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Ultrasound for peripheral and arterial access

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Peripheral venous access is perhaps the most commonly performed procedure in hospitals, urgent care, or surgical centers across the country. The ability to obtain peripheral intravenous (IV) access, and in a timely manner, is arguably one of the most important skill sets to be mastered by health care professionals. While skill and experience play a role in successful and timely vascular access, numerous patient factors such as obesity, diabetes, IV drug use, and chronic kidney disease may pose unique challenges to even the most skilled health care professional. In patients with difficult access, there are often multiple attempts, which can be both time consuming for the provider and painful for the patients. Direct visualization of blood vessels using ultrasonography has an advantage over the standard landmark technique and can improve the success rate of peripheral IV or arterial line placement in this patient population. Given the success of ultrasound guidance with access placement, it is imperative that all health care profesionals become proficient with this technique. The aim of this review article is to provide concise and practical information on the basics of ultrasound and its application to obtain peripheral venous and arterial access.

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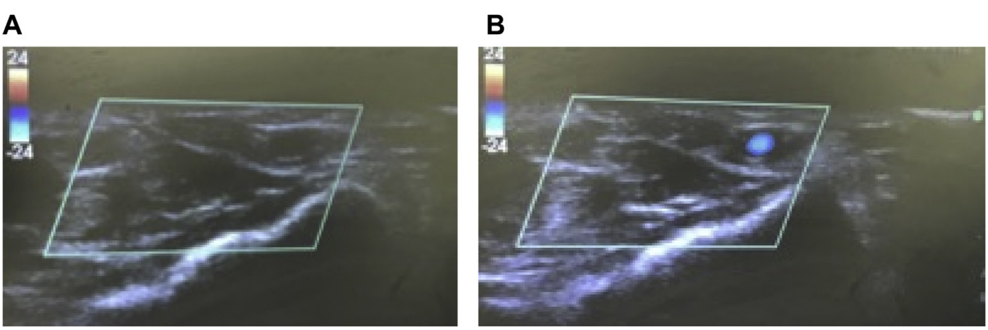
Introduction

Basics of ultrasonography

Ultrasound is defined as a sound wave or vibration with a frequency greater than 20,000 Hz, which cannot be detected by the human ear. Ultrasound probes used for medical imaging emit sound waves at frequencies of 1–20 million Hz. The waves emitted from the transducer probe return as a mechanical force that is translated into electrical energy depicted as an image, a concept known as the piezoelectric effect. When an ultrasound probe is placed on the body, the waves emitted can either penetrate or reflect off tissues depending on their relative densities and/or acoustic impedance. These waves then return or echo back to the probe forming an image with different levels of brightness, referred to as echogenicity.

Tissues that ultrasound waves cannot penetrate (or reflect strongly), such as air and fascia, often appear bright or hyperechoic on an ultrasound image, while tissues that ultrasound waves penetrate well and reflect weakly, such as solid organs, appear grayish or hypoechoic. Blood vessels and other fluid-filled structures as well as fat do not reflect the ultrasound beam and thus appear black or anechoic. Bone often appears black with a bright hyperechoic rim on ultrasound because the beam cannot penetrate the bone and thus casts an acoustic shadow behind it. Nerves can appear either hypoechoic or hyperechoic depending on their location. Those that are proximal, such as the brachial plexus, can appear hypoechoic, while more distal nerves such as the sciatic nerve tend to appear hyperechoic because of the presence of fascicles contrasting against the hyperechoic connective tissue background [1]. Deeper structures can also appear dark because the ultrasound waves are absorbed and scattered, as they traverse the tissue, a characteristic known as attenuation. Increasing the gain of the image can correct for attenuation by making echogenic structures appear the same despite being at different depths. Higher frequency probes provide high-resolution images but cannot penetrate deep tissues. On the other hand, lower frequency probes penetrate deeper tissues but at the expense of resolution [2] (see Images A and B).

The Doppler effect is defined as an increase or decrease in the frequency of a wave when either the source and/or the target moves toward or away from each other. This theory has been applied to ultrasound in the form of color flow Doppler. The color Doppler mode can be useful in ultrasonography, as it can identify the flow of blood within the lumen of blood vessels. It is important to know that the color seen within a vessel represents the direction of flow toward or away from the probe and does not denote arterial or venous flow. Blood flow toward the probe appears red, whereas blood flow away from the probe appears blue. BART (Blue Away Red Towards) is a helpful mnemonic to remember this point [3].



Images A and B. Use of a color flow Doppler to identify a blood vessel on ultrasound. The blue dot in the bottom image denotes blood flow away from the transducer.

Application for obtaining vascular access

Peripheral venous access

Indications for using ultrasonography to obtain vascular access

As a health care professional, intravenous (IV) catheter placement is a fundamental skill that can help save patients' lives. In some patients, it can be challenging to obtain IV access, categorizing these patients as “a difficult access” [4]. Multiple factors can play a role in making vascular access difficult, such as obesity, age, sex, history of IV drug abuse, volume status, other medical comorbidities, and the duration needed for IV access. Ultrasound guidance can improve the success of IV cannulation in these patients and has the potential to reduce time to cannulation as well as patient comfort [5]. More importantly, ultrasonography is indicated after two failed attempts using the standard technique or if a patient has a history of difficult IV access. Direct visualization and vessel characteristics appreciated using ultrasonography provide an advantage relative to the standard technique and can improve success in these patients with difficult access [6,7]. Health care providers who are proficient in standard IV placement techniques will find it easy to learn ultrasound-guided techniques.

