Ultrasound-Guided Procedures in the Emergency Department—Needle Guidance and Localization

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KEYWORDS

- Ultrasound • Procedures • Central venous access • Nerve blocks
- Peripheral venous

KEY POINTS

- Probe selection is important, especially when considering the depth of the target structure. High-frequency linear probes should be used to visualize more superficial structures, whereas lower-frequency probes are useful when visualizing deeper tissues.
- Probe orientation is extremely important when performing ultrasound-guided procedures. Always keep the probe marker toward the left of the person performing the procedure, to line up the probe marker with the marker logo on the display screen to improve accuracy.
- Become familiarized with local anatomy and general layout of structures to be scanned, specifically when it comes to visualizing the target structures, whether vascular or nerve bundle.

INTRODUCTION TO PROCEDURAL ULTRASOUND

Background

Historically, medical ultrasound was born out of SONAR (Sound Navigation and Ranging) technology after World War II. As SONAR technology improved, it opened the door to diagnostic imaging, using high-frequency sound waves and the pulse-echo principle to display normal and abnormal anatomy. Its use in emergency medicine comes in response to an increasing need to rapidly diagnose life-threatening conditions at the bedside. As a result, ultrasound is being used in emergent procedures for difficult and challenging patients. Its use in this setting has improved efficiency and safety in patient care.

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To adequately perform these life-saving procedures using ultrasound guidance, knowledge of the machine functions is imperative. Familiarity of the instrumentation improves accuracy and efficiency. This article provides a brief introduction to the ultrasound physics and instrumentation necessary to perform procedural ultrasound, followed by a description of anatomic findings, techniques, and pitfalls that may be encountered.

Physics Principles and Instrumentation

The ultrasound image is generated as the transducer sends intermittent pulses into soft tissue. These pulses interact with the tissue through reflection and refraction at organ boundaries. Some of the echoes are reflected back to the transducer where they are processed by the ultrasound machine and presented on the display (**Fig. 1**).[1,2]

The ultrasound instrument processes each received echo and presents it as a visual dot corresponding to the anatomic location. The collection of these dots creates the gray-scale image, which is also known as brightness mode (or B-mode). The brightness of each dot corresponds to the strength of the reflection: the stronger the echogenicity, the brighter the dot; the weaker the echogenicity, the darker the dot (**Fig. 2**).

Probe Selection

Transducers operate under what is called the piezoelectric effect, which means pressure electricity. Certain materials (elements or crystals) have piezoelectric properties, which means that an applied voltage will deform the crystals, thus emitting a sound beam. The thickness of the transducer element determines the frequency of the transducer. High-frequency transducers range from 7 to 13 MHz, and low-frequency transducers range from 2 to 5 MHz.

Transducer frequency affects resolution and penetration. Higher frequencies yield better resolution or detail; however, they have poorer penetration. Lower-frequency transducers will yield poorer resolution, but will penetrate a greater distance. It is

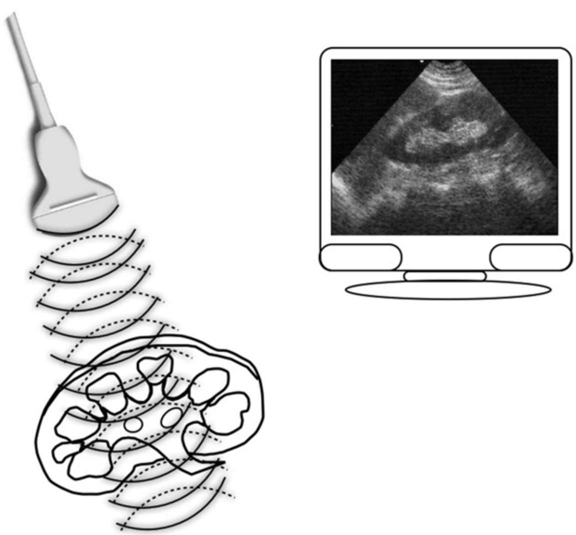

Fig. 1. Schematic representation of ultrasound waves traveling toward organ of interest being scanned.

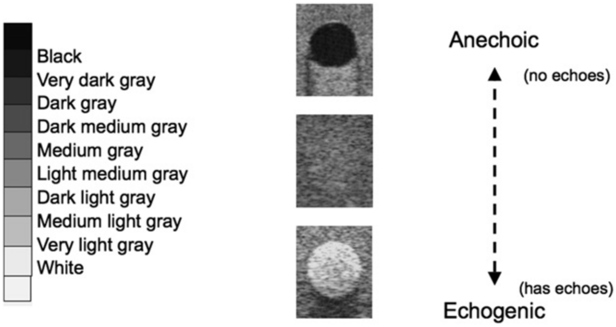

Fig. 2. Assignment of shades of gray related to the intensity of the received echo.

important to select the correct transducer frequency to obtain the penetration needed and still have the best resolution possible.

Transducer design also corresponds with anatomic structures to be imaged, and an appropriate match with frequency. A rectangular shape, known as a linear transducer, will have a high frequency and is excellent for imaging structures close to the skin's surface, such as vessels in the neck. Transducers that have a sector or convex shape are typically lower in frequency and are used to image deeper structures, such as the heart and gallbladder. **Fig. 3** shows different ultrasound transducers with their corresponding frequencies.

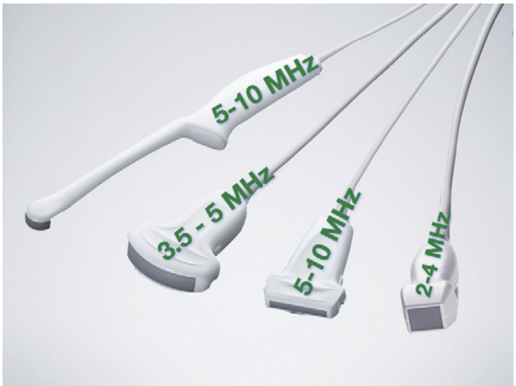

Fig. 3. Transducer selection with corresponding frequency.

Image Orientation

Orientation is imperative to understand, as are positioning and trajectory of the needle as it is being advanced. Each transducer has an orientation marker (**Fig. 4**) that correlates with a specific indicator on the display. For consistence, the orientation indicator on the display should be located toward the left of the person performing the procedure (**Fig. 5**).

The orientation of the transducer will depend on the object of interest being imaged. There are 2 basic axial planes that are primarily used in procedural guidance: longitudinal and transverse, noting that what may be transverse on a structure may not be exactly transverse to a body plane (**Fig. 6**).

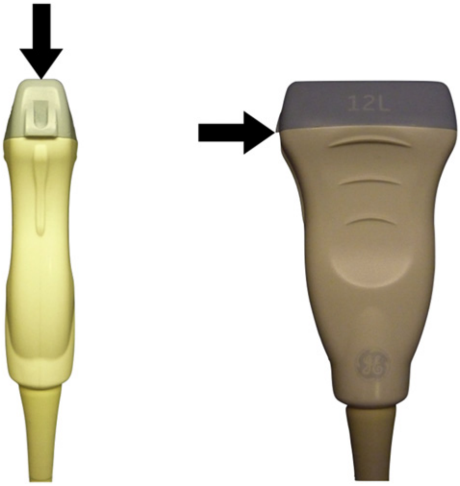

Fig. 4. Transducer orientation marker.

For consistency in procedural ultrasound, the indicator on the display should be aligned with the marker on the transducer. When imaging in the short axis or transverse plane, if the transducer marker is toward the left of the person performing procedure, then the transducer and display will be oriented correctly (**Fig. 7**).

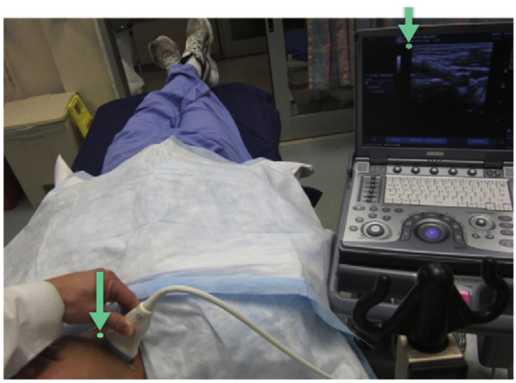

Fig. 5. Alignment of orientation marker with indicator on the display. (*Long arrow*) transducer marker, in reationship with (*short arrrow*) indicator in diplay.

Imaging Modalities

Most ultrasound imaging is performed using B-mode, which displays a 2-dimensional image. As previously mentioned, the reflected echoes appear as dots in which the brightness is proportional to the intensity of reflection.

Motion mode (also known as M-mode) is essentially B-mode stretched across a page. M-mode is primarily used in echocardiography of the adult and pediatric patient and for fetal heart imaging. It has also been used to evaluate for pneumothorax.

