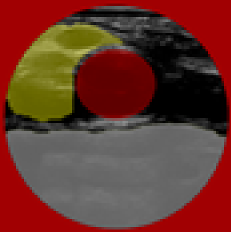

STUART A. GRANT
DAVID B. AUYONG

SECOND EDITION

Ultrasound Guided Regional Anesthesia

OXFORD

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Preface

The foundations of this book come from the practical experience gained in performing and teaching regional anesthesia techniques. Riding the initial waves of ultrasound guided regional anesthesia, we reviewed many texts and other sources and found them to be lacking. Our hope is to save the reader time and effort by sharing pearls and identifying pitfalls to set them on a path for success.

This book differs from others of similar subject matter in that we have designed it as a step-by-step practical companion. We succinctly lay down what we do and teach each day in an organized fashion. There can be many approaches to any nerve block, and in the right hands, many approaches can work. What we have conveyed are simple techniques based on a thorough understanding of anatomy and our many years of clinical knowledge. This book should provide all the necessary instruction to safely and accurately perform each nerve block covered without an overwhelming amount of extraneous information.

In this second edition, we have refined the images that made the first edition so successful. We have kept the format of clean, with unedited images next to colorfully annotated images so the reader can compare the two side by side. In the few years since the first publication, multiple additional ultrasound-guided techniques have been described in the medical literature. As in the first edition, we have distilled these down to the most clinically successful and practical approaches and added them to this new edition.

These specific nerve blocks are described in Chapter 2—Upper Limb, Chapter 3—Lower Limb, and Chapter 4—Trunk and Spine. Readers, whether novice or expert, should take time to read Chapter 1. Chapter 1 is unique in that it covers the essentials of not just the “How to Do It,” but the “How to Do It Well.” It contains many clinical pearls that can be useful in performing any ultrasound-guided procedure. A new appendix, “What Block for What Surgery?,” is found at the end of Chapter 1. This addition will be useful as a practical guide for clinical decision making.

It is beyond the scope of this book to be a comprehensive anatomy, physics, pharmacology, and neurophysiology reference, and we refer readers to the ample texts already published on these subjects. This book should be used as an everyday working practice guide to cover the most common blocks and surgical procedures. Within the following pages, we repeatedly convey the fact that there is no substitute for a good understanding of anatomy. As new blocks are introduced, we head directly for our anatomy textbooks and the cadaver laboratory to best understand how to make these new approaches work clinically. Fortunately, nothing has changed in the anatomy book that you purchased as a student, so it remains your best companion to supplement this textbook.

We are grateful to our families, friends, and colleagues for their patience and help during the writing of this book and throughout our careers. We thank our contributors for their enthusiasm and friendship. Lastly, we thank our teachers and mentors in the United States and in Scotland for their guidance.

Stuart A. Grant
David B. Auyong

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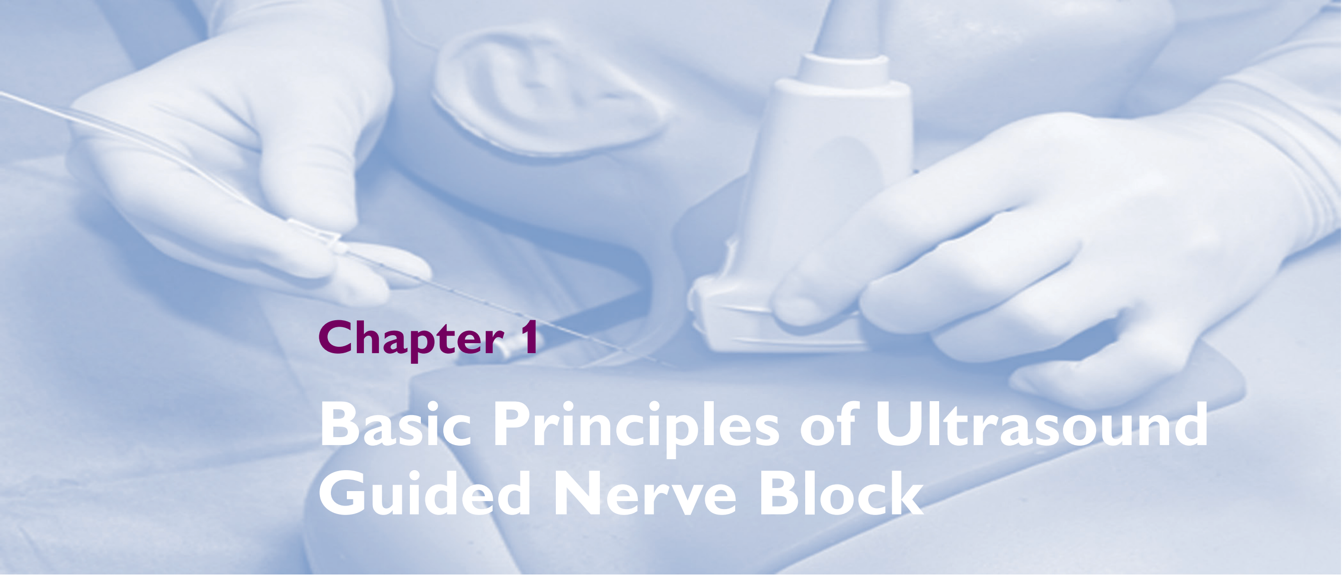


Chapter 1

Basic Principles of Ultrasound Guided Nerve Block

Ultrasound is revolutionizing regional anesthesia techniques that provide anesthesia and postoperative analgesia for patients undergoing surgery. Almost every nerve block previously performed with the use of traditional localization techniques (paresthesias or nerve stimulation) can now be performed under real-time ultrasound guidance. New nerve block approaches, such as the adductor canal nerve block, are not possible without ultrasound. Unlike other localization techniques, ultrasound allows the visualization of nerves and surrounding structures as well as the needle and the local anesthetic.

Ultrasound is most beneficial if a few basic concepts are understood.

Basic Ultrasound Physics and Ultrasound Machine Settings

Generation of Ultrasound Images

The term *ultrasound* refers to high-frequency waves produced by passing electricity through piezoelectric elements. These elements vibrate at a high frequency, creating ultrasound waves. The waves leave the ultrasound transducer and enter the body. They can then be reflected, refracted, scattered, or absorbed depending on the internal structures they encounter. The ultrasound transducer senses the reflected ultrasound waves, and ultrasound images are generated from these reflected waves. Practically speaking, knowing that ultrasound images show waves reflecting off structures in the body may help one to understand why certain structures are visualized better than others. For example, a needle or nerve that is perpendicular, or 90 degrees to the ultrasound wave, appears much brighter on the ultrasound image than a needle or nerve at 45 degrees to the ultrasound wave (Figure 1-1).

Transducer Selection

Almost every nerve block and vascular access procedure can be performed with the use of a linear, high-frequency transducer. When considering a linear, high-frequency transducer, there are several options to choose from. First, linear probes come in varying sizes. For regional anesthesia, appropriately sized linear probes are 25 to 50 mm wide (Figure 1-2). The smaller the probe, the more likely that it will fit into tight spaces on small patients. However,

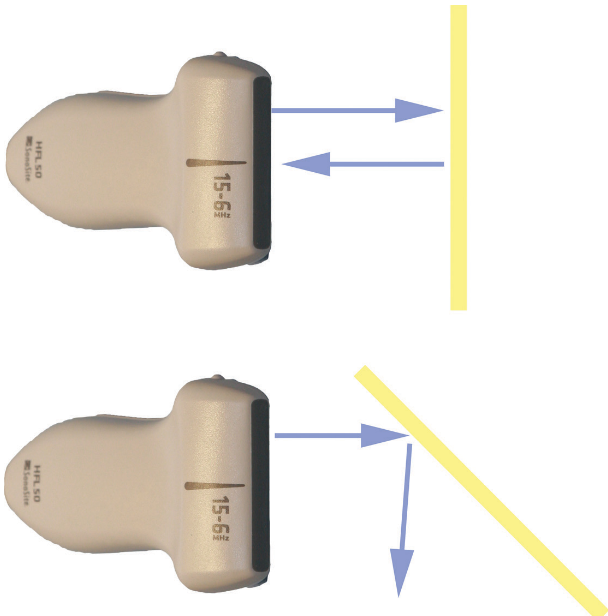


Figure 1-1 Reflections from structures are used to generate an ultrasound image. A structure that is perpendicular to the beam *(top)* generates maximal reflection. A nerve or needle that is at a steep angle *(bottom)* causes less reflection of sound waves to the probe.

Figure 1-2 Ultrasound transducers for regional anesthesia. A small linear probe *(left)* is used for tight areas and vascular access; a large, high-frequency linear probe *(middle)* for the majority of nerve blocks; and a large, low-frequency curvilinear probe *(right)* for deeper structures (e.g., neuraxial scanning).

small probes do not give a wide field of view, so it may more difficult to track a needle approaching a target.

Second, each transducer has adjustable frequencies in a range that varies from 1 to 20 MHz. In general, the higher the frequency, the better the image quality, and the lower the frequency, the better the penetration.

When choosing a transducer to perform a block, any linear probe that is able to generate at least 9 MHz will suffice. We recommend using the widest probe available (appropriate for patient size) to help with needle visualization and to allow visualization of surrounding tissue structures (e.g., lung, blood vessels, muscles). High-frequency linear probes are appropriate for many blocks, including interscalene, supraclavicular, infraclavicular, axillary, femoral, popliteal, sciatic, abdominal or chest wall, and adductor canal blocks.

Curvilinear transducers also come in different sizes. The curvilinear transducers are lower in frequency, so they allow visualization of deeper structures. These transducers are useful for imaging of the spine or paraspinous structures as well as the sciatic nerve. Some curvilinear transducers give a wide field of view but have a large footprint. These large, wide probes are very useful for sciatic and spine imaging (see Figure 1-2). The smaller curvilinear probes are useful for deep imaging and have a smaller footprint, permitting their use in tight spaces.

Frequency

Each transducer has adjustable frequencies. At high frequencies, the trade-off for better image quality is poorer penetration (Figure 1-3); at low frequencies, the trade-off for better penetration is poorer axial resolution due to the longer wavelength. The principle of *axial resolution* means that two distinct points in the body, sitting in the same vertical axis, will be delineated best on the ultrasound screen if a high-frequency ultrasound beam is used.

For shallow blocks, it is best to use high frequencies, and for deeper blocks, it is best to use lower frequencies. Instead of remembering the frequency numbers for each probe, some

Figure 1-3 To achieve the best axial (vertical) resolution, one should use the highest frequency possible. This reduces the wavelength of the sound waves and makes discrimination of small structures possible. The trade-off is poor tissue penetration. The short-wavelength, high-frequency sound waves dissipate more energy, leading to greater attenuation (i.e., less tissue penetration).

manufacturers have simplified frequency adjustments so that there are only three settings to remember:

- General (Gen): General imaging frequency—this is best for most blocks.
- Resolution (Res): High-frequency imaging—this is best for shallow blocks.
- Penetration (Pen): Low-frequency imaging—this is best for deep blocks.

For each probe, the image quality and penetration can be adjusted simply by using the Gen/Res/Pen settings.

Each brand of ultrasound transducers provides for frequency adjustment in a different way. Familiarity with the machine and learning to adjust the frequency result in improved imaging with ultrasound.

Depth

The depth should be adjusted so the nerve target is in the middle of the screen. Most ultrasound machines are preset with the focal zones in the middle of the screen. Focus allows the best possible axial resolution, improving image quality. This means that the clearest image of the target will be obtained if the target is in the middle of the screen. A depth setting that places the needle and nerve in the middle of the screen should be used whenever possible. Some machines require manual adjustment of focal zones.