Techniques for obtaining vascular access

Consent. Verbal consent should be obtained (or presumed during emergency scenarios) before the procedure. If the patient offers his or her upper or lower extremity for IV catheter placement, then this is an example of implied consent.

Supplies (Images C and D)

- Ultrasound machine with probe(s)
  - Linear array 5–14 MHz or short linear transducer probe
- Lubricant or gel for ultrasound probe

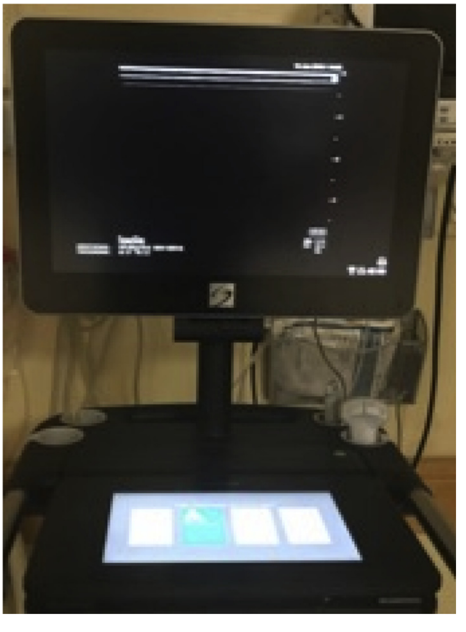


Image C. Ultrasound machine.

Image D. Supplies include 20 g and 22 g IV, IV tubing, saline flush, antiseptic wipes, tourniquet, Tegaderm, gauze, sterile gloves, and ultrasound probe cover.

- +/− probe cover
- Gloves
- Tourniquet, antiseptic swab, adhesive dressing, Luer-Lok adapter, saline flush, gauze, PIV tubing
- IV needle and catheters (24G to 14G and short vs. long catheters), drug(s) if necessary
- Analgesics
  - EMLA, LMX, tetracaine, vapocoolant, subcutaneous local anesthetic

Preparation. First, it is necessary to ensure all equipment needed for IV catheter placement is ready and available for use. This includes cleaning the ultrasound transducer with a germicidal solution before use. A probe cover can be used, if preferred. Universal precautions should be adhered to, including proper hand washing, before any procedure. The patient and the extremity to be used for IV catheter placement should be placed in the most optimal position. The patient should be seated (or lying flat, if there is a concern for vasovagal syncope) with the extremity extended at a level that is comfortable for the provider. When ready to proceed, a tourniquet is placed proximally on the extremity, the area is cleaned with an alcohol pad, and a sterile gel or a surgical lubricant is applied to the transducer. Now, we are ready to scan.

General steps for ultrasound-guided IV catheter placement. If the patient is on a stretcher, then the ultrasound machine should be placed on the contralateral side of the stretcher so that the monitor is in the direct line of sight for the provider. Alternatively, the monitor can be placed on the same side of the patient behind the extremity to be used. The machine is turned on and allowed to properly warm up. Patient data are entered (if required by the institution), and the appropriate vascular access preset is chosen to optimize the image, if available. A comfortable body position should be maintained during IV catheter placement, keeping your back straight and arms at the same level of the extremity used for the procedure. The correct transducer is chosen, and a preprocedural inspection of the potential veins is performed on the extremity from distal to proximal. This important step allows the provider to find and select the best vein to cannulate as well as the chance to optimize the image before the venous puncture [8]. The extremity is placed in the horizontal position to allow for comfortable probe placement and to ensure the procedure is performed in the vertical plane. The gain is adjusted to enhance the contrast between the vessel and the surrounding structures. The image is adjusted so that the vessel appears dark while the surrounding structures appear gray or white. It is to be remembered that the skin is at the top of the screen and depth is indicated by centimeter marks at the side of the screen. Left or right orientation of the probe is distinguished by the symbol on the top left corner of the monitor and an indentation or indicator mark on the transducer. Color dopper can be used to distinguish the compressible thin-walled vein from the pulsating, thick-walled artery. All possible veins potentially useful for cannulation should be evaluated, as vein characteristics and depth can improve success [8]. The safest approach (which is often the easiest) is chosen only after this scan [9].

Guidelines for selecting a vein for cannulation. When choosing a vein, distal extremity sites should be used preferentially to save proximal sites for subsequent cannulation, if needed, after failed attempts. The characteristics of a vein that can maximize the success of catheter placement are a larger vein diameter, superficial depth of the vein, and appropriate catheter length. For example, a standard IV (3.2 cm long) should be used for veins that are less than 1 cm deep and double-length catheters for veins greater than 2 cm deep. A 2010 observation study in the Journal of Emergency Medicine found that success rates were significantly higher for veins of moderate depth between 0.3 cm and 1.5 cm. Successful cannulation also vastly improved when the targeted vein diameter was greater than or equal to 0.4 cm^2 [7]. Catheter length should be selected depending on the distance to the vein to ensure the catheter will remain within the vessel.

