# Ultrasound: Why Should I Use It in My Practice?

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Over the last 10 years, ultrasound has become more widely used in several clinical arenas germane to anesthetic practice. There are several reasons why this has come about. An abundance of clinical research has reported numerous advantages of using ultrasound in perioperative patient care. As well, improvement in ultrasound machines have led to better imaging, friendlier user interfaces, and improved portability through a reduction in size and weight making them more attractive to use. Ultrasound, in the minds of many anesthesiologist-sonographers, has become an indispensable tool in their clinical practice tool box. They simply could not imagine going to work and not using ultrasound as an integral part of patient care. This is perhaps best reflected by the rising trend in residency programs that have integrated ultrasound use in a variety of forms into their clinical training programs.

So for the clinician who practices anesthesia without ultrasound, why use it? As with any new medical device, there are drawbacks, healthy suspicions that it does not do what it claims it can do, and limitations that merit discussion. Nevertheless, the purpose of this review will be to make a case for using ultrasound. It will be directed at clinicians who are relatively unfamiliar with ultrasound, but are considering its use in their practice. As examples, it will focus on three areas of ultrasound use that have enjoyed increasing popularity among anesthesiologists. These include ultrasound-guided placement of nerve blocks and central venous access, and ultrasound visualization of cardiac function outside the cardiac operating room suite.

## ULTRASOUND-GUIDED NERVE BLOCKS

Ultrasound has become increasingly popular in the placement of nerve blocks and catheters. It has been successfully used for placement of upper extremity [supraclavicular (1–3), infraclavicular (4–10), axillary (11–13), interscalene (14)] and lower extremity [femoral nerve (15,16), popliteal fossa/sciatic, tibial, and common peroneal nerves (17–22), and saphenous nerve (23)] nerve blocks and catheters.

Effective use of ultrasound requires a working understanding of imaged anatomy, how different tissues appear on ultrasound, and how to properly adjust ultrasound machine settings and manipulate the ultrasound probe (24). Nerve tissue can take on a variety of forms when imaged with ultrasound to include an echogenic (white) solid appearance, fascicular echolucent (black) appearance surrounded by echogenic connective tissue, or as a cluster of fascicles grouped together that have a "cluster of grapes" or "honeycomb" appearance. For example, nerves within the brachial plexus from the interscalene groove to the supraclavicular region have a honeycomb appearance. However, imaging of nerve tissue in the infraclavicular region, the posterior, medial, and lateral cords of the brachial plexus are more commonly echogenic as they travel alongside the axillary artery into the axilla.

A few points to consider when imaging nerves: 1) nerves are continuous and run through muscle and fascial planes or neurovascular bundles. Scanning along the pathway of a nerve should provide a relatively continuous visualization of the nerve. Tissue that may look like nerve such as tendon will not be continuous as it inserts into either muscle or bone (24). 2) Small movements of the probe that change the ultrasound beam angle can be used to better visualize subtle echogenic features of nerve tissue. This phenomenon is called anisotropy. Tendons, however, are even more echogenic with anisotropy and may be mistaken for nerve (25,26). Recent advances in ultrasound technology have led to the implementation of image compounding, a image pre processing technique that has substantially improved ultrasound image quality and minimizes the impact of anisotropy artifact allowing clinicians to better differentiate tendon from nerve (27,28). 3) Nerves are not always readily visualized, however, other structures known to be adjacent to nerves of interest are almost always easily visualized (i.e., the axillary artery when performing an axillary block). At times nerves do not become apparent until local anesthetic is injected where they are presumed to be. With the injection of local anesthetic, previously unrecognized nerves can appear to be "floating" within the injected fluid.

One of the potentially challenging tasks with ultrasound-guided nerve blocks is visualization of the needle. Orientation of the ultrasound probe to the site of needle entry plays a major role in needle tip visualization. Ultrasound probes used for nerve block placement typically generate a linear beam that generates an image that is approximately the width of the probe. There are two approaches to needle placement in relation to the ultrasound beam. With the first approach, needle entry is at the center of a linear array probe with a slight angle of entry so that the tip of the needle will cross through the ultrasound beam once underneath the skin. With this approach, tracking the needle tip can be difficult once the needle has passed through the ultrasound beam. Gentle movement perpendicular to the ultrasound beam may be useful in tracking needle advancement within the ultrasound beam. In the second approach, the needle enters the skin at an angle to the side of the linear array probe. With this approach, the needle remains underneath the probe and within the ultrasound beam allowing continuous visualization of the needle.

