Ultrasound-Guided Procedures in Emergency Medicine

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Ultrasound may be used as an adjunct in many common procedures performed in emergency medicine, and has been demonstrated to improve effectiveness and reduce complications in diverse applications. Although the evidence is strongest for ultrasound guidance in central venous access, the use of ultrasound has been studied in many areas of procedural guidance.

Emergent procedures may also be performed by consultants in a location other than the emergency department (ED). Some of these procedures may be similar or identical to procedures performed by emergency physicians (EPs) in the ED. This article focuses on procedures that are commonly performed by emergency physicians that may benefit from ultrasound guidance.

TRAINING AND CREDENTIALING FOR ULTRASOUND-GUIDED PROCEDURES

Ultrasound is a user-dependent technology and experience using ultrasound in procedures will improve success. How much experience is necessary to use ultrasound effectively is controversial, incompletely studied, and will vary among individuals. Although guidelines have often focused on numbers of examinations or procedures, emphasis has shifted in the past several years to assessing competency rather than simply counting how many examinations or procedures have been performed.

The effective use of ultrasound includes a basic understanding of the physics and instrumentation of ultrasound as well as psychomotor and cognitive elements of image acquisition and interpretation.

The American Medical Association has endorsed specialty-specific guidelines for ultrasound training.1 Within emergency medicine, the American College of Emergency Physicians (ACEP) has provided the most comprehensive specialty-specific guidelines for the use of emergency ultrasound, first published in 2001 and revised in 2008.2,3 ACEP describes both residency-based and practice-based approaches to training in point-of-care ultrasound. Although the 2008 guidelines place more emphasis on competency rather than numbers, ACEP has generally recommended 150 total examinations with 25 to 50 in each specific area as a minimum for competency in diagnostic ultrasound. Procedural ultrasound is included in these guidelines; however, specific numbers of procedures required for competency have not been defined.

Privileging for the use of ultrasound as an adjunct for procedural guidance is generally a function of a local hospital or group credentialing committee. In most cases, EPs will be privileged to perform a procedure without ultrasound guidance. Additional proctoring and experience performing an ultrasound-guided procedure may be helpful, but many credentialing committees do not require a specific number of documented ultrasound-guided procedures as long as general principles of ultrasound are understood and sterile procedures are followed. In some cases, privileging guidelines may include a certain number of...
proctored procedures before credentialing. Other avenues for training and assessing competency, including Web-based training and simulated procedures using phantoms have been advocated.\textsuperscript{4,5}

**GENERAL PRINCIPLES**

The use of ultrasound to guide procedures generally involves directing a metallic object (usually a needle) into the correct area of interest. Although the specifics of individual procedures are discussed in more detail in the following sections, there are general principles and considerations that apply to most ultrasound-guided procedures. As with all procedures, appropriate consent should be obtained and a “time-out” performed with verification of correct side.

**Machine and Transducer Selection**

There are a wide variety of ultrasound scanners available, from high-performance cart-based equipment to handheld machines. Image quality in the portable and ultra-portable is improving and in most cases is adequate for procedural guidance, although improved visualization will aid in difficult procedures.

Most ultrasound-guided procedures are best performed with a high-frequency linear probe. Most procedures performed in the ED are relatively superficial and benefit from the increased resolution of high-frequency probes. In addition, the linear array allows localization of the structures of interest directly below the probe.

In situations where a structure of interest is particularly deep, a lower frequency curvilinear probe may be more appropriate, and in difficult to examine areas (peritonsillar, supraclavicular fossa) a high-frequency endocavitary probe may be most appropriate.

A specific preset for “procedural” or “vascular access” may optimize visualization of the needle. If these are not available, the best preset is usually “vascular” or “soft tissue.” Tissue harmonic imaging may help to highlight the border of a fluid-filled structure.