Doppler is another modality that is used to detect motion. The Doppler principle is based on a change in frequency attributable to motion, which is known as the Doppler

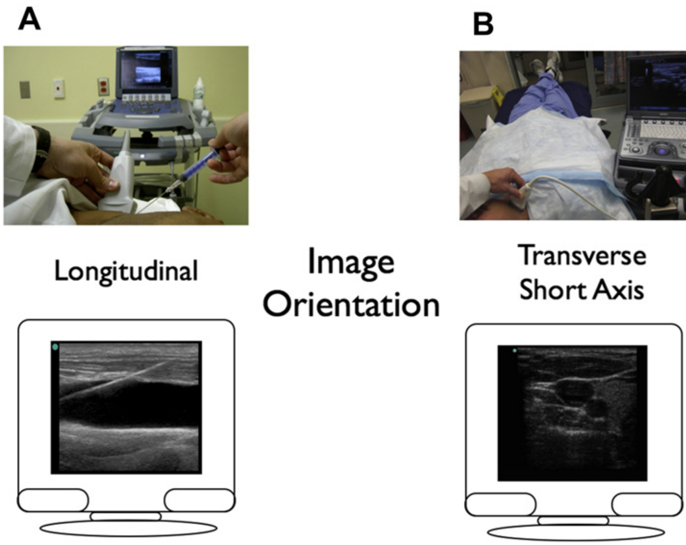

Fig. 6. Transducer orientation with basic axial views. (*A*) Demonstrates probe positioning to obtain a longitudinal or long-axis view of organ being scanned, in this case the IJ vein. (*B*) Demonstrates probe positioning to obtain a transverse or short-axis view.

effect. The Doppler shift is the difference in emitted frequency versus the received frequency. Doppler is primarily used to detect blood flow and can assess direction and velocity. Color Doppler also detects motion and is useful to identify the presence and direction of flow. In addition to identification of blood flow, Doppler has also been used in the detection of motion, such as urine jets in the bladder.

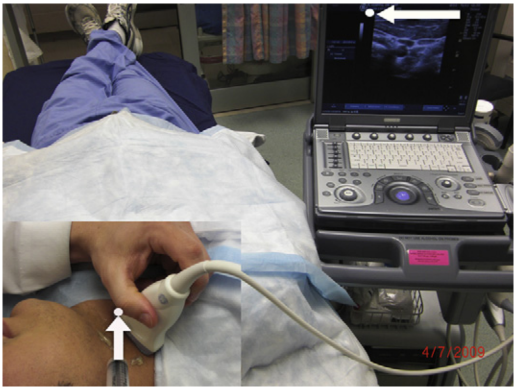

Fig. 7. Correct positioning of transducer with respect to marker in the display. If placed correctly, when moving the needle toward the transducer (*vertical arrow*), the marker will move the needle toward the display marker (*horizontal arrow*).

Artifacts

Artifacts represent deletions from or additions to an image that do not directly correlate with actual tissue. They are commonly seen and may be useful in diagnostic and

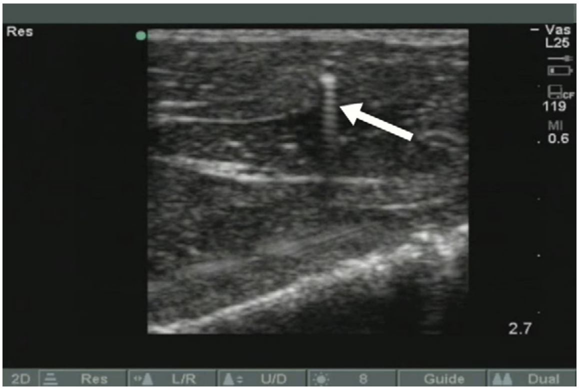

Fig. 8. Reverberation artifact (arrow points to the repeating reflections).

procedural ultrasound. Recognition of certain artifacts can help determine needle localization. The 3 major artifacts frequently identified in ultrasound-guided procedures are reverberation, refraction, and acoustic shadowing.

A reverberation artifact appears as multiple reflections that progressively weaken over time. It is caused by 2 strong reflectors. A needle is highly reflective and reverberation artifacts known as ring-down artifacts are frequently seen posterior to needles during procedural guidance (**Fig. 8**).

Refraction is a change in direction of the sound beam and is usually seen at the curve of a rounded object, such as the transverse axis of a vessel. It presents as a decrease or deletion of information known as an edge shadow (**Fig. 9**).

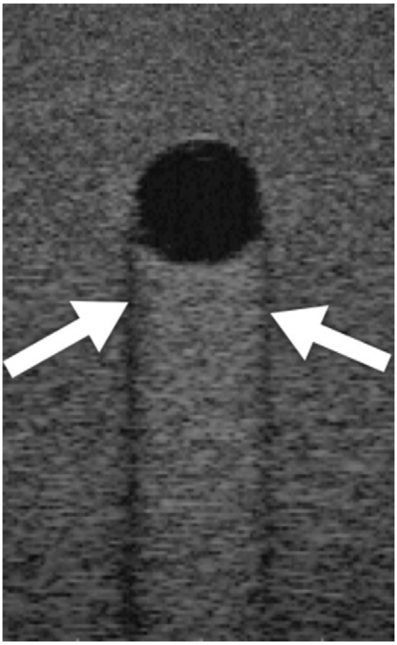

Fig. 9. Refraction artifacts at the edges of a cylindrical structure (*arrows* demonstrate edge artifact).

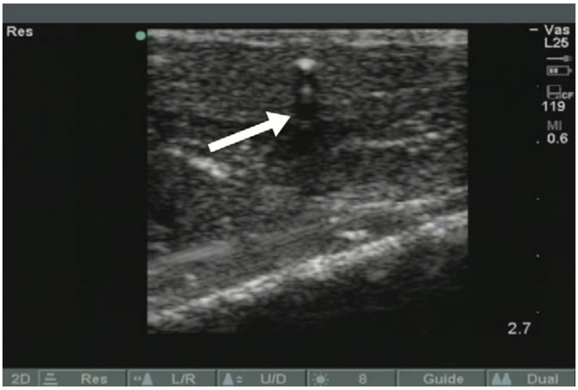

Fig. 10. Acoustic shadow (*arrow* points toward artifact).

An acoustic shadow occurs as the result of a highly attenuating structure, such as a calcification or metal. Posterior to a structure there will be a reduction in the amplitude of the sound beam. **Fig. 10** shows an example of this artifact.

Knobology

Ultrasound systems have similar functions, although the labeling may vary with different manufacturers. Knowledge of the locations and functions of basic controls ensures accuracy and efficiency when performing procedural guidance. Knobology is the study of the controls and their functions. The most important controls used for procedural guidance are image mode, transducer selection, gain, depth, calipers, and freeze.

ULTRASOUND-GUIDED CENTRAL VENOUS ACCESS

Background

Central venous access is an important procedure in the care of the critically ill patient in the emergency department (ED). Even with adequate training, the landmark technique approach carries complication rates that vary between 0.3% and 10.0%[3] and depend on multiple factors, including insertion site, host body habitus, and operator experience. Having adjuncts that can aid in these procedures is extremely valuable in our practice.

One such adjunct is ultrasound. Its use in central venous access has been described as early as 1978 for internal jugular vein localization,[4] with the first prospective randomized trial in 1990.[5] Since then, ultrasound has been used for central venous catheterization because of its ability to visualize target organs that otherwise would be impossible using landmark technique. Its use for central venous catheterization has demonstrated an increase in success rate, while reducing the number of attempts and complication rates for this procedure.[6–8]

In 2001, the Agency for Healthcare Research and Quality collected and reviewed data of common practices that could reduce the risk of adverse events related to exposure to medical care. They identified the 11 practices most highly rated in terms of strength of the evidence supporting more widespread implementation. Use of real-time ultrasound guidance during central line insertion to prevent complications was rated number 8 in this list, making it an essential component to our practice.[9]

Indications

Indications for ultrasound guidance are the essentially the same as for any central venous catheterization: intravascular depletion, hemodynamic monitoring, cardiopulmonary arrest, access for vasoactive medications, difficult peripheral intravenous (IV) access, total parenteral nutrition, and long-term IV access for medications, such as antibiotics.[3]

The added advantages obtained with ultrasound use are:

1. Localization of target vessels
2. Detection of anatomic variations
3. Real-time guidance
4. Detection of venous thrombosis

It can be extremely useful on high-risk patients, such as bariatric patients, end-stage renal disease, disorders of hemostasis, multiple prior catheter insertions, and intravenous drug users.[10–12]

Anatomy and Imaging

There are 3 major veins used for central venous access: the internal jugular (IJ), subclavian, and femoral veins. Although ultrasound guidance for the subclavian vein is possible, it can be challenging for novice users to perform, owing to anatomic barriers, such as the clavicle, that can make it a difficult procedure and a least-attractive site to perform. Femoral veins are also commonly used in the ED because of their low complication rate and ease of procedure; however, this location's inability to provide invasive hemodynamic monitoring information in a critically ill patient, the risks of thromboembolic events, and increased infection rate limits utility of the femoral veins. Therefore, in this article we focus on central venous access by the IJ vein.

