Introduction to Ultrasound-Guided Regional Anesthesia: Techniques That All Can Do

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An exciting revolution is currently occurring in regional anesthesia. Across the world, practitioners are actually visualizing neural structures prior to needle insertion. In addition, needle location and spread of local anesthesia are being watched in real time. Both internal normal and abnormal anatomy are now easily defined. Is this science fiction? Actually, the technology has been around for close to a century: ultrasound.

The first report of ultrasound guidance for nerve blocks dates to 1978. Here, La Grange et al reported the use of a doppler pencil probe to facilitate the identification of the subclavian artery prior to blockade of the brachial plexus using the supraclavicular approach (1). Since then, techniques have been described using ultrasound to facilitate the performance of all variations of brachial plexus, femoral, and sciatic nerve blocks (2-7). To date, there are only a handful of controlled trials which compare ultrasound guided techniques to conventional techniques. In two of these investigations, a single shot femoral nerve block was studied. In the first trial, ultrasound-guidance decreased onset time, improved density, and increased the percentage of actual 3-in-1 blocks when compared to nerve stimulation (6). In a follow up study, the same group found that ultrasound guidance allowed a reduction in the amount of local anesthetic (7). In 2003, Williams et al demonstrated that ultrasound-guided supraclavicular blocks were performed more rapidly and provided denser blocks in comparison to supraclavicular blocks performed by anatomical landmarks (8). In a randomized controlled trial comparing a trans-arterial technique to an ultrasound guided technique for axillary blocks, it was found that ultrasound improved performance times and improved the percentage of blocks that served as surgical anesthetics (9).

Ultrasound can be utilized in many different ways. Given the lack of controlled trials examining the various combinations and permutations of the use of ultrasound, what follows are the author's opinions and our clinical practice at the Dartmouth-Hitchcock Medical Center.

To get started, one should review the basics of ultrasound physics. For an in depth discussion of the physics of ultrasound, please refer to Weyman, 1994 (10). From a clinical perspective, there are two key concepts, penetration and resolution. Any wave, whether a sound wave or an ultrasound wave, is characterized by a specific wavelength and frequency. Frequency is expressed in MHz and is linked to the resolution of the system. Although there are several different types of resolution, in general, resolution refers to the ability to assess details of a given structure. In other words, resolution refers to how well a system can distinguish one object from another. The greater the resolution then the better the image detail will be. Wavelength is expressed as the distance between two pressure peaks of a sound wave and is linked to the penetration of the system. The larger the wavelength, the better the ultrasound can penetrate into tissue. Ultrasound systems with high frequencies (>10 MHz) can effectively visualize peripheral neural structures. However, given the shorter wavelength, these high frequency systems can only accomplish this visualization for superficial structures (< 3 cm) such as the interscalene brachial plexus. Therefore, as resolution (frequency) increases, penetration (wavelength) decreases. This relationship is a reflection of the law of conservation of energy. Since $E \sim f \cdot \lambda$, then if frequency increases, the wavelength must decrease.

With this as a background, let us look at what you need to get started. First, I will review some basic equipment needs, then I will review how to actually use ultrasound to guide peripheral nerve blocks.
We found that to reliably visualize the brachial plexus in the interscalene groove, supraclavicular region, or axillary region probe resolution should be greater than 8 MHz. We prefer to use a linear probe for these three blocks. We have two such probes, one is 25 mm in length, and the other is 38 mm in length. The larger footprint probe gives the operator better perspective on adjacent structures, such as the carotid artery and the lung. The downside to the larger footprint probe is that it is more ergonomically challenging to position in anatomically "tight" areas such as the supraclavicular fossa. For the performance of deeper blocks (> 4cm), such as the infraclavicular brachial plexus, subgluteal sciatic, and popliteal blocks, we prefer a linear probe with a frequency range between 5-10 MHz. This lower frequency allows better penetration while maintaining accurate localization of these neural structures. We recommend that you purchase an ultrasound machine that has color flow imaging capabilities. This software application allows the operator to identify vascular structures. True directional doppler is not needed for nerve blocks.

