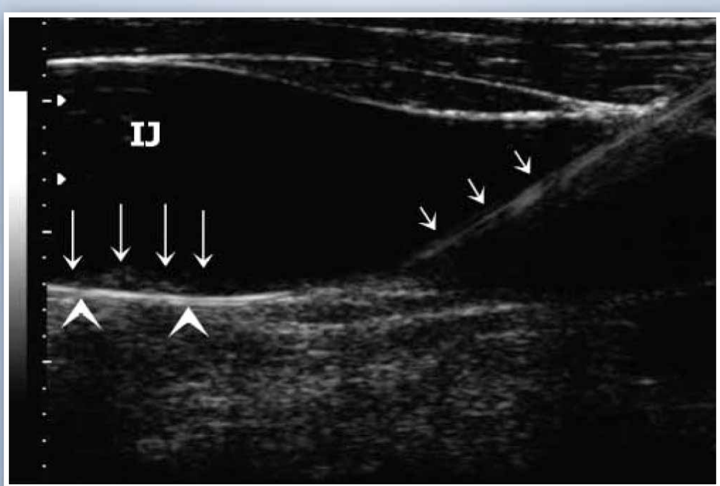
AIUM Practice Guideline for the

Use of Ultrasound to Guide Vascular Access Procedures

Guidelines developed in conjunction with the American Academy of Physician Assistants (AAPA), the American Association of Critical Care Nurses (AACN), the American Association of Nurse Anesthetists (AANA), the American Society of Diagnostic and Interventional Nephrology (ASDIN), the American College of Emergency Physicians (ACEP), the American Society of Echocardiography (ASE), the Association of Physician Assistants in Cardiovascular Surgery (APACS), the Association for Vascular Access (AVA), the Infusion Nurses Society (INS), the Renal Physicians Association (RPA), the Society of Diagnostic Medical Sonography (SDMS), and the Society for Vascular Ultrasound (SVU).



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The American Institute of Ultrasound in Medicine (AIUM) is a multidisciplinary association dedicated to advancing the safe and effective use of ultrasound in medicine through professional and public education, research, development of guidelines, and accreditation. To promote this mission, the AIUM is pleased to publish this *AIUM Practice Guideline for the Use of Ultrasound to Guide Vascular Access Procedures*, established collaboratively with many organizations whose members perform vascular access. We are indebted to the many volunteers who contributed their time, knowledge, and energy to bringing this document to completion.

The AIUM represents the entire range of clinical and basic science interests in medical ultrasound, and, with hundreds of volunteers, the AIUM has promoted the safe and effective use of ultrasound in clinical medicine for more than 50 years. This document and others like it will continue to advance this mission.

Practice guidelines of the AIUM are intended to provide the medical ultrasound community with guidelines for the performance and recording of high-quality ultrasound examinations. The guidelines reflect what the AIUM considers the minimum criteria for a complete examination in each area but are not intended to establish a legal standard of care. AIUM-accredited practices are expected to generally follow the guidelines with recognition that deviations from these guidelines will be needed in some cases, depending on patient needs and available equipment. Practices are encouraged to go beyond the guidelines to provide additional service and information as needed.

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I. Introduction and Scope of This Document

The contents of this guideline were developed collaboratively among the AIUM and other organizations whose members use ultrasound for guidance in vascular access procedures.[†]

This guideline 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 ultrasonography 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 guideline is intended to be evidence based when possible and to include selected references of importance, but 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 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 may be used to aid in central venous, peripheral venous, or arterial access procedures. 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 higher-risk procedures such as internal jugular (IJ) central venous access and for all elective jugular vein dialysis catheter placements.[4] While the evidence for ultrasound guidance in other vascular access procedures and situations is less robust, there is a consensus opinion that, with the exception of routine peripheral venous access in adults, ultrasound guidance offers substantial cumulative benefits in terms of safety and success. 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.

† Additional organizations represented during the drafting of these guidelines include: the American College of Cardiology (ACC), the American College of Radiology (ACR), the American Registry for Diagnostic Medical Sonography (ARDMS), the American Society of Anesthesiologists (ASA), the American Society of Nephrology (ASN), the Society for Critical Care Medicine (SCCM), the Society of Radiologists in Ultrasound (SRU), and the Vascular Access Society of America (VASA).

