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REVIEW ARTICLE

Bedside ultrasound procedures: musculoskeletal and non-musculoskeletal

Lydia Sahlani[1] · Laura Thompson[1] · Amar Vira[1] · Ashish R. Panchal[1]

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Abstract The widespread availability of ultrasound (US) technology has increased its use for point of care applications in many health care settings. Focused (point of care) US is defined as the act of bringing US evaluation to the bedside for real-time performance. These images are collected immediately by the practitioner, allowing for direct integration into the physician's medical decision-making process. The real-time bedside diagnostic ability of US becomes a key tool for the management of patients. The purpose of this review is to (1) provide a general description of the use of focused US for bedside procedures; (2) specify the indications and common techniques used in bedside US procedures; and (3) describe the techniques used for each bedside intervention.

Keywords Ultrasound · Point of care ultrasound · Ultrasound procedures

Introduction

The widespread availability of ultrasound (US) technology has increased its use for point of care applications in many health care settings. The use of focused ultrasound for procedures, compared to other uses of ultrasound, has become quickly integrated into overall clinical practice. This is primarily due to the large impact on patient safety through the use of ultrasound guidance [1]. With the associated improved patient outcomes and efficiency with the use of point of care ultrasound, many specialties have now integrated ultrasound guidance in their procedures [2, 3].

Focused (point of care) ultrasound is defined as the act of bringing ultrasound evaluation to the bedside for real-time performance [4]. These images are collected immediately by the practitioner, allowing for direct integration into the physician's medical decision-making process. The real-time bedside diagnostic ability of ultrasound becomes a key tool for the management of patients particularly those who are critically ill and may not have access to advanced imaging modalities [2, 5]. As patient numbers and complexity increases, so is the need for practitioners able to perform procedural bedside imaging to serve these patients. US has emerged as a valuable tool in the performance of real-time bedside procedures and can facilitate needle placement in many indications including: vessel cannulation, fluid aspiration, musculoskeletal, and superficial skin procedures [4]. The use of US can help increase overall success rate, decrease time to completion, and decrease complications associated with common bedside procedures [6, 7].

The purpose of this review is to (1) provide a general description of the use of focused ultrasound for bedside procedures; (2) specify the indications and common techniques used in bedside US procedures; and (3) describe the techniques used for each bedside intervention. To satisfy this objective, a literature search for this review was conducted using PubMed, with a focus on "bedside ultrasound," "point of care ultrasound", and "ultrasound procedures" to obtain literature highlighting the best practices for practical use of bedside ultrasound utilizing a combination of scientific studies and review sources.

✉ Lydia Sahlani
Lydia.Sahlani@osumc.edu

[1] Department of Emergency Medicine, The Ohio State University Wexner Medical Center, Columbus, USA

Table 1 I-AIM clinical practice model for physician-performed focused US examinations (adapted courtesy of Bahner et al. [8])

I-AIM clinical practice model	
(I) Indications	Evidence-based Mechanism-based Scope of practice
(A) Acquisition	Patient (positioning, exposure) Probe (transducer type acoustic, medium, hand positioning) Picture (scan, knobology, image capture) Protocol (FAST, TRINITY)
(I) Interpretation	Identification of potential landmarks Echogenicity of structures, Pattern recognition
(M) Medical decision making	Clinical context Pretest probability Image analysis Physician interpretation

The model defines 4 aspects of bedside procedures: indication, acquisition, interpretation, and medical decision making

General concepts for bedside ultrasound procedures

Bedside US procedures refer to the use of portable US modalities to directly image a structure to allow for procedural intervention. These techniques can be divided into two groups: those that utilize US assistance or real-time guidance. US-assisted procedures refer to the confirmation of procedure location (target for procedure as well as surrounding structures) in a landmark-based approach using US. US assistance does not include continuous visualization of the target, and as a result, it is the less favored method. US-guided procedures refer to the continuous visualization of the needle path during the procedure. It is the preferred method for procedural techniques as the location of the needle and needle tip are continuously visualized.

Bedside US procedures demand a systematic approach to assure a high rate of success and patient safety. To satisfy this need, Bahner et al. described a general framework for the performance of US-guided procedures including the concept "I-AIM" (Table 1) [8]. I-AIM provides a mnemonic and checklist for the performance of US-guided procedures. The model describes that each procedure should be performed being mindful of four key aspects: indication, acquisition, interpretation, and medical decision making (Table 1). The I-AIM model provides a means to ensure appropriate use of US and is helpful when applied to all bedside procedures using ultrasound.

General principles: visualizing the needle for bedside ultrasound procedures

For US procedures, visualization of the structure and the relationship to the needle tip is crucial for success. The structure can be visualized in one of the two primary views: long and short. It can also be seen in an oblique view, which is a combination of long and short views. The US representation of the needle in these different views varies making recognition of the different orientations imperative.

