Common Ultrasound-Guided Procedures

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KEYWORDS

• POCUS • Pericardiocentesis • Thoracentesis • Paracentesis • Lumbar puncture
• Vascular access

KEY POINTS

- Ultrasound guidance improves success rate and decreases complications when compared with landmark-based approaches for many emergency department (ED) procedures, including vascular access, pericardiocentesis, thoracentesis, paracentesis, and lumbar puncture.
- Clinicians may select static versus dynamic and out-of-plane (short-axis) versus in-plane (long-axis) ultrasound guidance techniques based on knowledge of their respective advantages and disadvantages, and comfort with each technique.

Video content accompanies this article at http://www.emed.theclinics.com.

INTRODUCTION

Point-of-care ultrasound (POCUS) for procedural guidance is fundamental to the practice of emergency medicine and a required component of residency training.[1,2] Compared with traditional landmark-based techniques, the use of ultrasound (US) guidance improves procedural success rate and time-to-completion, decreases pain and complication rates, and increases patient satisfaction. This article reviews ultrasound guidance for pericardiocentesis, thoracentesis, paracentesis, lumbar puncture, and vascular access.

DISCUSSION

Principles of Ultrasound Guidance

Probe selection

An appropriate US probe must be selected to optimize visualization of an anatomic target, its surrounding anatomy, and the needle directed at these structures. Most commonly, a linear probe will be utilized for vascular access and guidance for

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superficial target structures. For most thoracoabdominal procedures, a curvilinear or phased-array probe may be preferable.

Probe preparation and disinfection

Probe preparation, implementation of appropriate clean or sterile techniques, and post-procedural probe cleaning and disinfection are essential to the safety of US-guided procedures. The American Institute of Ultrasound in Medicine guidelines[3] recommend that all US-guided external percutaneous procedures utilize single-use sterile gel packets and single-use probe covers that match the sterility requirements of the specific procedure. Requirements for sterility and disinfection vary depending on the procedure being performed.

Dynamic and static ultrasound guidance

Procedural US guidance can be performed in a dynamic or static fashion. In dynamic guidance, the clinician uses real-time US visualization to guide the procedure, holding the needle with the dominant hand and the US probe with the other. Static guidance (ie, US-assisted procedure) involves using POCUS to identify relevant anatomic structures in advance, then performing the procedure without real-time US visualization. When relying on static guidance, it is important that the patient remains stationary after structures are marked; movement may change the position of target structures, jeopardizing success and increasing the likelihood of complications.

In-plane and out-of-plane techniques

Out-of-plane and in-plane techniques are commonly used for US-guided procedures (**Fig. 1**).

- *Out-of-plane (short-axis, or transverse)* technique permits visualization of the target structure and surrounding structures; however, the needle will only be visible where it transects the scanning plane. The US probe requires continuous adjustment to keep the needle tip (rather than the needle shaft) in view as it advances toward the target structure.
- *In-plane (long-axis, or longitudinal)* technique has the advantage of real-time visualization of the needle tip and shaft, but limits visualization of surrounding structures. Precision is required to ensure that the needle and probe remain aligned throughout the procedure.

Pericardiocentesis

US guidance is a best practice for pericardiocentesis, permitting alternate approaches to the pericardium beyond the traditional, landmark-based subxiphoid approach. Procedural indications and contraindications are reviewed in **Table 1**. In a case series of 1127 US-guided pericardiocentesis procedures, the success rate was 97% overall, with a 4.7% complication rate.[4]

Technique

A phased-array probe is used to assess the pericardial effusion using the parasternal, apical, and subxiphoid windows. The most suitable approach is selected, taking into consideration the following:

- Area of largest pericardial fluid pocket.
- Shortest distance from the chest wall.
- Absence of (or ability to avoid) vital structures in the anticipated needle trajectory.

Gather appropriate equipment, including a 16-gauge or 18-gauge spinal needle and a large syringe, or a preconstructed pericardiocentesis kit. An ideal patient position (ie,