The IJ vein originates from the jugular foramen at the skull base and courses inferiorly within the carotid sheath, accompanied by the internal carotid artery and vagus nerve. It descends posterior to the sternocleidomastoid muscle and lies laterally within the sheath. As it continues its trajectory, the inferior end of the vein passes deep between the sternal and clavicular heads of this muscle and then continues posterior to the sternal end of the clavicle, joining the subclavian vein to form the brachiocephalic vein (**Fig. 11**).[13,14]

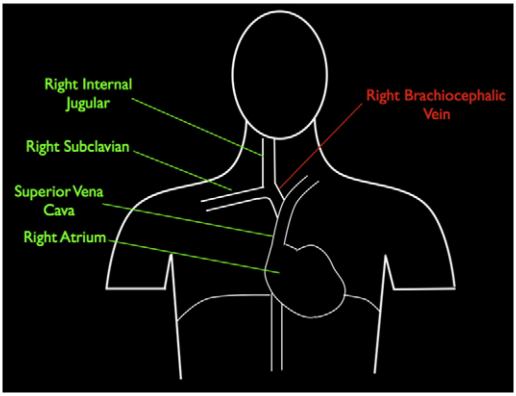

Fig. 11. Trajectory of the IJ vein.

There are 2 basic sonographic views used to obtain image of vessels: short axis or long axis. The short-axis view is a perpendicular view of the desired vessel. It is useful to evaluate structures surrounding the vein of interest. To obtain this image, simply follow the orientation rule discussed in earlier: probe marker toward the left of the person performing procedure, and align the marker from the probe with the indicator in the display (**Fig. 12**). **Fig. 13** shows an ultrasound image of the left IJ vein with all anatomic landmarks in view.

In contrast, the long-axis view is a parallel view of the vessel. This view has the advantage of allowing the user to assess the anterior and posterior walls of the vein being cannulated, helping to avoid double puncturing the vessel. To obtain this view, place the transducer in the long axis of the vessel with the probe marker away from the person performing the procedure (**Fig. 14**). **Fig. 15** demonstrates an ultrasound image of the long-axis view of the left IJ.

Once an image has been obtained, is important to differentiate between the vessels. Veins and arteries differ in 3 sonographic characteristics: compressibility, pulsatility, and respiratory variation. Veins are compressible, lack pulsatility, and have respiratory variation. Further confirmation could be accomplished by asking the patient to perform a Valsalva maneuver or placing the bed into a Trendelenburg position, in which case veins will increase diameter. Conversely, arteries are pulsatile, lacking both compressibility and respiratory variation.

As a note: The principles described for this procedure can be used in any of the different anatomic approaches for central venous access, but review of the anatomy is recommended to familiarize the user with sonographic findings.

Technique

This procedure requires a high-frequency transducer, sterile plastic cover kit (gel, probe cover, and securing elastic bands), a central venous catheter kit, and universal sterile precautions. The patient should be placed in a supine position, sterilized ,and draped in the usual fashion, including the sterile ultrasound probe with sterile gel in the sterile field. The ultrasound system should be placed parallel to the patient on the same side as the procedure to align anatomic landmarks with the image display.

Needle placement can be performed in either of the 2 views discussed earlier: short-axis or long-axis view. The short axis is also called the out-of-plane view, because the

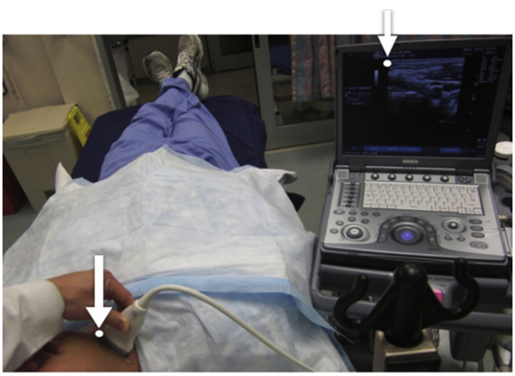

Fig. 12. Sonographic image of a short-axis view of the IJ vein with landmarks (*Long arrow* points toward transducer marker, *short arrow* marker in display).

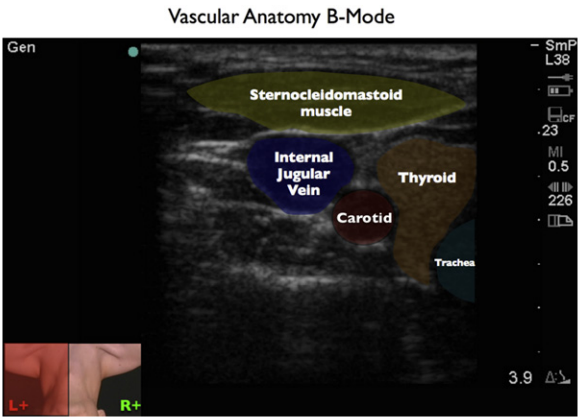

Fig. 13. Positioning of transducer to obtain a short-axis view and align probe marker with indicator display.

transducer is placed perpendicular to the vessel and you see only a cross-sectional view of the needle. Care must be taken to avoid losing the tip of the needle. The long axis is called an in-plane view because the transducer is parallel to the vessel and the needle is kept entirely in the field of view. Studies have shown similar success rates for both approaches, slightly favoring the long-axis view; however, novice users seem to favor the short-axis view because it is the most common approach.[2,15] Selecting the correct approach will depend on level of comfort of the user and experience with the procedure.

Regardless of the approach, the next series of steps will be used for both techniques; to remember the technique we use the mnemonic: *EASE* (mnemonic created by Nagdev and Tirado). *EASE* stands for the following: *E*xamine for best location, *A*nesthetize early to reduce error, *S*tick with a 45° to 60° angle, and *E*valuate for placement.

*E*xamine. Place the patient in a supine position, with the ultrasound system at the patient's side. Place the transducer and assess for best location by comparing both anatomic sites (eg, right and left IJs). Care must be taken to examine for anatomic variations, width and depth of vessel, and sign of venous thrombosis (**Fig. 16**).

Fig. 14. Positioning of transducer to obtain a long-axis view of the IJ vein.

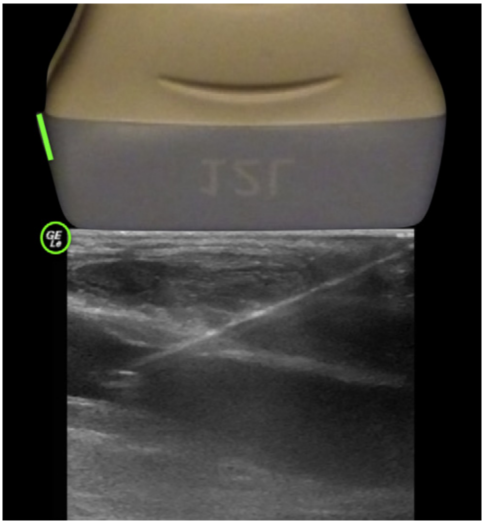

Fig. 15. Positioning of transducer to obtain a long-axis view of the IJ vein.

*A*nesthetize. Early anesthesia can reduce failure rate by controlling pain and movement of the patient while performing the procedure. Use lidocaine and inject around the trajectory of the needle, including muscles and subcutaneous tissue (**Fig. 17**).

*S*tick. The transducer with the probe cover is held in the nondominant hand resting on the patient's skin, and the 18-gauge needle is introduced with the dominant hand under real guidance, through the anterior wall of the vein and into the lumen.

In the short-axis approach, place the probe on top of the skin and center the vessel in the middle of the display (**Fig. 18**). To assess trajectory and distance of the needle to puncture the vessel, we use the principles of the Pythagorean Theorem for right-angled triangles (**Fig. 19**). If the vessel to cannulate is 1 cm deep, we need to

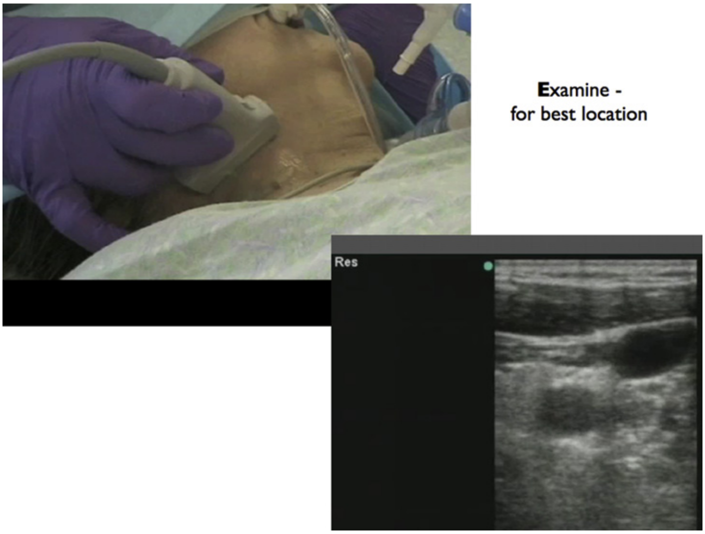

Fig. 16. Examine. Correct placement of probe to examine for best location.