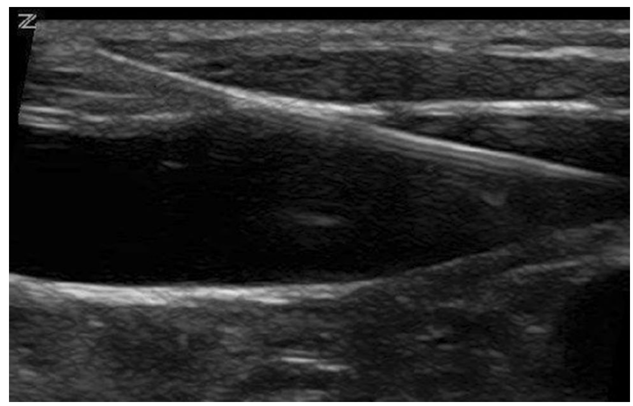

Fig. 1 Complete needle path and needle tip visualization in long axis vessel cannulation

Long axis refers to the "in plane" or longitudinal view of a structure. The needle is inserted in the same plane as the transducer and appears on the US screen as a linear structure. The needle can be visualized throughout the course of its entry with the US beam, to the structure of interest, without interruption (Fig. 1). It allows the advantage of visualizing the needle tip entering the vessel without moving the transducer. It is, however, technically difficult to perform. The US beam can slide off the target and needle tip, precluding visualization of both. The "ski lift" technique has been described in order to provide a systematic manner for placing the needle in long axis for vessel cannulation and allowing for visualization of the full needle length [9].

Short axis refers to the "out of plane" or transverse view of the structure. The needle is inserted out of plane (perpendicular) to the transducer and appears on the US screen as a "dot". The needle will only be visualized when the tip crosses the plane of the US beam. When the vessel is identified in short axis, the needle tip is introduced superficially underneath the skin, until it appears on the US image as a "dot". This is referred to as the "North Star" sign (Fig. 2). When the North Star sign is visualized, the needle tip location is verified. Then, the transducer is advanced (swept) distally along the length of the vessel until the needle tip is

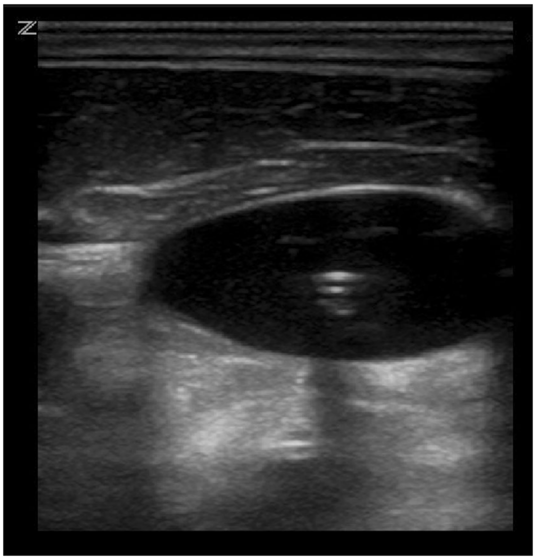

Fig. 2 Visualization of the needle tip in short axis cannulation. Notice the appearance of the needle tip as a "dot" which is referred to as the "North Star" sign

just out of view. When this occurs, the needle is advanced again until the needle tip (dot) is visualized. This is referred to as the "Leap Frog" technique and also described as the "vanishing target sign" [10]. The process is repeated until the needle reaches the vessel wall, and vessel cannulation is completed. In skilled hands, this is done fluidly with no interruption. The short axis view allows the advantage of visualizing the target as well as surrounding structures. Challenges in short axis technique include inability to follow the needle tip due to loss of needle tip visualization while advancing the transducer or by advancing the needle past the beam. Losing sight of the needle tip can result in damage to surrounding structures, and cause complications in vessel cannulation such as posterior wall penetration.

Oblique axis refers to another "out of plane" method but is a "cross angle" approach, which is a combination of transverse and longitudinal approaches [11]. This is not the primary approach when preforming bedside procedures. It is suggested that this view may be more advantageous in some vessel access techniques, though no studies compare the benefit of this specific view as compared to long or short axis views showing statistical difference in US-guided central venous catheterization exist [12].

Common focused bedside ultrasound procedures

As the use of US has become widespread, due to advances in both technology and economic considerations, the applications of focused US for bedside procedures have also expanded [4, 5]. Point of care US allows immediate assessment on a focused area that helps users to examine a particular organ to determine if a procedure is necessary. The operator can then use US guidance for the procedural attempt. This modality is especially useful in emergency situations as a diagnostic and therapeutic asset [13–15]. There are many procedures which specialists will use US for assistance with success. For example, specialists including anesthesia, cardiology, critical care, emergency medicine, endocrinology, gynecology/obstetrics, otolaryngology, and trauma surgery, to name a few, all have procedural applications of ultrasound pertinent to their medical specialty [4, 16]. Below, we review some of the most commonly used bedside procedures, including indications for performing each procedure as well as how to perform each procedure.

Vascular access (peripheral and central venous catheter)

Point of care US use in vascular access helps visualize peripheral and central veins, assess patency of vessels for access, allows for US-guided arterial puncture and cannulation, and minimizes number of access attempts [17]. US use for peripheral IV access has been shown to yield a high success rate in patients with difficult access [18]. Several studies have shown higher success rate of central venous catheter (CVC) placement under US guidance and with fewer associated complications [6, 19].

The procedural methodology followed for peripheral and central vessel cannulation using US is similar while the indications differ. First determine whether peripheral or central access is needed. The indications for peripheral vascular access include inability to obtain access by standard landmark methods or multiple unsuccessful attempts. The indication for CVC placement includes lack of peripheral access, need for hemodynamic monitoring, administration of medications, temporary cardiac pacing, hemodialysis, and apheresis catheter insertion. Contraindications to both peripheral access and CVC access include infection over the potential access site, pathologic process (such as vessel occlusion or scarring), and unfavorable anatomy (due to vessel location next to other structures of interest or trauma).