Veins greater than 7 mm beneath the skin surface are considered “deep” and those less than 7 mm are considered “superficial” [10]. In addition, the veins of the upper extremities are preferred, as there is an increased risk of thrombosis and thrombophlebitis associated with venous cannulation of the lower extremities [9–11]. Whenever possible, use of the dominant upper extremity should be avoided for patient comfort.

Upper extremity. If no forearm veins are adequate targets for cannulation, then the ultrasound probe is advanced proximal to the patient's upper arm. In the upper arm, the cephalic vein courses along the anterior portion of the biceps and its superficial course makes it an ideal target for ultrasound guidance. Joing et al. recommend the large cephalic vein as the best target in the upper arm, as it does not run along a nerve or an artery. Alternatively, the basilic vein courses on the medial edge of the upper arm and is a good target for ultrasound guidance, as it is deep, has a large diameter, and does not run along an artery [12]. Consideration should be given to the brachial veins as a potential target, but it should be noted that arteries and nerves nearby could make venous cannulation a challenge. Therefore, it is recommended to have experience with the ultrasound technique for IV catheter placement and a good understanding of the local anatomy around the brachial veins to reduce inadvertent damage to nearby structures [13]. The median antebrachial veins in the antecubital fossa can be used, if necessary; however, this should be avoided whenever possible because of the increased risk of catheter dislodgement as well as obstruction of the catheter's lumen or “kinking” when the patient's elbow is in flexion. IV catheter placement during trauma resuscitation is an exception to this rule.

Lower extremity. Venous access of the lower extremities should only be considered as first line if there are absolute contraindications to using the veins of the upper extremities. Common targets are the greater saphenous vein at the level of the medial malleolus, dorsal metatarsal veins on the dorsum of the foot, perforating veins, sural branch veins, and the lateral marginal vein of the foot.

Contraindications to use of an extremity [8]:

- Presence of arteriovenous fistula
- History of mastectomy and/or lymph node dissection on the ipsilateral side
- Potential sites that may be used an intended procedure (i.e., injured extremity that requires surgery)
- Veins that are firm to palpation due to possible sclerosis and/or repeated trauma from multiple puncture attempts (e.g., IV drug abuse)
- Veins with evidence of active phlebitis or thrombosis
- Areas with signs of active infection such as cellulitis
- Hematomas from recent failed attempts

Techniques

Transverse approach

The transverse approach to ultrasound-guided IV placement is performed with the ultrasound probe placed perpendicular to the direction of the vein. The ultrasound probe is placed in this orientation to identify the target vessel in cross-section (Images E, F, and G). The vessel will appear as a dark circle. The depth of the target vessel is noted, and it is ensured that the catheter length is sufficient to reach it as well as to be able to secure it in the vessel. Distinguishing factors of veins, as compared to arteries, are that they are thin walled, compressible, and pulseless. Of note, while Doppler is another way to distinguish veins from arteries, the compressibility of the vein is a more reliable method to distinguish a vein [8].

The probe is made steady with the nondominant hand, keeping the vessel in the middle of the screen. With the needle in the dominant hand, the midline mark on the transducer is used to move the needle distal on the extremity to a distance equal to the depth of the vessel. The needle is inserted at a 45-degree angle and advanced toward the vein until the needle tip is visualized. The needle tip will appear as a single bright dot with posterior shadowing because it is perpendicular to the ultrasound plane. As the needle is advanced, the probe is adjusted by fanning or tilting the transducer in the direction of the needle to keep it in plane. If the needle tip cannot be identified, then the movement of the adjacent soft tissue or “tenting of the anterior wall of the vein” can be sought for [8]. Bouncing or vibrating the needle will enhance this image. It is very important to look for blood return as the needle is advanced into the vessel wall. On obtaining blood return, the angle of the needle is decreased and advanced by 1–2 mm to ensure the catheter is in the vein. While holding the needle still, the catheter is advanced over the needle until its entire length is under the skin. The IV catheter is secured using the standard technique, and the IV is tested with a saline flush. If there is a question of extravasation, then the ultrasound can be used to look for pockets of anechoic fluid.

Image E. Transverse approach. Note how the transducer is placed perpendicular to the vein, and the needle is in the same plane as the middle mark on the transducer.

Image F. Transverse approach of the left saphenous vein on a toddler.

Image G. Transverse approach on an obese patient.

Longitudinal approach

The longitudinal approach to ultrasound-guided IV placement is performed with the ultrasound probe placed parallel to the direction of the vein. It is considered an advanced technique, as the length of the vessel will need to be in plane throughout the procedure.