**Static and Dynamic Imaging**

Ultrasound guidance for procedures can be static or dynamic. Static guidance involves assessing the area of interest and using ultrasound to note or mark where the needle should enter, at what angle, and so forth. Dynamic guidance involves watching the needle in real time, which can be done by the person performing the procedure (1-person), or by an additional person who does only the imaging while the other performs the procedure (2-person).

One-person dynamic guidance is a technique that involves simultaneous performance, ultrasound visualization, and visual monitoring of the procedure. This takes time and practice to master; however, for procedures involving small structures (especially nerve blocks and peripheral vascular access), 1-person dynamic imaging is preferred.\textsuperscript{6}

For other procedures where there is a large amount of fluid, in particular when the transducer may actually interfere with where the needle is placed for the procedure, a static technique may be preferable. This is often the case with paracentesis, thoracentesis, and pericardiocentesis, particularly when large amounts of fluid are present.

**Plane of Interrogation and Guidance**

It is best to scan through the area of interest in 2 orthogonal planes to get a complete visualization of the anatomy and any pathology before any procedure. However, in a dynamic procedure the needle must be visualized in a single plane as the actual procedure is taking place. Relative to a needle, the 2 options are “in-plane” and “out-of-plane” (Figs. 1 and 2). Although the out-of-plane may be easier to use at first,\textsuperscript{7} most sonologists prefer the in-plane approach for procedural guidance because the entire shaft of the needle, including the tip, is more easily visualized.\textsuperscript{8} There are times when a short axis may have an advantage, particularly in locating the center of a small linear structure, such as a peripheral vein. In dynamic procedural guidance, the plane may be changed or adjusted during the procedure.

The other axis to be considered is long axis versus short axis relative to a tubular structure, such as a vessel, nerve, or tendon. A combination of long axis or short axis and in-plane or out-of-plane may be used. For example, an in-plane long axis approach may be preferable for central vascular access, whereas an in-plane short axis approach to a nerve may be best.

**Sterile Technique**

Sterile technique should be observed for most invasive procedures. This is best accomplished with a sterile probe cover kit designed for the specific probe. These kits will typically include a nonlatex cover that the probe can be lowered into as well as sterile gel for the outside of the cover. Although it is possible to use a sterile probe cover as a single operator, an assistant is very helpful. Gel should also be placed inside of the cover, but it does not need to be sterile. Although commercial probe covers are easiest to use, sterile gloves can also be accommodated to cover the probe if commercial probe covers are not available.
Fig. 1. In-plane visualization of needle: A shows how the linear probe and the plane of the ultrasound is oriented relative to the needle; B shows how this should appear as a needle is advanced into a vessel using the in-plane approach (and long axis of the vessel). This approach has the advantage of visualizing the entire needle shaft and tip.

Fig. 2. Out-of-plane needle visualization: A and B show how the needle is oriented relative to the probe in an out-of-plane approach; C shows the “target sign” of the needle within the vessel. Although in this approach it is easier to find the vessel and the approach allows centering over the middle of the vessel, the plane of the ultrasound will need to be “fanned” (curved arrows in A and B) to find the tip, as a plane through the shaft will show the same image as C, while the tip may be deeper (arrows).
Certain procedures are not necessarily sterile, but should be performed in a clean manner. The probe should also be protected from blood or bodily fluids when possible by using a glove or tegaderm cover, again with gel on both the inside and the outside. The water-based gel available at the bedside for rectal examinations (“surgi-lube”) is also typically sterile.

**Other Equipment**

Although each procedure requires the supplies that would be used for the same procedure performed without ultrasound guidance, there are a few specialized supplies that may be helpful for ultrasound guidance.

For peripheral vascular access, a longer catheter is essential for vessels deeper than a few millimeters to minimize dislodgement. Most standard intravenous (IV) catheters are 1.25 inches, with catheters of 1.88 inches and larger being more useful for ultrasound-guided peripheral access.

