Ultrasound Guidance In Regional Anesthesia: Techniques for Upper-Extremity Nerve Blocks
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**Philosophy**

We believe that vision is the best of the primary human senses. Ultrasound allows the anesthesiologist to evaluate complex and varied neural anatomy prior to needle insertion. In addition to real-time guidance of the needle toward a nerve or plexus, ultrasound allows the anesthesiologist to witness (and alter) the spread of local anesthesia after the initiation of an injection. Ultimately, it is this visual confirmation of the perineural spread of local anesthesia that generates a rapid and successful block.

**Equipment Specification**

1) Ultrasound system
2) Ultrasound transducer, 13-6 MHz linear array with variable resolution settings
3) Stimulating needles
4) Ultrasound gel (sterile and non-sterile)
5) Sterile transducer cover
6) Nerve block kit containing sterile drape, skin wheal needles, extension tubing, and syringes of choice

**Optional Equipment**

7) Needle guide systems
B) Transducer-stabilizing device

**In-Plane Versus Out-of-Plane Technique**

Structures of interest (blood vessels, tendons, and nerves) can be imaged either on the short axis (cross-section) or the long axis. A short-axis view becomes a long-axis view when the probe is turned 90 degrees in either direction. Figure 1 demonstrates these principles.

There are 2 methods of needle insertion with respect to the ultrasound beam. State-of-the-art clinical imaging is currently 2-dimensional; the inserted needle can be visualized on either the long axis or the short axis (Figure 2). When the needle is inserted in the long-axis view, the entire needle can be visualized. This is known as the *in-plane technique*. This technique affords visualization of the entire needle and the tip, allowing the operator

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**Figure 1. Demonstration of the differences between imaging a structure on the short axis versus the long axis.**

For this demonstration, the patient is in the prone position. **A.** Transducer position in order to image the median nerve on the short axis in the forearm. **B.** The corresponding short-axis ultrasound image of the median nerve. Note the characteristic circular appearance of the nerve. On the short axis, the anesthesiologist has simultaneous anterior–posterior and lateral–medial perspectives on the nerve. **C.** If the probe position for the short-axis view is turned 90 degrees (clockwise or counterclockwise), the long-axis view of the same structure will be generated. **D.** The corresponding long-axis view of the median nerve. Note the characteristic tubular appearance. When imaging a nerve on the long axis, the operator loses the lateral–medial perspective. This can be disadvantageous when trying to identify needle location and the circumferential spread of local anesthetic around the nerve.

L, local anesthetic
For single-injection nerve blocks, we prefer the in-plane technique. The out-of-plane technique is preferred for continuous catheter placement. When using the out-of-plane technique, it is helpful to inject small amounts of saline, local anesthesia, or 5% dextrose solution to help define the location of the needle tip as it advances. The major learning obstacle for the in-plane technique is the ability to keep the needle in the path of the ultrasound beam. When using the out-of-plane technique, consider the following:

1. Use an ultrasound system with a high-frequency transducer (up to 13 MHz) for superficial blocks that are ≤3 cm deep. This allows the best resolution of the neural structures and surrounding tissue. Deeper blocks will require a lower-frequency transducer that provides better penetration of the ultrasound beam into the tissue.

2. The needle is visualized before being advanced when using the in-plane technique. The ultrasound beam is very thin, which means that subtle movements can bring the needle in and out of visualization.

3. Subtle pressure or angulation of the transducer (probe) can dramatically improve or worsen the image.

4. Practice your needle skills using a turkey breast with an olive placed in it. Interventional radiologists use this popular model to mimic a cyst in a human breast.

5. Ask the experts at your institution for clinical pearls and insights. We have gained many tricks of the trade by speaking with radiologists and ultrasonographers. Specifically, the operator should be familiar with depth, color flow indicators, gain, focus, frequency settings, and image storing.

6. Keep a database of your cases; you will quickly realize the improvement in efficiency and efficacy of your regional anesthesia service.