To acquire the image, a high-frequency (7–10 MHz) linear probe is used for vessel cannulation. This probe affords high-resolution images of superficial structures, such as vessels. The patient should be appropriately positioned for the procedure. Using internal jugular vein (IJ) CVC cannulation as an example, the patient should be placed in Trendelenburg with neck turned laterally to accentuate the anatomical distance between the IJ and carotid artery. The orientation of the probe is leading edge to the LEFT to ensure the movement of the probe and the needle correspond to what is visualized on the US image. Pre-procedure scanning is preformed to determine adequacy of the selected vessel for cannulation (Figs. 3, 4). During scanning, the vein and artery should be identified by noting the following: vessel wall thickness/shape (arteries are circular, thick walled), compressibility (arteries are non-compressible), and vessel pulsation (arteries are pulsatile). If uncertainty exists, vessel wave form evaluation via Doppler can be obtained to differentiate arterial and venous flow patterns.

Once the vessel of interest is identified and deemed to be adequate for cannulation, draping and preparation of cannulation begin. The standard sterile prep and draping techniques are performed including sterile prep of the US probe using a probe cover and gel. The IJ is then re-identified, confirming position of the vessel. The probe is manipulated until the IJ is centered on the screen, noting the relationship with structures of interest, in this case the carotid. The needle is then visualized using either Long or Short axis view to follow the needle tip and ensure appropriate vessel cannulation is achieved (Figs. 1, 2). A combination approach, using the short axis view to visualize the needle tip until it reaches the anterior vessel wall and then using the long axis view by rotating the probe to an in plane view to follow needle path to cannulation without posterior vessel wall puncture, is ideal. This approach allows for the advantages of both short and long vessel cannulations, while limiting the challenges encountered by each technique in isolation. An alternative method is oblique axis cannulation.

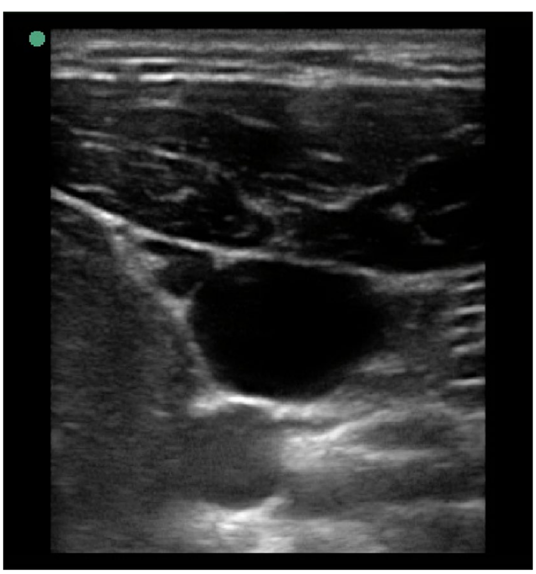

Fig. 3 Ultrasound evaluation of the internal jugular vein. The image shows the internal jugular vein and the carotid artery in the short axis (*out of plane*) view

Fig. 4 Ultrasound evaluation of the internal jugular vein. The image shows the internal jugular vein in the long axis (*in plane*) view

Fluid aspirations: thorax and abdomen

Thoracentesis

Indications for thoracentesis include diagnostic or therapeutic pleural effusion drainage. Complications of the procedure include pneumothorax, liver or spleen injury, or hematoma. The risk of complication, such as pneumothorax, is reduced using ultrasound guidance [20–22]. The diagnosis of pleural effusion is improved using ultrasound when compared to physical exam, and even small effusions can be tapped if needed. A low-frequency (3.5–5 MHz) curvilinear probe is appropriate for this procedure, as it allows deeper structures to be more adequately visualized.

The following technique is utilized to obtain access to the thoracic fluid pocket for the interventional procedure and to complete drainage using US guidance. US guidance is helpful in cases of small amount of fluid or loculated fluid collections. It is easiest to have the patient sitting in an upright position, making the pleural effusion dependent, and displacing the lung. In some instances, such as in a ventilated patient, where patient is in a supine position, the use of ultrasound becomes crucial in identifying the location of pleural fluid and avoiding complications. Studies have shown the feasibility, safety, and efficacy of accessing the pleural space with the patient supine, using ultrasound guidance [23, 24]. US was also shown to identify drainable effusions even in cases of effusions not seen on radiographic images [25]. The patient's head of the bed should be elevated and arm extended to help increase the dependent area of fluid and allow for wider rib spaces [26].

The area is sterilely prepped and the probe is covered with a sterile cover. At the midaxillary line, above the liver or spleen depending on the side of the effusion, an anechoic space should be visualized with lung floating in the fluid. The probe is placed at the site of insertion after sufficient local anesthesia is obtained, and the needle tip entering the chest wall tissue is visualized. Advance the probe and then advance the needle, watching the needle until the tip has entered the pleural cavity and fluid is returned. Place a pigtail catheter or chest tube as needed. Alternatively, ultrasound assistance can be used to demarcate the area where a fluid pocket exists, and is most often used in patients where there is a large effusion. The area of fluid just above the lower rib should be marked, and the distance between the transducer to the fluid pocket should be noted. The procedure is then completed after the site has been marked. US can then also be used to diagnose complications such as pneumothorax following the procedure [26]. Figure 5 shows a thoracic fluid collection using US.