An echogenic needle tip with microabrasions on the bevel may aid in needle tip visualization for central venous access or other procedures. Some ultrasound scanner manufacturers are also creating presets that are better at recognizing the needle.

Needle guidance aids are improving and becoming more widely available. Traditional biopsy guides use a needle guide that is physically attached to the probe, resulting in a set trajectory for the needle that is displayed on the screen. Although these may be helpful in certain situations, they are at a fixed and fairly steep angle that may not be appropriate for some procedures and can be cumbersome to use in a sterile manner. Recently, several needle-guidance techniques have become commercially available using stereotactic and magnetic positioning to anticipate the path of the needle without a physical attachment to the probe and allowing for different angles of approach. These will undoubtedly improve the ease and success of ultrasound procedures.

**VASCULAR ACCESS**

Vascular access is critical to emergency medicine, and ultrasound guidance of vascular access procedures can be invaluable in increasing success rates and reducing complications. Use of ultrasound guidance for central venous access procedures has been cited by the Agency for Healthcare Research and Quality as one of the top ways to reduce medical errors in the United States. For patients who do not require central access but have difficult peripheral access, ultrasound can potentially save the patient from a more invasive procedure.

When using ultrasound for vascular access, it is critical to differentiate veins from arteries. Veins are more easily compressible than arteries and are nonpulsatile. Although this difference may be obvious for central veins in a well-hydrated patient, it may be more challenging for peripheral vessels, particularly if the patient is dehydrated or hypotensive. Although color flow Doppler (CFD) may be helpful, it is recommended that any vessel in question be partially compressed (into an oval shape) and watched for a few seconds to be sure there are no arterial pulsations. In general, veins are easily compressible, although arteries may also compress with enough pressure or in a hypotensive patient. Absence of complete compression of a vein typically indicates a thrombus.

**ULTRASOUND-GUIDED CENTRAL VENOUS ACCESS**

There are approximately 5 million central venous catheter (CVC) procedures performed annually in the United States. CVCs are typically performed in patients who are critically ill, have difficult access, require vasoactive or multiple medications, need long-term access, or have some combination of these factors. Many central lines are placed in the ED setting, some in arrest or time-critical situations. Complications of CVCs are estimated to occur in up to 15% of line placements. Complications occurring during CVC placement include arterial puncture or laceration, pneumothorax, and others. Ultrasound guidance for CVC placement has been shown to improve success and minimize complications, particularly in difficult patients or with inexperienced operators. However, the use of ultrasound for CVC placement does not eliminate risk, particularly with inexperienced operators, if the tip is not completely visualized.

**Site Selection and General Considerations**

The 3 major sites for CVC access are the internal jugular (IJ), subclavian (SC), and femoral veins. Ultrasound guidance is most amenable to the internal jugular site as the landmarks may not always be obvious, anatomy may be variable, and there are no bony structures that obstruct the view. Ultrasound guidance has been most well studied for IJ access, and ultrasound-guided IJ placement has been shown to be safer than blind subclavian central venous catheterization. Ultrasound may be helpful for a supraclavicular approach to the subclavian vein or in accessing the axillary vein distal to the subclavian. Whereas
the femoral vein is not preferred for elective central access because of higher rates of infectious and mechanical complications, it may be most accessible in an arrest situation and ultrasound may be particularly helpful in this situation.

Time permitting, before sterile preparation the intended vessel should be prescanned in 2 planes to assess for abnormal anatomy, valves, scars, or thrombus. The vein should be patent and compressible. After sterile preparation, the intended area of entry should be anesthetized and may be done under ultrasound guidance to get a sense of needle orientation and depth. A small-gauge finder needle may also be used to aspirate from the vein before the larger needle.

A 1-person dynamic in-plane long axis approach is recommended for ultrasound-guided central venous access, as this will dynamically show the entire needle, minimizing complications from a misplaced tip. However, it may be helpful to begin the procedure out-of-plane in the short axis to ensure that the vein is being approached rather than the artery, and that the needle is advancing over the center of the intended vessel. When in the long axis it is important to ensure that it is the vein that is visualized rather than the artery. If there is a question, the probe should be rotated to a short axis view and compressed to ensure it is venous.