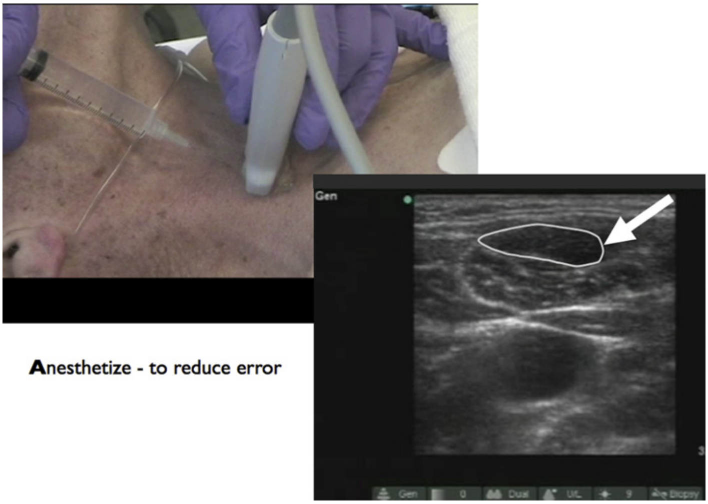

Fig. 17. Anesthetize. Inject lidocaine to area to be canalized.

puncture the skin 1 cm away from the transducer at a 45° angle to create an isosceles triangle. In this case, the vessel should be punctured at 1.4 cm. The needle will tent on top of the vessel and as it goes through, a dot will appear in the field of view. Other artifacts might appear that can help to determine the needle tip, such as reverberation artifact and acoustic shadow.[2,15,16]

For the long-axis approach, is important to keep the hand stable to place the transducer parallel to the vessel. Note: If sliding of the transducer occurs, the incorrect vessel might be canalized. Thus, it is recommended to become familiar with the short-axis approach before the long axis. Once both the transducer and the vessel

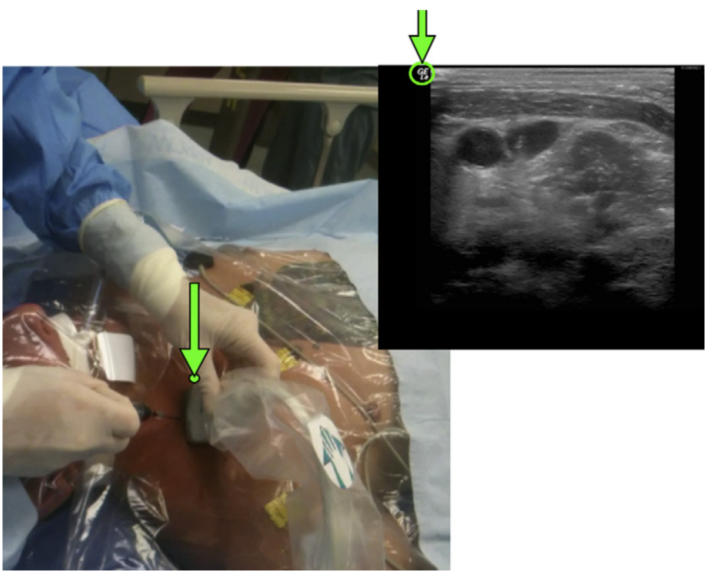

Fig. 18. Stick. Probe positioning with respect to the skin (*long arrow* transducer marker, *short arrow* display market).

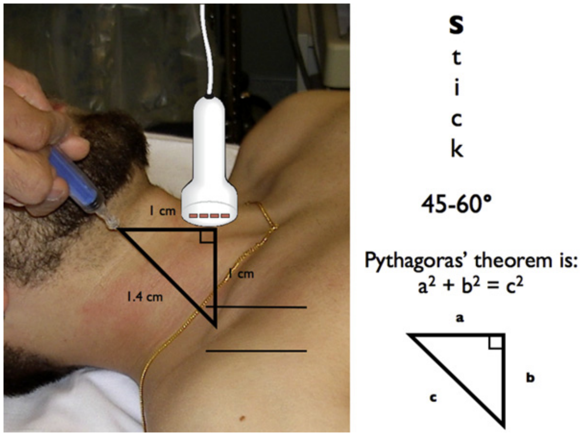

Fig. 19. Assessing trajectory of needle using Pythagorean Theorem.

are parallel, introduce the needle at a 45° to 60° angle aiming toward the probe marker, and follow the trajectory of the needle as it goes into the anterior wall of the vessel. If loss of trajectory occurs, gently withdraw the needle to the skin and reorient the needle toward the probe marker.

After the vein is punctured successfully, the ultrasound probe is removed and the procedure proceeds with the standard Seldinger technique.[2,15,16]

*E*valuate. Ultrasound can be used to confirm the guide wire within the lumen before dilating the vessel.[17] The catheter appears as a linear "white" shadow that is best appreciated in the longitudinal ultrasound view (**Fig. 20**).

Pitfalls

- Probe orientation still is one of the most common pitfalls for the procedure. If performing a short-axis view, always keep the transducer probe marker toward the left of the person performing the procedure, and if in doubt on which side the marker is, place a fingertip on the skin until you can orient yourself to the display.

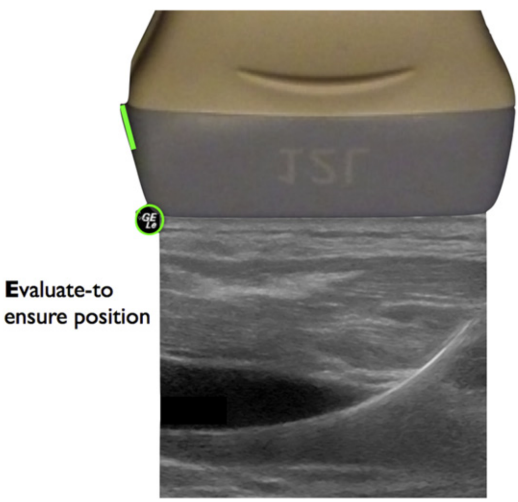

Fig. 20. Evaluate. Confirmation of intraluminal guidewire before dilating the vessel.

- Estimate the distance to the target vessel to avoid advancing the needle too deep and creating complications, such as carotid punctures or pneumothorax.
- Start at a 45° angle to keep the needle in the field of view.
- Always keep your eye on the needle and never advance the needle while looking at the screen because you might miss flashback.
- Last, always confirm wire placement before dilating the vessels, to avoid mechanical complications of the procedure.

ULTRASOUND-GUIDED PERIPHERAL VENOUS ACCESS

Background

Establishment of peripheral intravenous (PIV) access in the ED is a vital part of patient care both for analysis of blood samples and administration of fluids and medications. Traditional PIV access is attained by palpation and direct visualization using various combinations of needles and catheters (ie, angiocatheters). Although this method is successful during most attempts, it can be difficult in certain populations (eg, IV drug users, dialysis patients). Other options available to fulfill the urgent need for blood samples and fluid/medication administration include external jugular IVs, intraosseous lines, peripherally inserted central catheter (PICC) lines, and if necessary, central venous catheters. Although many of these options are available, they can be time-consuming and carry the risk of significant complications.

Ultrasound can aid in this process. As with central venous catheterization, it can detect deeper veins that are not apparent by palpation or direct visualization. By using the same technique as in ultrasound-guided central line placement, a care provider can access peripheral veins with excellent reliability and line stability.[18–21]

Indications

Indications are the same as for traditional PIV cannulation as a means to provide access to the patient's circulatory system. This access can be used for phlebotomy, delivery of medications and fluids in life-threatening conditions, and short-term nutrition administration. Ultrasound has been demonstrated to improve success rate in certain populations, such as bariatric patients, IV drug users, chemotherapy patients, patients with end-stage renal disease, nursing home patients with multiple IV scars, and recently hospitalized patients.[22,23]

Anatomy and Imaging

Although ultrasound can be used for any peripheral access approach, this section focuses on the 3 major vessels of the antecubital region: the basilic, cephalic, and brachial veins (**Fig. 21**). These veins are variable in location and are surrounded by nerves. Hence, ultrasound guidance is helpful when cannulating these veins.[14]

The basilic vein passes upward and anteromedially to the elbow, where it receives the medial cubital vein. Then it continues on the medial to the biceps brachii, deep to the fascia, until it joins the brachial vein and becomes the axillary vein at the border of the teres major. **Fig. 22**A demonstrates correct positioning of the transducer and **Fig. 22**B short-axis ultrasound view of the basilic vein.

