thrombosis.²⁷

1. Ultrasound Guidance for IJ Vein Cannulation

a. Overview and Evidence for Ultrasound Guidance in IJ Vein Access

There is clear evidence that ultrasound guidance for IJ vein cannulation improves first-pass and overall success rates and reduces the risk of procedure-related complications across diverse environments of care.^{28–30} The impact of ultrasound guidance in improving success and reducing complications is greatest in difficult patients, particularly in patients who are obese, have short necks, or are uncooperative.

Ultrasound guidance has also been shown to reduce the incidence of insertion failure, arterial puncture, hematomas, pneumothorax, and hemothorax when the operator is adequately trained in the use of ultrasound for guidance.^{4,31,32}

In mechanically ventilated patients, real-time ultrasound-guided IJ vein cannulation has been shown to improve the overall success rate and to

decrease mechanical and infectious complications, particularly in hypovolemic patients.²⁹

While there is less literature on the use of ultrasound guidance for IJ vein access in children, ultrasound guidance for IJ vein insertion using real-time guidance is recommended.^{4,33} Finally, the use of continuous wave Doppler ultrasound alone (ie, sound without an image) for guidance in IJ vein cannulation is discouraged. Although used extensively in the past, it does not offer benefit over 2-dimensional (B-mode) ultrasound imaging.³⁴ However, adjunctive use of Doppler (color or spectral) imaging may help clarify venous and arterial structures, as well as vessel patency. Doppler interrogation does not present additional risk or discomfort to the patient and should be left to operator discretion and the level of training.

In summary, one-person dynamic ultrasound guidance³⁵ is recommended for a central venous catheter at the IJ vein site.

b. Technique for Ultrasound-Guided IJ Vein Access

If the patient is able to tolerate it from a hemodynamic and respiratory standpoint, he or she should be placed in the Trendelenburg position to maximize the IJ vein size and minimize the possibility of air embolism.^{36,37} If a patient is cooperative, other maneuvers such as Valsalva or humming may also increase the IJ vein size.³⁸ While some head rotation may be required to maneuver the transducer and cannulation equipment, the amount of rotation is directly associated with increasing overlap of the IJ vein and carotid artery, and rotation should be minimized.¹⁴ Before beginning sterile preparations, interrogation of the IJ vein should be undertaken to assess the anatomy and patency and to choose the side and location of access. The operator should be positioned at the head of the bed, with the ultrasound screen facing the operator in a position where it can be easily visualized during the procedure. In a transverse or short-axis view, the transducer indicator should be oriented to the operator's left, corresponding to the left of the patient and the left side of the screen as it is viewed.

A site should be chosen where the IJ vein is lateral to the carotid artery, as close as possible to the surface of the skin. The classic anterior

approach is to insert the needle at the apex of the triangle formed by the sternal and clavicular heads of the sternocleidomastoid muscle. A posterior approach may also be used. Both approaches may be enhanced by visualizing the relationship of the sternocleidomastoid muscle with the IJ vein using ultrasound. The distance from the skin surface to the center of the vessel should be noted, accounting for the angle of the needle pass to determine how far from the transducer the needle should enter the skin. If it is impossible to avoid IJ vein and carotid artery overlap, an angle of approach should be chosen so that if the needle penetrates the IJ vein posteriorly, it will not enter the carotid artery.^{39,40} Once blood return has been obtained, the ultrasound transducer may be placed aside on the sterile field to continue with the procedure.

2. Ultrasound Guidance for Subclavian/Axillary Vein Access

a. Overview and Evidence

While the utility of ultrasound guidance for IJ vein catheterization is well demonstrated, the subclavian vein access site has been shown to have lower rates of infection and is a preferred site of access by some practitioners.^{41,42} However, in most dialysis patients, the subclavian site is contraindicated because of the high incidence of stenosis related to dialysis catheters in this location unless no other upper extremity access is planned on the ipsilateral side. While ultrasound-guided IJ vein access may result in fewer complications than blind subclavian vein access, the literature is less clear on the use of ultrasound in aiding subclavian vein access.