7. Many ultrasound systems provide optional needle-guide devices for their transducers. These devices secure the needle to the transducer and allow the operator to follow a predetermined course to the target of interest. Although on the surface these devices may sound attractive, we have found that

Figure 2. The needle in relation to the transducer.

A. The needle is in-plane (long axis) with the ultrasound beam. 
B. The corresponding ultrasound image of the needle in-plane with the ultrasound beam. 
C. The out-of-plane technique with the needle imaged on the short axis. This is also referred to as a cross-sectional view. 
D. The corresponding ultrasound image of the needle out-of-plane with the ultrasound beam and imaged on the short axis.

to make very precise real-time adjustments (Figures 2A and 2B).

When the needle is inserted in the short axis, a cross-sectional view of the needle will be obtained (Figures 2C and 2D). This is known as the out-of-plane technique. The out-of-plane technique results in the needle being imaged on cross-section. An 18- to 22-gauge needle imaged on cross-section appears as a small dot, which can be difficult to see in real time. In addition, the needle will cross the ultrasound beam only once. Therefore, when the needle is visualized, it may be well above or below the target nerve, depending on the angle of the insertion.
9. Place the ultrasound machine on the contralateral side of the patient and have the operator stand on the ipsilateral side of the extremity to be blocked. They often limit the anesthesiologist’s options. That is, once the needle is secured into the needle-guide device, one cannot change angles and approaches to the nerve that would allow generation of the circumferential spread of local anesthetic around the nerve.

8. The transducer is held in the operator’s nondominant hand and the needle in the dominant hand. The ability to use both hands to drive the needle will give those fortunate individuals an ergonomic advantage as they will find it easier to establish an ergonomically stable situation regardless of block type and patient position.

10. All transducers have an orientation marker that should be positioned at the upper-left corner of the ultrasound screen, allowing the skin surface to be uppermost. When scanning in a transverse/cross-sectional plane, the marker on the transducer should always point toward the operator’s left side, allowing reproducibility of image orientation.

11. Terminology: 
- **Hyperechoic**, whiter or brighter than surrounding tissue; 
- **Hypoechoic**, gray or darker in relation to the surrounding tissue; 
- **Anechoic**, black.

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**Figure 3. Setup for the performance of a right-sided, single-injection interscalene nerve block.**

The dotted line represents the interscalene groove and the solid line represents the lateral border of the sternocleidomastoid muscle. Following the identification of the carotid artery and the internal jugular vein, the transducer is moved in a lateral and posterior direction until it comes to rest as indicated in this photo.

**Figure 4. Ultrasound image of the brachial plexus.**

Horizontal arrows depict the roots of the brachial plexus at the level indicated by Figure 5. The roots of the brachial plexus appear as 2 to 4 hypoechoic circles with hyperechoic outer rings.

- **AS**, anterior scalene muscle; 
- **IJ**, internal jugular vein; 
- **MS**, middle scalene muscle; 
- **SCM**, sternocleidomastoid muscle
Interscalene Nerve Block

**Patient Position:** Supine with the head rotated toward the nonoperative side

**Transducer Location:** At level of or below the cricoid cartilage

**Frequency:** High

**In-Plane/Out-of-Plane:** In-plane

**Nerve Image:** 3 to 4 hypoechoic circles located between the anterior and middle scalene muscle bellies

**Needle Size:** 50 mm

**Local Volume:** 20-30 cc

1. Place transducer over the sternocleidomastoid muscle at the level of the cricoid cartilage (Figure 3).
2. Image the carotid artery and internal jugular vein in the short-axis view and then slide the transducer in a lateral and posterior direction. The roots of the brachial plexus should appear as 2 to 4 hypoechoic circles with hyperechoic outer rings (Figure 4). The nerves should be flanked medially and laterally by the anterior and middle scalene muscles.

3. The needle is advanced using the in-plane technique, either from the posterior aspect (posterior approach, Figure 5) or the anterior aspect (anterior approach, Figure 6) of the transducer footprint. For shoulder surgery, the needle should be advanced under direct guidance between the C5 and C6 nerve roots.