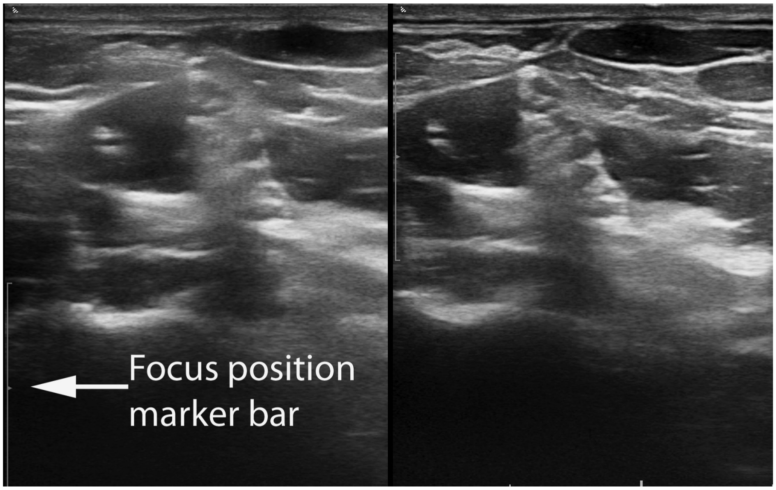


Figure 1-4 Focus position affects image quality. The identical interscalene anatomy is scanned on two images. On the left, the focus is set deep, and on the right, the focus is set at the level of the targeted nerves. The fascicles of the nerves are easier to identify on the right because the focus is set at the optimal depth for visualization of the nerve roots at the interscalene level.

Focus

Ultrasound beams can be focused, much as light can be focused through a lens on a camera. As in a photograph, ultrasound images that are out of focus appear less sharp. Correct focus improves lateral resolution (Figure 1-4). The principle of *lateral resolution* means that two distinct points in the body, sitting side by side, will be best delineated on the ultrasound screen if correct focus is used.

Some machines have the ability to set focal zones and to move these zones up and down. Focal zone markers usually appear as one to five small arrows on the side of the ultrasound image. The focal zone should be set at the depth at which the nerve or target vessel is located. Some machines have simplified the idea of focus and use a type of autofocus. With autofocus machines, there are no focal zone markers; the focal zones are preset in the middle of the screen. Therefore, the target should be placed in the middle of the screen by using the depth buttons to optimize image focus.

Gain

The term *gain* on ultrasound machines refers to screen brightness. There are no specific rules for adjusting the gain. Usually, each person has a preference for gain settings. However, some general suggestions can be made.

- The brightness of the screen should be adjusted so that vascular structures appear dark or anechoic (i.e., without echoes).
- Too much gain results in artifacts such as reverberation (discussed later); these artifacts can "repeat" bright structures such as fascial planes, obscuring targets.
- Because ultrasound beams returning from deeper structures become attenuated (i.e., return a weaker signal), increasing the distal gain can be helpful in visualizing these structures (Figure 1-5).

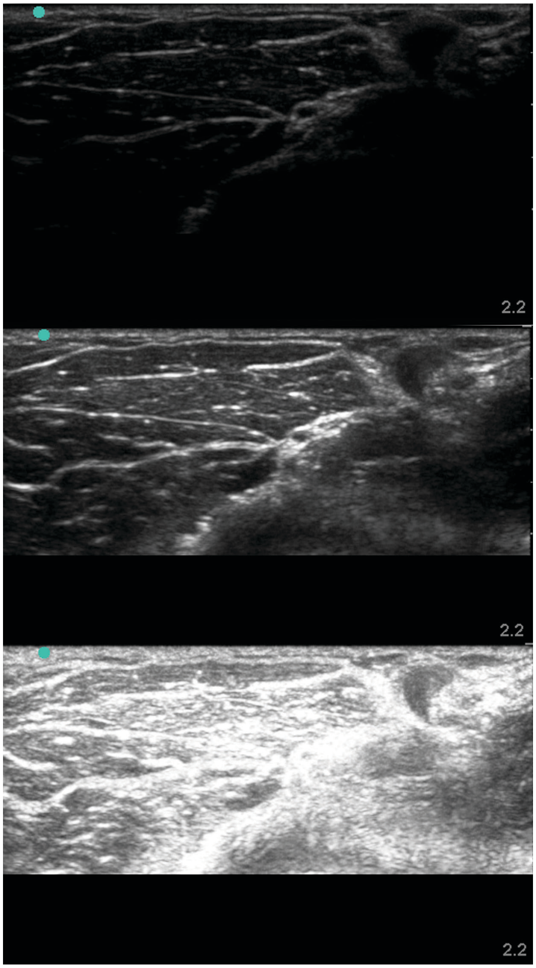


Figure 1-5 Overgained and undergained images. The center image demonstrates a bright radial nerve in the center with good detail of the surrounding musculature. The undergained image of the same nerve *(top)* is very dark, and the overgained image *(bottom)* is very bright. Vital detail is lost in both cases.

Time Gain Compensation

Time gain compensation (TGC) is the ability to adjust the gain (screen brightness) at several levels on the ultrasound image. Some machines have sliding knobs to perform this task, whereas others have dials to turn. Usually, the distal (bottom) part of the screen appears darker than the proximal (top) part of the screen. In order to produce a more uniform screen brightness, the TGC knobs should be increased distally and decreased proximally (Figure 1-6).

Color Doppler Imaging

Color Doppler ultrasound imaging allows visualization of flow. Flow can be the movement of arterial or venous blood or the movement of a local anesthetic into tissue after injection.

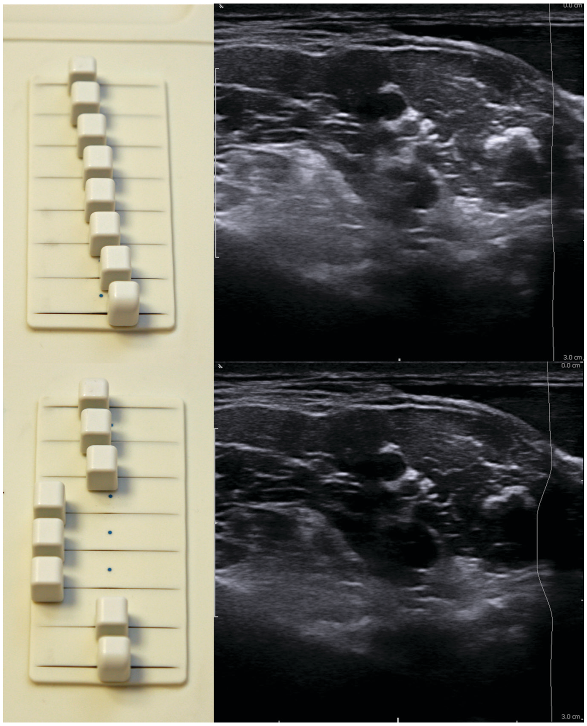


Figure 1-6 Time gain compensation (TGC) adjusts the brightness at various tissue depths on the screen. This can lead to artifact if the adjustment bars (shown at left) are not set correctly. In the top image, the TGC control bars are set appropriately and the nerves are visible. In the bottom image, one of the nerve roots is not visible because the TGC bars controlling that region have been moved. Usually, the distal TGC levels are set higher to compensate for attenuation.

It is important to remember that the red or blue color on the screen does *not* signify oxygenated (arterial) blood or deoxygenated (venous) blood. A red appearance on color Doppler imaging signifies that the fluid is moving toward the probe. A blue appearance means that the fluid is moving away from the transducer. The mnemonic B.A.R.T. (Blue, Away from you; Red, Toward you) may be used to remember this principle.

Sometimes, there is no color in a structure that appears to be a blood vessel. The Doppler principle works best when the angle between the flow of the blood and the transducer is less than 90 degrees. The Doppler equation uses the cosine of the angle between the transducer and the flow, and the cosine of 90 is 0. This means that if the transducer is at 90 degrees to the blood flow, the measured flow will be zero and there will be no color on the screen. The transducer must be tilted in one direction or the other to better visualize blood flow with color Doppler (Figure 1-7).

When performing nerve blocks, it is often beneficial to move the Doppler box over not only the large artery but also the path the needle will take toward the nerve. Moving the Doppler box over the projected needle path before needle insertion helps identify smaller vessels and prevent accidental vascular puncture.

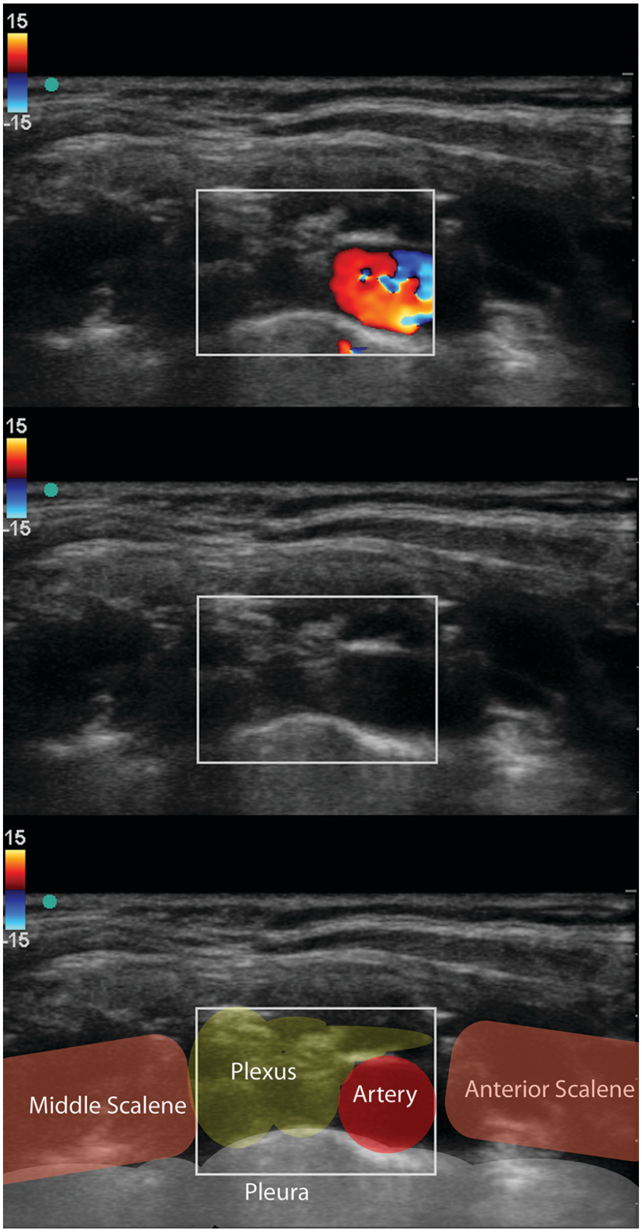


Figure 1-7 Color Doppler ultrasound can help identify vessels. Tilting the probe can make vessels appear to have better flow. This is important to help discriminate vessels from nerves. In the middle image, the probe is placed perpendicular to the direction of blood flow, resulting in limited Doppler signal. In the upper image of the same artery, the probe is tilted at an acute angle, producing a better Doppler signal. The lower image identifies the structures shown.

Clinical Case Scenario

The following clinical case example is provided to illustrate the importance of understanding the ultrasound controls. When reading through this scenario, practitioners are encouraged to reflect on how they utilize the ultrasound controls or move the ultrasound transducer.

A patient weighing 300 lb (136 kg) is scheduled to undergo complex ankle and foot surgery. The anesthetic plan is a popliteal nerve block and an adductor canal block.

After all equipment has been gathered, the consent has been obtained, the patient has been positioned and sedated, and the anesthesia time out (discussed later) has been performed, it is time to begin the procedure. The ultrasound machine should be positioned so that the operator can easily see the screen by simply gazing upward.

After the ultrasound machine is powered up, it will default to its usual startup settings. At our institution, with a high-frequency linear probe, the default depth is 2.5 cm and the default frequency setting is "Res" (resolution). In this obese patient, the popliteal artery will not be visible at these default settings. As most practitioners will recognize, an increase in depth is warranted. If the target structure is at a depth of 4 cm but the screen is set at a depth of 2.5 cm, the depth setting must be increased to view the target.

Does increasing the depth setting improve the imaging of structures deeper in the image? Sometimes a structure is so obvious that an increase in depth will help visualize the target. However, increasing the depth alone often does not make deeper structures visible because the deeper part of the image appears darker. Three additional aspects besides depth must be considered: frequency, gain, and focus.