The advantage of this technique is direct visualization of the needle throughout the procedure, reducing the risk of posterior wall injury [7]. The target vessel is identified using the longitudinal approach (as above), and the transducer is simply turned 90° to view the vessel in its long axis. The indicator mark on the ultrasound probe should be on the distal side of the extremity, as the IV will be placed from that side. In this view, the full length of the target vessel can be viewed. It is important to anchor the hand with the ultrasound probe on the patient to keep the transducer still and keep the vein in view throughout the procedure. At a 30-degree angle, the needle is advanced toward the vein in the same plane. If the needle is not visualized, then the transducer is adjusted slightly by tilting or sliding it and bringing it back into view while advancing toward the vein. If the needle is not well visualized, then it is likely lateral to the plane of the vein. It is not recommended to advance the needle when not in view. If needed, the needle is pulled back and redirected until it is in plane. As the needle traverses the tissue to reach the vein, movement of nearby tissues and structures as well as tenting of the anterior wall of the vein will become evident. If tenting of the vessel occurs, then a controlled yet quick forward motion with the needle is used to access through the vessel wall. Further, the catheter is advanced, secured, and tested as mentioned above [14].

Confirmation. Once the catheter has been secured, it is important to confirm IV placement. As with the standard technique, blood return and the ability to inject saline without signs of infiltration are usually sufficient for confirmation. However, ultrasound allows the visualization of the catheter in the long axis to ensure the entire length is within the vessel. Infusion of 5–10 mL of normal saline allows the visualization of the microbubbles that appear within the vessel – "saline flush test" [7]. The presence of hematomas or other complications that may occur later can also be assessed, such as inflammation, infection, infiltration, and phlebitis. Irritation of nerves, hematoma formation, and arterial puncture are some of the more serious immediate complications that can occur [15]. It could be helpful to remember the following simple keys to success for technique and confirmation:

- Keep the depth of scanning in relation to the skin surface in mind
- Ergonomics is important – Be comfortable when performing the procedure
- Proper transducer selection
- the "Direct Seldinger technique" for difficult access or when large-bore IV catheters are necessary

Outcomes

Ultrasound-guided IV catheter placement has demonstrated to improve success rates and decrease complications and pain for patients [14]. Joing et al. state that ultrasound guidance is associated with a 95–99% rate of successful cannulation with a decrease of early and late complications [12]. For example, ultrasound can help rule out early puncture-related complications (pneumothorax, local hematoma) and late complications such as tip migration, catheter-related venous thrombosis, and fibroblastic sleeve formation [14–16]. The risk of complications that are common in vascular access, such as hematoma, inadvertent puncture of nearby vessels or nerves, or unsuccessful cannulation, is significantly reduced with the use of ultrasound guidance [17]. In addition, it has been shown that the number of IV access attempts will be minimized, and it shortens the time to successful cannulation and reduces the costs of the procedure.

Furthermore, the use of the ultrasound has not been shown to increase infection rates or complication rates. In a study performed by Adhikari et al., there was no increase in infection rates in ultrasound-guided peripheral lines when compared with using the standard technique to place lines [18]. Frazee et al. demonstrated that methicillin-resistant *Staphylococcus aureus* (MRSA) and other clinically significant organisms were effectively eliminated from the transducer with the use of a quaternary ammonia-based germicidal wipe, but there is limited evidence on whether the probe covers have a benefit or are even necessary [19].

More importantly, peripheral IV access can be lifesaving and are an absolute must in emergency situations. Patients may need a fast and reliable peripheral venous access, which sometimes may be very difficult to obtain because of the patients' status, edema, obesity, hypovolemia, or local injuries. In this setting, ultrasound-guided placement of an IV catheter might be more rapid, safer, and more cost-effective than a central line [14]. Presley et al. emphasize this further by stating that the success of ultrasound-guided peripheral IV catheters has been associated with significant reductions in central venous catheter placement in the emergency department as well as enhanced patient satisfaction [5]. In 1 year, 76 long peripheral catheters were inserted using ultrasound guidance under emergency conditions. The success rate was 100%; most lines lasted >1 week and were used for different purposes, including contrast medium injection.

However, a systematic review conducted by Liu et al. showed that studies vary significantly, and the routine use of ultrasound guidance for IV catheter placement is not strongly supported by the literature [15].

There were no significant differences in time to successful cannulation (five trials) or number of percutaneous skin punctures (four trials). A separate systematic review found a reduced number of attempts in a pooled analysis of four trials in adults [20]. Interestingly, in the pediatric population, it is likely that the standard technique remains the most appropriate method for first attempts, especially when the operator can visualize or palpate the vessel [20]. In neonates, ultrasound has no role in peripheral venous access, while near-infrared (NIR) technology may prove to be useful in the future [21].

Overall, there are at least 150 to 200 million IV catheters placed each year in the United states, and 80% of patients receive an IV during their hospital stay. Unfortunately, many factors may complicate the process of inserting an IV—whether due to patient factors or even due to the medical staff and operator capability to place the IV. This past year, though, Presley et al. showed that use of the ultrasound to help guide the IV placement would help enhance the health care team outcomes [5]. Ultrasound guidance enables visualization of veins that are not seen on physical examination, results in fewer needle sticks, more rapid cannulation, and better patient satisfaction (especially difficult IV access). No complications unique to ultrasound-guided vascular access have been reported [14]. Moving forward, it seems that the main cause of adverse events, if any, during ultrasound-guided venipuncture is poor training of the operator. Thus, more health care team members should begin to learn these ultrasound-guided techniques. The pivotal role of training cannot be overemphasized [6,22–24].