Peritoneal aspiration

Indications for peritoneal aspiration include abdominal pain with ascites, therapeutic drainage of abdominal fluid, and diagnosis of hemoperitoneum. Complications of the procedure include infection, bowel perforation, intraperitoneal hemorrhage, and abdominal wall hematoma. Complications can be decreased and success rate increased when US is used as compared to a blind approach [2, 21, 27]. US-guided peritoneal aspiration is performed using standard safety precautions to prevent infection. Use of a low-frequency (3.5–5.0 MHz) curvilinear probe is appropriate.

Following a systematic approach, the patient is placed in a supine position, and the patient's abdomen is scanned to identify fluid within the peritoneal cavity while making note of potential impediments to the needle path, such as the bladder, bowel, solid organs, and the pregnant uterus [28, 29]. Figure 6 shows fluid within the peritoneal cavity. After the site has been sterilely prepped and a sterile cover placed on the US probe, an area of anechoic fluid is identified, most often in the lower abdomen. The most common site is about 2 cm below the umbilicus. It is sometimes helpful to empty the bladder prior to the procedure as a large bladder can result in more confusing images. Local anesthesia is injected at the site of planned needle insertion. The needle is inserted in the field visible by the ultrasound probe and followed by advancing the probe before the needle to ensure that the tip of the needle is always visible using North Star and Leap Frog techniques. The needle should be advanced under direct US guidance until it enters the peritoneal cavity and fluid returns. After a sufficient volume of fluid is obtained for testing or treatment, the needle is removed. The site can be dressed with a band-aid or other adhesive dressing with gauze.

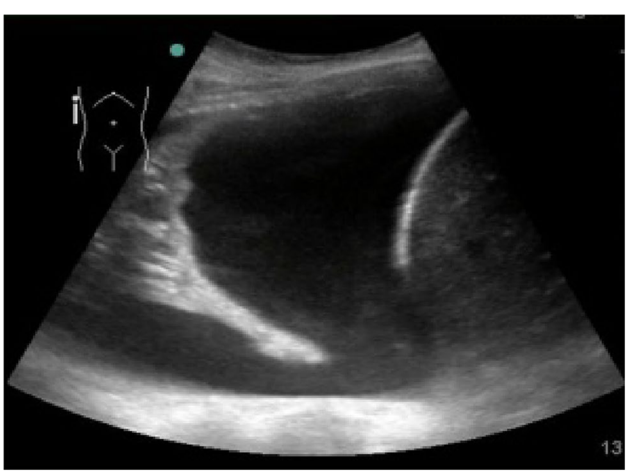

Fig. 5 Thoracic fluid collection. A pleural effusion is imaged prior to thoracentesis

Fig. 6 Fluid Collection for Paracentesis. The needle is visualized entering the peritoneal space for collection of fluid in the short axis (*dot in the middle of image*)

Pericardiocentesis

Pericardial effusion and resulting pericardiocentesis should be considered in patients with undifferentiated hypotension, history of trauma, malignancy, prior pericardial effusion, or recent myocardial injury. For example, in trauma patients where the Focused Assessment with Sonography for Trauma (FAST) application of bedside ultrasound is utilized, hemopericardium coupled with finding of hypotension without other explanation, such as pneumothorax, can indicate the need for pericardiocentesis [30, 31]. In these patients, a small effusion can lead to hemodynamic instability, requiring prompt identification and treatment for stabilization. There is a high degree of sensitivity and specificity using US for pericardial effusion detection, and decreased complications as compared to pericardiocentesis without ultrasound use [32]. Complications of this procedure, depending on the approach taken, include infection, inability to obtain fluid, pneumothorax, liver injury, and myocardial puncture. The rates of complication are decreased using an ultrasound-guided approach, and diagnosis of pericardial effusion is significantly improved using US when compared to physical exam alone [33, 34]. US assistance has also been successfully used for pericardiocentesis [35].

A phased array (2–4 MHz) cardiac probe is preferred given its small footprint as well as resolution for cardiac structures. The patient is placed in a supine position, and the heart is imaged from the subxiphoid view and the parasternal view. The sonographic view with the largest fluid pocket closest to the probe should be used for the procedure. Figure 7 shows a pericardial effusion using US. Using a long axis view, visualize the needle tip and advance the view of the probe in front of the needle, prior to advancing the needle further. Continue to advance the needle while visualizing the needle tip until the pericardial sac is reached and fluid return is achieved. If the anterior chest wall is a reasonable approach based on sonographic images, it reduces the risk of liver injury.

Musculoskeletal joint aspirations and injections

Arthrocentesis is an important bedside procedure to evaluate synovial fluid for both diagnostic and therapeutic indications. This procedure should be performed under standard sterile precautions, which include sterile prepping of the skin, draping and personal protective equipment, and sterile covering of the US probe. Care must be taken to prevent infectious inoculation of the joint.

For most indications, using a high-frequency (10–15 MHz) linear probe will provide the best resolution and visualization of the joint space [36]. After using US to identify the joint space of interest, it can be used to guide the needle into the joint space and visualize the fluid pocket for aspiration or injection into the joint space.

Knee

There are multiple recesses in the knee joint, but the suprapatellar recess is largest synovium lined pouch and is an extension of the knee joint [37]. This recess is located at the anterior distal femur just proximal to the patella and is where the deepest fluid collection will be found when an effusion is present. The patient should be placed in the supine position, with the knee slightly flexed. The effusion is located in both a longitudinal plane and transverse plane either medial or lateral to the midline to identify the best position to introduce the needle. A fluid collection is seen in Figs. 8, 9. Real-time guidance should be used with the probe in plane in the long axis to visualize the needle enter the recess. Once in this space, synovial fluid can be aspirated and medications such as local anesthetic or steroid can be injected.