4. Nerve stimulation may be used to confirm entry into the brachial plexus sheath.

5. Inject local anesthetic.
Clinical Pearls

- The best view of the brachial plexus is often found more inferior in the neck than expected by the conventional description (ie, more inferior than at the level of the cricoid cartilage).
- If you are having difficulty identifying the neural structures, obtain a supraclavicular image first (see below) and trace the neural structures superiorly up the neck.
- The tip of the lateral end of the sternocleidomastoid muscle should be slightly posterior–lateral to the superior neural structures in the interscalene groove.
- During needle insertion (using the posterior approach), the great vessels should not be viewed simultaneously with the brachial plexus in the interscalene groove (Figure 7). If the great vessels are in the image, you may need to move the transducer in a more posterior lateral direction.
- We use a mechanical device to hold the transducer. This device allows 1 person to perform the procedure as well as eliminating operator fatigue (Figure 8).

Supraclavicular Nerve Block

Patient Position: Supine with the head rotated toward the nonoperative side
Transducer Location: Parallel to the clavicle resting in the supraclavicular fossa
Frequency: High
In-Plane/Out-of-Plane: In-plane
Nerve Image: 3 to 6 hypoechoic circles located lateral and superior to the subclavian artery
Needle Size: 50 mm
Local Volume: 20-30 cc

1. Place the transducer parallel to the clavicle in the supraclavicular groove (Figure 9). Key structures to identify include the subclavian artery, the first rib, the pleura, and the hypoechoic nerves of the brachial plexus. The goal is to first identify the subclavian artery and then search for the nerves. You will see 1 of 2 appearances of the brachial plexus, depicted in Figures 10 and 11. The needle is inserted from the lateral aspect of the transducer. The goal is to situate the needle between the first rib and the most inferior nerve trunk or division. The needle may be repositioned around the more superior nerve structures if there is an inadequate spread of local anesthetic with the initial injection.

Clinical Pearls
- This block is nicknamed “the spinal of the arm” because it is a total upper-extremity regional anesthetic. This block should effectively replace all other blocks of the arm (except interscalene) because it is extremely easy and efficacious to perform. Injured extremities do not have to be moved. There should be optimal tourniquet coverage as well.
- Real-time ultrasound should be used to minimize the risk of an intra-arterial injection or a pneumothorax. Do not advance the needle unless the tip is visualized. Lying beneath the first rib is the pleura of the lung.

Figure 9. Setup for the performance of a right-sided, single-injection supraclavicular nerve block.

The high-frequency linear transducer is placed in the supraclavicular fossa. The goal is to first identify the subclavian artery and then search for the nerves. You will see 1 of 2 appearances of the brachial plexus, depicted in Figures 10 and 11. The needle is inserted from the lateral aspect of the transducer. The goal is to situate the needle between the first rib and the most inferior nerve trunk or division.

Figure 10. Divisions of the brachial plexus.
The divisions appear as 4 or more large hypoechoic circles in a superior–lateral perspective with respect to the subclavian artery. The divisions of the brachial plexus are indicated by the triangles and the chest cavity is indicated by the arrow. SC, subclavian artery
For hand surgery, the injection made around the most inferior aspect of the brachial plexus is critical to the success of this block. This injection should be accomplished first in case there is any tissue distortion with injection.

Two distinct appearances of the brachial plexus appear at the supraclavicular level. One can see a grape-like cluster of 5 to 6 hypoechoic circles, which probably represent the divisions of the brachial plexus (Figures 10 and 11). When only 3 hypoechoic structures are visualized, the operator may be visualizing the trunks of the brachial plexus.