Interference from the clavicle hinders the utility of ultrasound for subclavian central venous access.¹² However, the axillary vein (which drains into the subclavian vein lateral to the outer border of the first rib at the teres major muscle) can be easily visualized using ultrasound. There is some lack of clarity in the literature about whether studies of ultrasound-guided access in this area are referring to direct subclavian vein access or to subclavian vein access via the axillary vein. A recent meta-analysis found that ultrasound guidance for subclavian access reduced the incidence of

insertion failure, arterial puncture, hematomas, pneumothorax, and hemothorax.⁴

b. Subclavian/Axillary Vein Ultrasound Guidance Technique

There are 3 basic approaches to the subclavian vein: infraclavicular (proximal) approach, axillary vein (more distal infraclavicular) approach, and supraclavicular approach.

Visualization of the subclavian vein from an infraclavicular approach using dynamic ultrasound may be difficult, but ultrasound may aid in safely cannulating the subclavian or proximal axillary veins. This can be aided by using a smaller-footprint transducer (including an L-shaped “hockey stick” transducer or a high-frequency endocavitary transducer), but linear array (7–12-MHz) transducers usually will suffice.

Before the procedure, the clavicle, pleural line, vein, and artery should be clearly identified. Excessive pressure should be avoided to avoid collapsing the vein, particularly in a hypovolemic patient. When approaching the subclavian vein, the short-axis, out-of-plane view is safer than the long-axis, in-plane view, as differentiation between the vein and artery may be more difficult. The vein and artery should be clearly visualized as separate structures just below the distal half of the clavicle on a short-axis view. Proximal to this landmark, the vein is under the clavicle and cannot be visualized directly without positioning the transducer at a different site. Once the needle is visualized, the position of the tip should be carefully followed by “fanning” the transducer medially and cranially, noting its relationship with the location of the artery and pleura. Once the lumen is punctured, the needle may need to be angled laterally to allow for smooth advancement of the guide wire. Ultrasound may be used to aid correct guide wire placement and avoid migration of the guide wire or catheter into the ipsilateral IJ vein.

The axillary vein can be approached inferior to the clavicle in a similar manner. The vein can be differentiated from the artery by compression, although more force may be required to collapse the vein than usual because of soft

tissue and overlying muscle in the chest. On conscious (awake) patients, performing a “sniff test” while resting the ultrasound transducer over the subclavian/axillary vein helps identify a vein versus an artery.⁴³ Doppler imaging may be helpful in identifying the artery. The proximity of the pleura should be appreciated, as well as the risk of pneumothorax. Ultrasound may be used after the procedure to assess for the presence of pneumothorax.

A blind supraclavicular approach has been described in the procedural literature but in practice is rarely used, likely because of concerns about complications when a large needle is directed toward the mediastinum. However, with ultrasound guidance, the large venous target resulting from the confluence of the IJ and subclavian veins can be appreciated. Ultrasound guidance for this approach should use an in-plane, long-axis view to allow the transducer to fit into the supraclavicular space and to follow the shaft and tip of the needle.^{44,45}

3. Ultrasound Guidance for Femoral Vein Access

a. Overview and Evidence

For longer-term central access, the femoral vein site is not usually preferred because of higher infection rates and increased risk of deep venous thrombosis.⁴⁶ However, the distance from structures in the neck and chest reduces the chance of hemothorax or pneumothorax, and accessibility in trauma and resuscitation scenarios makes it a good choice in certain situations. For dialysis patients, this access point may be used to preserve the upper extremities for future access or if upper extremity vascular access is not possible. The proximal femoral vein is located medial to the femoral artery, but often, the femoral artery overlaps the vein, making the landmark technique problematic and risky for inadvertent arterial puncture.^{4,33,34} Particularly in situations in which a pulse is difficult to palpate (severe hypotension or cardiac arrest) as well as in pediatric patients, ultrasound guidance has been shown to improve successful femoral vein access.^{47,48}

Published literature on ultrasound guidance for femoral vein catheterization is less robust than that for ultrasound guidance in IJ vein

cannulation. A prospective trial of ultrasound guidance for hemodialysis access showed that the use of ultrasound improved first-pass and overall success rates as well as lowering the rate of arterial puncture and overall procedure time.⁴⁸ Another trial also demonstrated improvement in these metrics, although only in less-experienced operators.⁶ A small study of patients in cardiac arrest showed that ultrasound guidance for femoral vein access resulted in fewer needle passes and arterial catheterizations.⁴⁷ The use of ultrasound guidance for pediatric femoral vein access has been shown to markedly increase the first-pass success rate and shorten the time to cannulation.⁴⁹