Ankle

The anterior synovial recess is the most accessible aspect of the ankle joint and avoids important medial structures such as the dorsalis pedal and posterior tibial vessels and the deep peroneal nerve. The ankle should be in the supine position with the ankle in plantar flexion. A linear probe should be used in the sagittal plane over the anterior distal tibia. A “V” shaped recess will appear as the probe is slid distally, with the proximal hyperechoic line being the distal tibia and the distal hyperechoic line being the dome of the talus [37]. Real-time guidance should be used in long axis to visualize the pass through the joint capsule. Once in this space, synovial fluid can be aspirated and medications injected. Figure 10 shows an example of an ankle effusion, prior to aspiration of fluid for testing.

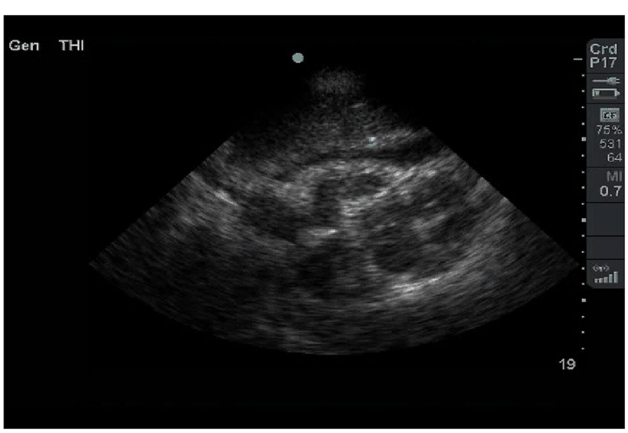

Fig. 7 Subxiphoid view of the heart demonstrating pericardial free fluid with needle tip visible in the near field

Fig. 8 Left knee effusion, visualized in short axis

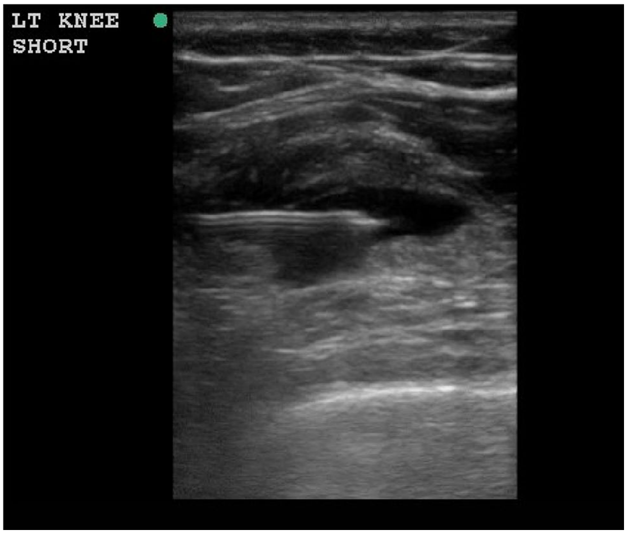

Fig. 9 Left knee effusion, visualized in the long axis. A needle is inserted to drain the effusion

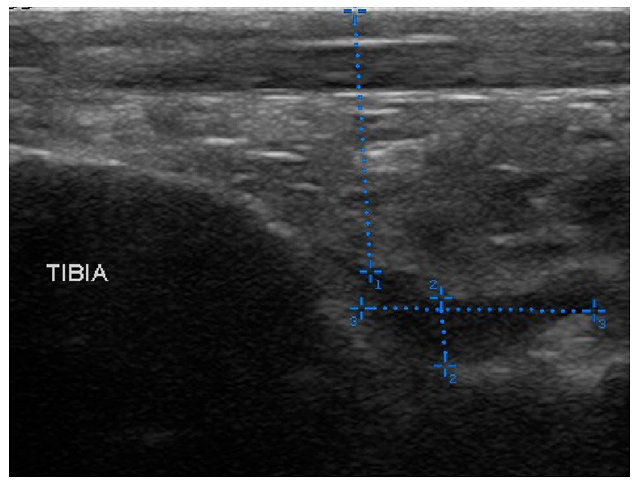

Fig. 10 Right ankle effusion visualized at the tibio-talar joint prior to collection for testing

Nerve and tendon blocks

Nerve and tendon blocks encompass a wide variety of procedures that can be enhanced by the use of US assistance and guidance. Preforming the blocks requires a thorough knowledge of anatomy to determine the optimal injection site and the optimal orientation to direct the needle to the accurate target. Nerves and tendons tend to have other important structures in their vicinity that need be avoided (Fig. 11).

A large number of nerve bundles can be anesthetized using ultrasound to aid in procedural anesthesia or decrease the use of intravenous analgesics for pain control. In general, a high-frequency (10–15 MHz) linear probe should be used to visualize superficial nerves and tendons, while a low-frequency (5–10 MHz) curvilinear probe should be reserved for deeper structures, such as the femoral nerve [38]. Common tendon blocks and injections that are performed include distal flexor tendon for trigger finger; peroneal, patellar, biceps or triceps tendon for tendinopathy, first dorsal compartment of the wrist for DeQuervain's disease. Common nerve blocks include brachial plexus, interscalene, radial, median, ulnar, femoral, or peroneal nerves [37].