Eighteen gauge needles, often used for nerve catheter placement, are relatively easy to visualize within an ultrasound image. By contrast, 22-gauge needles can be difficult to visualize especially when using the first orientation of needle entry in relation to the ultrasound probe. Often identification of needle location is by observing movement of tissue in the needle path. To better identify needle location, injection of small amounts of fluid (saline or local anesthetic) can be used to expand tissues around the tip of the needle (hydrodissection). This technique should be used with caution to minimize the amount of air that injected through the needle. Air is highly echogenic and small volumes can lead to significant disruption of ultrasound imaging deep to the injected air.

### Sonographic Technique

As an example of sonographic technique to place a nerve block, consider an approach to ultrasound-guided placement of an interscalene nerve catheter. It is important to recognize that there are many approaches to ultrasound-guided needle placement. With any approach, it is imperative to have an in depth understanding of key anatomic structures (i.e. location of arterial vessels, pleura, brachial plexus, etc) and their relationship to important landmark tissues within the ultrasound image (i.e., anterior and middle scalene muscles, bone, etc) and have a solid grasp of the spatial orientation of the ultrasound beam and needle trajectory in relationship to these structures.

For beginner sonographers, a useful approach is to identify a "home base" that represents an ultrasound image that is reproducible and easily obtained. For the brachial plexus, one such view is found when placing the ultrasound probe parallel and superior to the clavicle and perpendicular to the patient. This probe placement provides a short axis view of the subclavian artery as it passes underneath the clavicle. Posterior and cephalad to the subclavian artery is the brachial plexus. At this location, it appears as a group of echolucent fascicles surrounded by connective tissue giving it a honeycomb appearance. Moving the ultrasound probe up the lateral aspect of the neck (aiming the probe toward the base of the neck) brings into view the sternocleidomastoid muscle (clavicular head) and the anterior and middle scalene muscles (Fig. 1). As the transducer is moved up the neck, visualization of the brachial plexus at times can be lost. Keeping the plexus in the center of the ultrasound image is often useful to maintain visualization of the nerve fascicles while moving the probe.

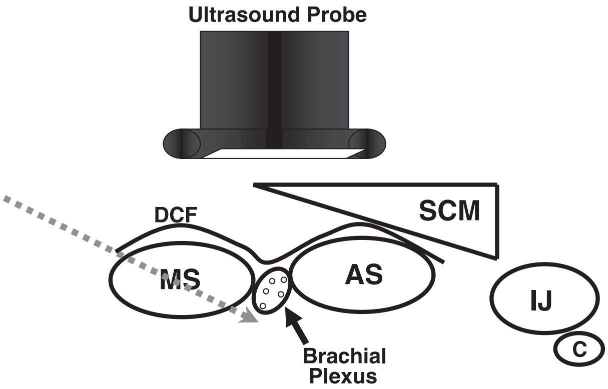

**Figure 1.** Schematic illustration of the brachial plexus at the level of the interscalene groove as visualized by ultrasound. SCM, MS, and AS represent the sternocleidomastoid, middle and anterior scalene muscles. IJ and C represent the internal jugular vein and carotid artery. DCF represents the deep cervical fascia. The gray dashed line represents the trajectory of the needle starting posterior to the interscalene groove and traveling through the middle scalene muscle and ending up anterior and deep to the brachial plexus.

Once the ultrasound probe has been moved up the neck, the sternocleidomastoid muscle and the anterior and middle scalene muscles come into view. The sternocleidomastoid muscle appears as a right triangle with the horizontal side much longer than the vertical side, the vertical side is medial, and the triangle tapers laterally as it passes over the anterior scalene muscles. The brachial plexus resides between the two scalene muscles and again appears as a cluster of grapes or honeycomb. If the brachial plexus cannot be readily visualized, subtle caudad scanning along the interscalene groove often helps in re-finding the nerve structures. Over the top of the interscalene muscles lies the deep cervical fascia. This is visualized as a thin echogenic (bright) tissue layer. It is important to visualize or at least appreciate where it is located, because placing local anesthetic superficial to the facial layer can lead to a failed block.