There are two major approaches to using ultrasound to facilitate peripheral nerve blocks. They are the live-guided technique and the surface marking technique. For the novice just starting out, we encourage the use of the surface marking technique. In this technique, the operator marks where they think the nerve should be based on conventional anatomical landmarks. The ultrasound is then used to examine this region and identify the nerve, its depth, and surrounding structures such as the lung and blood vessels. A skin mark is used to mark the actual location of the nerve. The ultrasound is put aside and the operator then proceeds with whatever technique he or she traditionally uses. The reason why we think this is a perfect training technique is that the operator learns neural identification, "knobology", and image optimization without being distracted by the ergonomics of the live method. A perfect block to introduce yourself to the marking technique is the femoral nerve block. Here, simply identify the femoral artery and nerve on axial section. Place a mark over the nerve and then put the ultrasound down. If using a nerve stimulator, the quadriceps contraction at 0.5 mA should be found within one or two passes below the skin mark.

It is the author's opinion that the ideal way to fully utilize ultrasound is the live method. The probe is placed in a sterile sheath and is put into position by the operator's non-dominant hand. The nerve is visualized in axial section and the needle is held in the operator's dominant hand. In our experience it is best if the needle is placed into the patient such that the needle comes into the ultrasound beam along its long axis (in-line technique).   If the needle is inserted through the ultrasound beam on short-axis (cross-section), it will be very difficult, if not impossible, to visualize the needle. This could result in malposition of the needle tip and potential iatrogenic injury. When the needle is inserted along the long axis of the ultrasound beam, the entire needle can be visualized and directed toward the target. When the needle is adjacent to the nerve, the injection of local anesthetic commences. With ultrasound visualization, one can see the local anesthetic as it is injected and the operator can appreciate whether or not the local is spreading around the nerve. If the local anesthetic appears to be going elsewhere (e.g. into muscle), the needle is repositioned slightly, in order to achieve what has been described as the "doughnut" sign (2). This doughnut sign is the local anesthetic spreading circumferentially around the nerve or reference blood vessel. It is our clinical experience that the most effective blocks occur if we generate the doughnut sign. We will often position the needle in several locations around the nerve(s) if a single site does not generate full circumferential spread. In using this technique we found that we can reduce our local anesthetic volume by around 30-40% in comparison to traditional techniques.

Many of you are probably wondering if you should use nerve stimulation in addition to the live guidance. This can only be answered via controlled trials. Our experience is that when the needle and nerve are visualized well and local anesthetic is "painted" around the nerve(s), rapid and profound blocks occur. The use of a nerve stimulator may serve to distract our attention away from the ultrasound image and what is happening in real-time. However, if there is question as to whether or not a structure is a nerve, then it makes sense to confirm your suspicions with a simultaneous technique such as nerve stimulation. In addition, nerve stimulation is a great physiological test of which nerve you are adjacent to. Our major concern with requiring a motor response prior to an injection is that we have identified a significant false negative rate of nerve stimulation. That is, with ultrasound verification of the needle indenting the epineurium of one of the trunks of the brachial plexus, we found that 13.5% of the time there was no corresponding motor response (11).

A few additional clinical points should be made.

1. When using the in-line technique, the needle should be visualized before being advanced. The ultrasound beam is very thin which means that subtle movements can bring the needle in and out of visualization.

2. Subtle pressure or angulation of the probe when in contact with the patient can dramatically improve or worsen your image.

3. Interventional radiologists practice their needle biopsy skills using a turkey breast with an olive in it, which mimics a cyst. We have our residents practice on this model during their regional anesthesia rotation. You are encouraged to practice on such a model.

4. There are many different machines on the market. We use both traditional cart based machines and hand-held machines. You are encouraged to trial different probes and machines prior to committing to one specific company, model, or make.