Ultrasound guidance is often used until flash is achieved, with the ultrasound then placed aside to proceed with standard placement of the guide wire and catheter. However, visualization of the guide wire may be easier than visualization of the needle, and visualization is recommended before dilation or catheter placement. Ultrasound may help delineate a valve or other mechanical issue, allowing for successful guide wire placement or repositioning. Ultrasound may also be used following line placement to ensure central venous placement by visualizing the right heart during an IV flush. Scanning the chest for lung sliding to rule out significant pneumothorax is recommended for any subclavian, axillary, or low IJ cannulation.

Simulated training in ultrasound-guided vascular access may help to develop procedural competency and reduce errors.

**Internal Jugular Access**

As described previously, either a static or 2-person dynamic approach may be used, but a 1-person dynamic approach is recommended. The clinician is at the head of the bed and the patient should be in Trendelenburg with sterile cover in place. Because the clinician is at the head of the bed, the ultrasound probe indicator should be oriented to both the patient’s and operator’s left side, so that the direction of needle movement will be consistent on the screen as it is viewed. This orientation of the indicator (to the patient’s left) is opposite of most diagnostic scanning (to the patient’s right).

The IJ vein is typically lateral to the carotid at the apex of the 2 heads of the sternocleidomastoid muscle, although anatomy may be variable. While the patient is often positioned with the head rotated to the contralateral side, this may in fact increase overlap of the IJ over the carotid and a more neutral position of the head may be desirable if the needle can be maneuvered with the patient in this position. Ultrasound should be used to identify the point where the vein is lateral to the artery and where the needle will pass through as little tissue as possible. This may include a central, anterior, or posterior approach relative to the sternocleidomastoid. If the IJ is superior to the carotid, an angle of approach is recommended that will not puncture the carotid if the needle goes too deep. Higher approaches will have less chance of causing a pneumothorax.
profusely into the chest before detection. The use of ultrasound for subclavian access has had mixed results in the literature.

The subclavian vein may be approached via a supraclavicular or infraclavicular approach. A blind supraclavicular approach has been advocated as superior to the blind infraclavicular approach, but is infrequently used in practice. However, the use of a small footprint high-frequency endocavitary probe has been shown to be feasible for ultrasound guidance of a supraclavicular approach to the subclavian vein. The presence of the clavicle makes ultrasound guidance from an infraclavicular approach challenging.

Although blind axillary vein cannulation is not usually performed because of the absence of external landmarks, the axillary vein is readily visible using ultrasound. Ultrasound-guided axillary vein cannulation has been shown to be feasible with few complications. The axillary vein is superficial to the axillary artery and can be found just distal to the clavicle. Because of the clavicle, it may be difficult to get an in-plane long axis view of the vessel and an out-of-plane short axis view may be required. Care should be taken to ensure the location of the needle tip during cannulation.

**Femoral Access**

As mentioned previously, femoral CVC access is not preferred because of increased complications, including long-term infection, but may be necessary if the torso is difficult to access such as in a trauma or arrest situation. Although blind femoral access is often considered straightforward because of the presence of a femoral artery pulse as a landmark, femoral access is associated with nearly twice the rate of arterial puncture compared with other approaches. This may be even higher in situations where the femoral pulse is not easily palpable. Using ultrasound for femoral access in an arrest situation was faster and more effective and resulted in fewer arterial punctures than a blind approach. This study also demonstrated that the pulse palpated during cardiopulmonary resuscitation is typically venous rather than arterial, which may make the landmark technique challenging in a code situation.