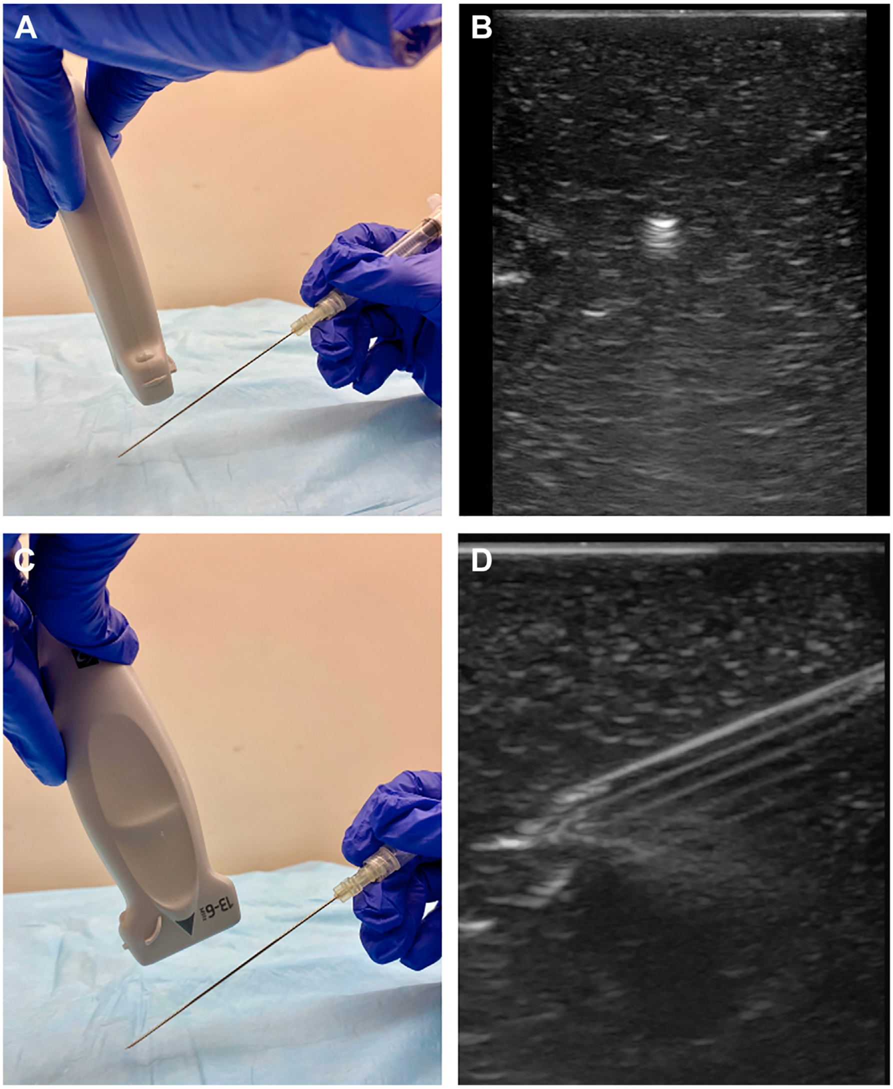

Fig. 1. Out-of-plane and in-plane guidance. (*A*) Out-of-plane technique yielding (*B*) a view of the echogenic needle shaft in its transverse axis. (*C*) In-plane technique, yielding (*D*) a view of the long-axis of the needle shaft and tip.

Table 1
Indications and contraindications to pericardiocentesis

Indications	Contraindications
Hemodynamic instability caused by pericardial tamponade.	No absolute contraindications to pericardiocentesis in pericardial tamponade Relative contraindications: • Active bleeding into the pericardium (eg, trauma, ventricular rupture after myocardial infarction, aortic dissection) requiring emergent operative management..[5] • Bleeding diathesis (eg, coagulopathy, thrombocytopenia).[6]

semi-recumbent with head of bed at 30°-45°, and slight rotation to the left) maximizes the size and accessibility of the pericardial fluid collection. Appropriate sterile precautions should be used whenever possible, within the limitations of a potentially emergent situation. In awake patients, anesthetize the skin and needle track, including soft tissue, periosteum of rib, and the pericardium itself.

After sonographic assessment and selection of the best approach (**Table 2**), the clinician may convert to a linear probe to optimize needle visualization using dynamic, in-plane guidance. If an intercostal approach is chosen (either parasternal or apical), introduce the needle at the superior border of the rib to avoid the neurovascular bundle inferior to the rib. While maintaining negative pressure on the syringe, advance the needle until the tip is seen in the pericardial space, and fluid or blood is aspirated (**Fig. 2**A). Notably, aspiration of fluid or blood may also be seen with needle malposition in the pleural or intraperitoneal spaces, or within a cardiac chamber. Correct needle positioning can be confirmed by injecting several milliliters of agitated saline and visualizing air bubbles within the pericardial space or by introducing and visualizing a guidewire in the pericardial space (**Fig. 2**B).

Fluid should be removed until hemodynamic improvement is seen. The procedure may require multiple aspirations (facilitated by a 3-way stopcock connected to additional larger syringes) or placement of an intrapericardial catheter. A repeat cardiac POCUS should demonstrate improved cardiac filling. Rapid evacuation of >1 L of fluid should be avoided to avoid the risk of pericardial decompression syndrome, characterized by ventricular dysfunction and pulmonary edema.[7]

Thoracentesis

POCUS enables dynamic localization of pleural effusion and real-time needle guidance, reducing risk of injury to adjacent structures.[8] Procedural indications and contraindications are reviewed in **Table 3**. Pneumothorax is the most common major complication of thoracentesis; a meta-analysis reported overall risk of 6.0%, significantly reduced using US guidance.[9]

Technique

Pleural effusion appears as an anechoic collection between the visceral pleura lining the lung and the parietal pleura lining the thoracic cavity. Non-loculated effusions collect in areas of gravity dependence. The margins of the effusion, as well as the position of the diaphragm, liver, and spleen, can shift dynamically with respirations.

Place the patient in an upright and forward-leaning position at the edge of the bed, supported by a table. Patients who are intubated or otherwise unable to sit upright may be placed in a semi-supine position with the head of bed elevated (30°-45°), or in a lateral decubitus position with effusion side down. Access to potential needle insertions sites at the mid-scapular line and/or posterior axillary line remains possible in these positions.

Assess the thorax using a curvilinear or phased-array probe and select the most suitable target, considering the region of maximal effusion size and distance from vital structures. The targeted fluid pocket should be at least 10 mm thick.[12] Evaluate several rib spaces superior and inferior to the target due to expected shifting with respiration. Gather appropriate equipment including a 16-gauge or 18- gauge needle of sufficient length and a syringe, or a preconstructed thoracentesis kit. Prepare the patient using appropriate sterile technique, and anesthetize the anticipated needle track (including skin, soft tissue, periosteum of rib, and pleura). Insert the needle superior to the rib to avoid injury to the inferior neurovascular bundle (**Fig. 3**). Thoracentesis may be performed under dynamic or static guidance (**Table 4**, **Fig. 4**).