Arterial line access

Arterial lines are an indispensable tool in operating rooms, emergency departments, and intensive care units. Indwelling arterial catheters provide clinicians with a reliable means of monitoring a hemodynamically labile patient's blood pressure on a continuous basis to provide timely and life-saving therapeutic intervention. Unfortunately, many factors may hinder a successful arterial line placement, including obesity, chronic kidney disease, and hypotension. Furthermore, as with any invasive procedure, insertion of an indwelling arterial catheter poses certain risks including hematoma, infection, damage of the surrounding nerves, and distal ischemia. Presumably, these risks may be amplified with each unsuccessful attempt. Thus, increasingly more clinicians turn to ultrasound for successful arterial cannulation. A recent meta-analysis of 13 randomized trials involving a total of 2402 patients comparing direct palpation and ultrasound-guided arterial line placement conclusively showed that the ultrasound-guided arterial line placement is indeed superior to direct palpation in categories such as first attempt failure (RR 0.52 to 0.87, 95% CI), mean time to successful placement (−80.2 to −6.1 s, 95% CI), and arterial line placement complications (RR 0.16 to 0.95, 95% CI) [25]. Importantly, using a trial sequential analysis technique in their systematic review, Gottlieb and Bailitz demonstrated that further trials would not likely alter their results [25].

Indications

Indications for arterial line placement include hemodynamic instability, acid-base derangements, and intraoperative blood pressure monitoring in high-risk surgeries or patients. In addition, arterial lines provide easy access to frequent blood draws intraoperatively or in a critical care setting. The radial artery is the most common site of arterial line placement [26]. However, femoral access is preferred and often is necessary when large bore access is required, such as in various interventional neuro/cardiac procedures. Other possible access points include ulnar, axillary, brachial, and dorsalis pedis arteries.

Guidelines for selecting an artery for cannulation

Upper extremity

Radial artery

For radial access, the first step historically has been to conduct Allen and/or Barbeau test to evaluate for the potency of ulnar artery collateral flow to the palmar arch. However, in two large randomized clinical trials, namely, the RADAR and MATRIX, in patients with abnormal Allen or Barbeau test results, no clinical or subclinical signs of hand ischemia were identified post-radial artery access [27–29]. If laterality is not dictated by the procedure or surgery, then the nondominant hand is preferred for the patient's comfort.

Technique. The selected hand can be taped (the volar aspect of the forearm and wrist facing upward) to an armrest board, with a rolled towel positioned under the patient's wrist (as shown in Image H).

Once the hand is secured, the general area of insertion must be appropriately sterilized using chlorhexidine or betadine. Using a minimum depth of ultrasound penetration, the selected hand is then scanned by positioning a sterile ultrasound probe 1–2 cm proximal to the radial styloid process. The clinician's nondominant hand is used to hold and maneuver the ultrasound probe, while the dominant hand is used for catheter insertion (see Image I).

The blood vessels appear as a black (anechoic) circles surrounded by a gray (hypoechoic) circular wall in cross-sectional view. Arteries appear thick walled and pulsatile, while veins are thin walled and easily collapsible with the ultrasound probe. Once the radial artery is identified and an appropriate site of insertion is determined, 0.5–1 mL of lidocaine can be injected to make a skin wheal, without distorting the arterial anatomy in awake patients.

Next, the needle is positioned 30–45° directly over the insertion site. Optimally, the ultrasound probe, the radial artery anterior wall, and the insertion site should form an equilateral triangle so that when the needle tip reaches the anterior wall of the radial artery, it will be in plane with the ultrasound waves. The impression of the needle can usually be seen by the movement of the surrounding soft tissue. Once the needle punctures the anterior wall and is in the lumen of the artery, a pulsatile flow will fill the needle chamber (Image J).

At this time, the needle should be carefully held in place using the clinician's nondominant hand, while the guide wire is advanced through the needle using the dominant hand (Image K).

Once the guide wire is sufficiently advanced, the needle is then carefully removed and the catheter is advanced in small rolling motion over the guide wire using the clinician's nondominant hand while holding the end of the guide wire with the dominant hand (Image L).

Lastly, the arterial catheter is secured and connected to the transducer apparatus, and a sterile dressing is applied over the indwelling arterial line catheter [30,31].

Ulnar artery

The ulnar artery runs almost parallel to the radial artery at the volar aspect of the wrist, over the ulnar bone. The ulnar artery provides the primary blood supply to the wrist and digits through the deep and superficial palmar arch. In addition, the ulnar artery is smaller than the radial artery and has a theoretical concern for a higher rate of complications, although there is active debate regarding the matter. Given the absence of a definitive answer, access to the ulnar artery should be reserved only when other options have been exhausted. The technique of ultrasound-guided arterial line placement is similar to that of the radial artery as described above.