Frequency does not change when depth is increased. Increasing the depth alone does not improve the ability of the sound waves to penetrate into the tissues. Frequency and depth are not linked on the ultrasound machine. To improve the visibility of deeper structures, the frequency range should be reduced. It is vital to understand how to do this on the specific ultrasound machine being used. Some machines require dial adjustments with a specific frequency number, whereas others provide nomenclature delineating a frequency range (i.e., Resolution, General, and Penetration). Decreasing the frequency can reduce the resolution of fine detail, but if this adjustment allows the target structure to appear more obvious, it is a trade-off that can be tolerated. If increasing the depth and lowering the frequency is still not enough, changing the transducer to one with an even lower frequency can be a feasible step. This is one reason why a prescan or scout scan is good practice.

The second important adjustment is gain (image brightness). When the image depth is shallow, brightness often looks uniform. If the depth is increased, it becomes much more obvious that gain is not uniform. The deeper parts of the image appear much darker because of *attenuation* (scattering and absorption of ultrasound waves). The operator can increase the overall gain, which allows the deeper target area to be better visualized, but often at the cost of loss of detail in the superficial structures because they are now too bright. Almost all ultrasound machines have a TGC capability, which allows the operator to adjust the brightness at multiple levels from superficial to deep. Some machines allow TGC adjustments in two areas (i.e., proximal and distal); others have multiple TGC controls to allow adjustments in up to eight different levels. Learning where the gain controls are and how to use them is important to improve imaging in challenging patients.

Finally, the focus of the ultrasound machine is important. Focus helps improve the resolution of the image. In some popular machines, the focus is always in the middle of the ultrasound image. For example, if the depth is set at 2 cm, the focus will be at 1 cm; if the depth is set at 6 cm, the focus will be closer to 3 cm. A machine with independent focus controls often permits a change in focal depth and in the number of focal zones. A change of focus position can improve image quality. It must be understood that depth adjustments do not change frequency, but a change in depth can change the focus.

To summarize, one should first change the depth setting, then consider (1) lowering the frequency, (2) adjusting the gain, and (3) adjusting the focus position.

Once the nerve is visible, the operator should consider techniques to improve needle imaging. Most important for imaging of the needle is the insertion point of needle entry. The depth of the target structure should be determined, and the operator should plan to insert the needle sufficiently far from the transducer so that it can be advanced at a flat angle (<30 degrees if possible). Even for a shallow block in which the target is less than 2 cm deep, plan to start the needle about 1 cm away from the transducer. For deeper blocks at 4 to 5 cm, consider inserting the needle up to 5 cm away from the transducer (Figure 1-8).

Another adjustment to improve needle imaging is to ensure that there is a marked heel-toe tilt of the transducer away from the point of needle entry (see later discussion). This movement is particularly important in obese patients, in whom the needle trajectory can be very steep. Steep needle trajectories make needle imaging difficult, and a heel-toe tilt can decrease the perceived steepness, resulting in improved needle brightness. The following section describes a step-by-step process for needle visualization.

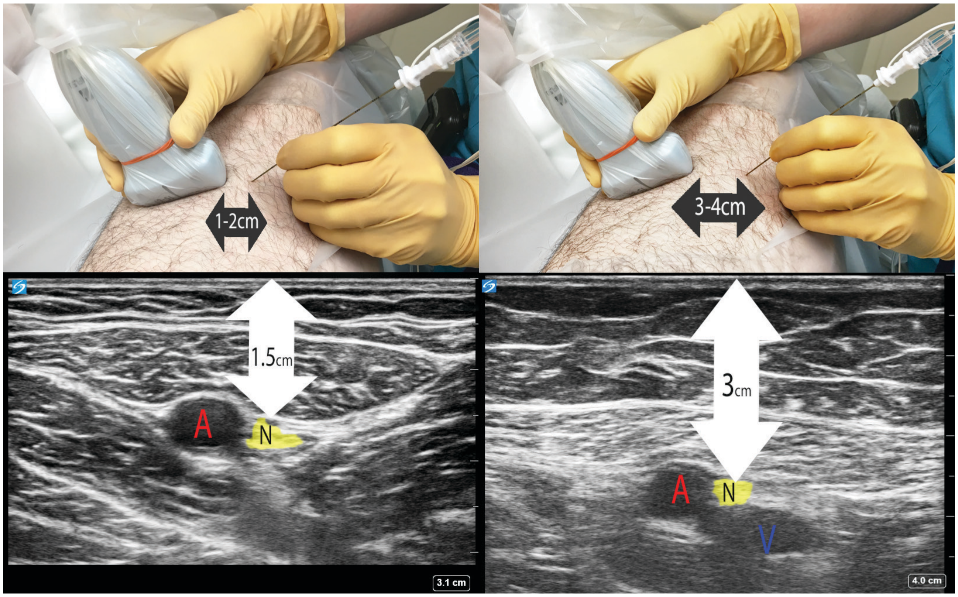


Figure 1-8 Adjusting the needle insertion site. Two examples of an adductor canal block are shown: a shallow nerve target at 1.5 cm *(left)* and a deeper nerve target at about 3 cm *(right)*. To perform a nerve block with a shallow target, the needle should be inserted 1 to 2 cm lateral to the transducer. To perform a nerve block for a deeper target, the needle insertion site may be 3 to 4 cm lateral to the probe. Starting the needle insertion farther from the probe for deeper blocks allows for a flat needle angle that better reflects the ultrasound waves. This results in better needle visibility during the nerve block. A, artery; N, nerve; V, vein.

How to Visualize Nerves and Needles

The term *axis* in ultrasound guided regional anesthesia is used to describe the view obtained of a structure (nerve or vessel) in relation to the ultrasound beam. A *long axis* view is an image along the length of the nerve. A *short axis* view cuts across the diameter of the nerve. Usually, the goal is to obtain a short axis view of the nerve.

The term *plane* in ultrasound guided regional anesthesia is used to describe the needle position relative to the ultrasound beam. Most nerve blocks are performed with an *in-plane* approach (see later discussion). If performed correctly, this approach allows the entire needle (shaft and tip) to be visualized (Figure 1-9). As a result, the user can place the needle tip with the greatest amount of confidence and, potentially, the greatest safety. *Out-of-plane* approaches, if done correctly, can also be an effective way of targeting nerves or vessels with needles. Both techniques have risks and benefits, and the practitioner must decide which needle approach is suitable for each block or target.

In-Plane Needle Approach

A Three-Step Process for In-Plane Needle Imaging

The following three-step process should be performed in the order shown to quickly locate and image the needle in-plane.

1. **Step 1: Look at Your Hands.** Look down at your hands and physically line up the transducer with the needle. Aligning the needle and transducer for in-plane imaging is difficult when looking at the image on the ultrasound screen. The quickest way to align the probe and the needle is to take your eyes off of the ultrasound screen and look down at your hands to physically line up the needle with the exact center of the transducer (Figure 1-10). The center of the probe and the needle must be in exact alignment to produce a needle image. Spending a few seconds to ensure that the needle and transducer are in perfect alignment by physically looking at your hands holding the needle and transducer can most efficiently improve needle visualization under ultrasound.

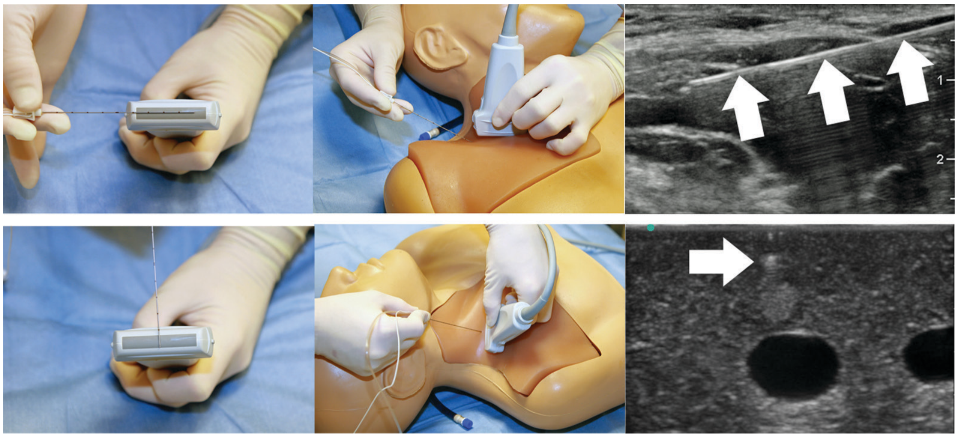


Figure 1-9 In-plane and out-of-plane needle approaches. The upper images demonstrate an in-plane needle approach with needle-probe alignment in space (upper left), needle-probe on a mannequin (upper middle), and ultrasound image of an in-plane needle (upper right). The lower images demonstrate an out-of-plane needle approach with needle-probe alignment in space (lower left), needle-probe on a mannequin (lower middle), and ultrasound image of an out-of-plane needle (lower right).

Figure 1-10 **Step 1: Look at Your Hands.** To most quickly find a needle, look at your hands, the needle, and the probe *(left)*. Spend some time to physically line up the probe and the needle before looking up at the ultrasound screen *(right)*. A common beginner's mistake is to try to align the needle by looking only at the ultrasound screen. Look down at your hands first. Once the needle and probe are grossly aligned, only slight probe movements will be required to image the needle brightly.

2. **Step 2: Slide to See the Needle.** Slide the probe back and forth across the needle to visualize the needle on the ultrasound screen. If the needle has been properly aligned (Step 1), the next step is to slide the transducer across the needle (Figure 1-11). Sliding is much more effective than other transducer movements (e.g., tilt, rotation, pressure) in finding the needle. If the needle and probe are in exact alignment, the most effective way to visualize the needle with ultrasound is to slide the probe only a few millimeters back-and-forth across the needle because the needle must cross the path of the ultrasound beam with this movement. Sliding also helps to maintain good visualization of the target structures during needle advancement.
3. **Step 3: Heel-Toe the Ultrasound Beam into the Needle.** Aim the ultrasound beam into the needle with a heel-toe transducer movement. If the needle is still not visible after Steps 1 and 2, heel-toe the probe by moving the top of the transducer away from the needle entry point. This orients the ultrasound beam coming from transducer more to the position of the needle, which in turn improves reflection of the ultrasound waves from the needle, enhancing needle brightness on the ultrasound image (Figure 1-12).

Needle visualization with an in-plane approach is not easy, but following the steps in this section will greatly increase success. In addition, practicing the technique as described improves the time required to perform regional anesthesia at the bedside. The three-step process for in-plane needle visualization can be practiced in a gel phantom or a piece of meat obtained from the grocery store. Out-of-plane needling technique is described next and can also be practiced in the same manner.

Out-of-Plane Needle Approaches

Out-of-plane needle approaches most closely resemble the needle approaches that were used when paresthesia or nerve stimulation was the means of locating nerves. Some people prefer out-of-plane needle approaches because they are more comfortable with the traditional approaches to locate nerves. However, out-of-plane nerve blocks do not visualize the tip of the needle at all times and therefore do not offer the same level of confidence and potential safety that comes with always knowing where the needle tip is located. Out-of-plane needling techniques are particularly useful for vascular access procedures and deep nerve blocks.