Table 2
Pericardiocentesis approaches, including an overview of technique, advantages, and disadvantages

	Technique	Advantages	Disadvantages
Parasternal	Obtain a parasternal long-axis view lateral to the left sternal border. Needle is introduced in-plane at a steeper angle (>45°), just lateral to the sternum near the left fifth or sixth intercostal space, at the superior border of the rib. Needle entry >1 cm lateral to sternum risks injury to the internal thoracic (mammary) vessels. While left parasternal access is more frequently described, a right parasternal approach is also possible with the use of US.	• Most direct trajectory with shortest distance to the pericardium.	• Risk of pneumothorax. • Risk of injury to the coronary or internal thoracic (mammary) vessels, located 1–2 cm lateral to the sternal border.
Apical	Obtain an apical view near the left fifth-to-seventh intercostal space. Needle is introduced in-plane inferior and lateral to the cardiac apex, at the superior border of the rib, and advanced toward target.	• Short distance to pericardium, which lies adjacent to the chest wall in this position. • If punctured, the thicker left ventricle wall can more easily self-seal.	• More difficult sonographic view to obtain. • Risk of pneumothorax. • Risk of left ventricular puncture causing dysrhythmia.
Subcostal	Obtain a subcostal view inferior to the xiphoid process and/or costal margin. Needle is introduced between the xiphoid and left costal margin, directed under the rib cage, and then advanced at a shallower angle (15°–30°) toward the target. This may require deliberate passage through the left liver lobe.	• Easy sonographic view to obtain, particularly in patients with hyperinflated lungs (eg, chronic obstructive pulmonary disease). • Technique may be familiar if blind approaches previously used • Lower risk of pneumothorax	• Needle entry point is a greater distance from the heart, requiring a needle of adequate length. • Needle tip may be more difficult to visualize. • Risk of injury to the diaphragm, phrenic nerve, liver, inferior vena cava, and bowel.

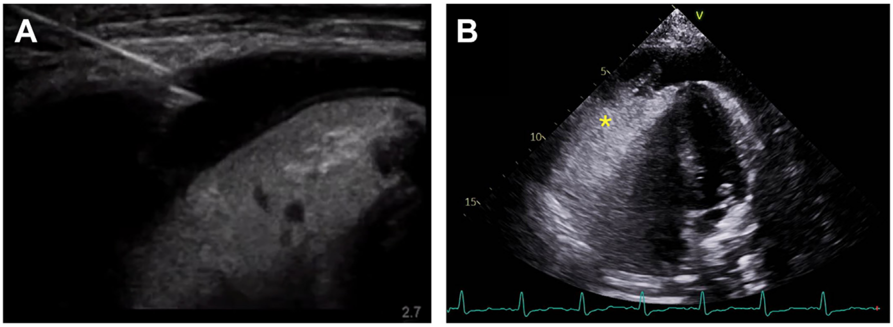

Fig. 2. Ultrasound (US)-guided pericardiocentesis. (*A*) In-plane using a linear probe, visualizing needle tip entering the pericardial fluid collection. (*B*) Agitated saline (asterisk) is seen in the pericardial space on apical 4-chamber view. (*Photo Courtesy* of Stephen Alerhand, MD.)

A small-volume aspiration (typically <50 mL) may be performed for diagnostic purposes. If a large-volume drainage is necessary, a pleural catheter can be placed via Seldinger technique. A needle alone should not be used if a larger volume of fluid will be drained, due to risk of injury to the pleura or lung. For therapeutic thoracentesis, sufficient fluid should be removed to improve the patient's respiratory status. Avoid rapid removal of large volumes (no more than 1500 mL during an attempt)[12] which may lead to hypotension and re-expansion pulmonary edema. Immediately post-procedure, POCUS may be used to evaluate for pneumothorax.

Complications include a "dry tap" without fluid return, pain, bleeding, infection, pneumothorax, and puncture or laceration of nearby structures, including lung, diaphragm, liver, spleen, or heart.

Paracentesis

Paracentesis is frequently performed to remove intraperitoneal fluid for both diagnostic and therapeutic purposes. Indications and contraindications are reviewed in **Table 5**. One randomized controlled trial saw 95% success with US guidance, compared to 61% using landmark-based technique. Furthermore, 25% of those randomized to the US group had paracentesis appropriately deferred due to insufficient ascites, and most patients who failed landmark-based paracentesis had a successful rescue procedure performed under US-guidance.[13]

Table 3
Indications and contraindications to thoracentesis

Indications	Contraindications
• Pleural effusion causing respiratory compromise. • Diagnostic thoracentesis to determine the etiology of a pleural effusion (less common in emergency settings.)	• Inadequate pleural fluid volume to safely perform a thoracentesis. • Skin or soft tissue infection at the planned site of needle entry. • Bleeding diathesis (eg, coagulopathy, thrombocytopenia) with unacceptable bleeding risk. • Positive pressure ventilation is a relative contraindication, increasing relative risk of pneumothorax; however, overall risk remains low.[10,11]

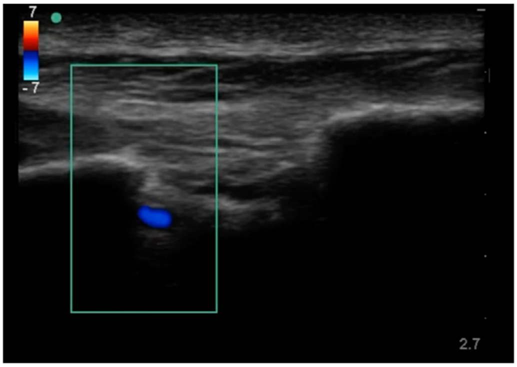

Fig. 3. Intercostal artery visualized at inferior border of rib using color Doppler US. The probe marker (*left side of image*) is directed cephalad. (*Photo Courtesy* of Ria Dancel, MD.)