5. Talk to your local radiologists and sonographers for tips and hints on using ultrasound. Specifically, the operator should be familiar with color flow indicators, gain, focus, and image storing.

6. Keep a database of your cases, you will quickly realize that your blocks will be faster, better, and will likely improve patient satisfaction.

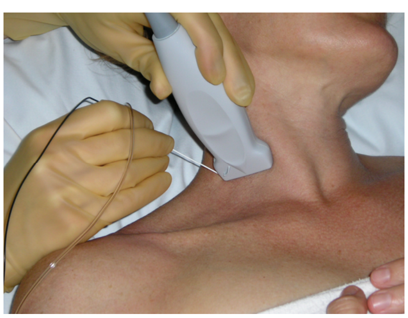
7. Many ultrasound systems come with needle guide systems for their probes. These are devices that secure the needle to the probe and allow the operator to follow a predetermined course to your target of interest. Although on the surface these devices may sound attractive, we found that they often limit the options of the anesthesiologist. That is, once the needle is secured into the needle guide, one can not change angles and approaches to the nerve that would allow generation of the doughnut sign.

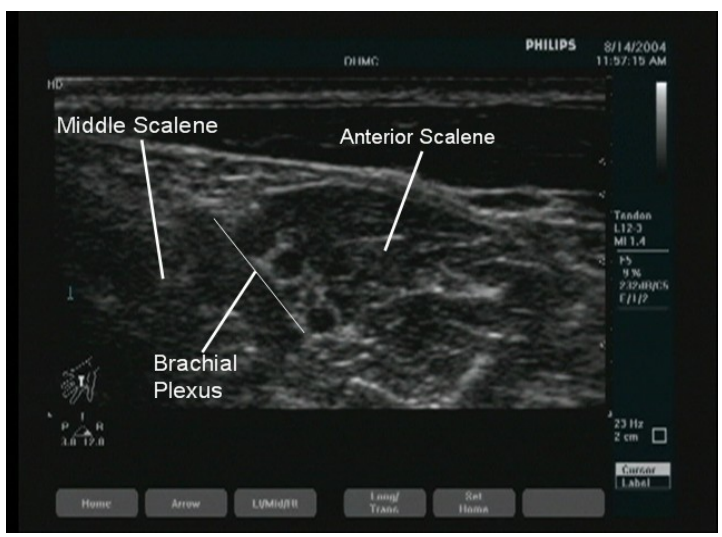
Summary of echo appearance of various structures:

- Veins: compressible anechoic (black)
- Arteries: pulsatile anechoic (black)
- Fat: hypoechoic (dark)
- Fascia: hyperechoic (white)
- Muscle: hypoechoic with hyperechoic striations (white and black)
- Tendons: hyperechoic (white)
- Cartilage: anechoic (black)
- Bone: hyperechoic (very white)
- Nerves: hyperechoic/hypoechoic
- Local anesthesia: anechoic (black)

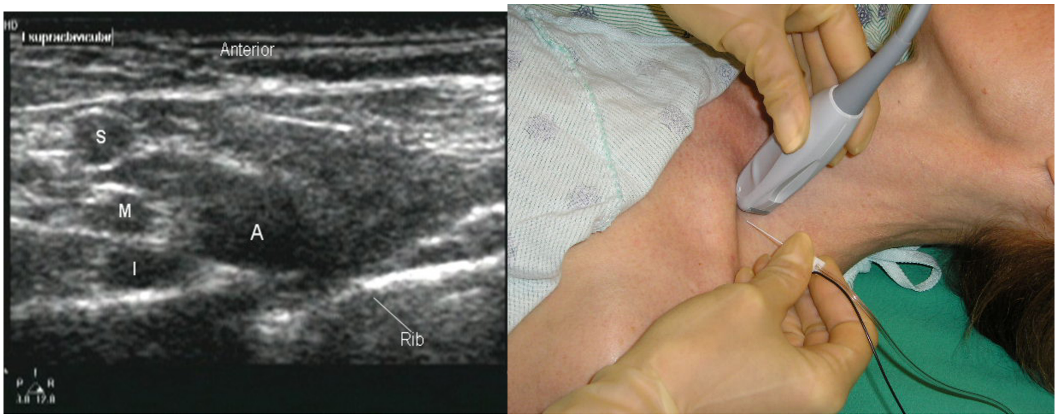
Summary of various techniques of live-ultrasound guidance (All needles are b-bevel, the actual size depends on body habitus):