The common femoral vein is found just distal to the inguinal ligament and medial to the common femoral artery. Ultrasound can identify the saphenous vein entering the common femoral vein from the medial side of the common femoral vein. Ultrasound will also demonstrate how quickly the femoral vein will dive deep to the femoral artery as it goes distally, illustrating why a blind technique may frequently result in arterial puncture.

Hip abduction and external rotation (“frog leg” positioning) will improve femoral vein exposure and decrease overlap of the femoral artery.

**ULTRASOUND-GUIDED PERIPHERAL INTRAVENOUS ACCESS**

Peripheral venous access in healthy nonobese adults is typically straightforward using visualization and palpation of veins. However, peripheral access may be challenging in obese or dehydrated patients, in those who have frequent access procedures (dialysis, sickle cell anemia, intravenous drug abusers), and in pediatric patients. The inability to obtain peripheral access may require more invasive measures including external jugular cannulation, CVC placement, or intraosseous access.

In difficult patients, ultrasound guidance can be among the most difficult ultrasound-guided procedures because of the small size of the vessel and vessels that may roll or be scarred down in dialysis patients, intravenous drug abusers, and patients with sickle cell anemia. It is recommended that the clinician become comfortable with ultrasound-guided IV placement in less difficult patients before attempting it in difficult patients.

The upper extremity is usually most amenable to ultrasound-guided peripheral access. A tourniquet should be used. The arm should be interrogated attempting it in difficult patients.

A tuberculin or insulin syringe with lidocaine may be used for patient comfort, particularly with deep IVs. A long catheter (1.88 inches or longer) should be used for anything 5 mm or deeper. In a short axis in-plane approach, many times peripheral vessels are too small or irregular to visualize well in the long axis.

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a “target sign.” The endothelium of the vein may tent in some before puncture creating a target sign but not allowing the catheter to be threaded. In this case, the angle should be flattened and the catheter pushed forward slightly until a slight pop is felt and there is a flash allowing the catheter to be threaded. Backwalling may occur, requiring the needle to be drawn back slightly.

In particularly difficult patients, a modified Seldinger technique may be performed using catheters commonly used for arterial catheterization. Static marking of the skin using ultrasound has not been shown to offer any advantage over dynamic guidance for peripheral IV placement.

PARACENTESIS

Paracentesis is commonly performed both diagnostically and therapeutically in the ED setting, usually for ascites from liver failure. Diagnostic paracentesis is usually done to rule out spontaneous bacterial peritonitis in a patient with known or demonstrated ascites and abdominal pain, fever, or altered mental status. Therapeutic paracentesis in the ED setting is typically reserved for tense ascites with respiratory compromise.

Large-volume or known ascites may be clinically obvious and easily accessible without ultrasound. However, physical examination is insensitive and nonspecific for less obvious ascites. Ultrasound can aid in determining the presence of ascites as well as identifying the largest pocket and avoiding structures such as the inferior epigastric vessels, the bladder, and any adherent bowel. In a randomized study, the use of ultrasound was shown to dramatically increase the frequency of successful paracentesis. Although ultrasound may be able to detect as little as 100 mL of ascitic fluid, it is highly sensitive once there is approximately 500 mL or more.

Depending on where the fluid collection is most evident, paracentesis may be performed in the midline through the linea alba below the umbilicus, or in either lower quadrant lateral to the rectus sheath. Although the inferior epigastric vessels should be avoided by going lateral to the rectus sheath, the use of a linear probe with Doppler may help to identify the exact location of these vessels.

With larger volumes of ascites, it is reasonable to use a static ultrasound technique to mark the point of entry on the skin and then proceed with the procedure. With smaller volumes or if there is concern about structures to be avoided, a dynamic technique may be preferable. A small-gauge needle may be used for diagnostic paracentesis, whereas a paracentesis kit is recommended for larger volumes.