Axillary artery

The axillary artery, in contrast, is much larger and easily palpated slightly lateral to the belly of the pectoralis major muscle, close to the anterior fold of the axillary fold. The ultrasound-guided arterial

Image H. Positioning of extremity for radial arterial line placement.

Image I. Recommended clinician's hand position during insertion of catheter.

Image J. Pulsatile flash of blood indicates correct cannulation.

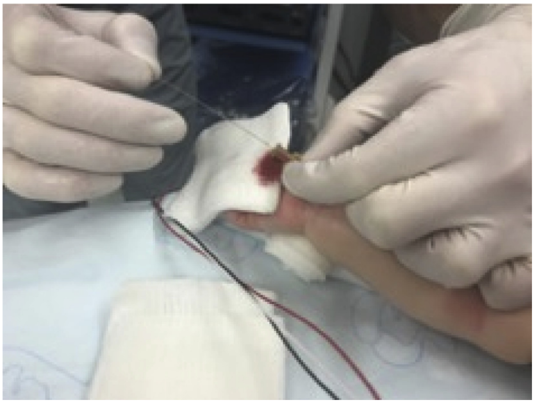


Image K. Recommended clinician hand positioning during guide wire positioning.

Image L. Demonstration of advancement of catheter in small rolling motions.

line placement is similar to that of the radial artery described above, with the addition of ipsilateral arm abduction for better accessibility. The axillary artery is enveloped by the branches of the brachial plexus and may be challenging to access. In addition, the axillary artery is the sole blood vessel to the entire upper limb, and its compromise can result in devastating ischemia in the entire extremity. Therefore, accessing the axillary artery is recommended only as the last resort when attempts to obtain other arterial line access have failed and the need for this access is deemed absolutely necessary.

Brachial artery

The brachial artery is the continuation of the axillary artery beyond the lower margin of teres major muscle. Thus, similar to the axillary artery access, the brachial artery cannulation is considered problematic and risky because of the lack of collateral blood flow to the upper limb [32]. The ultrasound-guided arterial line placement of the brachial artery is achieved in a similar fashion as the axillary artery cannulation mentioned above, with the ipsilateral arm abduction. The artery can be easily found on the ventral aspect of the arm, in the junction of biceps and triceps brachii.

Lower extremity

On the lower limb, the primary access sites for arterial line placement are the dorsalis pedis, posterior tibial, and femoral arteries. The dorsalis pedis artery runs over the bony prominence of the navicular bone at the mid-dorsal aspect of the foot and can be easily palpated. Given that there is ample collateral circulation to the foot, the dorsalis pedis artery is the preferred access site for lower extremity [32]. The ultrasound-guided cannulation is similar to the technique described above, with the exception that the needle is positioned in a near-perpendicular angle to the skin as if performing a venipuncture.

Posterior tibial artery

The posterior tibial artery runs immediately posterior to the medial malleolus and is the second major arterial supply to the foot [32]. In comparison to the dorsalis pedis artery, the posterior tibial artery is smaller in diameter and thus has higher potential for occlusion and distal ischemia. The posterior tibial artery is best accessed by slight dorsiflexion, eversion, and abduction of the ipsilateral foot. The ultrasound-guided technique is similar to that of the radial artery.

Femoral artery

The common femoral artery is the largest arterial supply of the lower limb and a common site of access, especially in cardiac catheterization laboratories. The common femoral artery runs medial to the anterior aspect of the thigh and enters the lower limb inferior to the inguinal ligament. The common femoral artery then bifurcates into superficial and deep femoral arteries. While both the common femoral artery and superficial femoral artery may be accessed for arterial line placement, the superficial femoral artery is faster and more often successfully accessed than the common femoral artery cannulation [33]. However, the superficial femoral artery has a slightly higher rate of pseudoaneurysm formation than the common femoral artery cannulation (17.9% vs. 2.9%, $p = 0.059$), while the latter has a higher hematoma rate (14.3% vs. 2.6%, $p = 0.095$) [33]. Because of the proximity of the femoral artery to the perianal region, there is a theoretic risk for higher infection rates than radial artery cannulation; however, an extensive study of 4932 patients was unable to identify such a risk [34]. In addition, as femoral artery pulse may still be palpable in a hypotensive patient, in the absence of an ultrasound, the femoral artery may be preferred relative to the radial artery for arterial cannulation [35]. The ultrasound-guided access to both vessels is similar to that of the radial artery described above.

Other sites of access

Another possible site for a peripheral arterial line placement is the superficial temporal artery, which runs anterior to the earlobe in the temporal aspect of the skull. The temporal artery is almost never utilized for an arterial line placement because of the negative cosmetic consequences in case of occlusion or extravasation, except in rare cases such as burns or trauma. Given its superficial course, the temporal artery is cannulated as if performing a venipuncture, with the needle position almost perpendicular to the skin; otherwise, the technique of arterial line placement is similar to that described above.

In neonates, one of the two umbilical arteries could also serve as a possible site of arterial cannulation, if the umbilical stump is not yet involuted. A normal umbilical stump clearly displays three vessels to the naked eye—two small thick-walled vessels, the umbilical arteries, and one large thin wall vessel, the umbilical vein. The umbilical artery can be easily cannulated, without ultrasound, using the sterile technique described above.