- Interscalene: First identify the carotid artery on short axis and then move the probe laterally on the neck. Next, image 3-4 dark circles between the scalene muscles on axial section (see below). These represent the roots of the brachial plexus. Use the highest frequency (MHz) probe possible. We prefer a linear probe. Insert the needle in the longitudinal plane either through the middle scalene muscle (as below) or through the anterior scalene muscle (whichever is easiest). Visualize local spreading between muscles around the nerves.





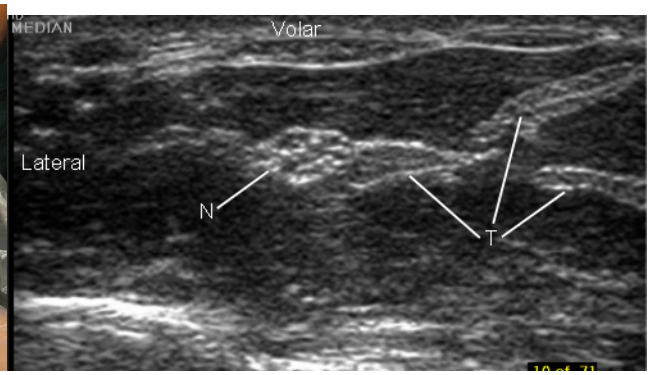
- Supraclavicular: This has become our most popular block. In fact, it has essentially replaced axillary nerve blocks. It has been referred to as the "spinal of the arm." This block gets excellent tourniquet coverage and definitively anesthetizes the musculocutaneous nerve. We use a linear probe (25 or 38 mm), with at least 10 MHz resolution, and place it in the supraclavicular fossa such that the subclavian artery is imaged on axial section. Just superior-lateral to the artery appears a grape like cluster of hyoechoic circles with hyperechoic rings. Often one can see the individual trunks of the brachial plexus: 3 hypoechoic circles representing the superior, middle, and inferior trunks (S, M, I in image below). A 2 inch stimulating needle is inserted from either the medial or lateral aspect of the probe (whichever is ergonomically easiest) and directed between the artery and the nerve complex. A distinct pop is palpated and visualized on the screen. If using nerve stimulation, a corresponding twitch will ensue and the injection commences. The local anesthesia should be visualized filling the brachial plexus sheath and not spreading above visualized fascial planes. If this occurs, the needle is repositioned. This block is extremely safe, as the 1st rib, artery, needle, and lung are all visualized!