THORACENTESIS

It is estimated that there are 1.5 million pleural effusions diagnosed in patients in the United States annually, and that the incidence of pneumothorax with blind thoracentesis may be as high as 20% to 39%. Ultrasound is more sensitive and specific than chest radiograph for pleural effusions and may help increase success and decrease complications, particularly pneumothorax. In one series, the use of ultrasound decreased the incidence of pneumothorax to less than 2% in mechanically ventilated patients.

Ultrasound has been shown to be more accurate than chest radiograph in predicting the volume of fluid that can be aspirated. A maximum measure of the fluid pocket between the thoracic wall and the collapsed lung of 20 mm correlated to an average aspirate of 380 mL, whereas 40 mm correlated to an average aspirate of 1000 mL.

Aspiration of thoracic fluid should be performed from a posterior approach with the needle passing over the rib where the maximum fluid collection is present, avoiding the diaphragm and lung. A static technique is usually recommended for a large effusion, although a dynamic technique can be used (Fig. 4). Although large-gauge thoracostomy tubes are typically recommended when there is a hemothorax from trauma, smaller gauge catheters may often be used for simple effusions. A pigtail catheter (10–16 French gauge) is a good choice for uncomplicated effusion, particularly if ongoing drainage is desired.

INCISION AND DRAINAGE OF ABSCESES

Although abscesses may be clinically obvious, there is often a concern about whether pus will be obtained if the abscess is incised, the optimal location to incise, and the extent of the abscess pocket. Ultrasound has been shown to alter management in nearly half of cases where there is concern for cellulitis with or without abscess, increasing the yield of incision and drainage of a suspected abscess. Peritonsillar abscess may be particularly difficult to differentiate from peritonsillar cellulitis, and ultrasound with an endocavitary probe has been shown to assist with localization and drainage of a peritonsillar abscess cavity.

An abscess pocket appears as an irregular hypoechoic collection underneath the skin (Fig. 5). It is hypoechoic but may not be completely anechoic and may show a “sloshing” motion.
when pressure is applied. Recently, elastography (a color sonographic representation of tissue stiffness) has been shown to have a role in determining the extent of the abscess pocket and surrounding induration.37

**ARTHROCENTESIS**

For large effusions in large joints, such as the knee, ultrasound has not been shown to increase success compared with the landmark technique, although it did increase confidence and allow more fluid to be drained.38 However, in smaller joints or where there is a question of intra-articular fluid, ultrasound improves identification and successful aspiration of joint fluid.39,40 The use of ultrasound makes the emergent aspiration of deeper and more difficult joints such as the hip and ankle more feasible in the ED setting, including in pediatric patients.41 A joint effusion is identified as an anechoic space between hyper-echoic shadowing bones and allows ultrasound needle localization.

**PERICARDIOCENTESIS**

In a stable patient, pericardiocentesis is ideally performed in a controlled situation with all available equipment, such as in the cardiac catheterization lab. However, if a patient is hemodynamically unstable with a large pericardial effusion/cardiac tamponade, emergent pericardiocentesis may be necessary. The increased availability of point-of-care ultrasound has made the possibility of detecting this entity definitively in an acutely ill patient presenting to the ED more common. Although dynamic guidance may be used, in most cases static guidance is probably preferable, as the probe is not in the way. Two approaches are described in the literature, a subxiphoid and parasternal approach. Ultrasound should be used to localize the largest pocket and shortest path to the fluid with the point of entry and angle of approach noted.42,43 In emergent situations, a 60-mL syringe and a 2.5” or longer spinal needle may be used, although placement of a pericardial drain using a dedicated pericardiocentesis kit may be preferable for large effusions.44

**FOREIGN BODY LOCALIZATION AND REMOVAL**

Although ultrasound is not completely sensitive for detection of soft tissue foreign bodies, it may detect foreign bodies that are not seen on plain radiographs, particularly wooden splinters.45–47 When visualized, ultrasound can be helpful in dynamic localization and removal of an object, which can be challenging when looking at 2-dimensional radiographs.48

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**Fig. 4.** In-plane dynamic thoracentesis on a phantom: A shows a dynamic approach with the effusion visualized using a curvilinear probe; B shows the ultrasound image, with the long axis of the needle entering the pleural effusion. (Courtesy of Blue Phantom, www.bluephantom.com; with permission.)