If the brachial plexus is in the middle of the image, the carotid artery and at times the internal jugular may be visualized along the medial aspect of the scanning image. If the carotid and internal jugular vein are in the center of the scanning image, than the ultrasound probe has most likely migrated medially and may loose visualization of the brachial plexus along the lateral aspect of the image.

Key features of ultrasound imaging are important to consider when the brachial plexus is not well visualized. Using an ultrasound probe with a high frequency (10–12 MHz) allows for finer resolution just below the skin. Setting the depth to 3 cm is adequate in most necks. The focus marker should be set just deep to where the plexus is located. To optimize imaging, dimming the room lights is helpful and maintaining the gain at mid levels helps avoid washing out the image with over amplification (a temptation in brightly lit rooms).

The approach for needle placement is at the discretion of the clinician placing the block and may depend on probe position where the plexus is best visualized and variations in individual anatomy (such as differences in neck length, redundant tissue in obese patients, positioning difficulties in patients complaining of pain, etc). One approach is to place the needle in a perpendicular fashion to the interscalene groove above the plexus and advance the needle until it has pierced the deep cervical fascia. On ultrasound, the needle is seen advancing from the skin in the middle of the image until approximating the nerve fibers. Although direct and easily visualized on ultrasound, this approach may lead to inadvertent paraesthesias because the distance between the deep cervical fascia and the brachial plexus is often very short.

Another approach is to introduce the needle posterior to the ultrasound probe over the middle scalene muscle (Fig. 1). On ultrasound, the needle is seen advancing from the posterior side of the image going through the middle scalene muscle. The intent of this approach is to place the tip of the needle just posterior or deep to the brachial plexus. With this approach, the risk of paraesthesias may be less because the need to pierce a fascial layer in close proximity to the nerve fibers is not required to get an effective block. Hence, the needle can be kept at a distance that avoids a potential paraesthesia yet provides adequate access for injection of local anesthetic. When injecting, it is common to see displacement of the plexus bundle and surrounding tissue in a superficial and anterior fashion as the plexus is encompassed by local anesthetic. This real-time visualization of local anesthetic placement aids in the adjustment of needle placement if, over the course of injection, there is needle migration into an area where the block will not be effective (i.e., a muscle belly or a blood vessel).

Once local anesthetic has been placed, ultrasound can also be used to verify placement of a perineural catheter. Although catheters are not echogenic, sonographers can often approximate where the catheter is going by observing tissue movement (in this case interscalene muscles) as the catheter is advanced.

### Training Opportunities and Certification Requirements

Several courses reviewing techniques in ultrasound-guided nerve blocks are offered in most large-scale anesthesia meetings. Some of the meetings offer hands on workshops that make use of human models to visualize anatomy. Additional training is also offered as part of fellowship training in acute pain management and regional anesthesia. At present, no formal certification exists for ultrasound-guided nerve blocks.

## ULTRASOUND-GUIDED CENTRAL VENOUS CANNULATION

Central venous access in patients with well-defined landmarks by experienced trained clinicians is often easily accomplished. However, when experienced personnel are not available or optimal conditions do not exist, central line placement can be more challenging. Factors that may contribute to increased difficulty in placing a central line include obese necks that obscure landmarks, recent prior instrumentation of neck veins with an associated hematoma, existing intravascular hardware (i.e., pacing wire), anatomic variations (i.e., internal jugular vein diameter <5 mm), and venous thrombosis.

In 2001, an Agency for Healthcare Research and Quality Evidence Report identified ultrasound guidance of central cannulation as one of the "Top 11 Highly Proven" patient safety practices that are NOT routinely used in patient care. It recommended that ALL central lines be placed with real-time ultrasound guidance (29). These recommendations, however, were based on a study that used ultrasound guidance for subclavian venous cannulation (30), an approach that is perhaps the least amenable to ultrasound guidance (31).

Several investigations, however, have explored the potential benefit of using ultrasound in cannulating the internal jugular vein and have reported improved success rates in a variety of clinical arenas (31–37). Metrics of comparison between the conventional landmark approaches and ultrasound-guided central line access include 1) success on first attempt, 2) success in "difficult stick" patients, 3) incidence of carotid puncture, 4) time to cannulation, and 5) detection of anomalous vascular anatomy or small caliber vessels. In all metrics, ultrasound improves clinician ability to successfully cannulate the internal jugular vein.