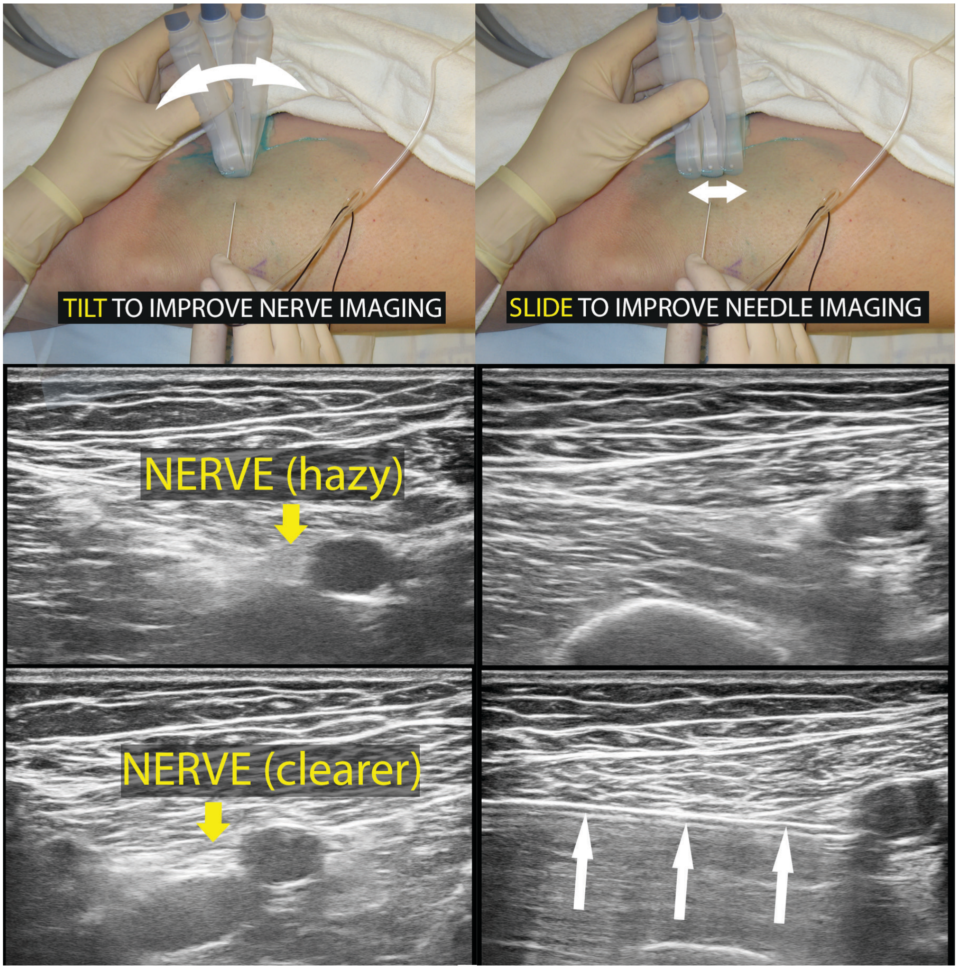


Figure 1-11 **Step 2: Slide to See the Needle.** Once the needle is physically aligned as described in Step 1, only slight sliding of the probe back and forth across the needle will be required in most cases to image the needle *(right images)*. Although tilting the probe is useful for improving the imaging of nerves *(left images)*, tilting the probe to find the needle will degrade the image of the target structures. This can be summarized in the statement, "Tilt to see nerves, slide to see needles."

An out-of-plane approach to needle insertion appears simple but can be difficult. The major fault with these approaches is that the needle appears as a hyperechoic or bright dot on the ultrasound screen. This bright dot can be the tip of the needle (and is often assumed to be the tip of the needle even when it is not), but it can also be the shaft of the needle. Assuming that the hyperechoic dot on the screen is the needle tip is a common beginner's mistake. In an out-of-plane approach, the shaft of the needle looks no different from the tip, but the tip may actually be much deeper in the tissues. Another fault is that the dot of the needle sometimes is not visible at all. As with in-plane needle advancement, needles inserted at shallow angles will appear brighter on the ultrasound image. Therefore, a flat needle angle should be used for insertion in the out-of-plane needle orientation whenever possible. The

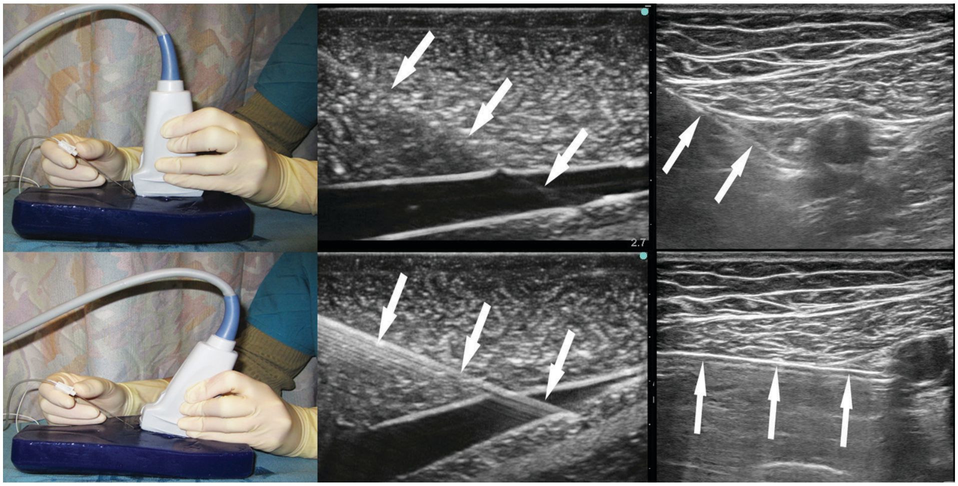


Figure 1-12 **Step 3: Heel-Toe the Ultrasound Beam into the Needle.** Aim the ultrasound beam into the needle to image needles inserted at steep angles. Often just a small angling of the probe into the needle allows for significantly improved needle visualization. The top images were obtained with the probe oriented vertically; in the bottom images, the probe is tilted. The images at left and middle were done with the use of a gel phantom and illustrating the improved needle visualization when the ultrasound beam is angled into the needle. This is highlighted in a clinical adductor canal block, where needle imaging is improved using this technique *(right images)*.

dot on the screen will appear much brighter because of improved ultrasound reflection from the needle.

Good out-of-plane needle technique follows the tip of the needle as it is advanced through tissue. Three techniques are used to follow the needle tip.

Out-of-Plane Technique 1—Slide the Probe

The needle is advanced out-of-plane until a bright dot is visualized above (i.e., shallow to) the target (Figure 1-13). Once this dot is visualized, needle movement stops. The probe is then advanced forward (away from the needle) until the dot disappears. Next, the needle is advanced again until the dot reappears; it should now be deeper and closer to the target. The probe is then advanced until the dot disappears again. The needle is then re-advanced. These steps are repeated until the dot is near the target. The dot must appear and disappear as the needle and the probe are alternately advanced. This way, the tip is confirmed as it approaches the nerve or vessel target.

Out-of-Plane Technique 2 –Tilt the Probe

This technique is similar to the sliding technique, but it allows the probe to stay in one spot and may be useful in tighter areas where the probe cannot slide very far (Figure 1-14). The needle is advanced out-of-plane until a bright dot is visualized above (shallow to) the target. Once this dot is visualized, needle movement stops. The ultrasound beam is then tilted forward (away from the needle) until the dot disappears. The needle is then advanced until the dot reappears. The dot should now be deeper and closer to the target. The ultrasound beam is again tilted forward until the dot disappears. The needle is then re-advanced. This process is repeated until the dot is near the target. Essentially, the dot must appear and disappear as the needle and probe are alternately moved. This way, the tip is confirmed as it approaches the nerve or vessel target. This technique is better for vessels than for nerves; nerves often disappear if the probe is tilted too much.

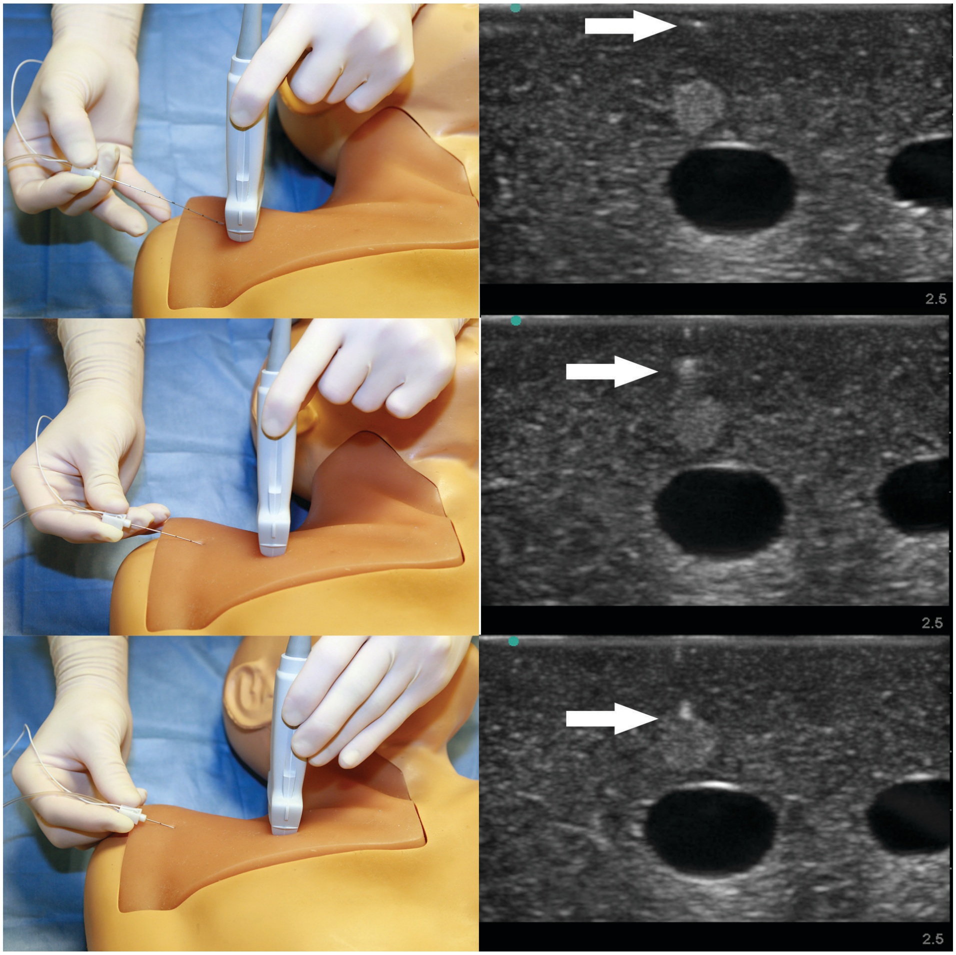


Figure 1-13 **Out-of-Plane Technique 1—Slide the Probe.** Hold to probe over the target. Advance the needle slowly in a shallow plane with the bevel up (to make the needle most visible). Look carefully for the hyperechoic dot as the needle cuts the plane of the beam, then stop advancing the needle immediately *(top images)*. Slide the probe forward beyond the needle tip. Increase the needle angle appropriately, and advance the needle again, looking carefully for the hyperechoic tip. Stop as soon as the needle tip is visible *(middle images)*. Repeat the process until the needle descends down onto the target *(bottom images)*.

Out-of-Plane Technique 3—Adjust the Needle

This technique allows the probe to remain completely stationary. The needle is advanced out-of-plane until a bright dot is visualized above (shallow to) the target. Once this dot is visualized, needle advancement stops. The needle is then withdrawn (but not completely out of the body), and the dot should disappear. The needle angle is steepened, and the needle is advanced again until the dot reappears (Figure 1-15). The dot should now be deeper and closer to the target. The needle is again pulled back, making the dot disappear, then re-advanced at a yet steeper angle. This process is repeated until the dot works deeper and is