Table 4
Dynamic and static thoracentesis techniques, describing procedural steps and pearls

	Technique	Pearls
Dynamic	• Use a curvilinear or phased-array probe to identify the optimal target. • Convert to a linear probe during the procedure to facilitate needle visualization. • Place the probe between and parallel to 2 ribs and introduce the needle in-plane, observing movement of the tip toward the target. • Appropriate needle positioning can be confirmed by visualization of the needle tip in the fluid collection, aspiration of pleural fluid, and observing bubbles in the pleural cavity following injection of a small amount of saline.	• Dynamic guidance is beneficial for smaller sized or loculated effusions, and in mechanically ventilated patients. • During aspiration, the fluid pocket may shrink visibly; the needle should be repositioned or withdrawn accordingly to avoid injury to surrounding structures.
Static	• Identify the target pleural fluid collection and mark the planned needle insertion site (eg, by indenting the skin with the cap of a needle) • During the US survey, note the following: ○ Angle of the US probe where the target was best visualized, and replicate this trajectory with the needle. ○ Distance from chest wall to the effusion, to predict the depth of needle advancement at which fluid should be aspirated. ○ Distance from the chest wall to nearby vital structures, to predict a maximal safe depth of needle advancement.	• Evaluate several rib spaces superior and inferior to the target due to expected shifting of anatomic structures during respiration. • Avoid any patient repositioning between the time the insertion site is selected and the procedure is performed.

Fig. 4. Measurements obtained during planning of US-guided thoracentesis, including distances from the chest wall to effusion (left caliper), and the chest wall to the lung (right caliper).

Technique

First use a curvilinear or phased-array probe to survey the abdominopelvic anatomy, then a linear probe to evaluate superficial anatomy. Important structures to localize include:

- Ascites and largest accessible pockets.
  - Initial survey for intra-abdominal fluid often begins with a right upper quadrant view similar to the focused assessment with sonography in trauma; however, in chronic ascites, fluid may not gather in Morison's pouch despite the presence of larger quantities located elsewhere.
  - Loculations or other fluid complexities should be noted.
  - While some cite 2 to 3 cm as a safely accessible fluid pocket, there is no literature-supported consensus, and the characteristics of a "safe pocket" vary depending on clinician experience and patient-specific factors.

Table 5
Indications and contraindications to paracentesis

Indications	Contraindications
• Diagnosis of spontaneous bacterial peritonitis or the etiology of a new presentation of ascites. • Removal of larger fluid volumes for patients with tense ascites causing respiratory impairment, mechanical obstruction, or pain.	• Bleeding diathesis with unacceptable bleeding risk; notably international normalized ratio (INR) correlates poorly to bleeding risk in patients with chronic liver disease and an INR threshold of 2.0–3.0 is considered acceptable in these patients.[14] • Abdominal wall infection at needle insertion site. • Co-morbidities increasing procedural risk (eg, bowel obstruction, ileus, prior abdominal surgery with suspected adhesions, gravid uterus). When paracentesis is required in higher risk patients, there is a particular benefit to US guidance.

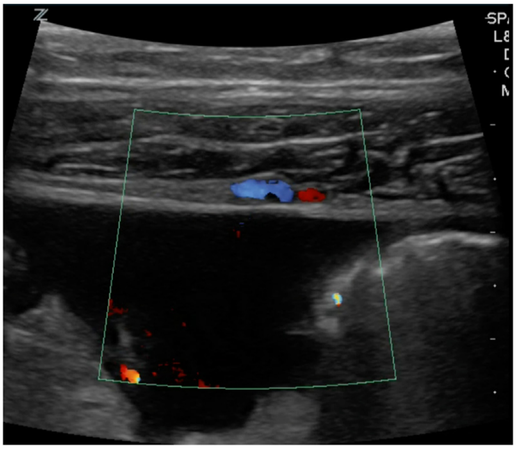

Fig. 5. Inferior epigastric artery and vein overlying an ascites pocket, seen on color Doppler assessment of abdominal wall.

- Surrounding vital organs, including bowel, stomach, and bladder.
  - Pleural or pericardial fluid collections may be mistaken as ascites, requiring careful assessment.
- Vasculature, using both B-mode and color Doppler US.
  - Inferior epigastric arteries, seen running longitudinally along the rectus abdominis sheath (Fig. 5).
  - Other vascular structures that may be dilated due to portal hypertension.

Table 6
Dynamic and static paracentesis techniques, describing procedural steps and pearls

	Technique	Pearls
Dynamic	• After an appropriate site is selected, use a linear or curvilinear probe with reduced depth to facilitate needle visualization. • Using an in-plane technique, continually visualize the needle tip as it enters the fluid collection (Figure 6).	• Dynamic guidance is advantageous for smaller volumes of ascites or when available insertion sites present anatomic obstacles. • A "heel-in maneuver" (pressing in with the side of the probe distal to needle) may augment needle visualization by directing the beam more perpendicular to the length of the needle.
Static	• Identify the target fluid collection and measure the distances (Figure 7) from the following ○ Skin-to-fluid collection: to predict depth of needle advancement at which ascites fluid should be aspirated, and where troubleshooting is required if still not aspirated. ○ Skin-to-nearest bowel loop: to predict a safe maximal depth of needle advancement. • Mark the planned needle insertion site (eg, indent skin with the cap of a needle)	• May be preferred by those who have challenges concurrently manipulating the US probe and needle. • Avoid any patient repositioning between the time the insertion site is selected and the procedure is performed, as intraabdominal structures (in particular bowel), shift with patient position.