In summary, ultrasound guidance for femoral vein access improves the success rate and reduces complications for femoral vein cannulation.^{45,46}

b. Technique for Ultrasound-Guided Femoral Vein Access

The patient should be in a supine position with the leg slightly externally rotated (“frog leg” position). This will minimize overlap of the femoral artery and femoral vein, keeping the vein medial. It is essential during the preprocedure ultrasound assessment as well as during the procedure that the course of the femoral vein is appreciated and that it is accessed at a sufficiently proximal point in the thigh, as overlap will often occur only slightly distal to the inguinal ligament. Because of the close relationship of the artery and vein in this area, it is particularly important that the guide wire is appropriately placed before advancement of the dilator. Correct guide wire placement can be verified by using direct visualization with ultrasound. After securing the catheter, appropriate placement may be confirmed by visualizing the inferior vena cava and/or right atrium during a saline flush.

4. Ultrasound Guidance for Arterial Access Procedures

a. Overview and Evidence

Arterial access is an important aspect of vascular cannulation for monitoring and procedural purposes. Although vascular ultrasound imaging of arterial vessels is an established technique for detecting atherosclerosis, ultrasound can also be used to aid in accessing or cannulating arterial

vessels. The choice of access site depends on the intended use, accessibility, and complication rate for both access and maintenance but may include the femoral, radial, brachial, axillary, and dorsalis pedis arteries. Ultrasound-guided arterial cannulation is particularly useful in patients with obesity, altered anatomy, low systemic perfusion, or nonpulsatile blood flow and in those patients in whom previous cannulation attempts have been unsuccessful.³

Ultrasound has been compared to fluoroscopic guidance in a large trial of patients undergoing retrograde femoral artery cannulation.^{50,51} While there was no significant difference in the primary end point of the cannulation success rate for the overall group, the subgroup of patients with a “high bifurcation” (above the femoral head, occurring in approximately 30% of patients) showed substantially better cannulation rates with ultrasound guidance. Ultrasound guidance also improved the first-pass success rate, reduced the number of attempts, reduced the risk of venipuncture, reduced the time to access, and reduced the risk of vascular complications when compared to fluoroscopy.

Ultrasound guidance improves cannulation success and reduces the time to cannulation when compared to the palpation method in the placement of radial arterial catheters.⁴² Several studies have demonstrated improvement in first-pass success rates for ultrasound-guided radial artery access in the emergency department and operating room settings.^{4,52–54} The advantages of the radial artery site are its accessibility, predictable location, and low complication rates associated with both its access and use. It is usually palpable and is also not typically the sole blood supply to the distal extremity, unlike the axillary, brachial, and femoral arteries.

In the pediatric population, one study found that the use of ultrasound for arterial cannulation substantially improved the success rate, whereas another investigation did not find this benefit (although the operators in this investigation had minimal experience with ultrasound).^{55,56}

In summary, ultrasound guidance for arterial access may be helpful in certain subgroups; the

evidence is strong that it offers significant advantages over palpation and fluoroscopy.

b. Technique for Ultrasound-Guided Arterial Access

A site for access should be chosen by using ultrasound guidance before sterile preparation. Arteries should be identified and differentiated from veins. Identification of plaque, an arterial spasm, hematoma, or a decreased luminal diameter with ultrasound prevents futile cannulation attempts and directs the operator to a more desirable location. Real-time ultrasound-guided insertion of an arterial catheter using a sterile technique is preferred over a skin-marking static imaging technique.

For radial artery cannulation, an Allen test or, more objectively, a Barbeau test (radial artery compression with observation of the pulse oximetry waveform) for collateral perfusion should be performed. Optimal positioning of the wrist should include a support that allows the wrist to be approximately 45° extended (>45° may cause the vessel to be compressed).⁵²

Conditions such as hypotension, low cardiac output, and an excessive limb circumference that contribute to arterial cannulation failures with a landmark-guided technique may be equally challenging despite ultrasound guidance.