III. Qualifications of the Ultrasound User for Vascular Access

It is assumed that practitioners who perform vascular access are performing this procedure within their scope of practice, with or without ultrasound. Training and 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 practice of ultrasound, instruction in the techniques of ultrasound guidance for vascular access, and proctored assessment of competency in a simulated or actual patient care setting.[3,5,6]

IV. 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, written informed consent should generally 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. Short-Axis (Out-of-Plane) Versus Long-Axis (In-Plane) Visualization (Figure 1)

Using basic B-mode imaging, the plane of the ultrasound image may be oriented relative to the vessel in the short (out-of-plane) or long (in-plane) axis. In a short-axis view, the image plane is perpendicular to the course of the vessel and to the needle (needle is "out of plane"). The vessel should appear as an anechoic circle on the screen with the needle visualized as a hyperechoic point in cross section. In a long-axis view, the image plane is parallel to the course of the vessel (needle is "in plane"). The image should show the course of the vessel across the screen and the shaft and point of the needle as it is advanced.

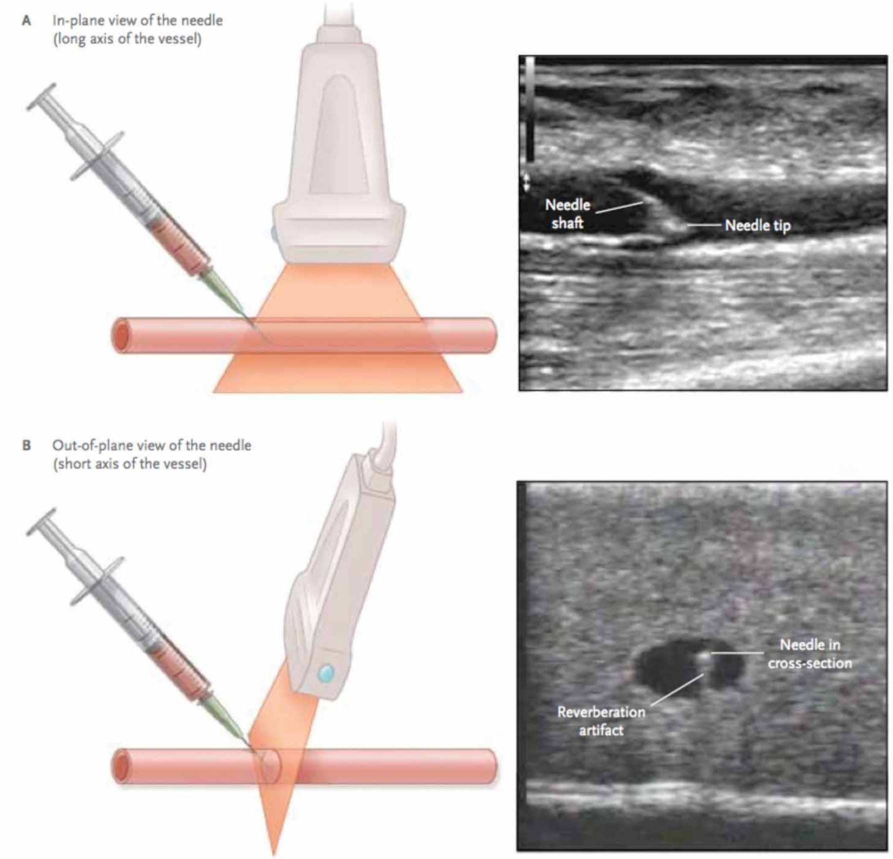

Figure 1. Planes of ultrasound visualization for vascular access procedures. Panel A shows a long-axis, "in-plane" view of the needle. Although it may be more difficult to keep the needle and structure of interest in view, the long-axis view is advantageous because it shows the entire needle, including the tip (ultrasound image at right). Panel B shows a short-axis approach, 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 the short axis 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]).

The 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. While the long-axis view has the advantage of allowing visualization of the entire needle shaft and tip,[7] 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.[8] The long-axis 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 short-axis approach is adequate and sufficient to follow the needle tip location. It may be helpful to start a procedure with a short-axis view to ensure that the needle is centered over the middle of the vessel and then rotate the probe to a long-axis/in-plane view as the needle is advanced.

B. Differentiating Arteries From 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 coapt 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. 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.