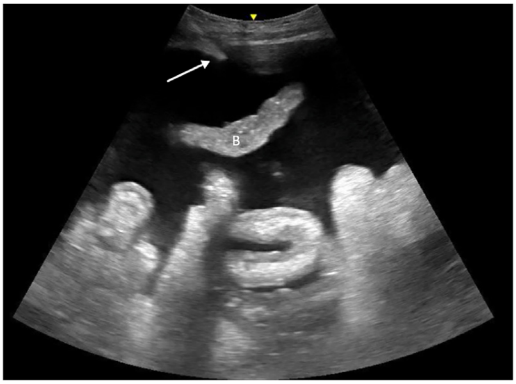

Fig. 6. Real-time ultrasound guidance of paracentesis with visualization of needle tip (*arrow*) entering fluid collection and adjacent loop of bowel (*B*).

Place the patient in a semi-upright and lateral oblique position to allow dependent fluid to gather in a safely accessible location. Assemble appropriate equipment including an 18-gauge or 20- gauge needle of appropriate length and a syringe, or a preconstructed paracentesis kit. Select the largest fluid pocket that allows needle access while avoiding any vasculature or important intraabdominal structures. If a full bladder is seen, ensure voiding prior to the procedure. A paracentesis may be performed under static or real-time US guidance (**Table 6**).

Reducing the risk of fluid leakage using a Z-track is recommended regardless of US-specific technique. With real-time guidance, the probe itself can be used to gently displace the skin relative to the peritoneal cavity. If drainage of larger volumes is required, a catheter may be placed via Seldinger technique.

Complications, even for blind paracentesis procedures, are uncommon and even more rare using POCUS.[15,16] They include inability to remove fluid, post-procedural bleeding (hemoperitoneum or abdominal wall hematoma), inferior epigastric artery injury leading to bleeding or aneurysm formation, infection (puncture site or peritonitis), bowel injury, and persistent ascites fluid leak.

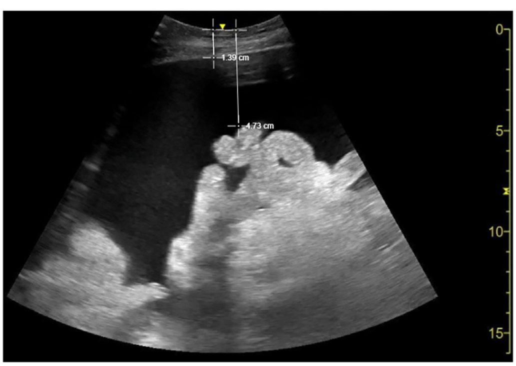

Fig. 7. Measurements obtained during planning of US-guided paracentesis, including vertical distances from the skin to fluid collection (left caliper) and the skin to the nearest bowel loop (right caliper).

Lumbar Puncture

Lumbar puncture (LP) is a frequently performed procedure used to remove cerebrospinal fluid from the subarachnoid space. Procedural indications and contraindications are reviewed in **Table 7**. The rates of unsuccessful first puncture and traumatic puncture are high.[17] Meta-analyses including LP in adults and children[18] showed that US assistance was associated with higher success rates, shorter time to successful LP, fewer traumatic taps, and decreased pain scores. However, a recent meta-analysis of randomized controlled trials performed in a pediatric population did not find an overall difference in success between US-assisted and landmark-based LP; POCUS did improve first puncture success in infants but not in older children.[19]

Table 7
Indications and contraindications to lumbar puncture

Indications	Contraindications
• Diagnostic evaluation for: ◦ Central nervous system infection (meningitis, encephalitis) ◦ Subarachnoid hemorrhage ◦ Idiopathic intracranial hypertension • Therapeutic drainage of cerebrospinal fluid in patients with neurologic symptoms resulting from idiopathic intracranial hypertension.	• Increased intracranial pressure due to a space-occupying lesion. • Infection near the planned puncture site or concern for spinal epidural abscess. • Bleeding diathesis with unacceptable bleeding risk.

Table 8
Procedural steps for midline and paramedian approaches to lumbar puncture

Midline Approach	Paramedian Approach
Identify the spinal midline: • Orient the probe in the transverse plane of the lumbar spine near the iliac crests. • Identify the *spinous process*, a small hyperechoic bony cortex with posterior acoustic shadow; several may be marked on the patient's skin. Identify the interspinous space: • Rotate the probe into a sagittal plane in the midline. • Starting at the level of the sacrum and sliding cranially, identify each spinous process (ie, S1 to L5 to L4), as well as the *interspinous spaces* between them. • Mark the targeted interspinous space(s) at L3–L4 or L4–L5. *Identify the needle insertion site* at the intersection of the marked spinal midline and desired interspinous space.	Consider this technique if the spinous processes are difficult to visualize using the midline approach. Identify the spinal midline: • Technique is the same as described using the midline approach, using an axial imaging plane to map several spinous processes. Identify the articular processes • Rotate the probe into a sagittal position in the spinal midline, slide 2–3 cm laterally, and angle toward midline. • The articular processes appear as echogenic humps, typically 2–3 cm deeper than the previously visualized spinous process. • These correspond to the interspinous spaces and can be marked at the desired level(s) at L3–L4 or L4–L5. *Identify the needle insertion site* at the intersection of the marked spinal midline and desired interspinous space.

Technique

A dynamic US-guided technique is limited by space constraints and more challenging needle visualization through bone. Thus, static US assistance is more commonly employed for preprocedural landmark identification and selection of an appropriate site for needle entry. Place the patient in a lateral recumbent or seated position with the spine flexed. Depending on patient habitus and the depth of the spine, a linear or curvilinear probe can be used. The 2 primary approaches to US-assisted LP are midline and paramedian (Table 8, Figs. 8 and 9).[20] It is essential that the patient remains in the same position following mapping of US landmarks. LP is subsequently performed at the marked site using usual sterile techniques.