5. Ultrasound Guidance for PICCs

a. Overview and Evidence

Peripherally inserted central catheters help meet the demand for venous access in the growing population of patients with poor venous integrity, as well as providing intermediate-term access in inpatient and outpatient adult and pediatric patients.^{44,45,57,58} Peripherally inserted central catheters are typically appropriate when intravenous therapy will exceed 14 days, although guidelines such as the Michigan Appropriateness Guidelines for Intravenous Catheters guidelines may be consulted.¹³ Peripherally inserted central catheters should be avoided in patients with chronic kidney disease to preserve future dialysis access. While PICCs may be placed by practitioners of different backgrounds, approximately 70% of the 3 million PICCs placed annually in the

United States are placed by nurses, and the availability of ultrasound equipment and appropriate training for nurses who perform PICC placement is recommended.⁵⁹

The use of ultrasound guidance for PICC placement enhances vein assessment techniques, provides a better selection of optimal veins for access, and enhances success while decreasing complications. The use of ultrasound for PICC placement has been shown to substantially increase overall success rates while minimizing the risk of thrombosis.^{60–63} When using a “blind” approach to PICC placement, most practitioners rely on a landmark such as an artery to find the adjacent vein (ie, the brachial artery and adjacent veins in the upper arm). In addition to clarifying the relationship of adjacent arteries and veins, ultrasound can find and guide access to veins that do not travel with arteries (such as the basilic vein), minimizing the risk of arterial puncture.

Based on evidence and an evolving standard of care, it is the recommendation of this group that ultrasound equipment and training should be provided to practitioners who place PICCs and that ultrasound guidance should be used routinely to aid in PICC placement.⁴

b. Technique for Ultrasound-Guided Peripherally Inserted Central Catheter Placement

This technique assumes that the operator is competent using the modified Seldinger technique for PICC insertion. Supplies, patient positioning, and skin preparation should be compliant with patient safety and infection control standards of care when incorporating maximal sterile barrier precautions.¹⁵ Once the central line equipment has been prepared, the single-operator technique can be used for PICC placement based on operator preference.

The first and perhaps most important step in successful placement of the PICC is the initial ultrasound examination of the upper arm to determine the best site for needle puncture and PICC site location.⁶⁴ If patients are able to tolerate it, they should be positioned in a recumbent, supine position with the extremity of choice extended on a flat surface, palm up. The

ultrasound transducer should be placed in close proximity to the patient's bed or examination table. A linear transducer should be used to identify and track the basilic, cephalic, or brachial veins to determine the optimal location for access based on the vessel location, patency, size, depth, and adjacent and overlying structures. Once the site has been chosen, sterile precautions should be initiated.

Ultrasound should be used to guide the needle and to verify correct insertion of the guide wire using a modified Seldinger technique. Once correct placement has been verified, the PICC should be advanced to the desired length and location.

Ultrasound may be used to verify PICC placement by visualizing agitated saline from an intravenous flush in the right atrium of the heart after placement. Ultrasound may help identify and correct malposition of a PICC, particularly inadvertent placement into the IJ vein.⁶⁵ Peripherally inserted central catheter placement should be verified and adjusted such that the tip dwells between the lower third of the superior vena cava to the right atrium.⁶⁶ Electrocardiographic guidance and other US Food and Drug Administration–approved non-radiographic techniques are optimally used to verify and adjust the tip position. In the event that electrocardiographic guidance and other Food and Drug Administration–approved devices for such purposes are unavailable, the catheter tip position must be verified by chest radiography before use.

6. Ultrasound-Guided Peripheral Venous Access

a. Overview and Evidence

Ultrasound guidance for peripheral venous access can be an invaluable technique when short-term access is needed in patients who are difficult or impossible to access via the landmark technique.⁶⁷ While ultrasound-guided peripheral venous access can be very effective when performed by an experienced individual, this procedure can be quite challenging, as the vessels are small and can be deep.¹² Without sufficient operator experience with both intravenous access and ultrasound guidance for procedures, ultrasound may consume time and cause patient discomfort

without benefits.⁶⁸ Ultrasound use by nurses has shown a particular benefit as an adjunct for peripheral venous access in difficult patients.⁶⁹

b. Technique

Vessels in the upper extremity are usually preferred for ultrasound-guided peripheral venous access, although others may be identified. Veins may be found in the forearm, antecubital fossa, or upper arm. When available, superficial veins are preferred, as they are closer to the surface and not typically near arteries or nerves. Superficial veins include the median antebrachial vein on the volar surface of the forearm, the antecubital vein, the cephalic vein (radial side), and basilic veins (ulnar side). Deep veins of the forearm are paired with arteries and are often found with one on each side of an artery. Nerves travel adjacent to arteries as well. Any potential vessel should be evaluated for patency, diameter, depth, course, and surrounding or overlying structures. A vein depth of about 5 mm is usually ideal, and a depth of greater than 1.5 to 2 cm makes peripheral access very challenging even with ultrasound guidance, although larger-diameter vessels may be accessed deeper than others.⁷⁰ Proximal placement of a rubber tourniquet may distend the vessel and improve the ability of the catheter to puncture the vein without also passing through the posterior wall.