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 determining this location, 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 the needle tip placement and has been shown to be superior to the static approach in most situations.[9]

D. One-Person Versus Two-Person Technique

Using dynamic visualization, it is possible for one person to perform the ultrasound 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.[10] 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 needle with one hand while directing the ultrasound probe in 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.[11]

E. Site Selection and Preparation

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. Although ultrasound will allow direct visualization of the vessel, optimizing the anatomy before the procedure is extremely important for inexperienced operators. In venous access, it is extremely important, particularly in central access procedures, 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.[12]

Once a site has been chosen, the site and ultrasound equipment should be prepared for the procedure, and preprocedural local anesthesia may be applied and/or injected. Adequate anesthesia will ensure both patient comfort and patient cooperation, reducing the risk of unwanted complications caused by unexpected patient movement. After adequate anesthesia, the chosen site for central venous or arterial access should be prepared using maximal sterile barrier precautions.[13] Maximal sterile barrier precautions are not required when using ultrasound guidance to perform peripheral venous access.[13,14]

In addition to skin preparation and barrier precautions, a sterile sheath is required for the ultrasound probe. There are commercially available probe cover kits that include both a sterile cover (sheath) for the probe and sterile gel. Typically the probe is "dropped" into a sheath, which then extends up the cord of the probe 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, with sterile gel used on the outside. Avoid air bubbles between the face of the probe and the inner surface of the sterile sheath, as this will lead to suboptimal visualization.

F. Performing the Procedure

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. Using ultrasound to identify the depth of the center of the intended vessel, the point of skin entry should be about the same distance from the probe, assuming an approximately 45° angle, set back from the probe 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 probe, while 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 short-axis ultrasound visualization and centering the vessel on the screen, then using the center of the probe as a guide for where the needle should enter. Whether using either in-plane or out-of-plane needle visualization with ultrasound, the tip of the needle must be identified throughout the procedure.

During initial penetration of the needle through the skin, the operator should note a depression of the skin on the ultrasound monitor. If the needle is aligned correctly, this soft tissue depression should be located directly over the target vessel. The operator should be looking at the patient's arm and the needle during any adjustments in needle position. 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 probe 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 catheter enters the vessel, a "target sign" is seen in the short axis (see Figure 1). Typically a flash of blood will be seen in the catheter. The catheter 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.

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 can ensure proper placement.[15] Sterile technique should be maintained at all times.

G. Use of Ultrasound After the Procedure

Ultrasound may be used after cannulation to ensure appropriate placement and to assess for complications. It is recommended that for venous access procedures, a "postprocedure flush" using agitated normal saline 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. 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 using a low-frequency probe such as a curvilinear or phased array transducer.

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. For novice operators, needle guides have been shown to increase first-pass success, although the rate of arterial puncture was not decreased.[16] Using needles with "echogenic" needle tips as well as ultrasound machine algorithms that enhance visualization of the needle may be very helpful, particularly for less experienced users. Products using other means of needle localization and guidance that do not interfere with needle manipulation as much as traditional needle guides are becoming commercially available and may make ultrasound guidance for vascular access procedures even safer and easier in the future.

V. Specifications of Specific Ultrasound-Guided Access Procedures

A. Ultrasound-Guided Central Venous Catheterization

It is estimated that approximately 5 million central venous catheters (CVCs) are inserted annually in the United States.[14] 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 three major sites for accomplishing CVC access: IJ, subclavian, and femoral. 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 three 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.

1. Ultrasound Guidance for Internal Jugular Cannulation

a. Overview and Evidence for Ultrasound Guidance in Internal Jugular 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.[17,18] 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 provide more benefit to operators less experienced with CVC insertion, although ultrasound may still provide benefit to clinicians experienced with CVC insertion when the operator is adequately trained in the use of ultrasound for guidance.[19,20]

In mechanically ventilated intensive care unit 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.[18]

While there is less literature on the use of ultrasound guidance for IJ access in children, ultrasound guidance for IJ vein insertion using real-time guidance is recommended.[21]

Finally, the use of continuous wave Doppler ultrasound alone (ie, sound without an image) for guidance in IJ vein cannulation is discouraged. Though used extensively in the past, it does not offer benefit over 2-dimensional (B-mode) ultrasound imaging[22]. 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 guidance[23] is recommended for a CVC at the IJ vein site.

b. Technique for Ultrasound-Guided Internal Jugular 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.[24,25] If a patient is cooperative, other maneuvers such as Valsalva or humming may also increase the IJ vein size.[26] While some head rotation may be required to maneuver the probe 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.[12] 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 probe 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 to 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 probe 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.[27,28]

Once blood return has been obtained, the ultrasound probe may be placed aside on the sterile field to continue with the procedure. Advancement and correct positioning of the guide wire may be aided by ultrasound visualization.[15] Once the catheter is secured, a postprocedure assessment should be performed using ultrasound by visualizing the right atrium of the heart with a saline flush to determine central venous placement. Lung sliding may also be assessed using ultrasound to help demonstrate the absence of pneumothorax.[29]

2. Ultrasound Guidance for Subclavian/Axillary 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.[30] However, in most dialysis patients, the subclavian site is contraindicated because of the high incidence of stenosis related to dialysis catheters in this location. 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 in aiding subclavian central venous access.[11] However, the axillary vein (a continuation of 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 a 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 prospective randomized trial of static ultrasound imaging versus the landmark technique for "subclavian" vein catheterization found no difference in the complication rate or cannulation failure rate.[30]

For inexperienced operators, real-time ultrasound guidance compared to the landmark technique improved overall success and complication rates and lessened the average number of attempts.[31] To date, we are not aware of studies supporting the use of ultrasound guidance for axillary vein cannulation compared to landmark techniques. However, extrapolation of IJ vein cannulation data to this site might suggest a role.