Post-procedural headache and back pain at the procedure site are common complications of LP. Rarer complications include meningitis, spinal epidural hematoma, intracranial hemorrhage, and cerebral herniation.

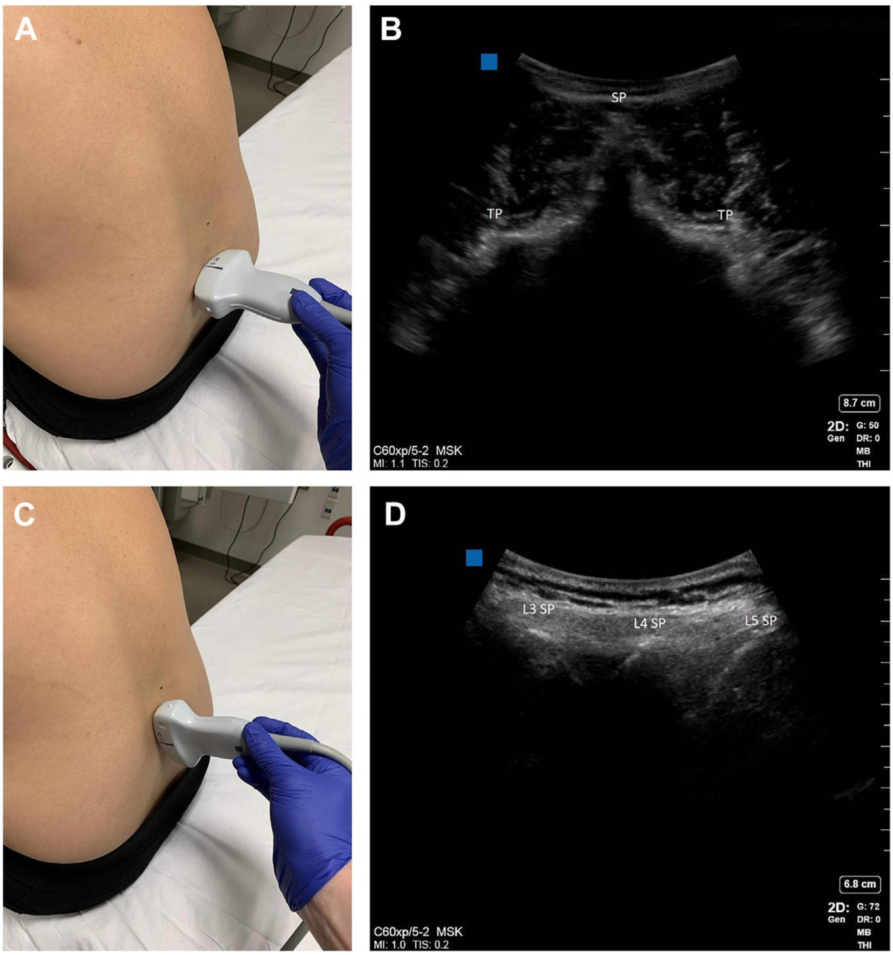

Fig. 8. Midline approach to lumbar puncture. (*A*) A curvilinear probe is oriented in the axial plane over the midline lumbar spine, generating (*B*) an US image visualizing the spinous process (SP) and transverse processes (TP). (*C*) The probe is rotated into the sagittal plane over the midline lumbar spine, generating (*D*) an US image of the SP of the L3–L5 vertebrae.

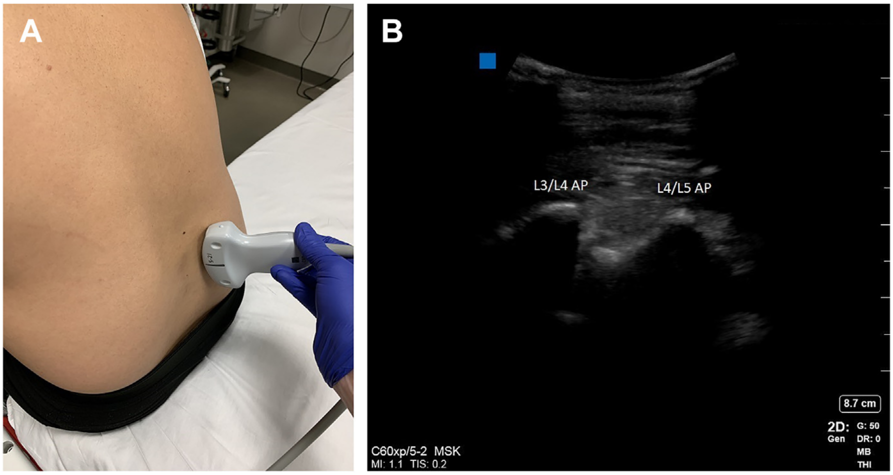

Fig. 9. Paramedian approach to US-assisted lumbar puncture. (*A*) A curvilinear probe oriented in the sagittal plane, 2 to 3 cm lateral to midline lumbar spine, tilted toward midline, creating (*B*) a paramedian US image of the articular processes at the L3-L4 and L4-L5 levels, corresponding to the interspinous spaces at these levels.

Vascular Access

Vascular access is a basic but essential intervention in the care of ED patients. Numerous studies support the benefit of US for placement of central venous catheters,[21] arterial lines,[22] and peripheral intravenous lines.[23] US increases the rate of success, and reduces the number of procedural attempts, time-to-cannulation, and complication rate, including pneumothorax, arterial puncture, and catheter-related infections.

Indications and contraindications

The indications and contraindications for performing US-guidance vascular access procedures mirror those using blind techniques. US guidance is considered a standard of care for central lines.[24,25] US may be particularly beneficial in patients at higher risk for procedural complications (eg, mechanically ventilated patients requiring central venous access, coagulopathy) and those with a history of difficult intravenous access.