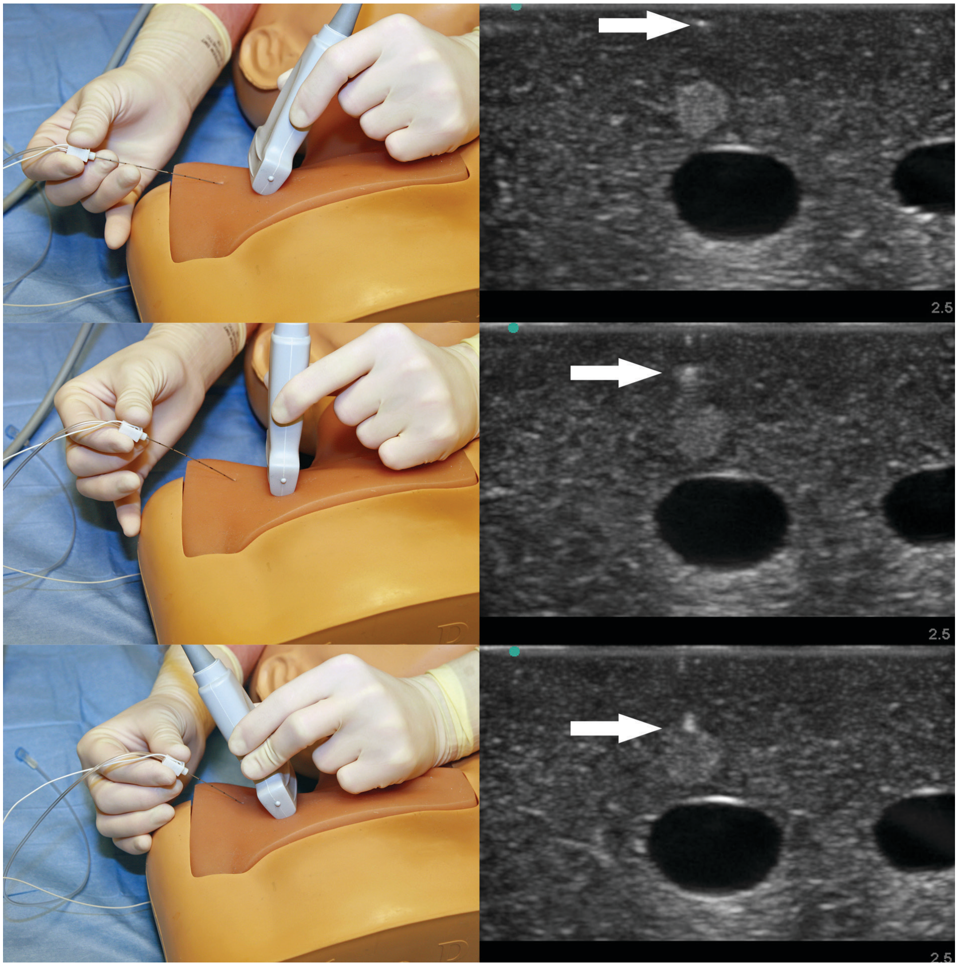


Figure 1-14 **Out-of-Plane Technique 2—Tilt the Probe.** Hold the probe over the target with the probe tilted so that the ultrasound beam faces the needle. This increases the reflection from the needle and provides room to tilt the probe toward the needle as it is advanced. Advance the needle slowly in a shallow plane with the bevel up. Look carefully for the hyperechoic dot as the needle tip appears on the screen. As soon as the needle is visible, stop advancing immediately *(top images)*. Tilt the probe to ensure that the ultrasound plane is just beyond the tip of the needle. Next, advance the needle toward the target. Again, as soon as the needle breaks the plane of the beam, stop *(middle images)*. Repeat the process until the target is reached *(bottom images)*.

near the target. Essentially, the dot must appear and disappear as the needle is advanced and withdrawn. This way, the tip is confirmed as it approaches the nerve or vessel target.

All of these techniques require one important quality when looking for the bright (hyperechoic) dot of the needle: the bright dot must appear, then disappear, then appear again as the needle is advanced through the tissue. If the dot does not disappear, there is no way to rigorously confirm that the dot is the needle tip.

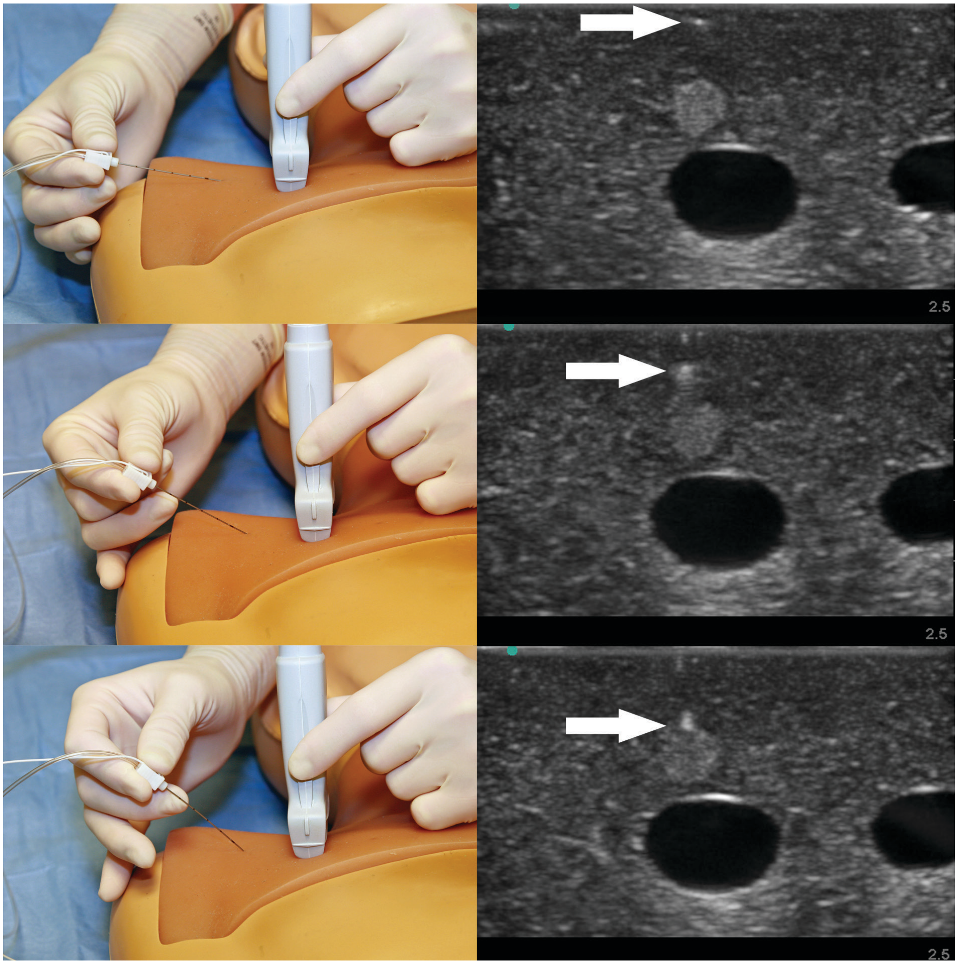


Figure 1-15 **Out-of-Plane Technique 3—Adjust the Needle.** Hold the probe over the target. Advance the needle under the middle of the probe with a shallow insertion angle. When the tip of the needle appears visible as a bright dot on the screen, immediately stop needle advancement *(top images)*. Withdraw the needle, and redirect it at a steeper angle. Advance the needle until the tip is seen, and stop again *(middle images)*. Repeat the process at steeper angles until the target is reached *(bottom images)*. The hyperechoic tip can be viewed in a stepwise fashion as it descends toward the target.

Visualizing the Injection

Probably the best marker for ruling out intravascular injection of local anesthetic is ultrasound visualization of the injectate. If local anesthetic spread is not obvious on the ultrasound screen, the injection should immediately be halted and the needle tip position reconfirmed. It should be assumed that the needle tip is intravascular if no spread of the local anesthetic is visualized.

Nerve Stimulation

Nerve stimulation is a good way to confirm that a nerve has been reached when using ultrasound. Many centers routinely use nerve stimulation in conjunction with ultrasound.

Nerve stimulation used in combination with ultrasound performs a different role than when it is used alone. Nerve stimulation used alone is a nerve location and needle proximity tool. When it is used with ultrasound, the target nerve has already been visualized, and nerve stimulation serves only as confirmation of that nerve. Over time, with improved experience using ultrasound and identifying nerve targets, nerve stimulation may not be necessary.

When ultrasound is used, the nerve stimulator may be turned off while the needle is advanced through muscle tissue to decrease direct muscle contractions and improve patient comfort. As the needle approaches the nerve, the stimulator is turned on and set to 0.8 to 1.5 mA, and an appropriate twitch is sought. Appropriate twitches and nerve stimulation are more fully discussed in other regional anesthesia texts. The point of this text is to encourage best practice in interpreting the ultrasound image.

Transfer of Experience with Nerve Stimulation to Use of Ultrasound

There are many advantages for a practitioner who is already experienced with nerve stimulation that can assist in adopting ultrasound for needle and nerve localization. In addition to the anatomic knowledge that comes from nerve stimulator guided regional anesthesia, one must incorporate a basic knowledge of ultrasound equipment, controls, and physics. For example, when performing a popliteal sciatic nerve block using nerve stimulation, knowledge of surface anatomy and recognition of a peroneal or tibial nerve twitch correlates with success. When ultrasound is used, knowledge of the relative anatomic positions of muscles, vessels, and nerves must be translated to recognition on an ultrasound screen. Additionally, in comparison with nerve stimulation, ultrasound requires different needle insertion points and dynamic movement of the probe along the nerves so that a three-dimensional picture is created.

The following step-by-step approach is suggested to move from nerve stimulation to ultrasound:

1. Understand the ultrasound equipment (see discussion at the beginning of this chapter).
2. Be familiar with the anatomy and sonoanatomy (specific nerve blocks are discussed in later chapters).
3. Begin by using ultrasound and nerve stimulation together. Set the nerve stimulator to 0.8 to 1.5 mA as the needle is advanced to the nerve. Look at the appropriate twitch as the needle contacts the nerve. Often the needle must be placed very close to the nerve to elicit a twitch.
4. After some experience is gained, set the stimulator up just to confirm the nerve. Do not start with the nerve stimulator on. Turn on the stimulator only after the needle is close to the nerve. This approach often improves patient comfort during the procedure because slow increases in current can gently stimulate the innervated muscles.
5. After you are familiar with the ultrasound, attach the nerve stimulator but turn it on only if you are unsure of the image or nerve location.
6. Finally, do not use the nerve stimulator regularly but have it available.

The time it takes to transition from nerve stimulation to ultrasound depends on the individual learner. If some tissue movement on the screen is the only goal during needle advancement, as opposed to striving for a clear needle image, then your technique may never improve. Several needle imaging tips were outlined earlier in this chapter. We recommend methodical needle imaging and not advancing the needle close to the nerve until the needle tip is visualized.

Ideal Needle–Nerve Approximation for Regional Anesthesia

The ideal needle–nerve approximation for regional anesthesia is an issue of debate among the experts in the literature and at national and international meetings. Often, performance of exactly the same block places the tip of the needle in a different spot in different patients. The major consideration is safety first, then speed of onset and block quality. Things to consider when performing nerve blocks are patient factors, anesthetic factors, and specific block factors.

Patient factors include preexisting conditions such as neuropathy, preexisting nerve injury, and medications including anticoagulants. The benefits of a nerve block must be weighed against the risks of bleeding or nerve injury.

Anesthetic factors to consider before performing a nerve block include the reason for placing the block. If the block is the sole anesthetic and it is critical to avoid a general anesthetic, one may be more aggressive with the dose and ensure that the local anesthetic is delivered in very close proximity to the nerve. If the block is being performed as an analgesic technique combined with a general anesthetic, a more conservative placement may be used as speed of onset and block density are less critical.

Individual block factors include the position of the block and the depth of the block. The interscalene nerve roots are sometimes surrounded by a sheath. Under no circumstances should the regionalist attempt to enter any of the dark anechoic circles in the interscalene region. On the other hand, the multiple fascial layers surrounding the nerves in the popliteal fossa make it preferable to place the needle deep to the fascia (paraneural sheath), usually between the tibial and peroneal components. Deeper blocks, such as the infraclavicular block, often do not have the ultrasound image detail that shallower blocks have, so areas around the artery may be targeted instead of specific nerves.

Common Artifacts and Errors

Dropout

When dropout occurs, certain areas under the probe are not well visualized (Figure 1-16). To remedy this situation, ensure that the probe is in good contact with the patient and that there is enough ultrasound gel between the probe and the patient. If a probe cover is used (see later discussion), ensure that there is plenty of gel inside the probe cover and transducer; a paucity of gel here often leads to poor image quality. If a simple occlusive dressing such as Tegaderm is being used, it can be adhered directly to the probe, without gel.

Attenuation

With attenuation, deeper areas of the ultrasound picture are not well visualized (Figure 1-17). The remedy is to increase distal gain (TGC) or change to a lower frequency.

Needle Sliver

If the needle is not completely in-plane, a needle sliver may be seen. Not imaging the entire needle can lead to a false understanding of how deeply the needle is actually inserted. The tip of the needle may be deeper than it appears on the ultrasound screen (Figure 1-18). Needle–probe alignment must be confirmed visually on the screen and by looking down at the needle and probe (review the three-step process for in-plane needle imaging described earlier). Usually the probe can be rotated over the needle to obtain a complete view of the needle.

Bayonet Effect

In the bayonet effect, the needle appears bent when it is not (Figure 1-19). Different tissues transmit ultrasound waves at slightly different speeds. Therefore, when the needle passes from one type of tissue to another, the needle can appear slightly "bent" because the ultrasound waves returning to the transducer are moving at different speeds through the different tissues. There is no fix for this artifact. One must simply recognize that it is an artifact, not an actual bending of the needle.