Tendons appear as linear hyperechoic structures and should be visualized using US along the entirety of tendon to find the safest place for injection. Special attention must be taken to recognize surrounding nerves or vessels that appear hypoechoic tubular structures. Nerve bundles will appear as a bundle of hypoechoic structures relative to the surrounding tissue; however, as the nerve travel more distal, they will be more hyperechoic internally and a dominant fascicle may be seen. Color or power doppler may be used to distinguish between a vessel and nerve or tendon (Fig. 12).

The procedure should be performed under sterile conditions in the transverse view of the nerve, so the needle tip can be visualized in long axis under the tendon or nerve sheath and ensure anesthetic is not injected intra-tendon or intra-neural. Medications typically used for blocks include lidocaine, bupivacaine, and ropivacaine; special attention should be made to bupivacaine with can be cardiotoxic if injected intravascularly [39]. An ulnar nerve block, a common forearm block, can be used as an example of nerve block. The patient's affected extremity should be held palm up, resting on a hard surface. The volar surface of the forearm should be systemically scanned, starting distally as in Fig. 12, locating the pulsatile ulnar artery, which can be confirmed by Doppler (Fig. 13). Sweeping the probe distally allowed detection of the nerve at a location adequately spaced from the ulnar artery. The ulnar nerve can be blocked at the wrist, forearm, and just proximal to the elbow. This reduces risk of arterial puncture. When the appropriate location for nerve anesthesia is located, the area is prepped in sterile fashion, and a wheal of anesthetic is placed over the skin entry site. A needle with lidocaine filled syringe is used. Once the target ulnar nerve is located on ultrasound, the needle is introduced on the ulnar side of the probe, in long axis view, and continuously visualized until it approaches the ulnar nerve. There should be no nerve penetration. When the site is visualized, draw back on the syringe to ensure the needle is not in a vessel. Next, anesthetic is slowly injected, creating an area of anechoic fluid around the nerve border. If the patient experiences pain or paresthesias, the needle should be withdrawn, as this could indicate intra-neural injection. The injection of anesthetic is continued until a "donut" shape is formed around the vessel. Most forearm nerve blocks can be accomplished with 10 mL or less of anesthetic agent.

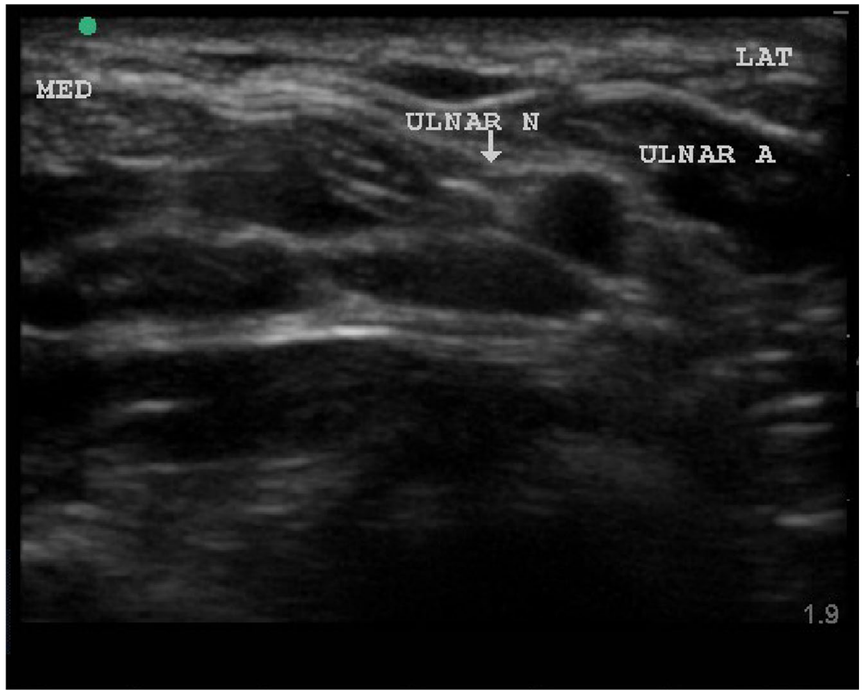

Fig. 11 US of the ulnar nerve and surrounding structures prior to nerve block. US can be used to localize structures when preforming a nerve block, paying special attention to surrounding structures that could be damaged by the injection of anesthetic

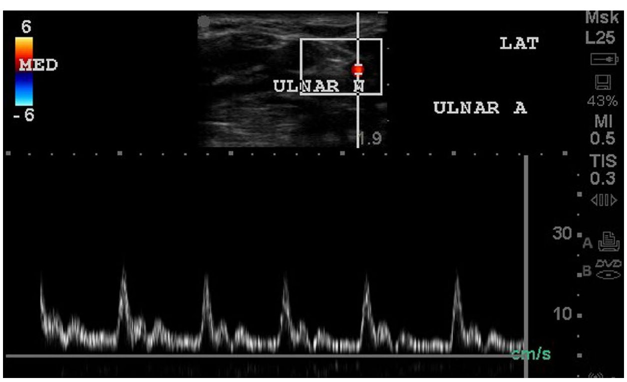

Fig. 12 US can be used to verify surrounding structures, such as arteries, that should be avoided during injection of anesthetic