Technique

Veins and arteries both appear anechoic but can be distinguished by several sonographic characteristics (**Table 9**).

The techniques for US-guided vascular access are analogous, whether the vessel accessed is a central vein, peripheral vein, or artery. Positioning is important for procedural success. The operator should ergonomically position the US machine so that both the targeted anatomic area and US monitor are within the same line of sight—often with the US machine on the opposite side of the bed. A linear probe is appropriate for most vascular access procedures. Dynamic needle guidance may be performed using either out-of-plane or in-plane techniques (**Table 10**).

Central venous catheterization

Internal jugular vein With the patient in a Trendelenburg position, place the probe on the lateral neck near the apex where the sternal and clavicular components of the

Table 9
Sonographic characteristics of veins and arteries

	Vein	Artery
Shape	Round/ovoid	Round
Vessel wall appearance	Thinner and less echogenic wall	Thicker and more echogenic wall
Compressibility	Easily compressed	Non-compressible
Doppler characteristics	Phasic flow, changing with respiration	Pulsatile flow, corresponding to heart rate

sternocleidomastoid muscle meet (**Table 11**). Identify the internal jugular vein (IJV) superficial and lateral to the carotid artery (**Fig. 10**). The patient's head may be turned 30° to 45° toward the contralateral side or maintained relatively neutral; POCUS may be used to determine the ideal head position where the IJV and carotid artery are maximally separated.[26] An out-of-plane technique may be preferred in patients with shorter neck length, as the amount of space to perform the procedure in-plane is more limited.

Table 10
Description of out-of-plane (short-axis) and in-plane (long-axis) approaches to vascular access and relative advantages and disadvantages

Out-Of-Plane (Short-Axis)	In-Plane (Long-Axis)
• Orient the probe perpendicular to the long-axis of the target vessel. • Identify relevant surrounding anatomy, including arteries, veins, and nerves. • Compress to confirm which visualized structures are venous; normal compression also confirms absence of thrombus. • Center the target vessel under the probe. • The needle punctures the skin at the center of the probe using a 30°–45° angle, depending on the vessel depth. • Once the echogenic needle tip is visualized, alternate advancement of the probe and needle to maintain visualization of the needle tip until it enters the vessel (Video 1).	• Survey relevant anatomy in short-axis. • Once the target vessel is identified, position the probe parallel to the long-axis of the vessel. • Fan/tilt the probe to assure the true center of the vessel is identified. • The needle punctures the skin in a plane parallel to the long-axis of the probe using a 30°-45° angle. • Shallower angles are more frequently used in the in-plane approach compared with out-of-plane; thus, a needle of adequate length must be selected. • Visualize the length of the needle from tip to shaft, advancing toward the target vessel and entering the lumen (Video 2).
Advantages • Permits simultaneous visualization of target and important surrounding structures (eg, arteries, veins, nerves). • Less technically challenging, particularly for novice operators. Disadvantages • Accurate visualization of the needle tip is more difficult, with increased risk of puncture through the posterior wall of the vessel.	Advantages • Continuous probe advancement is not required to visualize the needle tip continuously. Disadvantages • More technically challenging to maintain both the target vessel and needle in the same narrow plane as the US beam. • Limited view of surrounding structures.

Table 11
Advantages and disadvantages of the internal jugular, subclavian, and femoral sites for central venous catheterization

Approach	Advantages	Disadvantages
Internal jugular vein (IJV)	• Right IJV provides direct path to superior vena cava. • Lower risk of infection. • Easily compressible vessels if bleeding occurs.	• Risk of pneumothorax. • Not accessible if patient requires cervical collar.
Subclavian vein	• Less collapse even during hypovolemia. • Lowest risk of infection • Most comfortable for patient.	• Highest risk of pneumothorax. • Vessels difficult to compress if bleeding. • Catheter malposition more common.
Femoral vein	• Easier to access in patients requiring concurrent procedures (eg, chest compressions, intubation). • No pneumothorax risk. • Easily compressible vessels, preferred in coagulopathy. • Does not require Trendelenburg position (eg, for patients in respiratory distress).	• Highest risk of infection. • Highest risk catheter-related deep vein thrombosis. • Limits patient mobility.

Subclavian vein Access is often performed on the left side as it provides a more favorable angle to reach the superior vena cava. An infraclavicular approach is most commonly used. With the patient in a Trendelenburg position, place the probe in the infraclavicular fossa, first perpendicular to the clavicle to visualize the vein (more anterior) and artery (more posterior) (Fig. 11). US visualization of the subclavian vein (SCV) is challenging due to its position under the clavicle. Sliding laterally, to the intersection of the SCV and axillary vein, will improve visualization and provide the benefit of additional distance from the pleura. After the SCV is identified in short-axis, maintain visualization of the vein while rotating to a long-axis. Advance the needle in-plane at 30° toward the SCV, taking care to avoid the pleura. While SCV cannulation is preferably performed in-plane, the procedure may also be performed

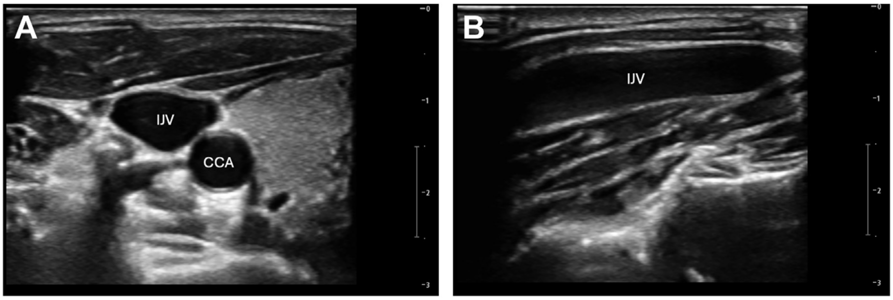

Fig. 10. Ultrasound views of the internal jugular vein and common carotid artery visualized in (*A*) short-axis and (*B*) long-axis.