Intraneural Injection

Injection near a nerve should produce a dark (anechoic) area of local anesthetic around a nerve. Occasionally, the needle gets too close and is actually inserted inside a nerve. During injection of the local anesthetic, the patient may or may not feel a paresthesia. If the nerve is not visualized expanding during injection, the needle is likely outside the nerve. If the nerve

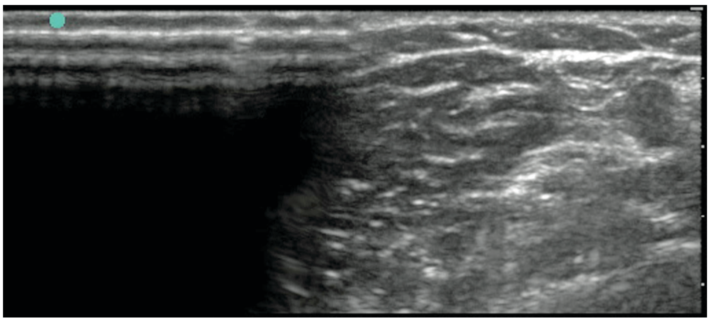


Figure 1-16 Dropout artifact is caused when the entire foot of the probe is not in contact with the skin surface.

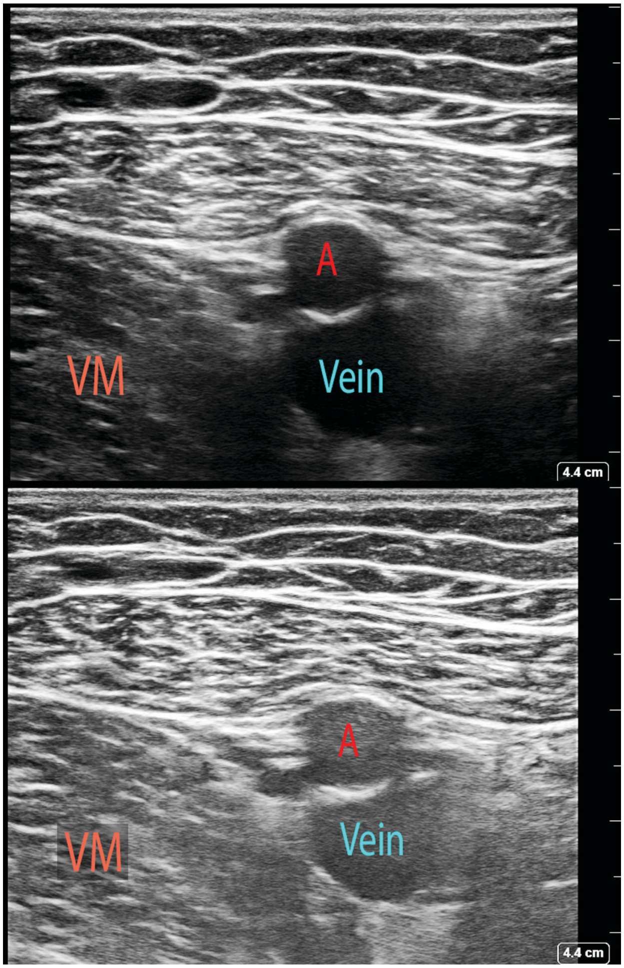


Figure 1-17 Attenuation occurs as ultrasound waves penetrate tissues and are scattered and absorbed. In the upper image, the distal field is dark and there is loss of the vein definition and muscle definition in the vastus medialis (VM). In the lower image, the distal gain has been increased to make the distal portion of the image more visible. Other ultrasound adjustments to view deeper structures include reducing the frequency and setting the focus to a deeper position. A, artery.

expands during injection (Figure 1-20), the needle is likely intraneural. The injection should be immediately stopped and the needle withdrawn from the nerve. Current thinking is that if the injection is sub-epineural (i.e., outside the covering of a nerve bundle), there is only a small chance for permanent injury. If the injection is sub-perineural (i.e., inside a nerve fascicle), the likelihood of prolonged neuropathy is increased.

Reverberation Artifact

When the needle is completely in-plane, it will have a “shadow” below it. The ultrasound beam is bouncing between the anterior and posterior walls of the needle, creating a shadow effect below the needle. This is called a reverberation artifact. The reverberation artifact

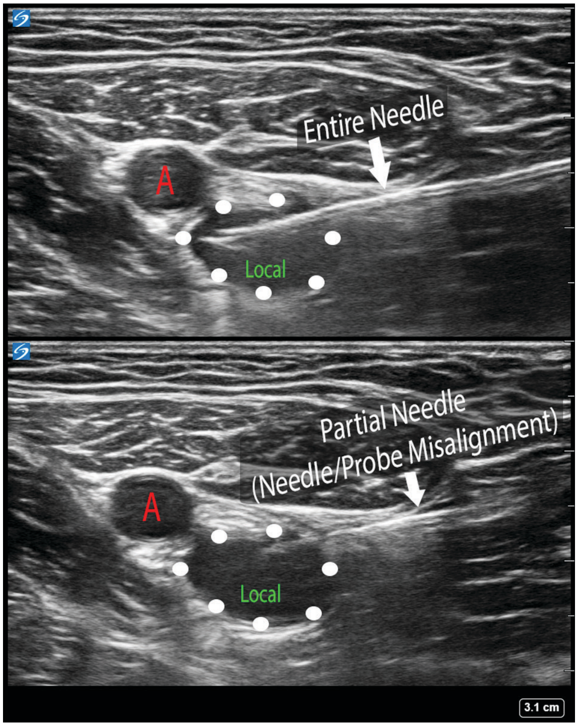


Figure 1-18 Needle misalignment is common and can lead to incorrect identification of the needle tip. In the two ultrasound images, the needle has not been moved but because of misalignment of the needle and the transducer, the needle tip position appears different in the bottom image.

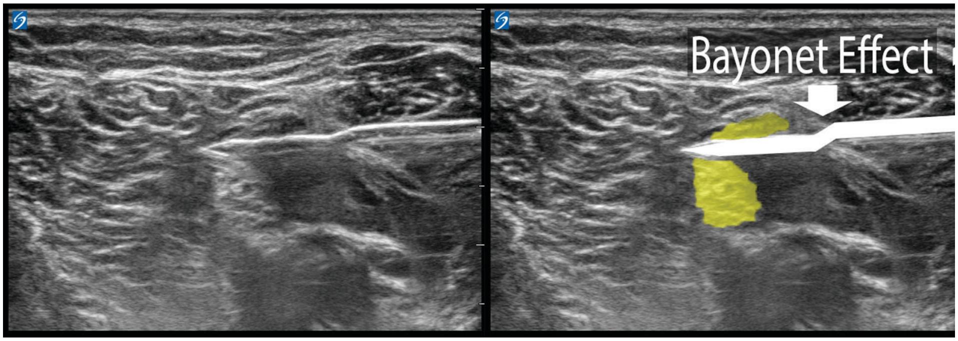


Figure 1-19 Bayonet effect. The needle appears bent as it passes through different tissue types (i.e., fat and muscle) that transmit ultrasound waves at different speeds. The different speeds in adipose tissue surrounding the nerve (slower) and in muscle (faster) cause a bayonet needle artifact.

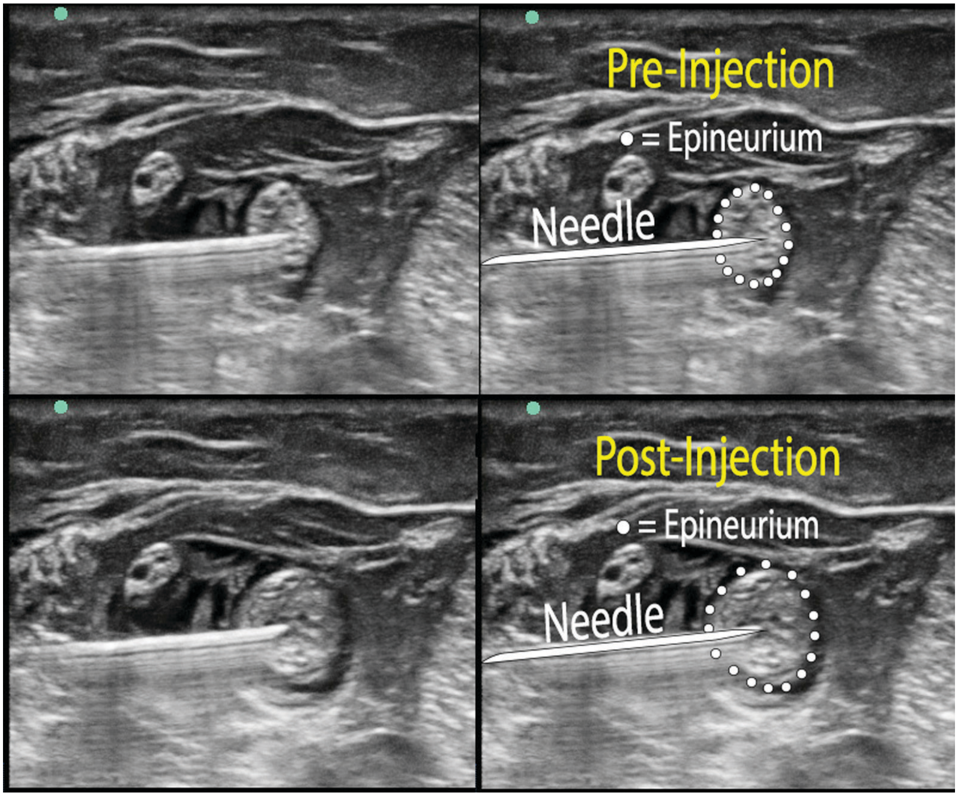


Figure 1-20 Intraneural injection. Ultrasound images on the left were taken before *(upper)* and after *(lower)* an intraneural injection within the tibial nerve. The swelling of the nerve due to intraneural injection is obvious. In the labeled images on the right, the epineurium surrounding the nerve is identified as small white dots.

indicates that the needle is completely in-plane, and this is actually the preferred view, unless it is obscuring important structures below the needle (Figure 1-21).

Step-Off Technique

If a reverberation or shadow artifact is obscuring structures deep to the needle, use of the "step-off" technique may be considered. Instead of always imaging the needle, the operator purposely slides the probe away from the needle, "stepping-off" from the good needle image (Figure 1-22). This allows visualization of structures that may be hidden beneath a good needle image. Another situation in which this technique may be useful is in visualizing local anesthetic spread. Often, the local anesthetic spreads in other planes besides the two dimensions imaged with the ultrasound and needle. To assess local anesthetic spread, the transducer may be slid away from the needle, even during dynamic injection. With this technique, large pools of local anesthetic often can be located away from the actual injection site.

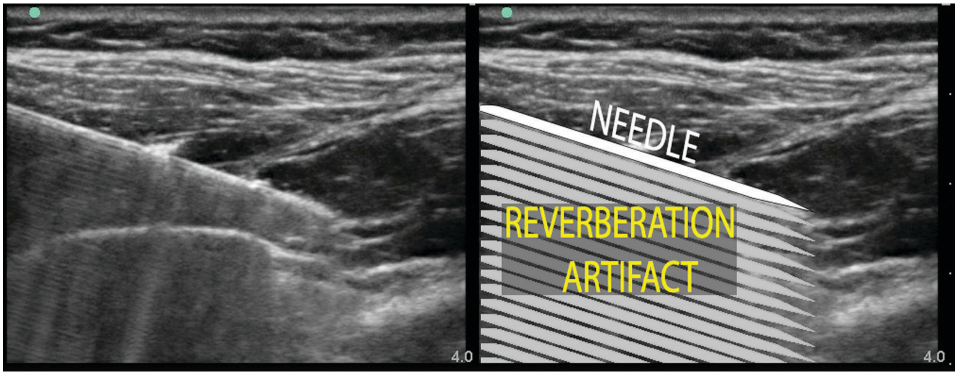


Figure 1-21 Reverberation artifact. There is an obvious reverberation artifact beneath the needle in a paravertebral block *(left)*. The labeled image on the right highlights the effect. The ultrasound image deep to the needle is compromised by the multiple reverberations.