The brachial vein forms the deep venous system, which can be isolated or paired to continue to the axillary vein. It is accompanied by the brachial artery and the nerves of the upper limb. **Fig. 23**A demonstrates correct positioning of the transducer and **Fig. 23**B short-axis ultrasound view of the brachial vein.

The cephalic vein lies laterally in the superficial fascia of the antecubital fossa and it ascends along the lateral side of the forearm and upper arm. **Fig. 24** demonstrates

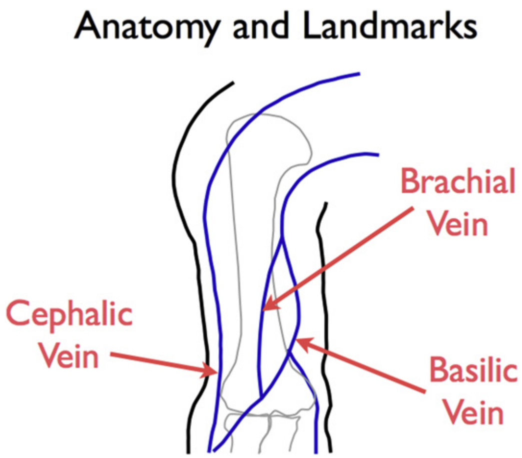

Fig. 21. Anatomic positioning of the major vessels of the antecubital region. the basilic, cephalic, and brachial veins.

correct positioning of the transducer and a short-axis ultrasound view of the cephalic vein.

As with central venous access, place the transducer in the short-axis view and scan the vessels in the antecubital fossa. Move the probe from lateral to medial to assess vessel location.

Technique

To perform this procedure requires all the equipment necessary for a traditional PIV approach: a high-frequency linear transducer, gel, and a long angiocatheter (at least 1.88 inch). Because this is a peripheral line, sterile sleeves or gel are not required, but if avoiding contact of blood products is a priority, the probe can be protected with Tegaderm after adding gel onto the surface of the transducer (**Fig. 25**).

Prepare the patient as shown in **Fig. 26**, with the patient in an upright and comfortable position, with tourniquet in place and the arm fully extended. Lay all materials on a flat surface within close reach of the anticipated IV site.

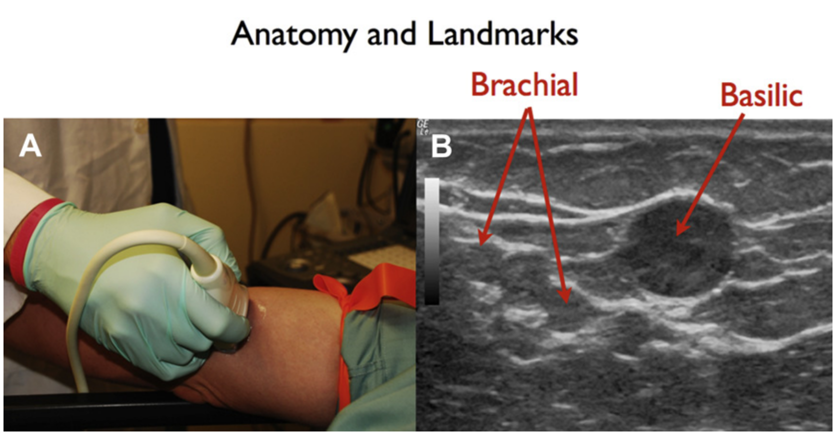

Fig. 22. (*A*) Transducer positioning to obtain basilic and brachial vein view. (*B*) Short-axis view of the basilic and brachial vein.

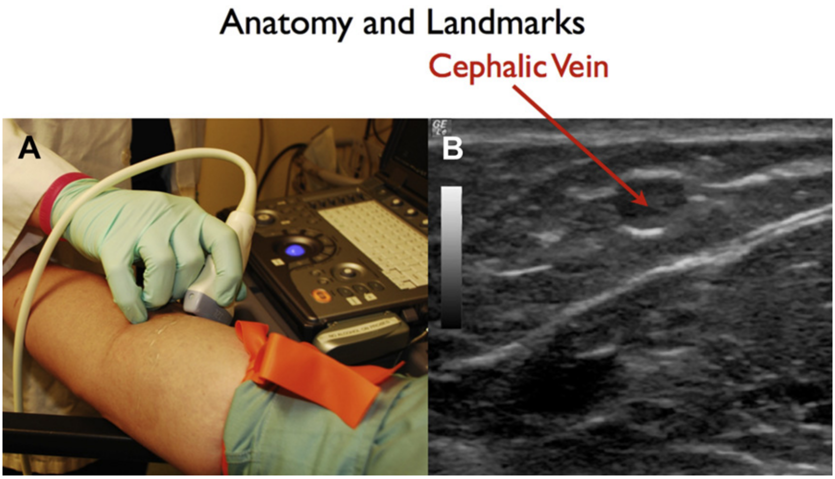

Fig. 23. (*A*) Transducer positioning to obtain cephalic vein view. (*B*) Short-axis view of the cephalic vein.

Examine the area for best location and evaluate the different veins of the antecubital fossa. Move the probe from lateral to medial and avoid applying excessive pressure to the surface of the skin, because this may cause veins to collapse. Hold the probe with the marker toward the left of the person performing the procedure to align the probe marker with the indicator in the screen display.

Using the short-axis approach, hold the angiocatheter, as shown in **Figs. 3–5**, and insert it at a 45-degree angle to the skin, centered in the middle of the probe. Remember to keep the probe perpendicular to the skin surface at all times. As soon as the needle is inserted in the skin, attempt to find the tip by sweeping distally with the probe. When the needle is located, determine if the trajectory needs to be adjusted by comparing its location with that of the target vein. Return the probe to its normal position (perpendicular to the skin), and advance the needle. Advance slowly and orient yourself with the screen to keep track of the needle tip. If the trajectory and alignment of the needle are appropriate, eventually the tip will begin to compress the wall of the target vein. When you observe this on the screen, very slowly advance the needle, while constantly

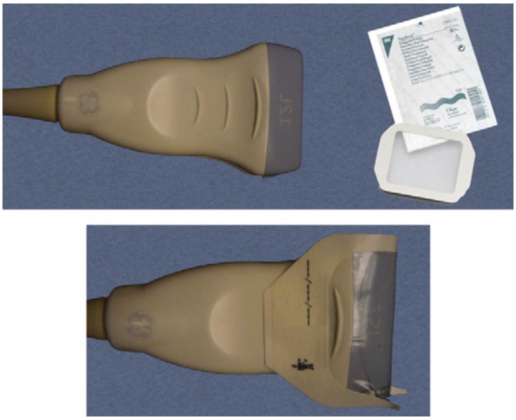

Fig. 24. Tegaderm to protect transducer from body fluids.

Fig. 25. Patient positioning for ultrasound-guided peripheral IV insertion.

watching for flash in the angiocatheter chamber. When flash is obtained, attempt to thread the catheter over the needle tip to cannulate the vein and secure the catheter.

When the catheter has been successfully inserted into the vein, you can evaluate for position by changing your plane of view to longitudinal. Determine if the tip of the catheter is inside the vascular space. Set the probe down and complete the IV process as usual.

Pitfalls

- One commonly encountered difficulty unique to ultrasound-guided peripheral access is the inability to determine if the catheter is in the vessel. The angiocatheter's flash chamber may fill up with blood, but between that instant and the attempt to pass the catheter over the needle, it may dislodge or puncture through

Fig. 26. Positioning ultrasound system in respect to patient position, placing ultrasound toward the head of the patient.

the vein. In addition, the catheter itself may accidentally dislodge the needle from the vessel lumen with the first attempted pass. If this is the case, you may meet resistance when trying to thread the catheter.

- Other complications of ultrasound-guided peripheral IV access are similar to any peripheral access procedures: venous infiltration, arterial puncture, nerve damage, pain, bleeding, and infection. Many of these adverse outcomes can be avoided with sterile technique, but most can be minimized by the use of ultrasound for real-time visualization.
- For a more reliable venous cannulation, a radial artery catheterization set may be used in place of the traditional angiocatheter. As soon as flash is seen in the plastic tubing, thread the guidewire past the tip of the needle, similar to the Seldinger technique.