**Fig. 5.** Abscess pocket. This pocket is nearly completely anechoic, whereas many abscesses will show some debris. There is “cobblestoning” (a nonspecific sign of edema) in the surrounding tissue.
NERVE BLOCKS

Regional anesthesia is useful for pain control and procedures in the ED. Simple procedures such as digital nerve blocks may be performed without ultrasound guidance, but ultrasound has expanded the range of blocks that may be effectively performed in the ED setting. Ultrasound has been shown to be more effective than blind techniques with decreased complications and lower amounts of anesthetic required to achieve an effective block. Although a complete discussion of ultrasound-guided nerve blocks is outside of the scope of this article, we provide an overview of the technique and applicable blocks in the ED.

For a short-acting block, 1% to 2% lidocaine may be used. For a longer-acting block, bupivacaine may be used or mixed with lidocaine. Bupivacaine is more cardiotoxic and care should be taken to avoid intravascular injection, with some authorities recommending a lipid emulsion available as a rescue therapy. Epinephrine in the anesthetic will lower the amount of anesthetic required and will lengthen the block. Although impact of the needle bevel has been debated, most authorities recommend a short-bevel needle to minimize the chance of intraneural injection. A spinal needle may be used but care should be taken not to advance it too far.

The nerve is best identified on ultrasound in short axis and will appear as a fascicular structure with a honeycomb pattern. Nerves may appear similar to tendons in cross section but have slightly larger and more hypoechoic fascicles and should not move with limb motion. With the nerve visualized in short axis, in-plane ultrasound visualization of the needle should be performed, with anesthetic deposited in a way to surround the nerve (Fig. 6).

Upper extremity blocks that may be relevant to the ED setting include the interscalene, supraclavicular, and forearm blocks. The interscalene block is performed near the origin of the brachial plexus in the neck. The 3 trunks of the brachial plexus are identified in a “stoplight” configuration between the scalene muscles in the neck. An interscalene block provides effective anesthesia for the shoulder and upper extremity. A significant proportion of patients undergoing interscalene block experience temporary hemidiaphragmatic paralysis, which is not usually consequential in healthy patients but makes the block contraindicated in patients with respiratory compromise.

A supraclavicular block is more distal than an interscalene block and does not involve the phrenic nerve but provides anesthesia for the shoulder and upper extremity. It is approached from the supraclavicular fossa, where the nerve is located lateral and superficial to the subclavian artery. Ultrasound block of the distal nerves of the forearm (radial, ulnar, median nerves) has been shown to be feasible and helpful for emergency procedures. The ulnar nerve is ulnar to the ulnar artery, and the radial nerve is radial to the radial artery, however the median nerve is not paired with an artery.

For elderly patients with hip fractures, a regional block may allow for more effective pain control with fewer side effects than parenteral analgesia.

Nerve block for hip fracture includes the femoral nerve block, the 3-in-1 nerve block, and the fascia iliaca block. The femoral nerve is lateral to the artery and located under the fascia iliaca, which must be penetrated to achieve a block. A 3-in-1 block is performed more laterally than a direct femoral nerve block, with pressure applied distally for several minutes to allow the anesthetic to diffuse through the fascial compartment, providing a block of the lateral femoral cutaneous and obturator nerves, which may improve anesthesia for more proximal fractures. The fascia iliaca block is performed more proximally and may perform better than other blocks for proximal hip injury or pain, as it involves the more proximal lumbar plexus. The needle is advanced under ultrasound guidance 0.5 to 1.0 cm caudal to the lateral two-thirds of the inguinal ligament, first through the fascia lata and then under the fascia iliaca where the anesthetic is deposited and should spread proximally.