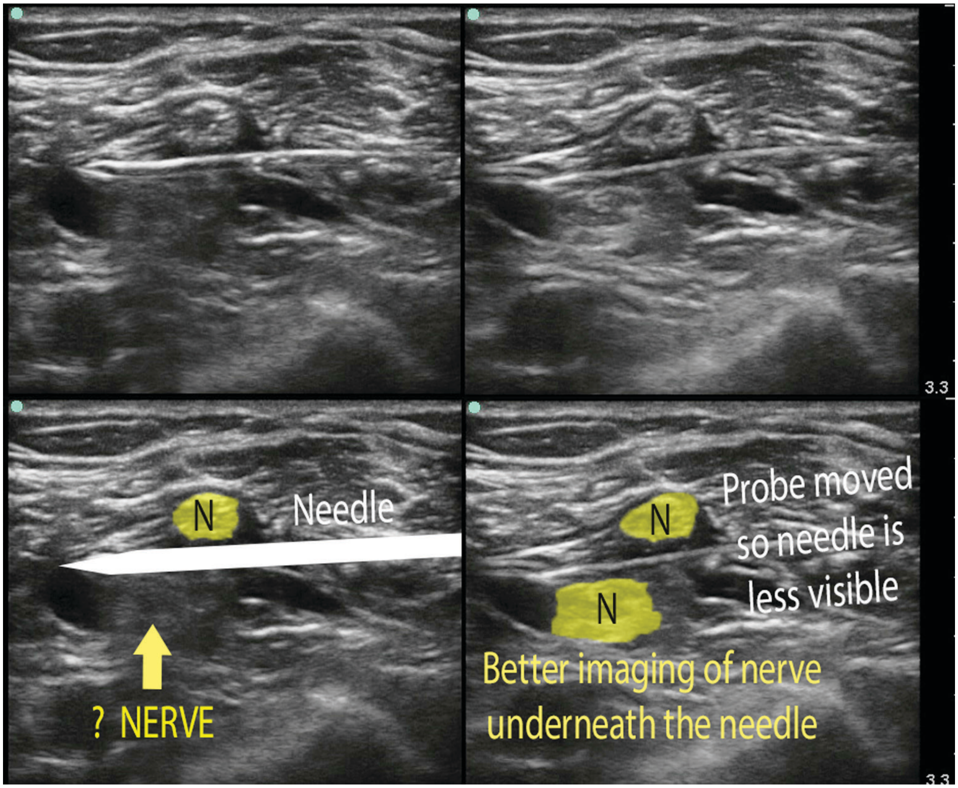


Figure 1-22 Step-off technique. The left images show good needle placement for a popliteal sciatic nerve block. However, the needle shadows the possible nerve structure below. In order to confirm the nerve (N) and visualize good local anesthetic spread, the probe is "stepped-off" from the needle by sliding it away from the good needle view, as shown in the right images. This allows better visualization of structures deep to the needle, including the nerve and surrounding anechoic local anesthetic.

Positioning the Patient

There are several important considerations when positioning a patient for an ultrasound guided nerve block:

1. Ultrasound probe and needle position: In-plane needle approaches usually require slightly longer needles (10 cm for most adult blocks), and therefore more space is required to advance the needle.
2. Ultrasound machine location: Place the machine in line of sight, with the patient between the operator and the ultrasound machine, so that the patient, the screen, and the needle can easily be viewed with minimal repositioning (Figure 1-23).
3. Comfort of the patient:
   a. Can the patient remain still for the time required to complete the block?
   b. Can the patient be sedated safely?
4. Comfort of the operator performing the block:
   a. Which hand is advancing the needle? Most operators use the dominant hand to advance the needle and the nondominant hand to hold the ultrasound probe, modifying their position if necessary to maintain this relationship (Figure 1-24).
   b. Can the operator's arms and hands rest comfortably during performance of the block to steady the probe and needle? (Figure 1-25).

Subsequent chapters in this book describe optimal patient positioning for various blocks, including alternate patient positions in some cases.

Figure 1-23 Positioning of the ultrasound machine. The ultrasound machine is placed in line with the operator's hands and the patient *(left)*. This way, the operator does not have to turn away to view the ultrasound screen, as when the machine is poorly positioned *(right)*.

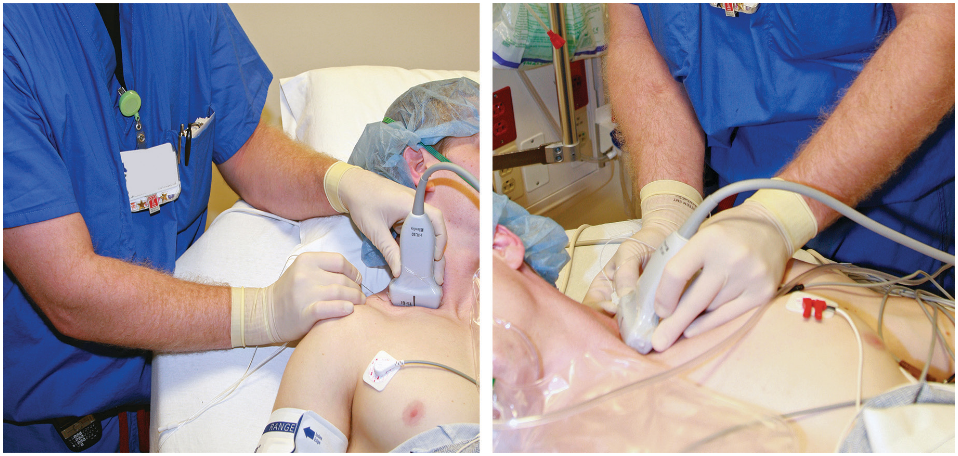


Figure 1-24 The stance of the operator can be changed to allow use of the dominant hand on the needle regardless of the side on which the block is to be performed. For an upper extremity block on the patient's right side, the operator stands more at the head of the patient to hold the needle in the right hand *(left)*. For an upper extremity block on the patient's left side, the operator stands at the patient's side and uses the right hand to advance the needle *(right)*.

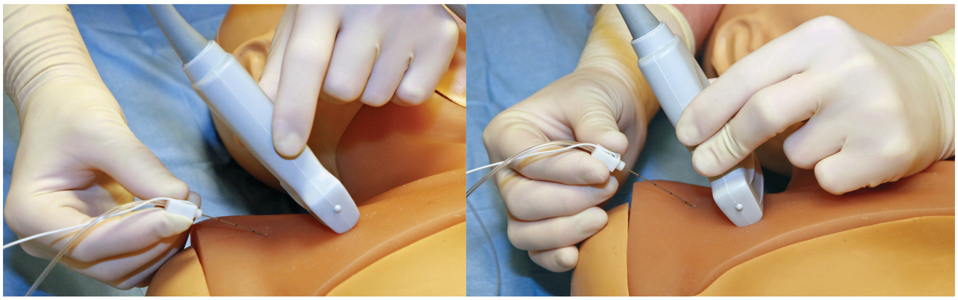


Figure 1-25 To prevent fatigue and provide a stable image, avoid holding the probe with a hand that is not resting on the patient *(left)*. Instead, hold the base of the probe and use the little finger or hypothenar aspect of the hand to provide a stable platform *(right)*.

Equipment and Preparation

Needle Type and Length

More important than needle type is needle length. We recommend using a 10-cm (4-inch) needle for most blocks. This allows the operator to start the needle 1 to 4 cm away from the ultrasound transducer, depending on target depth. Often, these needles are longer than what traditionally would have been used to perform the same block under nerve stimulation. The longer needles allow for a flatter needle angle (and therefore improved visibility with ultrasound). In addition, the excess needle length outside the patient allows the operator to better physically align the transducer and needle for an in-plane technique, as outlined in the three-step process described earlier.

There are several high-quality needles that are marketed as echogenic. However, only a handful of these needles actually improve needle brightness under ultrasound. One should test several needle brands and consider the increased cost if deciding to move from a standard block needle to an echogenic needle. Most needle types traditionally used for regional anesthesia are also appropriate for ultrasound guided regional anesthesia.

Some qualities of regional anesthesia needles that may be helpful are the following: (1) extension tubing that can easily attach to the syringe of local anesthetic; (2) an insulated block needle with an attached wire to allow for nerve stimulation if desired; (3) a blunt-tip needle that can be useful in avoiding nerve penetration and also in giving additional tactile feedback during advancement of the needle through tissues. In general, larger-gauge needles are more visible under ultrasound.

Skin Preparation

Chlorhexidine, betadine, or alcohol may be used to prepare an area for needle insertion. We recommend chlorhexidine and alcohol in combination because of the extended bacteriocidal properties and ease of application. Strict aseptic technique is important at the needle entry site to avoid infection.

Probe Cover

If a continuous indwelling catheter is present, full draping and full probe covers are recommended to maintain strict aseptic technique. For single-injection nerve blocks, probes can be covered with a clear adhesive dressing; the dressing can be placed directly on the probe face (without any gel). Air bubbles must be limited because ultrasound cannot pass through air very well. (Figure 1-26).

Monitoring

The following standard monitors are used for nerve block procedures: (1) pulse oximeter, (2) continuous electrocardiographic (ECG) monitor (single lead), (3) noninvasive blood pressure monitor.

Sedation

Once the operator has achieved facility with ultrasound guidance, patient sedation can be significantly minimized compared to what is needed with nerve stimulation guidance. The basic sedation medications are midazolam, fentanyl, and propofol. For outpatient surgery, limiting even moderate-duration sedatives (i.e., midazolam and fentanyl) can result in more rapid discharge from the postanesthesia care unit (PACU). Often, nerve blocks can be performed with 10 to 50 mg of propofol only, or with no sedation at all.

Figure 1-26 Equipment for ultrasound guided regional anesthesia includes a probe cover or clear adhesive dressing, gel in multiuse bottles or sterile packets, local anesthetic, skin preparation materials, needle and catheter, gloves, and a probe cleaning solution or wipes.

Time Out

Before block placement, an anesthesia "time out" should be performed to check that the patient, procedure, and setup are correct. The time out includes

1. Patient identification, any allergies or anticoagulation issues
2. Surgery and surgery side confirmed
3. Block and block side confirmed
4. Monitors and equipment available, including rescue medications
5. Proper patient and ultrasound position

Keys to Ultrasound Success

No matter what nerve block is being performed, there are basic tenants of ultrasound that improve one's ability to perform ultrasound guided regional anesthesia. These have been distilled down to seven rules for success.

1. **Set up the machine properly**. The machine should be positioned so that the operator, the needle, the target site, the operator's hands, and the machine are all in line. This allows the operator to see the patient, the needle, the probe, and the ultrasound screen (Figure 1-27). Imagine a pool player lining up over a shot. She does not stand to the side and hope to sink the shot. The player, cue, and cue ball are all lined up. It is also very important to properly orient the probe. Each probe has a marker on it that corresponds to a marker or dot on the screen. The probe should be oriented in a direction that makes the most sense to you (Figure 1-28).
2. **Find the best ultrasound image before inserting the needle in the skin**. Find the target nerve, and then make it look better. The best movement to improve nerve imaging is to tilt the transducer. Tilting of the transducer improves reflection of the ultrasound beam off anatomic structures in the body (Figure 1-29). This tilting usually is not drastic; a subtle movement of 5 to 10 degrees may be all that is needed to significantly improve image quality (see Figure 1-11). Other transducer movements that can improve imaging include sliding the probe proximally and distally along the nerve and increasing the pressure on the skin. Evaluate the surrounding structures looking for areas of danger such as small arteries or veins. Most importantly, just before the needle is inserted, get the very best image of the target.

Figure 1-27 Proper setup is critical. Alignment of the operator, needle, target site, probe, and ultrasound screen ensures success.