ULTRASOUND-GUIDED NERVE BLOCKS

Background

EDs are the front line for painful injuries and conditions, with emergency physicians becoming the "de facto proprietor" of acute pain. Unfortunately, management of pain in the acutely injured patient is fraught with difficulty. The classically taught technique of IV opiate medication can lead to serious systemic side effects, including apnea, hypotension, and altered level of consciousness, leading clinicians to commonly underdose pain medications. Even at centers that specialize in treating acute pain, inadequate treatment of pain, oligoanalgesia, is a common phenomenon.[24,25]

Ultrasound-guided nerve blocks (UGNB) have recently become a mainstay in anesthesiology practice, demonstrating a high level of efficacy and safety. Ultrasound permits direct visualization of the needle, nerve, blood vessels, and associated structures and allows real-time imaging of anesthetic injection. Direct visualization has revolutionized regional anesthesia by making it safer for the more inexperienced practitioners. A Cochrane Review in 2009 demonstrated ultrasound-guided regional anesthesia to be quicker, have a faster time of onset, and be as efficacious as nerve stimulation.[26] Also, outside of the operating room, data from the US Army has shown early aggressive pain management, including ultrasound-guided regional anesthesia, not only reduces pain, but blocks the afferent neural pathways, a route thought to lead to chronic pain syndromes.[27]

Recently, emergency medicine providers have integrated UGNB into the clinical practice of the acutely injured patient as a part of the multimodal approach to pain management.[28–32] Along with pain reduction, UGNBs have been shown to be a useful adjunct in procedural sedations, specifically in patients who may be poor candidates for ED sedation. The goal of ED UGNB is different from that of our anesthesia colleagues. Whereas anesthesiologists measure success in terms of complete sensory and motor blockade, avoiding the need for general anesthesia, in the ED the goal is to effectively reduce pain in the acutely injured patient. We discuss 3 commonly performed ED nerve blocks that can be incorporated into clinical practice and aid in the pain reduction and clinical management of the acutely injured patient.

Patient Selection

Caution should be taken in patients judged to be at a high risk for compartment syndrome, and a discussion with consulting orthopedic surgical and/or pain services should occur before performing the procedure. Also, patients who are unable to cooperate with a neurologic examination because of intoxication, confusion, or dementia, or have an acute neurologic deficit, should not be blocked, because the operator will not be able to evaluate for neurologic complications following the procedure.

Positioning

Every patient, regardless of the block being performed, should have the same stepwise process undertaken to ensure safety and success. First, place the patient on a cardiac monitor, including pulse oximeter, and place the ultrasound system contralateral to the nerve being blocked (**Fig. 27**). The operator should be able to visualize both the ultrasound screen and the cardiac monitor in the same visual axis. The high-frequency linear probe is used for the blocks in this discussion, and should be cleaned in a standard manner (commonly a quaternary ammonia compound) between every use.

Supplies

Having a central location for all UGNB supplies, like a central line cart, allows the physician to efficiently gather the materials needed for a block. We recommend collecting a clear adhesive dressing that is large enough to cover the footprint of the transducer, a small-gauge syringe for the skin wheal, and a chlorhexidine skin prep. To perform the block, we recommend using a 3.5-inch 20-gauge to 22-gauge spinal needle attached to a 20-mL syringe (**Fig. 28**). Control syringes are ideal, but not required. For the novice provider, lidocaine with epinephrine is safer than bupivacaine because of the lower risk of LAST (local anesthetic associated systemic toxicity). We recommend always aspirating before injection to confirm lack of vasculature puncture, and halting the block if anechoic fluid is not seen on the ultrasound screen when anesthetic is deposited.

Individual Nerve Block Technique

Femoral nerve block

Indications The ultrasound-guided femoral nerve block is a basic and useful block for the emergency medicine provider. Classic indications include hip fractures (intertrochanteric and subtrochanteric), proximal and midshaft femur fractures, and patella injuries. The obturator and lateral femoral cutaneous nerves also innervate the proximal hip, but a well-performed femoral nerve block can still provide adequate analgesia to the area.

Anatomy The femoral nerve is one of the major branches of the lumbar plexus. It typically traverses inferior to the inguinal ligament lateral to the femoral vessels adjacent to the femoral artery. It lies beneath the fascia iliaca and superficial to the psoas muscle. A femoral block results in anesthesia to the entire anterior thigh and most of the femur and knee joint.

Survey scan Place the patient in a supine position. Attempt to externally rotate and abduct the hip, realizing that it is often not possible in the acutely injured patient and may not be needed. Place the linear probe with the probe marker facing the patient's right side just below and parallel to the inguinal crease. Locate the femoral artery and

Fig. 27. Adequate needle. 3.5-inch 20-gauge to 22-gauge spinal needle attached to a 20-mL syringe.

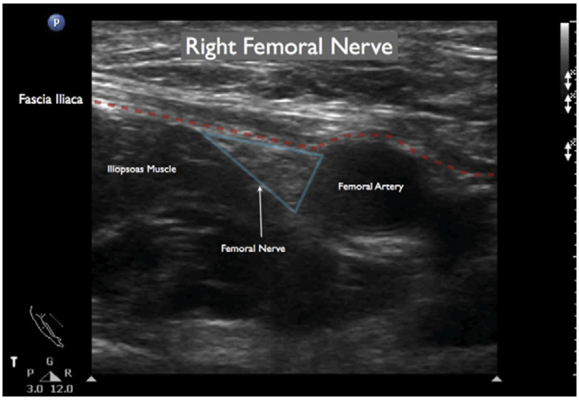

Fig. 28. Ultrasound of right femoral nerve with corresponding structures: fascia iliaca, iliopsoas muscle, femoral nerve, and femoral artery.

vein (similar to central venous cannulation). The operator should ensure that this is proximal to the take-off of the profunda femoris artery. Slowly move the probe lateral to identify the hyperechoic femoral nerve. The femoral nerve will have a triangle shape and a "honeycomb" appearance. Slightly fanning the probe in a caudal direction (from a perpendicular orientation) will often allow for better visualization of the nerve. The operator should also locate the fascia iliaca, which is the fascial covering that runs over the femoral artery and covers the femoral nerve (**Fig. 29**).

After cleaning the skin with an alcohol pad, place 2 to 3 mL of lidocaine with or without epinephrine about 0.5 to 1.0 cm lateral to the ultrasound probe. This will be the location of entry for the block needle, and adequate local anesthesia will allow for patient comfort during the block. Prep widely with a sterilizing solution, such as chlorhexidine. The ultrasound probe should be cleaned and covered with a sterile adhesive dressing across the contact surface (**Fig. 30**).

Technique We suggest a lateral to medial in-plane approach, aiming toward the corner of the femoral nerve (**Fig. 31**). After the femoral nerve and overlying fascia iliaca are identified, enter the skin with the needle bevel up about 0.5 to 1.0 cm lateral to the

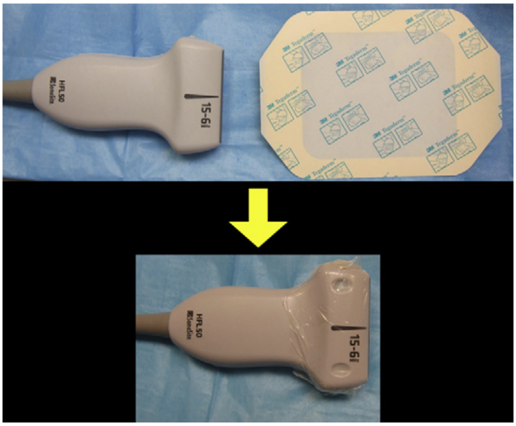

Fig. 29. Tegaderm technique as sterile adhesive dressing.

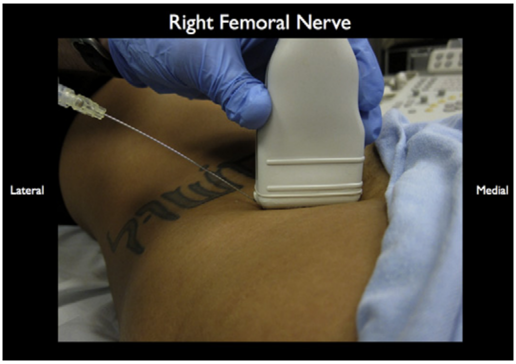

Fig. 30. In-plane approach, aiming toward the corner of the femoral nerve.

probe. The angle of entry will depend on the depth of the target depth of the fascia iliaca. More shallow angles of entry will improve needle visibility.

Advance the needle slowly, maintaining the shaft and tip in view at all times. Target the hyperechoic fascia iliaca overlying the iliopsoas muscle 1 to 3 cm lateral to the femoral nerve. Once beneath the fascia iliaca, aspirate to confirm the needle tip has not entered a vessel, and then slowly inject 3 to 5 mL of local anesthetic. With the needle tip in view, the spread of hypoechoic injectate should be visualized in real time with superficial movement of the fascia iliaca (**Fig. 32**). After confirming optimal needle tip location, proceed to inject a total of 10 to 20 mL of local anesthetic in 3-mL to 5-mL aliquots. If at any point the spread of local anesthetic is not visualized, intravascular injection should be suspected and the procedure halted. After injection, examine the patient for any signs of local anesthetic toxicity, such as perioral numbness, dizziness, or convulsions. Having your needle 1 cm lateral to the femoral nerve and vessels, yet under the fascia iliaca, reduces the risk of vascular puncture and intraneural injection.