One technical nuance that warrants discussion is whether or not to use ultrasound real time from needle puncture through catheter cannulation or simply for a pre-puncture assessment of the vascular anatomy and then proceeding without ultrasound guidance. One significant difference in these techniques is the need to place the ultrasound probe inside a sterile sheath versus visualizing the neck vascular anatomy before prepping the skin. This represents an incremental cost in equipment and time and does require a third hand (a second person) to hold the ultrasound probe while placing the line. Nevertheless recent work suggests that clinicians may be as successful with a one-person technique using ultrasound when compared to a more typical two-person technique (38).

The 2001 Agency for Healthcare Research and Quality Evidence Report on patient safety strongly recommended at that time that real-time dynamic guidance be used for all central line cannulations.

They also dismissed prepuncture use of ultrasound for central line placement (29). Investigators since that report have suggested a more sophisticated approach that is driven by initial assessment of internal jugular vein diameter (31). For example, jugular veins that are of diameter $<5$ mm (4.3% incidence) should be considered a relative contraindication and cannulation should be avoided (i.e., look somewhere else). Veins that are between 5 and 10 mm (25% incidence) should be cannulated with real-time ultrasound guidance. Veins of diameter greater than 10 mm (71% incidence) can be done with a prepuncture evaluation followed by three attempts, and if unsuccessful, convert to real-time ultrasound guidance.

### Sonographic Technique

Ultrasound visualization of the internal jugular vein is typically accomplished with a linear probe using transducer higher frequencies (i.e., 7 MHz or more), where the probe is placed perpendicular to the neck such that the internal jugular vein and carotid artery are visualized in the short axis. Higher frequencies can be used because the vein is usually superficial and deep penetration of the ultrasound beam is unnecessary. The depth is initially set at 3–4 cm and adjusted as necessary to fully visualize the internal jugular vein and carotid artery. Depth settings beyond the depth required to see these vascular structures is unnecessary. Special attention should be given to probe orientation and the ultrasound display such that the clinician introducing the needle understands which aspect of the display image is medial and lateral and the associated relationship between the carotid artery and jugular vein. It is helpful to orient the ultrasound machine display in such a way that the clinician placing the central line does not have to significantly divert one's gaze from activity at the puncture site to see the ultrasound display.

### Training Opportunities and Certification Requirements

Several courses reviewing techniques in ultrasound-guided central line access are offered in most large-scale critical care and anesthesia meetings. Some of the meetings offer hands on workshops that make use of human models to visualize anatomy and simulation mannequins that accommodate use of ultrasound and needle cannulation of vessels. Additional training is also offered as part of fellowship training in critical care medicine and cardiac anesthesia. No formal certification exists for the use of ultrasound to place central lines.

## ULTRASOUND TO EVALUATE CARDIAC FUNCTION OUTSIDE THE CARDIAC OPERATING ROOM

Ultrasound has emerged as a useful tool in the perioperative assessment of cardiac function both inside and outside the cardiac operating suite. Anesthesiologists are often called upon to assess cardiac function in patients with significant cardiac dysfunction while undergoing noncardiac surgery. In many clinical settings, transesophageal and transthoracic echocardiography (TEE and TTE) have been found to be useful in the diagnosis and management of unexplained hypotension in a time sensitive manner (39–45). Perioperative hypotension is frequently considered to be a function of excessive anesthesia or intravascular volume depletion. When typical efforts to correct these problems prove ineffective, additional information regarding patient cardiovascular function is helpful. Conventional characterization of cardiovascular function often involves placement of invasive monitors (arterial line, central lines, and pulmonary artery catheters), which can be time consuming to place, require special equipment to properly monitor, and at times difficult to interpret. Sonographic images are, by contrast, quickly obtained and offer real-time visualization of cardiac function and effectiveness of therapeutic interventions. As a previous investigator has reported, TEE used to explore sources of unexplained hypotension, confirmed the presumed diagnosis only 50% of sequential series of 60 patients (42). In the remaining patients, TEE played a key role in identifying the correct problem and in selected cases avoided potential reoperations based on the presumed diagnosis. In a similar fashion, prior work has illustrated how TEE effectively detects intravascular volume depletion in the setting of left ventricular hypertrophy where pulmonary capillary wedge pressures report normal to elevated filling pressures (40).