**Infraclavicular Nerve Block**

**Patient Position:** Supine with the head rotated toward the nonoperative side

**Transducer Location:** Infraclavicular, perpendicular to the clavicle along the lateral segment and in the infraclavicular fossa

**Frequency:** 10-5 MHz, depending on the depth of the plexus from the surface

**In-Plane/Out-of-Plane:** In-plane

**Nerve Image:** 3 hyperechoic exterior nerve structures distributed around the subclavian artery at 3, 6, and 9 o’clock positions

**Needle Size:** 100 mm

**Local Volume:** 20-30 cc
Clinical Pearls

- Because the needle must transgress through 2 thick muscle beds (pectoralis major and minor), this block can be uncomfortable for some patients.
- A transducer with a smaller footprint is sometimes better than the traditional larger linear transducers because the infraclavicular fossa is small and the larger-footprint probes can hang over the clavicle.
- The cords of the brachial plexus tend to be more difficult to visualize compared with the roots, trunks, and divisions. This difficulty is secondary to the deeper location of the cords.

1. Place the transducer in the infraclavicular fossa, perpendicular to the clavicle along its lateral segment. The infraclavicular fossa is a natural depression about 1 cm medial to the coracoid process of the scapula. This should allow you to visualize the axillary artery in the short-axis view (Figure 12). Key structures to identify are the pectoralis major muscle, pectoralis minor muscle, axillary artery, and the axillary vein (Figure 13).

2. Advance the needle from either the inferior or superior side of the transducer using a 100-mm needle. The goal for the needle position is between the axillary artery and the posterior cord of the brachial plexus (between 6 and 8 o’clock).

3. Redirect the needle as needed to get circumferential spread of local anesthesia around the axillary artery.

Figure 13. Anatomy seen during an infraclavicular nerve block.

The axillary artery and vein are seen in the short-axis view.

A, axillary artery; L, lateral cord; M, medial cord; P, posterior cord; PMa, pectoralis major muscle; PMi, pectoralis minor muscle; V, axillary vein

Figure 14. Setup for performing an ultrasound-guided, axillary nerve block.

The transducer is placed in the axilla. The goal is to first image the axillary artery on the short-axis view. The needle can be inserted from either aspect of the transducer.
Deeper structures cannot be imaged with the highest frequency (highest resolution) transducers.

- We reserve infraclavicular blocks for situations in which there is a relative contraindication to a supraclavicular block (e.g., subclavian artery pathology, localized infection, and severe chronic obstructive pulmonary disease [COPD]). Because one may anesthetize the phrenic nerve with a supraclavicular block, this block should be performed judiciously in a patient who has severe COPD.

**Axillary Plexus Block**

**Patient Position:** Supine with the head rotated toward the nonoperative side. The patient’s arm is abducted and externally rotated.

**Transducer Location:** In the axilla at the crease formed by the pectoralis major and biceps muscles; perpendicular to the axillary artery

**Frequency:** High

**In-Plane/Out-of-Plane:** In-plane

**Nerve Image:** The nerves will be located in a variable fashion around the axillary artery. The nerves appear as complex, hyperechoic, and circular or oval structures with the internal fascicles appearing as multiple hypoechoic smaller circles.

** Needle Size:** 50 mm

**Local Volume:** 20-30 cc

*Note:* The musculocutaneous nerve will be addressed in the next section.

1. Place the transducer in the axilla perpendicular to the course of the axillary artery and roughly at the level of the crease formed by the pectoralis major and biceps muscles (Figure 14).
2. Obtain an image of the axillary artery and vein(s) in the short-axis view. You may use color Doppler to distinguish the artery from the vein. The artery should be noncompressible and pulsating, and the vein should be compressible and have continuous steady flow. The median, ulnar, and radial nerves most likely will surround the artery in a triangular pattern; however, their exact location may vary significantly among patients. The median nerve tends to appear consistently at the 12 o’clock position with the ulnar nerve between the 2 and 5 o’clock positions. The radial nerve varies, but tends to appear between 4 and 9 o’clock (Figure 15).
3. Advance the needle from either side of the transducer, using the in-plane approach. First, we recommend targeting the nerves that are anticipated to be involved in the surgery. Following an injection, there can be significant distortion of the anatomy.
4. Inject local anesthetic. Depending on the image quality, the goal will be to visualize the local anesthetic surrounding the targeted nerves. You may reposition the needle as needed to obtain appropriate coverage.