Pitfall

- The most common pitfall of the UGNB of the femoral nerve is the failure to get under the fascia iliaca. Test doses of anesthetic should be visualized under the fascial plane with spread of anechoic fluid. Injecting anesthetic under the fascial plane and watching fluid track around the femoral nerve decreases the concern of intraneural and intravascular injection, while reducing patient discomfort.

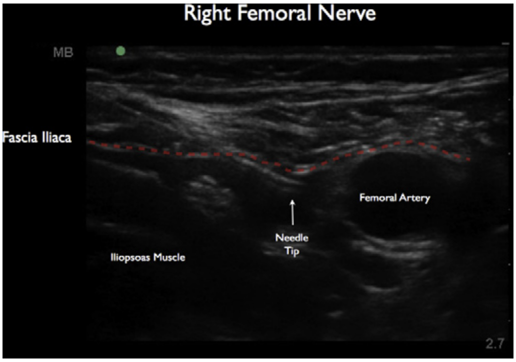

Fig. 31. Needle tip in view, with spread of injectate hypoechoic anesthesia with superficial movement of the fascia iliaca in femoral nerve block.

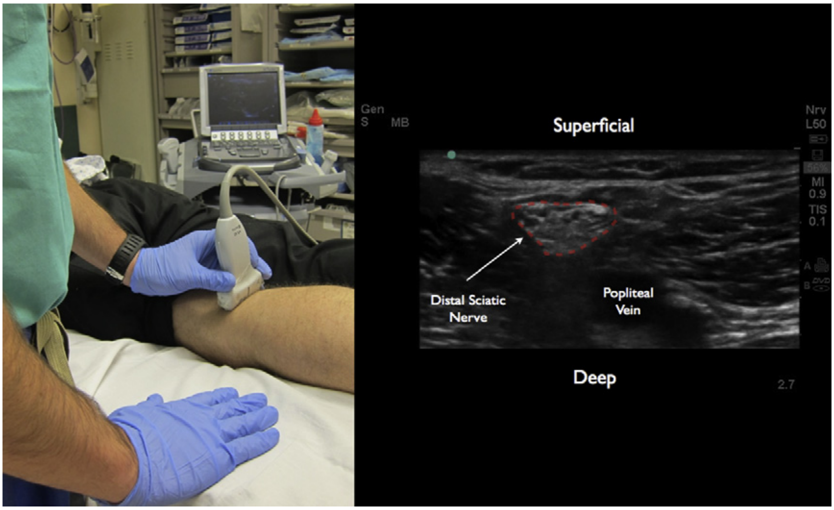

Fig. 32. Prone position for distal sciatic nerve block with sonographic images in screen display demonstrating distal sciatic nerve and popliteal vein.

Distal Sciatic Nerve Block at the Popliteal Fossa

Indications

The ultrasound-guided distal sciatic nerve block is an excellent block for distal tibia and/or fibula fractures, Achilles tendon rupture, pain control following ankle reduction, or other injuries to the lower extremity distal to the knee. Again, high-energy injuries to the distal tibia/fibula that are a concern for compartment syndrome should be blocked only in conjunction with the consulting service that will be managing the patient's inpatient course.

Anatomy

The lumbosacral plexus forms the sciatic nerve in the posterior aspect of the pelvis. As the nerve tracks down the posterior thigh, the nerve enters the popliteal fossa, bordered by the long head of biceps femoris superolaterally and by semimembranosus and semitendinosus superomedially. Just before entering the popliteal fossa, the distal sciatic nerve bifurcates into the common peroneal (medial) and tibial (lateral) nerves. A sciatic block at the popliteal fossa provides anesthesia to the distal leg, ankle, and foot.

Survey scan

We recommend prone positioning for the sciatic nerve bock. This enables the provider to place the probe on the patient without coming under the leg. Also, when performing the block in the prone position, needle movements will correlate with images on the screen (**Fig. 33**). If the patient's injuries do not allow for prone positioning (such as patients in cervical spine immobilization), the patient may be positioned supine with the lower leg supported in mild flexion at the knee, and the foot propped on enough pillows or blankets to allow for the probe to fit comfortably between the bed and the popliteal fossa (**Fig. 34**).

Place the linear probe with the probe marker facing the patient's right side at the popliteal crease. Locate the popliteal artery and vein (similar to a deep venous thrombosis scan). If performing the scan in the prone position, we recommend mild flexion at

Fig. 33. Alternate supine position technique for distal sciatic nerve block.

the knee to prevent collapse of the popliteal vein. Once both the popliteal vein and artery are noted, locate the tibial nerve (superficial to the popliteal vein) and scan cephalad slowly. If you are unable to locate the neural bundle, fan the probe caudal (Fig. 35) to obtain the most perpendicular axis to the nerve, which allows for better visualization (an ultrasound phenomenon termed anisotropy). Slowly move the probe in a cephalad manner, following the tibial nerve until the common peroneal nerve is identified on the lateral aspect of the screen. As the probe is moved more cephalad, the 2 nerves will join together to form the distal sciatic nerve in the popliteal fossa (approximately 7–10 cm proximal to the popliteal crease).

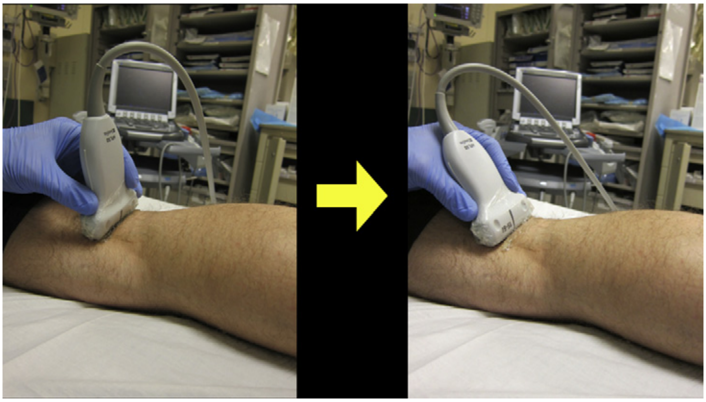

Fig. 34. Anisotropy phenomenon to obtain most perpendicular axis to the nerve, for better visualization.

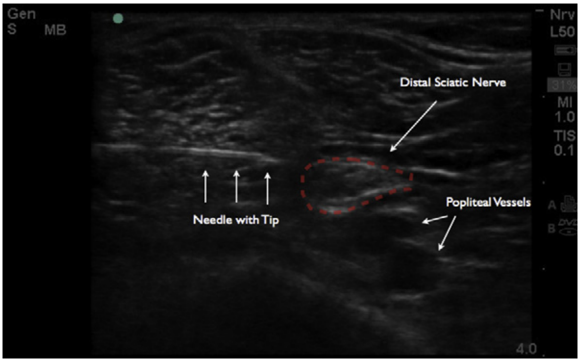

Fig. 35. Correct needle-tip positioning just above the sciatic nerve.

Unlike the femoral nerve block, in which the needle is placed just adjacent to the probe, for the distal sciatic nerve block, we recommend entering the skin much farther away from the probe. The distal sciatic nerve is often 2 to 4 cm deep to the skin surface, and a steep needle angle would prevent visualization of the needle tip on the ultrasound screen. We recommend measuring the depth of the nerve and entering the lateral knee/leg at a similar depth with a fairly flat angle. After cleaning the skin with an alcohol pad, place 1 to 2 mL of lidocaine with or without epinephrine in the specified location in the lateral knee/leg. This will be the location of entry for the block needle, and adequate local anesthesia will allow for patient comfort during the block. Prep widely with a sterilizing solution such as chlorhexidine. The ultrasound probe should be cleaned and covered with a sterile adhesive dressing across the contact surface.

Technique

Advance the needle slowly at a parallel angle to the probe with an in-plane technique, maintaining the shaft and tip in view at all times. Target the honeycomb appearance of the sciatic nerve without placing the needle directly into the nerve. We recommend placing the needle tip just above the nerve to reduce intraneural injection, while being close enough to get anesthetic deposited in an ideal location (**Fig. 36**). Aspirate to confirm there has been no vascular puncture, then slowly inject 3 to 5 mL of local anesthetic. With the needle tip in view, the spread of hypoechoic injectate should be visualized in real time (**Fig. 37**). Once a small bit of anechoic fluid has begun to encircle the nerve, the provider can reposition the needle tip and continue injecting in 3-mL to

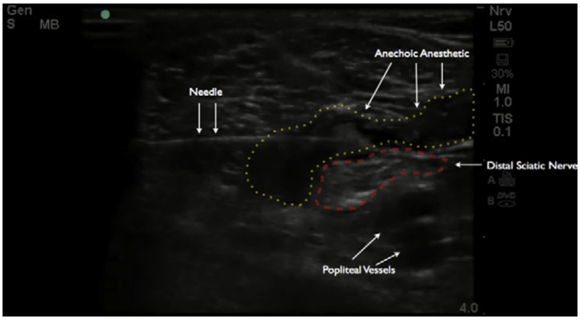

Fig. 36. Real-time visualized of hypoechoic injectate anesthetic in distal sciatic nerve block.