We suggest that the evidence does not support outcome improvement for ultrasound guidance of subclavian vein catheterization over the landmark technique for experienced operators. Ultrasound guidance may be beneficial for novice operators, assessing vessel location and patency, and as a rescue technique after unsuccessful landmark-guided attempts.

b. Subclavian/Axillary Vein Ultrasound Guidance Technique

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

As mentioned above, there is some blurring in the literature between when ultrasound is used to access the axillary vein in the chest and the subclavian vein (proper). A direct subclavian infraclavicular approach using dynamic ultrasound may be difficult but with experience will allow the operator to safely cannulate the subclavian or proximal axillary veins under direct ultrasound guidance. This can be aided by using a smaller-footprint probe (including an L-shaped "hockey stick" probe or a high-frequency endocavitary probe), 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 entered, 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. Doppler imaging may be helpful in identifying the artery. In addition to arterial puncture, 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 from this approach should use an in-plane, long-axis view, both to allow the probe to fit into the supraclavicular space and to follow the shaft and tip of the needle.

3. Ultrasound Guidance for Femoral Venous Access

a. Overview and Evidence

For longer-term central access, the femoral vein site is not usually preferred because of higher infection rates. However, the distance from structures in the neck and chest reduces the chance of significant complications, and accessibility in trauma and resuscitation scenarios makes it a good choice in certain situations. The relatively constant location of the femoral vein medial to the femoral artery makes the landmark technique fairly reliable by using arterial palpation as a guide. However, the femoral vein travels deep to the artery as it moves distally, making inadvertent arterial puncture not uncommon.[32,33] Particularly in situations in which a pulse is difficult to palpate (severe hypotension or cardiac arrest) as well as in pediatric patients, ultrasound guidance may help improve successful femoral vein access.[34,35]

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.[36] 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.[34] The use of ultrasound guidance for pediatric femoral venous access has been shown to markedly increase the first-pass success rate and shorten the time to cannulation.[35]

In summary, ultrasound guidance for femoral vein access may improve the success rate and reduce complications for femoral venous cannulation, although this benefit may be more important with novice operators, in pediatric patients, or in patients without adequate pulses for landmark guidance.

b. Technique for Ultrasound-Guided Femoral 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 on top of the 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 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 of arterial vessels is an established technique for detecting atherosclerosis, ultrasound can also be used to aid in accessing or cannulating arterial vessels. Ultrasound guidance aids in identifying and accessing the arterial lumen at the more traditional locations that have good external anatomic landmarks and may expand options for access of nontraditional sites whose external landmarks are less well defined. 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 among 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.[37] 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 with the palpation method in the placement of radial arterial catheters.[38] Several studies have demonstrated improvement in first-pass success rates for ultrasound-guided radial artery access in the emergency department and operating theater settings.[39–41] The advantages of the radial artery 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 investigation found that the use of ultrasound for arterial cannulation substantially improved the success rate, while another investigation did not find a benefit (although the operators in this investigation had minimal experience with ultrasound).[42,43]

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

For radial artery cannulation, an Allen test for collateral perfusion should be performed. Optimal positioning of the wrist should include a support that allows the wrist to be approximately 45° extended (more than 45° may cause the vessel to be compressed).[39]

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 Peripherally Inserted Central Catheters

a. Overview and Evidence

Peripherally inserted central catheters (PICCs) 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] Peripherally inserted central catheter lines should be avoided in patients with advanced kidney disease to preserve future dialysis access.[4] 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 line placement is recommended.[46]

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.[47–50] When using a "blind" approach to PICC line 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 PICC lines and that ultrasound guidance should be used routinely to aid in PICC line placement.

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.[13] 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.[51] 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 probe should be placed in close proximity to the patient's bed or examination table. A linear probe should be used to identify and track the basilic, cephalic, or brachial veins to determine the optimal location for access based on vessel location, patency, size, depth, and adjacent and overlying structures. Once the site has been chosen, sterile precautions should be initiated.