Conclusion

In conclusion, ultrasonography is an innovative tool traditionally used to guide central venous line placement, but it is versatile enough to be used for peripheral venous and arterial line access. This technique has been shown to increase the success rates of obtaining peripheral vascular access by decreasing the number of failed attempts. The success of this technique depends on appropriate patient selection and proficiency of the provider with ultrasonography. As there is a steep learning curve associated with the use of ultrasound-guided techniques, this is often the rate-limiting step when deciding how vascular access should be obtained in certain patient populations. As imaging modalities continue to enhance our ability to deliver high-quality patient care, ultrasonography is an invaluable tool that can help guide he successful placement of peripheral venous and arterial catheters.

Practice points

- Understand basics of ultrasonography.
- Understand the anatomy of peripheral veins and arteries pertaining to line placement.
- Differentiate arterial venous based on compressibility and color Doppler.
- Familiarize with the line placement technique including maintaining proper sterility, needle entry angle with regard to the ultrasound probe, and threading and securing the catheter in difficult arterial and venous access.

Research agenda

- There is scarcity of studies in literature with regard to peripheral intravenous (IV) and arterial access.
- Studies need to be conducted to determine the learning curve of clinicians who are new to ultrasound-guided peripheral venous and arterial access.
- Comparison studies are needed to assess the success rate of ultrasound-guided IV and arterial access with newer techniques such as micropuncture kits.

References

[1] Garcia T, Hornof WJ, Insana MF. On the ultrasonic properties of tendon. Ultrasound Med Biol 2003 Dec;29(12):1787–97. PubMed PMID: 14698346. eng.
[2] Madsen EL, Dong F, Frank GR, et al. Interlaboratory comparison of ultrasonic backscatter, attenuation, and speed measurements. J Ultrasound Med 1999 Sep;18(9):615–31. PubMed PMID: 10478971. eng.
*[3] Ihnatsenka B, Boezaart AP. Ultrasound: basic understanding and learning the language. Int J Shoulder Surg 2010 Jul;4(3): 55–62. PubMed PMID: 21472065. PMCID: PMC3063344. eng.
*[4] Egan G, Healy D, O'Neill H, et al. Ultrasound guidance for difficult peripheral venous access: systematic review and meta-analysis. Emerg Med J 2013 Jul;30(7):521–6. PubMed PMID: 22886890. Epub 2012/08/11. eng.
[5] Presley B, Isenberg JD. Ultrasound guided intravenous access. StatPearls. Treasure Island; 2019.
[6] Lamperti M, Bodenham AR, Pittiruti M, et al. International evidence-based recommendations on ultrasound-guided vascular access. Intensive Care Med 2012 Jul;38(7):1105–17. PubMed PMID: 22614241. Epub 2012/05/22. eng.
[7] Stolz LA, Stolz U, Howe C, et al. Ultrasound-guided peripheral venous access: a meta-analysis and systematic review. J Vasc Access 2015 2015 Jul-Aug;16(4):321–6. PubMed PMID: 25656255. Epub 2015/02/04. eng.
*[8] Troianos CA, Hartman GS, Glas KE, et al. Guidelines for performing ultrasound guided vascular cannulation: recommendations of the American Society of Echocardiography and the Society of Cardiovascular Anesthesiologists. J Am Soc Echocardiogr 2011 Dec;24(12):1291–318. PubMed PMID: 22115322. eng.
[9] Tager IB, Ginsberg MB, Ellis SE, et al. An epidemiologic study of the risks associated with peripheral intravenous catheters. Am J Epidemiol 1983 Dec;118(6):839–51. PubMed PMID: 6650485. eng.
[10] Clutton-Brock TH. Vascular access. How to set up a drip and keep it going. Br J Hosp Med 1984 Oct;32(4):162. 164, 166–167. PubMed PMID: 6487875. eng.
[11] Brunner MAM, Suddarth. Textbook of medical surgical nursing. 13 ed. Philadelphia: Wolters Kluwer Health/Lippincott Williams & Wilkins; 2014.
*[12] Joing S, Strote S, Caroon L, et al. Videos in clinical medicine. Ultrasound-guided peripheral i.v. placement. N Engl J Med 2012 Jun;366(25):e38. PubMed PMID: 22716992. eng.
[13] Keyes LE, Frazee BW, Snoey ER, et al. Ultrasound-guided brachial and basilic vein cannulation in emergency department patients with difficult intravenous access. Ann Emerg Med 1999 Dec;34(6):711–4. PubMed PMID: 10577399. eng.
*[14] Scoppettuolo G, Biancone M, Pitoni S, et al. Technique of ultrasound-guided peripheral venous access in the emergency room. Crit Care 2013:262.
[15] Liu YT, Alsaawi A, Bjornsson HM. Ultrasound-guided peripheral venous access: a systematic review of randomized-controlled trials. Eur J Emerg Med 2014 Feb;21(1):18–23. PubMed PMID: 23880981. eng.
[16] Galen BT, Southern WN. Ultrasound-guided peripheral intravenous catheters to reduce central venous catheter use on the inpatient medical ward. Qual Manag Health Care 2018 2018 Jan/Mar;27(1):30–2. PubMed PMID: 29280905. eng.
[17] Roberge RJ. Venodilatation techniques to enhance venepuncture and intravenous cannulation. J Emerg Med 2004 Jul; 27(1):69–73. PubMed PMID: 15219306. eng.
*[18] Adhikari S, Blaivas M, Morrison D, et al. Comparison of infection rates among ultrasound-guided versus traditionally placed peripheral intravenous lines. J Ultrasound Med 2010 May;29(5):741–7. PubMed PMID: 20427786. eng.
[19] Frazee BW, Fahimi J, Lambert L, et al. Emergency department ultrasonographic probe contamination and experimental model of probe disinfection. Ann Emerg Med 2011 Jul;58(1):56–63. PubMed PMID: 21256624. Epub 2011/01/21. eng.