Fig. 37. Shoulder support with pillow or roll of sheets under the ipsilateral scapula to allow for more room for needle entry.

5-mL aliquots up to 20 mL of total anesthetic with a goal of forming a doughnut of hypoechoic fluid around the nerve. If at any point the spread of local anesthetic is not visualized, intravascular injection should be suspected and the procedure halted.

Pitfall

- The most common pitfall of the UGNB of the sciatic nerve at the popliteal fossa is not getting the anesthetic completely around the nerve. The popliteal fossa is filled with fat and local anesthetic is lipophilic. If the anesthetic is not placed in close proximity to the nerve, it will be easily absorbed by the adipose tissue and the block will not be effective. To obviate this pitfall, be sure to inject 3-mL to 5-mL aliquots with the needle positioned circumferentially around the nerve.

Interscalene Approach to the Brachial Plexus Block

Indications

The ultrasound-guided interscalene brachial plexus block is ideal for pain relief from arm abscesses, humeral fractures, elbow dislocations, and forearm injuries.

Anatomy

The brachial plexus originates from the C5-T1 ventral rami. The cords track between the anterior and middle scalene muscles (interscalene groove in the neck) and join the subclavian artery anterior to the first rib and posterior to the clavicle. This neurovascular bundle travels to the axilla and supplies both motor and sensory innervation to the entire upper extremity. A brachial plexus block provides anesthesia to the shoulder, arm, and elbow.

Survey scan

The patient should be positioned supine with the head of bed in approximately 30° reverse Trendelenberg and the patient's head turned to the contralateral side. We recommend placing a pillow or roll of sheets under the ipsilateral scapula to allow for more room for needle entry (**Fig. 38**). As previously stated, the ultrasound screen

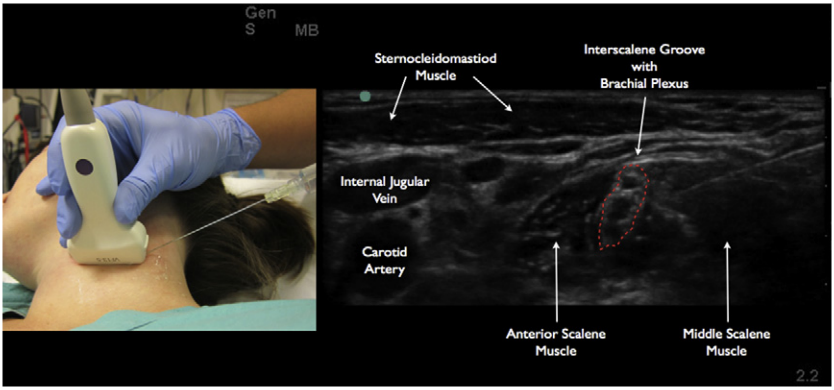

Fig. 38. Proper probe placement transverse on the neck (probe marker pointing to the patient's right), with corresponding sonographic findings: interscalene groove with brachial plexus, anterior scalene muscle, middle scalene muscle, and needle placement.

and cardiac monitor should be contralateral to the side being blocked. Identification of the interscalene location of the brachial plexus is often difficult and we recommend 2 techniques to improve success.

First, place the probe transverse on the neck (probe marker pointing to the patient's right), locating the carotid artery, IJ vein, and thyroid cartilage (**Fig. 39**). Identify the sternocleidomastoid muscle (SCM) and slowly move the probe laterally until the anterior and middle scalene muscles are noted. The cords of the brachial plexus will be found as large hypoechoic circular structures in the groove between the anterior and middle scalene muscles, commonly called the "stoplight" sign.

Alternately, place the high-frequency linear probe just proximal and parallel to the clavicle in the supraclavicular fossa with the probe oriented to the patient's right. The probe should be directed caudad and moved lateral to medial in a rocking fashion to identify the first rib and the subclavian artery traversing across the rib surface. The trunks of the brachial plexus should appear as hypoechoic oval structures posterolateral to the pulsatile subclavian artery and superficial to the first rib. From here, move the probe in a cephalad manner, following the plexus of nerves, until the probe is approximately at the level of the thyroid cartilage and in a transverse position on the neck. Here, you should recognize the bundle of hypoechoic nerve roots that rest between

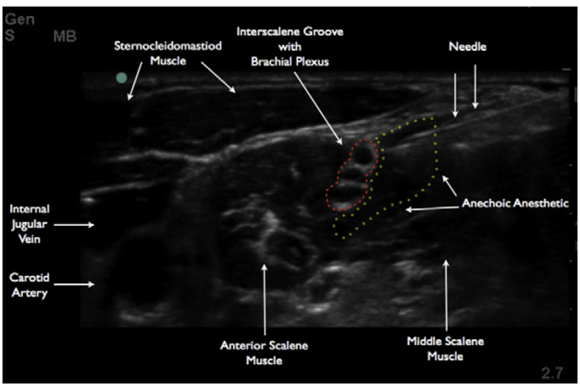

Fig. 39. Real-time visualized of hypoechoic injectate anesthetic in interscalene approach.

the anterior and medial scalene muscles deep to the SCM. If the anatomy is challenging to interpret, you can use color flow Doppler to confirm the vascular structures.

After cleaning the skin with an alcohol pad, place 2 to 3 mL of lidocaine with or without epinephrine about 0.5 to 1.0 cm lateral to the ultrasound probe. This will be the location of entry for the block needle, and adequate local anesthesia will allow for patient comfort during the block. Prep widely with a sterilizing solution such as chlorhexidine, and place a sterile drape. The ultrasound probe should be cleaned and covered with a sterile adhesive dressing across the contact surface.

Technique

We recommend a lateral to medial in-plane approach given this is a more advanced block. After the brachial plexus and surrounding structures are identified, enter the skin with the needle bevel up about 0.5 to 1.0 cm lateral to the probe. The external jugular vein may be in the path of your puncture; therefore, we recommend probe adjustment to be slightly medial or lateral to this easily located vein. Enter the skin at a shallow angle, which will improve needle visibility and improve safety.

Advance the needle slowly, maintaining the shaft and tip in view at all times. You will be entering through the middle scalene muscle and should try to get the needle tip into the interscalene groove. Aspirate to exclude vascular puncture and then slowly inject 3 to 5 mL of local anesthetic. With the needle tip in view, the spread of hypoechoic injectate should be visualized. After confirming optimal needle tip location, proceed to inject a total of 10 to 20 mL of local anesthetic in 3-mL to 5-mL aliquots. If at any point, the spread of local anesthetic is not visualized, intravascular injection should be suspected and the procedure halted. After injecting about 5 mL of anesthetic, the interscalene groove will be more noticeable, because the anechoic fluid should slowly separate the cords of the brachial plexus from the middle scalene muscle.

Pitfalls

- As mentioned, this is a more advanced block with a higher risk of complications because of the proximity of surrounding structures (pleura, subclavian vessels) and the complicated anatomy.
- Be sure to clearly delineate all structures before beginning your block and visualize your needle tip at all times, especially before injecting.
- This block is also associated with a risk of phrenic nerve involvement leading to hemidiaphragmatic paresis or paralysis. This should be assumed in all patients in whom the block will be performed. Very rarely does this affect patient breathing, but in patients with severe baseline respiratory pathology, the interscalene approach to the brachial plexus may not be ideal.
- Also, because of the inferior location of the of C8/T1 nerve root, the patient may get the least amount of sensory loss in the ulnar nerve distribution.

GENERAL NERVE BLOCK PITFALLS

From simple pain reduction to facilitating a procedure, the goal of a UGNB should depend on the patient. Common mistakes of novice providers include inadequate local anesthetic, poor visualization of the needle tip, and not visualizing the anechoic spread of anesthetic when injecting the recommended small aliquots. To reduce error, confirm the needle tip during the entire procedure, aspirate before all injections, and ensure deposition of anechoic fluid from the needle tip; this will ensure a high level of safety and success. And finally, the speed of the block is dependent on the proximity of the anesthetic deposition to the nerve epineurium. For less experienced providers, we recommend keeping a safe distance from the nerve, and therefore a moderate period of waiting (15–20 minutes) may be required before onset of the block.

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