Ultrasound guidance 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 confirm 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 line, particularly inadvertent placement into the IJ vein.[52] Peripherally inserted central catheter placement should be verified and adjusted such that the tip dwells in the lower third of the superior vena cava but not beyond the junction of the superior vena cava and right atrium. Electrocardiographic guidance and other US Food and Drug Administration–approved nonradiographic 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. While ultrasound-guided peripheral 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.[11] Without sufficient operator experience with both intravenous access and ultrasound guidance for procedures, ultrasound may consume time and cause patient discomfort without benefits.[53] Ultrasound use by nurses has shown a particular benefit as an adjunct for peripheral venous access in difficult patients.[54]

b. Technique

Vessels in the upper extremity are usually preferred for ultrasound-guided peripheral 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.[55] 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 should be used, but maximum sterile barrier precautions are not required for peripheral venous access.[13] A sterile ultrasound probe cover may be used, or a transparent film dressing may be placed over the probe. Sterile gel, typically available in small packets in the clinical care setting, is preferred. An appropriate-gauge catheter (usually 18 or 20 gauge) of sufficient length should be used. It is essential that the catheter be longer than the typical intravenous catheter (1.25 inches), or the catheter will not reach (or will not remain in) the veins as they are deeper than those accessed via the landmark technique. A catheter length of greater than 1.75 inches is recommended. A modified Seldinger technique may be used (often performed with kits designed for radial artery access).[56] The site may be anesthetized 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 access by experienced users. Ultrasound guidance in peripheral veins is almost always performed using an out-of-plane orientation, visualizing the short axis of the vessel, as smaller vessels with more frequent turns are difficult to keep in view longitudinally.[11] The ultrasound probe 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.

VI. Documentation

As in all procedures, vascular access using ultrasound guidance requires adequate documentation, both of the procedure and the use of ultrasound. Documentation of ultrasound guidance includes written documentation in the patient's medical record as well as image retention. Retention of the ultrasound examination should be consistent both with clinical needs and local health care facility requirements. As such, we recognize that the following important elements of documentation should be considered. In emergency, remote, out-of-hospital, or disaster situations, documentation and/or image retention may need to be abbreviated.

A. Written Elements

1. Procedural consent (written consent for major procedures such as central vascular access; may be verbal for peripheral access) by the patient, family member, or health care proxy when the clinical scenario permits (ie, except in emergent cases);
2. Indications for the procedure;
3. Safeguards taken for major procedures (time out, correct side);
4. Methods and measures taken to ensure sterility;
5. Procedural sedation, if used, including the agent, amount, and full accompanying sedation documentation as dictated by the clinician's specialty or institution;
6. Local anesthetic agent, concentration, and amount infiltrated;
7. Anatomic site, target vessel patency, and approach to the target vessel;
8. Use of ultrasound, in plane or out of plane, and visualization of needle entry;
9. Type, gauge, and length of the catheter used;
10. Number of passes/attempts and any complications;
11. Confirmation of successful placement; and
12. Postprocedural annotation of patient tolerance of the procedure and appearance of the site.

B. Image Retention

Images should be labeled with the patient identification, facility identification, and side of the anatomic site imaged. Ideally this would include the following as dynamic (cine loop) images, although the difficulty of recording images during a procedure is recognized and may not include all elements:

1. Preprocedure venous compressibility and patency and surrounding structures;
2. Entrance of the needle tip into the vessel lumen; and
3. Postprocedure flush to ensure intraluminal placement.

Reporting should be in accordance with the *AIUM Practice Guideline for Documentation of an Ultrasound Examination*.

VII. 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, with higher frequencies better for more superficial vessels and lower frequencies better for deeper vessels. Small-footprint probes (including the "hockey stick"–type probe) 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 probe covers should be available for all central access procedures. Echogenic needle tips for access may improve sonographic visibility. Longer intravenous catheters (>1.75 inches) are essential for peripheral venous access of deeper vessels identified with ultrasound.

VIII. Quality Control and Improvement, Safety, Infection Control, and Patient Education Concerns

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

Additional care needs to be taken for infection control while using ultrasound equipment to aid in procedural guidance, particularly in central vascular access, where sterility must be maintained. The introduction of an additional piece of equipment adds complexity to keeping these procedures sterile. Sterile probe covers should be readily available with all equipment. An additional person is often required to assist with sterile preparation of the ultrasound probe and machine operation. Consistent adherence to additional infection control guidelines, including hand hygiene, the use of chlorhexidene skin preparation, and maximum sterile barrier precautions, has been shown to contribute significantly to positive patient outcomes in central vascular access.

Equipment performance monitoring should be in accordance with the *AIUM Standards and Guidelines for the Accreditation of Ultrasound Practices*.

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