[20] Heinrichs J, Fritze Z, Vandermeer B, et al. Ultrasonographically guided peripheral intravenous cannulation of children and adults: a systematic review and meta-analysis. Ann Emerg Med 2013 Apr;61(4):444–54. e1. PubMed PMID: 23415740. Epub 2013/02/15. eng.

[21] Bair AE, Rose JS, Vance CW, et al. Ultrasound-assisted peripheral venous access in young children: a randomized controlled trial and pilot feasibility study. West J Emerg Med 2008 Nov;9(4):219–24. PubMed PMID: 19561750. PMCID: PMC2672282. eng.

[22] Moureau N, Lamperti M, Kelly LJ, et al. Evidence-based consensus on the insertion of central venous access devices: definition of minimal requirements for training. Br J Anaesth 2013 Mar;110(3):347–56. PubMed PMID: 23361124. Epub 2013/01/29. eng.

*[23] AIUM practice guideline for the use of ultrasound to guide vascular access procedures. J Ultrasound Med 2013 Jan;32(1): 191–215. PubMed PMID: 23269727. eng.

[24] Saugel B, Scheeren TWL, Teboul JL. Ultrasound-guided central venous catheter placement: a structured review and recommendations for clinical practice. Crit Care 2017 Aug;21(1):225. PubMed PMID: 28844205. PMCID: PMC5572160. Epub 2017/08/28. eng.

[25] Gottlieb M, Bailitz J. Is ultrasonographic guidance more successful than direct palpation for arterial line placement? Ann Emerg Med 2016 08;68(2):227–9. PubMed PMID: 27083859. Epub 2016/04/13. eng.

[26] Feldman DN, Swaminathan RV, Kaltenbach LA, et al. Adoption of radial access and comparison of outcomes to femoral access in percutaneous coronary intervention: an updated report from the national cardiovascular data registry (2007-2012). Circulation 2013 Jun;127(23):2295–306. PubMed PMID: 23753843. eng.

[27] Valgimigli M, Gagnor A, Calabró P, et al. Radial versus femoral access in patients with acute coronary syndromes undergoing invasive management: a randomised multicentre trial. Lancet 2015 Jun;385(9986):2465–76. PubMed PMID: 25791214. Epub 2015/03/16. eng.

[28] Santucci A, Valgimigli M. Digital gangrene following transradial coronary angiogram. JACC Cardiovasc Interv 2016 05; 9(9):980–1. PubMed PMID: 27151614. eng.

[29] Ronald A, Patel A, Dunning J. Is the Allen's test adequate to safely confirm that a radial artery may be harvested for coronary arterial bypass grafting? Interact Cardiovasc Thorac Surg 2005 Aug;4(4):332–40. PubMed PMID: 17670425. Epub 2005/04/28. eng.

[30] Sandoval Y, Burke MN, Lobo AS, et al. Contemporary arterial access in the cardiac catheterization laboratory. JACC Cardiovasc Interv 2017 11;10(22):2233–41. PubMed PMID: 29169493. eng.

*[31] Hofmann LJ, Reha JL, Hetz SP. Ultrasound-guided arterial line catheterization in the critically ill: technique and review. J Vasc Access 2010 2010 Apr-Jun;11(2):106–11. PubMed PMID: 20119907. eng.

*[32] Louisdon P, Keenaghan M. Arterial lines. StatPearls. Treasure Island (FL); 2019.

[33] Gutzeit A, Graf N, Schoch E, et al. Ultrasound-guided antegrade femoral access: comparison between the common femoral artery and the superficial femoral artery. Eur Radiol 2011 Jun;21(6):1323–8. PubMed PMID: 21188594. Epub 2010/12/28. eng.

*[34] Frezza EE, Mezghebe H. Indications and complications of arterial catheter use in surgical or medical intensive care units: analysis of 4932 patients. Am Surg 1998 Feb;64(2):127–31. PubMed PMID: 9486883. eng.

[35] Kaye W. Invasive monitoring techniques: arterial cannulation, bedside pulmonary artery catheterization, and arterial puncture. Heart Lung 1983 Jul;12(4):395–427. PubMed PMID: 6345469. eng.