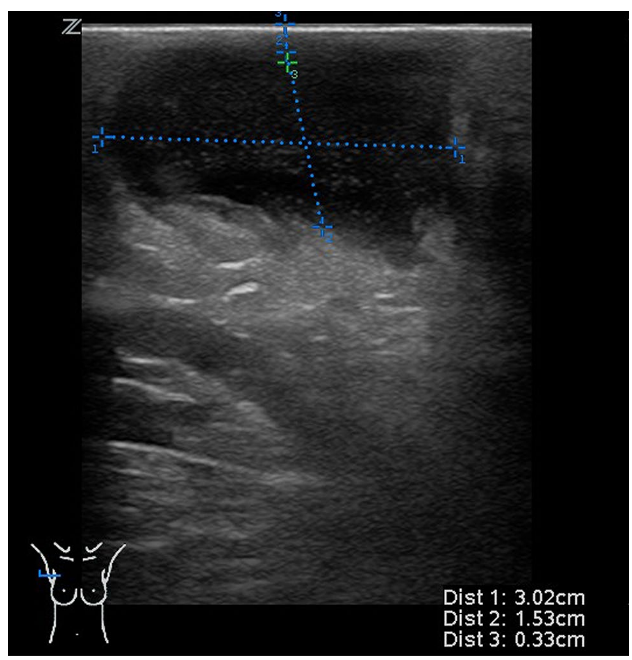

Fig. 13 Right anterior chest wall abscess characteristics visualized and measured via US. Measurements of skin abscess and abscess size help guide I&D procedures

When the anechoic area around the nerve is achieved, the needle can be withdrawn, and a dressing placed over the entrance site. Anesthesia should be assessed by asking the patient if they can feel a sharp object after approximately 10- to 15-min post-procedure. Using lidocaine should provide sufficient anesthesia for 30- to 60-min duration.

Superficial skin procedures

Skin abscess

US can be used to identify anechoic fluid pockets in soft tissue structures. Studies have shown that US enhances the ability to detect abscess as compared to the physical exam alone and thus changes clinical management in some patients with clinical cellulitis [40–42]. Deeper abscesses can be imaged with a low-frequency probe (5 MHz) but superficial abscesses are best imaged using a high-frequency (7.5–10 MHz) linear probe. After identifying surrounding structures and obtaining sufficient local anesthesia, the probe is aimed anterior to the site of the scalpel entering the tissue. The scalpel should follow the ultrasound probe, keeping the tip in view at all times until the fluid pocket is entered. The incision can then be lengthened if needed and the abscess drained, breaking up loculations as necessary. Often times, US assistance is utilized in simple abscess drainage. The site can be marked using ultrasound, and then later drained, as seen in Fig. 13.

Peritonsillar abscess (PTA)

The use of US can help differentiate peritonsillar abscess from peritonsillar cellulitis and avoid the need for blind needle aspiration of the tonsillar fossa [43–46]. Similar to an abscess incision and drainage, the anechoic fluid pocket in the tonsil should be identified. Utilizing US for PTA drainage can be challenging, given the extent of trismus a patient may have and the need to place the US probe and needle into the patient's oropharynx for drainage. Therefore, it is important to ensure patient comfort. Adequate topical anesthesia and overall pain control can help. An endoluminal probe provides the best images. The size and depth should be measured, and surrounding structures should be identified prior to the procedure, with particular attention to the location of the carotid. An example of a PTA is seen in Fig. 14. With the patient seated upright, after adequate pain control has been achieved, a needle is inserted into the fluid pocket using a needle guard to prevent penetrating deeper structures, including the surrounding vasculature. When the purulent material is aspirated, the needle is removed.

Foreign body (FB) removal

US can be utilized to detect radiolucent soft tissue foreign bodies and decrease complications associated with blind exploration. US is effective at identifying foreign bodies that are radiolucent, including wood or plastic, and has been shown to be an accurate tool for detection and removal of FB that can be difficult to visualize using routine radiography [47–49]. Use of a high-frequency (7–10 MHz) linear probe is generally most effective for finding foreign bodies in soft tissue. Once the FB is located, the probe is placed directly above it to aid visualization. Relationships to surrounding structures, including vessels or anatomic landmarks, should be noted. After sufficient anesthesia is obtained, follow the hemostat tip in a manner similar to following the needle tip in other US-guided procedures until the hemostats are able to reach and remove the foreign body. Figure 15 shows a metallic FB using US.

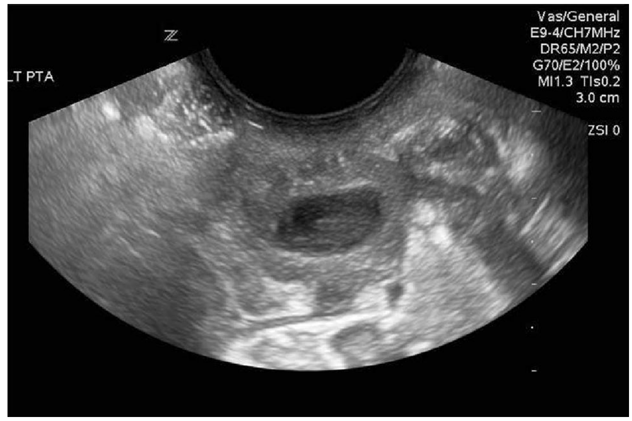

Fig. 14 Left peritonsillar abscess identification using US

Biopsies

Ultrasound guidance can also be used for biopsies of different organs or tissues. Some common examples include liver, thyroid, prostate, and breast biopsies; however, any tissue with a clear line of site by ultrasound is a possible candidate for biopsy. The primary concern in the decision making process is the presence or absence of vascular structures in the area of interest. For example, one of the complications of thyroid biopsies is damage of the superior thyroid artery [50, 51]. Thorough assessment of this must be done prior to any procedure. This includes thorough video sweeps in the area in all plane and evaluation of vascular structures with power Doppler. When conducting the procedure, it is most important to keep track of the needle tip throughout the entirety of the procedure, demanding that the procedure be done in plane and not in the oblique or out of plane [50–52].