FRAC TURE AND DISLOCATION DIAGNOSIS AND REDUCTION

Reduction of fractures or dislocations may be performed blindly or with radiologic guidance.
Although fluoroscopy has typically been the radiologic method of choice, this method involves significant ionizing radiation, and equipment may not be readily available. Ultrasound may be used to diagnose and guide reduction of long-bone fractures, with long-bone fractures of the forearm being most amenable to ultrasound-guided reduction and alignment. In pediatric patients, fluoroscopy should be avoided if possible, and ultrasound has been shown to effectively help guide reduction of forearm fractures in this population.

Long-bone fractures will show a disruption of the hyperechoic bony cortex, and may show angulation of the 2 pieces (Fig. 7). Ultrasound guidance aims to provide optimal alignment of displaced fractures and is typically performed using a 2-person dynamic technique with appropriate anesthesia. A static technique (ultrasound examination after reduction) may also provide guidance.

**TRANSVENOUS PACING**

Emergent transvenous pacing may be lifesaving in a patient presenting with third-degree atrioventricular block. Although transcutaneous pacing may be temporarily helpful, transvenous pacing provides more definitive support. Transvenous pacing is typically performed via a centrally inserted catheter, which may be inserted using ultrasound guidance as described previously. Ultrasound may be used to track the pacing wire through the tricuspid to the apex of the right ventricle, and is helpful in determining appropriate pacer location and correcting misplacement.

Ultrasound may also demonstrate mechanical capture of either transcutaneous or transvenous pacing.

**INTUBATION AND AIRWAY MANAGEMENT**

Endotracheal intubation is frequently performed in the ED for definitive airway management. Although direct laryngoscopy may be possible in most patients, a subset have difficult airways. In addition to other adjunctive airway techniques, ultrasound has been shown to reliably detect tracheal as well as esophageal intubation.

The trachea is identified between the lobes of the homogeneous thyroid as a hyperechoic structure with distal scattering from encountering air. When properly performed, the endotracheal intubation will be seen as sliding just inferior to the identified trachea. Esophageal intubations will show an additional hyperechoic shadowing structure, predominantly to the left of the trachea.

In the case of a failed intubation, emergent cricothyrotomy may be required. Ultrasound has been shown to be of use in delineating the anatomy relevant to performing a cricothyrotomy.

**LUMBAR PUNCTURE**

Ultrasound has been shown to reduce the number of failures on lumbar puncture (LP) in difficult patients. Ultrasound has also been used to define the optimal positioning of pediatric and adult patients for LP. Ultrasound is used to identify the gap between the spinous processes by placing the linear probe vertically and identifying the hyperechoic spinous processes with shadowing and the gap in between. In some patients, additional structures, including the ligamentum flavum and the epidural space, may be identified, helping to determine the depth of the required puncture.

The skin can then be marked in both vertical and lateral directions and the procedure performed in a static fashion.

**URINARY CATHETERIZATION**

Urinary catheterization is a minor but invasive procedure. Particularly in children, in whom obtaining a clean urine sample is commonly important, the use of ultrasound to ensure adequate volume before catheterization has been shown to reduce failed urinary catheterizations, especially in children younger than 2 years. The use of a “urinary bladder index” (anteroposterior × transverse diameter) of greater than 2.4 cm² has been shown to predict successfully obtaining at least 2 mL of urine on catheterization. In cases where urethral catheterization is unable to obtain urine, ultrasound may help guide suprapubic aspiration or catheter placement.

Ultrasound may also help to ensure correct placement of a Foley catheter, and may help to elucidate problems.
with Foley catheter function (clot, mass in the bladder).

SUMMARY

Although ensuring adequate training for this user-dependent technology is essential, ultrasound may be very helpful in successfully performing a wide variety of emergency procedures with less adverse events than a blind technique. It is an invaluable adjunct for many procedures and can be considered standard of care for central venous access.

REFERENCES