**Clinical Pearls**

- Nerve stimulation may be helpful in identifying nerves several centimeters away from the artery and in a variable orientation. The nerve stimulator is a great physiologic test of your anatomic assumptions.
- The ulnar nerve may be located several centimeters from the artery. In addition, this nerve may be situated next to one of the axillary veins instead of the axillary artery.
- There may be multiple veins associated with the axillary brachial plexus.

- Arguably less artistic, but easier to do, is to simply use ultrasound guidance to generate local anesthetic spread in a circumferential pattern around the axillary artery (the doughnut sign). We reserve this technique for situations in which it is a struggle to image the individual nerves.
- Because local anesthetics are hypoechoic, the spread of the injection is very easy to visualize. If the local anesthetic is injected into a blood vessel, the drug will be carried away and thus not visualized. Therefore, if the local anesthetic is not visualized spreading around the artery, the practitioner should assume an intravascular injection and reposition the needle.
1. Abduct and externally rotate the patient’s arm to reveal the axilla. Place the transducer in the axilla perpendicular to the course of the axillary artery at the junction of the pectoralis major and biceps muscles (Figures 16 and 17).

2. Move the transducer superiorly toward the biceps muscle. The goal will be to image the MCN on the short-axis view. The MCN will appear either in the body of the coracobrachialis muscle or in the plane between the coracobrachialis muscle and the biceps muscle.

3. Advance the needle using the in-plane approach.

4. The goal of the injection is to generate the circumferential spread of local anesthesia around the nerve.

Musculocutaneous Nerve (MCN) Block

**Patient Position:** Supine with the head rotated toward the nonoperative side. The patient’s arm is abducted and externally rotated.

**Transducer Location:** In the axilla, perpendicular to the axillary artery. Start the transducer in the same position as for the axillary block.

**Frequency:** High

**In-Plane/Out-of-Plane:** In-plane

**Nerve Image:** Large, singular hyperechoic structure with small, internal hypoechoic fascicles, usually located in a fascial plane between the coracobrachialis and biceps muscles

**Needle Size:** 50-100 mm

**Local Volume:** 5-10 cc

Figure 18. Setup for performing an ultrasound-guided, radial nerve block in the antecubital fossa.

The transducer is placed in the lateral aspect of the antecubital fossa. It is easiest to insert the needle in-plane with the ultrasound beam from the lateral aspect of the transducer.

Figure 19. Key structures involved in a radial nerve block.

The fascial compartment that houses the radial nerve is indicated by the arrows.

B, brachialis muscle; Br, brachioradialis muscle; JS, joint space

1. Abduct and externally rotate the patient’s arm to reveal the axilla. Place the transducer in the axilla perpendicular to the course of the axillary artery at the junction of the pectoralis major and biceps muscles (Figures 16 and 17).

2. Move the transducer superiorly toward the biceps muscle. The goal will be to image the MCN on the short-axis view. The MCN will appear either in the body of the coracobrachialis muscle or in the plane between the coracobrachialis muscle and the biceps muscle.

3. Advance the needle using the in-plane approach.

4. The goal of the injection is to generate the circumferential spread of local anesthesia around the nerve.
1. The patient’s arm should be abducted to 90 degrees at the shoulder and then the hand should be supinated (Figure 18).
2. Place the transducer in the antecubital fossa lateral to the biceps tendon.
3. The nerve will appear in the short-axis view as a hyperechoic oval structure. It is located between 2 easily identifiable muscle beds: brachialis and brachioradialis muscles (Figure 19).
4. Insert the needle using the in-plane approach from the lateral perspective of the transducer. If using nerve stimulation, a wrist extension should be noted as the needle makes contact with the hyperechoic oval structure.