- Infraclaviclar: Image the brachial plexus 1 cm lateral to the corocoid process. There is a natural fossa here. The probe which we prefer is a 25 mm linear transducer with a frequency of 5-10 MHz which fits nicely into this fossa and allows easy visulization of the structures in cross-section. The lateral, medial, and posterior cords appear as hyperechoic circles. The needle is inserted so that it appears in the longitudinal plane of the ultrasound. The exact entrance site will depend on the individual anatomy. As with the interscalene block, one should visualize the local spreading around the various cords of interest. If using the nerve stimulator technique with ultrasound, one can easy stimulate the various cords of the brachial plexus which are imaged surrounding the subclavian artery.
- Axillary. Any probe and frequency will do. The higher frequency probes allow visualization of the individual nerves. Alternatively, lower end equipment can be used to simply image the axillary artery. Regardless of technique, the axillary artery is imaged on short axis. The needle is inserted in the longitudinal plane of the ultrasound beam (usually through biceps muscle). Multiple injections through a single skin insertion site are needed to either circumferentially spread local anesthesia around the artery or to individually deposit local anesthetic around each of the nerves. Our experience is that the radial nerve can be the most difficult to image.
- Femoral: The femoral artery and nerve are visualized on cross-section just below the inguinal ligament. The needle is inserted from lateral to medial in the longitudinal plane of the ultrasound beam. The nerve usually appears as a hyperechoic triangle. This nerve can be difficult to visualize in some patients. The other interesting structures that can be easily visualized are the fascia lata (superficial hyperechoic line) and the fascia iliac (deeper hyperechoic line). The major goal is to deposit local anesthetic circumferentially around the nerve. This can usually be accomplished with a single injection.
- Saphenous: Prior to the use of ultrasound, this block was not reliable (for us) in terms of generating surgical anesthetic conditions. We often couple this block to a popliteal block for complete anesthesia of the lower leg. This block relies on the intimate association of the saphenous vein with the saphenous nerve. In fact, anyone who has ever harvested a saphenous vein for coronary artery bypass surgery realizes that the operator must physically dissect the nerve off of the vein. Therefore, for this ultrasound technique, we place an IV tourniquet on the thigh to dilate the saphenous vein. With the patient in either the prone or supine position, we image the saphenous vein in the proximal lower leg using our 25 mm linear probe. Any probe frequency will do since the vein is very superficial. A 2 inch b-bevel needle is inserted in the long axis of the ultrasound beam until it just dimples the vein. The goal, once again, is to generate circumferential spread of local anesthesia around the vein. Usually, 5 ml of local is all that is needed. We

sometimes have to readjust the needle to get complete coverage around the vein. This block does not rely on the ability to visualize the saphenous nerve, only the saphenous vein.

- Infragluteal sciatic. We prefer the small foot print (25 mm) probe with 5-10 MHz of resolution. The patient is placed in the prone position. The gluteal crease is identified and the biceps femoris tendon is palpated at this level. The nerve is imaged on cross-section approximately 1 cm lateral to this tendon which appears as a hyperechoic (bright) single structure. The needle is inserted from lateral to medial and in the longitudinal plane of the ultrasound beam. Because this nerve can be difficult to visualize, we will often use nerve stimulation as an adjunct.
- Popliteal. This is our favorite block and technically the easiest with ultrasound. The sciatic nerve in the popliteal fossa is an ideal structure to be localized by ultrasound. This is because the nerve is surrounded by adipose tissue, which creates a strong echo interface. The nerve appears as a bright (hyperechoic) structure surrounded by the dark (hypoechoic) adipose tissue. The same probe set up is used as for the infragluteal approach. We examine the popliteal fossa between 5-10 cm proximal to the popliteal crease. The division point of the sciatic nerve is identified by imaging the common peroneal-tibial nerve complex on cross section. We then visualize the sciatic nerve 1-2 cm proximal to this division point. The needle is inserted from lateral to medial and in the longitudinal plane of the ultrasound beam. When the needle is just about to touch the nerve, the local is injected. The doughnut sign should be visualized. The needle is readjusted as necessary and local anesthetic is injected so as to circumferentially surround the nerve.
- Wrist Blocks : The median and ulnar nerves are all easily imaged with high resolution linear probes in the mid-forearm. We have replaced the need for bier blocks for carpal tunnel releases and minor hand procedures. We image the median nerve (N in picture) approximately 6 cm from the radial-lunate articulation. A 2 inch b-bevel needle is inserted from either the ulnar or radial aspect of the probe until it just contacts the median nerve. 5 ml of 0.25% bupivacaine is injected. The needle is repositioned if needed to force local anesthetic to spread circumferentially around the nerve. At the same proximal location of above the wrist, the probe is moved to the ulnar side, such that the ulnar artery is imaged with the nerve lying on the ulnar side of the artery. The same injection sequence is repeated for the ulnar nerve. The wrist block is completed by placing a subcutaneous wheal of local in the anterior-lateral aspect of the wrist to cover the superficial radial nerve.

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