**Table 1.** Features of the Transgastric Short Axis View of the Left Ventricle

| | Normal |
|---|---|
| End diastolic area: | 14 $\text{cm}^2$ |
| Endocardial excursion (46): | Change in radius of 30% |
| Myocardial wall thickening (46): | Change of 30%–50% |
| End systolic area | 6 $\text{cm}^2$ |

### Sonographic Technique

An example of how TEE is used to quickly evaluate basic features of cardiac function is the transgastric short axis view of the left ventricle. This view represents one of the eight basic cross section views that make up a standard basic examination. These eight views were adapted from the 20 cross section views delineated in a comprehensive examination as defined by the 1996 guidelines for perioperative TEE (46). In this view, the ultrasound beam originates in the stomach and is aimed across the heart. It captures an image across the midsection of the left ventricle at the level of the papillary muscles. Conventional presentation of this image shows the ultrasound probe at the top of the screen and the scanned sector below. Depth is typically set at 11–12 cm and a transducer frequency of 5–7 MHz provides adequate visualization of the myocardium and surrounding tissues. This view is helpful in identifying and differentiating numerous sources of hypotension to include hypovolemia, poor contractility, cardiac tamponade, and reduced afterload (47).

Table 2. Differential Diagnosis of Unexplained Hypotension

| Etiology | End diastolic area | Myocardial thickening | Endocardial excursion | End systolic area |
|---|---|---|---|---|
| Hypovolemia | ↓ ↓ | ⇆ | ↑ ↑ | ⇆ |
| LV Failure | ↑ ↑ | ↓ ↓ | ↓ ↓ | ↑ ↑ |
| Reduced afterload | ⇆ | ↑ ↑ | ↑ ↑ | ↓ ↓ |

Features of this view that are of interest include the end systolic and diastolic areas, myocardial wall thickening, and endocardial wall excursion (Table 1). Estimates of the end diastolic and end systolic areas are made by measuring the area encompassed by the endocardium at the appropriate points in the cardiac cycle. Myocardial wall thickening is estimated as a percentage change in the myocardial wall from diastole to systole. Endocardial wall excursion is a metric of how the left ventricle chamber radius changes through the cardiac cycle. Evaluation of these features can provide a quick estimate of cardiac function in terms of preload, contractility, and afterload. A summary of how these features change with different diagnoses is presented in Table 2 (48).

Hypotension as a result of intravascular volume depletion presents as a small end diastolic area and normal or exaggerated endocardial wall excursion. Poor contractility presents as an enlarged end diastolic area and reduced endocardial excursion and myocardial wall thickening. Pericardial effusions leading to cardiac tamponade present as fluid accumulation (echolucent) around the heart accompanied by marked reduction in the end diastolic area. Of note, chronic pericardial effusions can become large yet not lead to tamponade. By contrast, acute accumulation of pericardial fluid that surrounds the entire view of the heart in this view is worrisome for tamponade if it hasn't already developed. Reduced afterload presents as a hyperdynamic ventricle (enhanced endocardial excursion) and a small end systolic area.

In summary, a quick assessment of end diastolic and systolic areas (small, normal, or enlarged) and contractility via myocardial thickening and endocardial excursion (low or high) can differentiate between hypotension that is due to low preload, poor contractility, or low afterload.

### Training Opportunities and Certification Requirements

Although many diagnoses quickly observed with TEE appear readily obvious, considerable expertise is required to acquire and interpret all the information available in TEE and TTE (49), hence numerous echocardiography training opportunities exist for anesthesiologists. The primary source of training is through fellowship programs in echocardiography. Additional training is also offered as course series and workshops at major meetings in echocardiography, cardiology, and cardiac anesthesia. Formal certification requirements have been developed for basic and advanced levels of training (50,51) and in conjunction with the testamur examination in perioperative echocardiography are part of the board certification process offered by the National Board of Echocardiography.

## CONCLUSIONS

In summary, reasons to make ultrasound a part of an anesthesiologist's practice are compelling. Ultrasound is emerging as an extremely useful tool in the effective placement of nerve blocks and catheters as well as in reducing the time required to place them (24). Emerging guidelines for ultrasound-guided central line placement indicate that use of ultrasound will improve success rates and shorten the time required to place them (31). Finally, ultrasound, through echocardiography, offers a powerful alternative to conventional cardiovascular monitoring that can be quickly utilized for diagnostic purposes and to monitor real-time ongoing resuscitative measures.

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