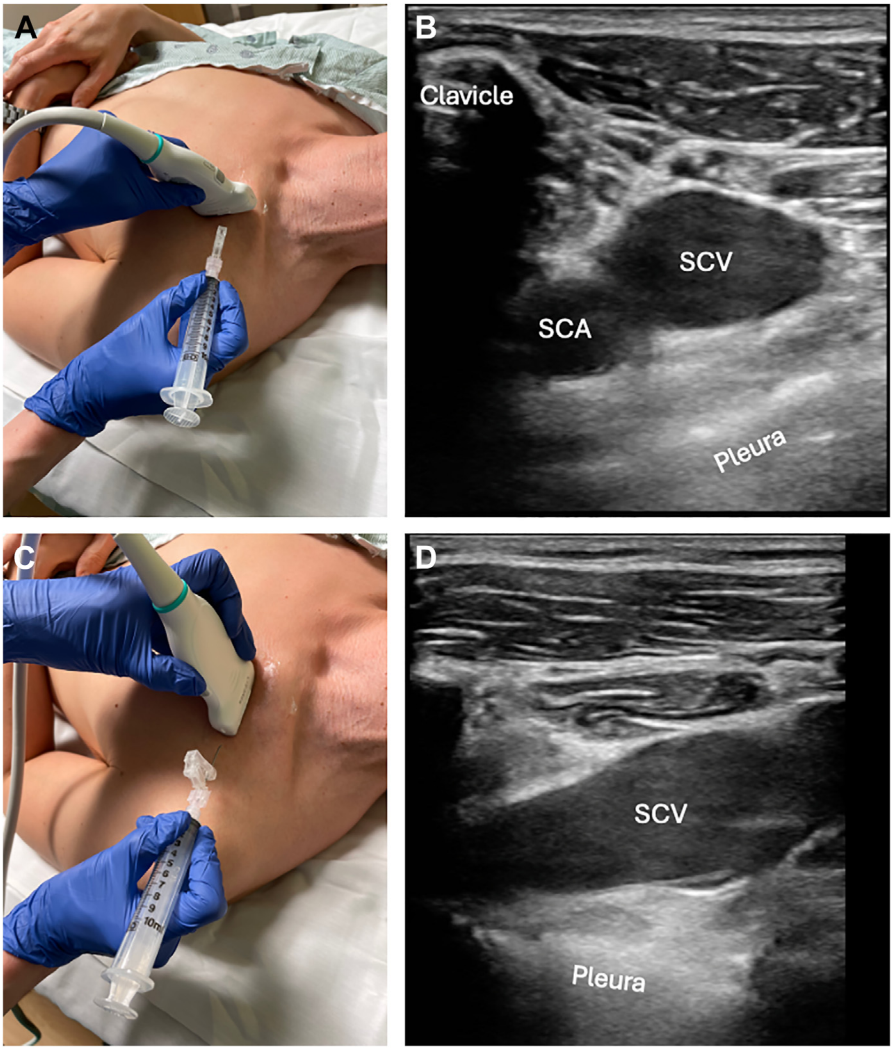

Fig. 11. Subclavian central venous access approaches using (*A*) out-of-plane technique (*B*) visualizing the clavicle, subclavian vein and subclavian artery in short-axis. (*C*) Using an in-plane technique, (*D*) the subclavian vein is visualized in long-axis.

using an out-of-plane approach. This allows concurrent visualization of both the SCV and artery.

Femoral vein *Femoral vein* cannulation is performed with the leg slightly abducted and externally rotated. Place the US probe near the inguinal ligament to identify the common femoral vein medial to the common femoral artery. An out-of-plane or in-plane approach may be used, depending on operator comfort.

Central line confirmation can also be performed using POCUS. Flushing IJV or SCV catheters with agitated saline should produce the rapid appearance of bubbles in the right atrium seen on a subxiphoid or apical view of the heart.[27] A thoracic US may then be performed to rule out pneumothorax.

SUMMARY

Ultrasound guidance is fundamental to procedural safety and success. For many ED procedures, the use of ultrasound improves first-pass success rate, time-to-completion, and complication rate when compared with traditional landmark-based techniques. Once learned, the general principles of ultrasound guidance may be adapted across a broad range of bedside procedures.

CLINICS CARE POINTS

- US guidance has been shown to increase success rate and decrease complications for many common and uncommon emergency medicine procedures.
- During US-guided pericardiocentesis, choose a parasternal, apical, or subxiphoid approach based on largest fluid pocket, shortest distance from chest wall, and absence of intervening vital structures.
- Procedural planning for US-guided thoracentesis includes dynamic localization of pleural fluid and key surrounding structures (lung, diaphragm, heart, liver, spleen), which shift with patient positioning and respiration.
- During paracentesis, dynamic US guidance is preferred for smaller volumes of ascites or when available insertion sites pose anatomic obstacles.
- Static US guidance is more often used for lumbar puncture, identifying the needle entry site at the intersection of the spinal midline and interspinous spaces.
- During US-guided vascular access procedures, continuous visualization of the needle tip, whether using an out-of-plane or in-plane approach, is the key to safety and success.

DISCLOSURE

The authors have nothing to disclose.

SUPPLEMENTARY DATA

Supplementary data to this article can be found online at https://doi.org/10.1016/j.emc.2024.05.012.

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