The site should be prepared by cleaning with an appropriate antiseptic agent, and clean gloves (sterile gloves per some standards)¹⁷ should be used, but maximum sterile barrier precautions are not required for peripheral venous access.¹⁵ An appropriate-gauge catheter of sufficient length should be used. For ultrasound-guided peripheral venous access, a catheter length of greater than 1.75 inches is recommended, as these veins are often deeper than those accessed using a landmark technique. The typical intravenous catheter (1.25 inches in length) may not reach or remain in deeper veins. There are also longer peripheral catheters (≈ 2.5 inches) that include a wire to use a Seldinger technique for deeper or more difficult peripheral access.^{70,71} If these are not available, some practitioners have used the

radial artery catheters with Seldinger guidance for peripheral venous access.^{70,71} The site may be anesthetized by using topical or injectable lidocaine and a small-gauge needle (ie, tuberculin or insulin syringe).

Static guidance has been shown to be helpful in pediatric patients when veins are not easily seen, but one-person dynamic guidance is usually the preferred method for ultrasound-guided peripheral venous access by experienced users. Ultrasound guidance in peripheral veins is almost always performed by using an out-of-plane orientation, visualizing the short axis of the vessel, as smaller vessels may be tortuous and can be difficult to keep in view longitudinally.¹² The ultrasound transducer should be centered over the vessel. The catheter should be grasped with the hand over the top of the catheter to allow improved manipulation of the angle of insertion, allowing it to be more parallel to the skin if necessary. Once the catheter tip is appropriately placed in the lumen, the catheter should be advanced over the needle and should slide in easily. Resistance usually means the tip is not properly positioned. Once the catheter is placed, blood should return easily, and the catheter should be flushed and secured. Ultrasound visualization of the vein more proximal to the catheter while a flush is performed can confirm appropriate placement.

7. Midline Catheters

Midline catheters are longer than most peripheral catheters but shorter than PICCs and are typically 8 to 20 cm in length.⁷² These catheters are recommended for medium- to long-term intravenous therapy and are recommended by the Centers for Disease Control and Prevention and other guidelines when therapy is expected to exceed 6 days.¹³ As with PICCs, midline catheters should be avoided in patients with chronic kidney disease who may need dialysis, as they may compromise future dialysis access. Midline catheters are considered peripheral as they do not terminate in a central vessel; however, it is generally recommended that full barrier precautions be used, which may limit feasibility in the acute setting.⁷³ The use of ultrasound guidance for midline placement should be similar to that for PICC placement.

VII. Documentation

Adequate documentation is essential for high-quality patient care and should be in accordance with the *AIUM Practice Parameter for Documentation of an Ultrasound Examination*.

VIII. Equipment Specifications

Ultrasound guidance for vascular access procedures should be performed using broadband high-resolution linear array transducers. Frequencies between 7.5 and 12 MHz are generally preferred. Higher frequencies are better for visualizing more superficial vessels, and lower frequencies are better for visualizing deeper vessels. Small-footprint transducers (including the “hockey stick”-type transducer) may be helpful in pediatric patients or in areas where space is limited, such as near the clavicle. Color or spectral Doppler imaging may be helpful for identifying flow in vascular structures and in aiding the differentiation of arteries and veins.

In addition to ultrasound equipment, certain additional equipment may be required or helpful for ultrasound guidance of vascular access procedures. Sterile transducer covers should be available for all central access procedures. Echogenic needle tips for access may improve ultrasound visibility. Longer intravenous catheters (>1.75 inches) are essential for peripheral venous access of deeper vessels identified with ultrasound.

IX. Quality Control and Improvement, Safety, Infection Control, and Patient Education

Policies and procedures related to quality control, patient education, infection control, and safety, including equipment control monitoring, should be developed and implemented in accordance with the *AIUM Standards and Guidelines for the Accreditation of Ultrasound Practices*.

X. ALARA Principle

The potential benefits and risks of each examination should be considered. The ALARA (as low as reasonably achievable) principle should be observed when

adjusting controls that affect the acoustic output and by considering transducer dwell times. Further details on ALARA may be found in the AIUM publication *Medical Ultrasound Safety*, Third Edition.

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