**Clinical Pearls**
- The MCN has an undulating pattern and sometimes can actually be imaged in the long-axis view at 1 site and in the short-axis view at another.
- As the transducer is moved more proximally in the arm, the MCN gets closer to the axillary artery.
- Because this nerve is flanked by muscle, it is very easy to see. The nerve is hyperechoic, brighter than the surrounding muscle, whereas the muscles are dark (hypoechoic).

**Radial Nerve Block**

**Patient Position:** Supine with the head rotated toward the nonoperative side. The patient’s arm is abducted to 90 degrees with the hand supinated.

**Transducer Location:** In the antecubital fossa lateral to the biceps tendon.
Transducer Location: Volar surface of the distal forearm
Frequency: High
In-Plane/Out-of-Plane: In-plane or out-of-plane
Nerve Image: Single hyperechoic structure with small hypoechoic fascicles
Needle Size: 50 mm
Local Volume: 5-10 cc

1. The patient’s arm should be abducted to 90 degrees with the hand supinated (Figure 20).
2. The transducer should be positioned over the volar surface of the forearm proximal to the wrist.
3. The median nerve can be located between the palmaris longus tendon and the flexor carpi radialis tendon and traced proximal to the desired level for placement of the block. The goal is to see the nerve on the short-axis view at a...
Tendons can be easily confused with the median nerve (Figure 22). The tendons appear flatter than the nerve and become less distinct as the transducer is moved proximally in the arm.

**Ulnar Nerve Block**

**Patient Position:** Supine with the head rotated toward the nonoperative side. The patient’s arm is abducted to 90 degrees with the hand supinated.

**Probe Location:** Volar surface of the distal forearm

**Frequency:** High

**In-Plane/Out-of-Plane:** In-plane or out-of-plane

**Nerve Image:** Hyperechoic structure with small internal hypoechoic fascicles

**Needle Size:** 50 mm

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Figure 24. The ulnar nerve in the distal forearm.

The ulnar nerve is indicated by the triangles. The nerve is hyperechoic and triangular.

A, ulnar artery

Figure 25. Setup for performing an ultrasound-guided ulnar nerve block in the mid-forearm.

The ulnar nerve at this level has been separated from the ulnar artery. In the mid-forearm, the in-plane approach is preferred, inserting the needle from the radial side of the transducer.

- Tendons can be easily confused with the median nerve (Figure 22). The tendons appear flatter than the nerve and become less distinct as the transducer is moved proximally in the arm.

**Clinical Pearls**

- Small linear transducers with high frequencies tend to work best.
- The more proximal in the arm the block is performed, the less painful it is for the patient.
- The more proximal in the arm the block is performed, the more motor block may result.
Clinical Pearls

- Small linear transducers with high frequencies tend to work best.
- The more proximal in the arm the block is performed, the less painful it is for the patient.
- The more proximal in the arm the block is performed, the more motor block may result.
- We prefer to slide the probe proximally in the arm until the ulnar nerve separates from the artery in order to help avoid an arterial puncture.
- The nerve can be blocked at the wrist crease; however, we prefer to follow the nerve proximally until the ulnar nerve separates from the artery by about 1 cm. This minimizes the risk for an inadvertent arterial puncture (Figures 25 and 26).

Figure 26. The ulnar nerve in the mid-forearm.

The ulnar nerve is indicated by the triangles. Note that it has been separated from the ulnar artery.

A, ulnar artery

Local Volume: 5-10 cc

1. The patient’s arm should be abducted to 90 degrees with the hand supinated (Figure 23).
2. The transducer should be positioned over the volar surface of the forearm proximal to the wrist (Figure 23).
3. The ulnar artery should be identified first, located at the ulnar side of the ulnar artery (Figure 24). The ulnar nerve on the short-axis view appears as a triangular, hyperechoic structure with small, internal hypoechoic fascicles. Because of the ulnar nerve’s intimate association with the ulnar artery, the in-plane technique is preferred.