Lumbar puncture

US can be used in lumbar puncture (LP) procedures to assist with localization of landmarks as well as help in patients that have had multiple failed LP attempts. Certain patient attributes, such as obesity, pregnancy, arthritis, scoliosis, and prior back surgeries, can make anatomic landmarks difficult to palpate. Using US to define the correct lumbar level as well as anatomic midline creates a systematic approach to an otherwise blind procedure [53]. A randomized control trial showed increased success using US versus palpation alone in preforming LP on obese patients [54]. A low-frequency (3.5–5.0 MHz) curvilinear probe is preferentially used, as it is most helpful for identifying anatomy on obese patients.

The patient is seated in an upright or lateral decubitus position, based on physician preference. With the leading edge cephalad, the probe should be swept laterally until the

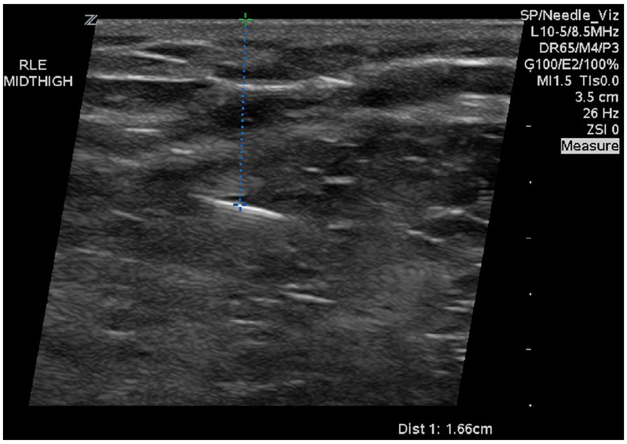

Fig. 15 A linear, hyperechoic FB is visualized in the right thigh of a patient. Measuring tools can be used to determine depth to retrieval as well as object size

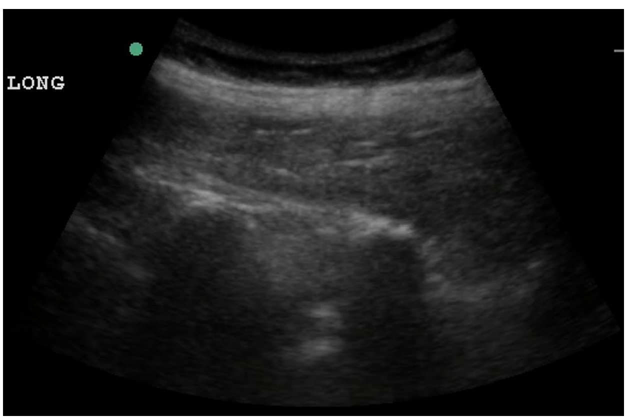

Fig. 16 The articular processes appear as "humps" on US. Visualizing the sacrum allows for identification of L5–S1, L4–5, and L3–4 for LP procedure landmarks

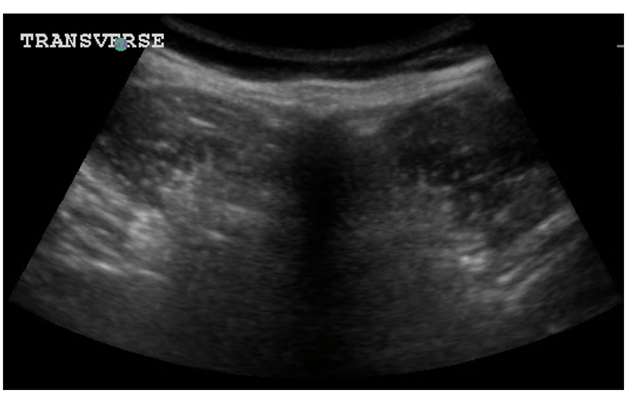

Fig. 17 Marking the location of the spinous process allows identification of midline in preforming an LP

facet joints are noted. These will appear as humps (Fig. 16). Slide the probe caudad until the sacrum is visualized. Mark the L3, L4 facet joints on the skin surface (correspond to L3–L4; L4–L5). The probe is than rotated to the patient's left in order to identify true midline by marking the location of the spinous process (Fig. 17). Connecting the markings at L3–L4, L4–L5, and the true midline will provide the location for LP needle insertion. Standard LP technique should then be followed. It is important that the patient maintain similar position during marking and the procedure, so that the anatomical relationships are maintained.

Conclusion

Point of care ultrasonography can be utilized to increase success and decrease complications associated with a variety of US-assisted and guided bedside procedures. Employing systematic approaches as highlighted in this review can aid the practitioner in performance of ultrasound-guided and assisted procedures.

Conflict of interest Lydia Sahlani, Laura Thompson, Amar Vira, and Ashish Panchal declare that they have no conflict of interest.

Compliance with ethical requirements This article does not contain any studies with human or animal subjects performed by any of the authors.

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