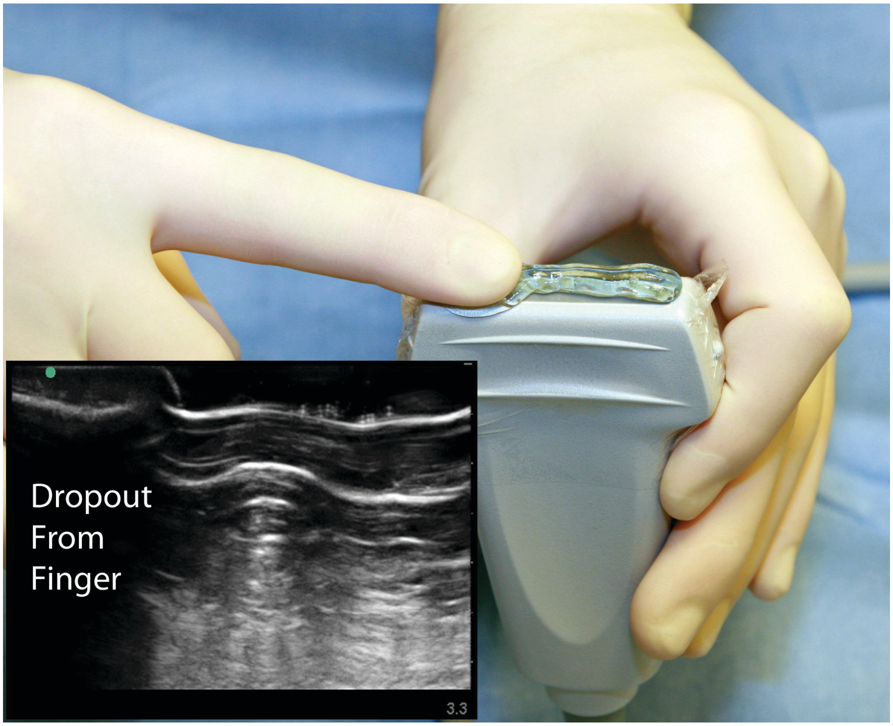


Figure 1-28 Check the probe orientation by touching one end of the probe with your finger and looking for a change on the screen.

3. **Hold the transducer with a solid base.** The more stable the hands, the easier it is to keep the transducer and needle in alignment. Three tips for holding a transducer are (1) hold it near the base (closest to the patient), to allow contact between you and the patient; (2) hold it at the widest part, to improve control while lessening hand fatigue; and (3) hold it by the tips of the fingers to improve subtle control and allow for fine adjustments (see Figure 1-25, *right image*). For most ultrasound guided procedures, it is preferable to use one's dominant hand to hold the needle and the nondominant hand to hold the ultrasound transducer. Sometimes, especially with blocks of the upper extremity, the patient and transducer positions required to perform the block make this difficult. In these situations, one can stand more at the head of the bed and still maintain the use of the dominant hand on the needle and the nondominant on the ultrasound transducer (see Figure 1-24). If comfortable, the needle can be advanced with either hand, making changes in position less necessary.
4. **Keep the needle perpendicular to the ultrasound beam**. The ultrasound waves must reflect off the needle in order to be seen on the ultrasound screen. If the needle has a steep angle of approach, the beam will not reflect off the needle very well, and the needle will not be represented very brightly on the ultrasound screen. If the needle has a flat angle of approach, the ultrasound beam will reflect off the needle, and the needle will appear bright on the screen. The wider the probe used, the brighter the needle, because a wide probe requires a flatter needle angle. Also, the needle insertion site should be started at least 1 cm away from the probe if possible. This allows for a flat approach with the needle.

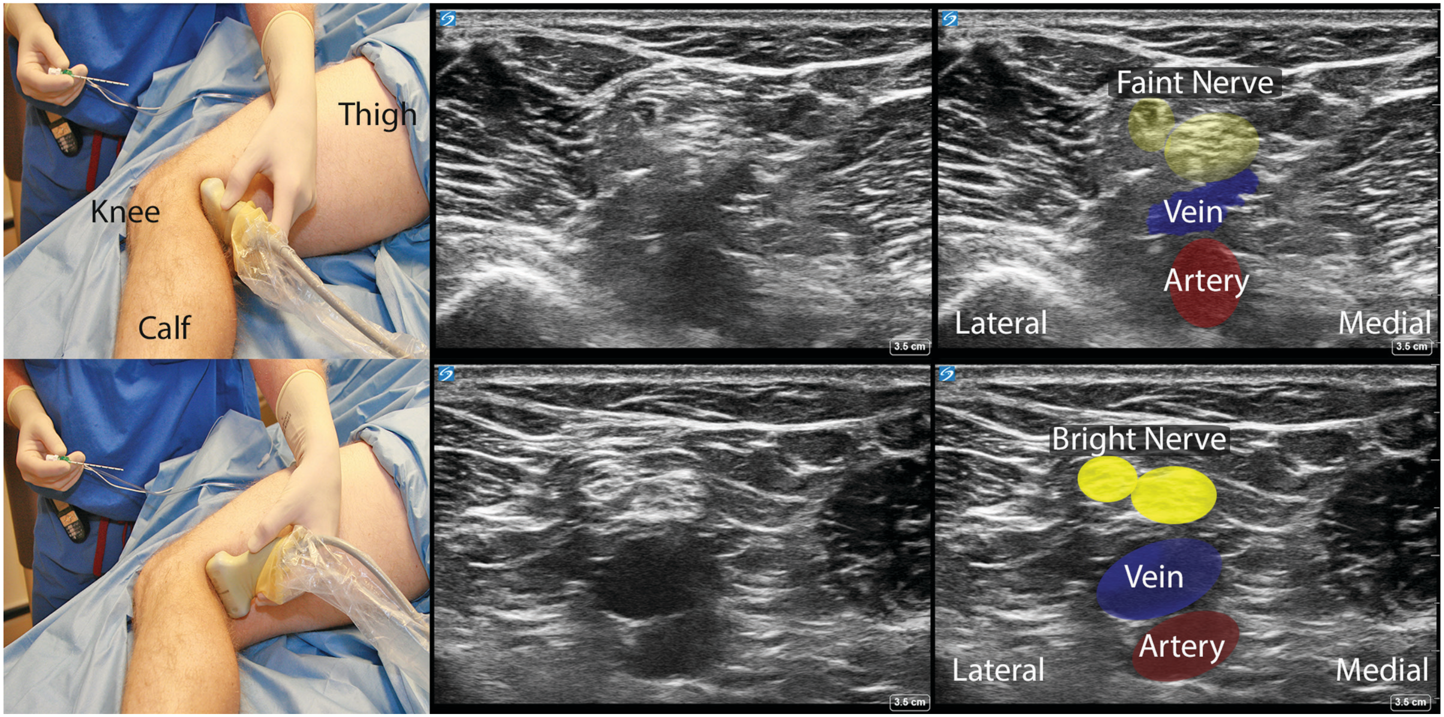


Figure 1-29 Identify the nerve as well as possible using a tilting motion of the probe. For a popliteal sciatic block, a 10- to 20-degree tilt from perpendicular usually achieves the best image of the nerve *(bottom images)*. Continue to keep that same angle when locating the needle on the ultrasound screen after needle insertion. Rather than changing the angle (tilting), use a sliding motion for needle visualization. Do not tilt the probe to find the needle because, although the needle may be visualized, the nerve will disappear *(top images)*. This is a common beginner's mistake.

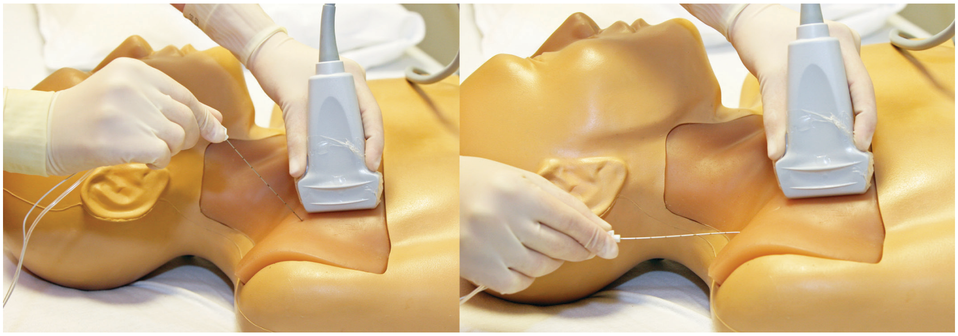


Figure 1-30 The insertion point and the angle of the needle are both important. Inserting the needle at some distance from the probe allows for a shallower insertion angle. Usually, needles are inserted about 1 cm away from the probe for shallow targets *(left)* and 3 to 5 cm away from the probe for deeper targets *(right)*.

For deep blocks, consider starting the needle 3 to 5 cm away from the ultrasound transducer (Figure 1-30).

5. **Keep the bevel pointed at the ultrasound transducer**. Almost all needles used for regional anesthesia have a bevel or injection hole. This part of the needle actually increases

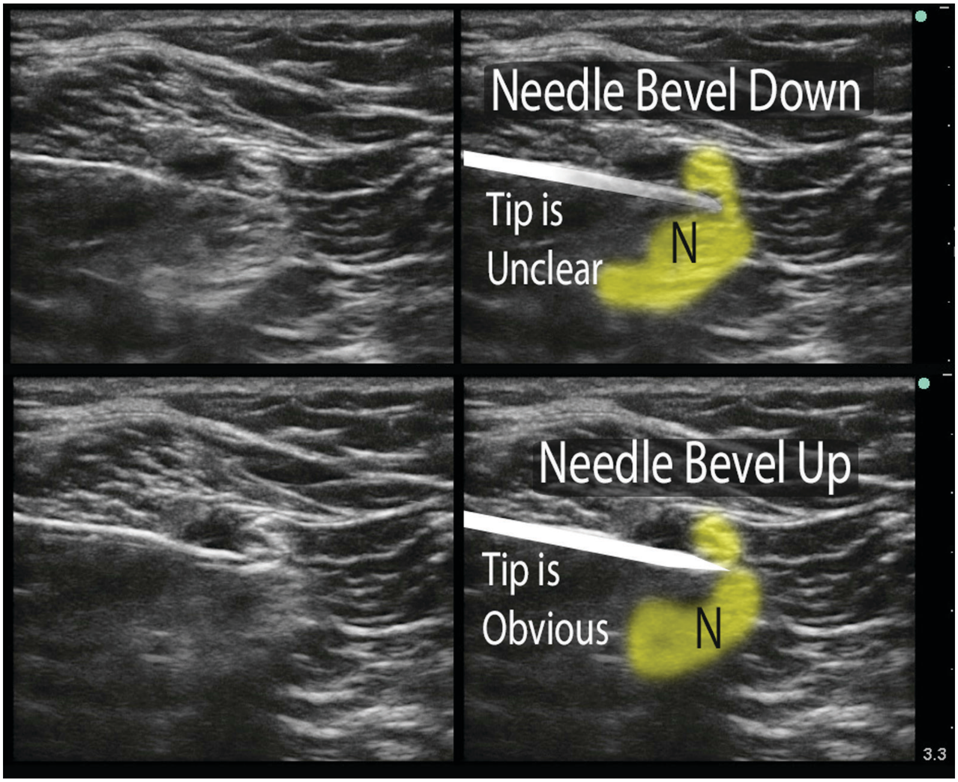


Figure 1-31 Aim the bevel of the needle at the ultrasound probe. This allows improved reflection off the needle tip, assisting the operator with identifying the location of the needle. The top images show a needle with a bevel not directed at the transducer and, as a result, a needle tip that is unclear. The bottom images show a clear needle tip approaching the nerve target (N).

ultrasound beam reflection compared with the shaft of the needle. If the bevel is kept pointed at the ultrasound transducer, the needle tip will often appear brighter. Remember that it is the tip of the needle that injects the local anesthetic, but it is also the tip that does the damage if it is advanced into the wrong structures (Figure 1-31).

6. **Advance the needle only when you see the needle**. Once the needle is inserted under the probe in-plane, it should be immediately located and visualized (review the three-step process for in-plane needle imaging described earlier). If the needle is inserted several centimeters away from the transducer (as recommended), one can slide the transducer closer to the needle to track it as it is advanced toward the nerve. Any time the needle is moved, it should be directly visualized. Many people infer the location of the needle tip by visualizing tissue movement. However, this is not an adequate marker of the actual needle tip. The entire needle should be visualized. Do not accept anything less.
7. **Inject deep to the target first, saving shallow injections for later**. If performing a multiple injection technique, try to perform deep injections first, deferring shallow injections for later (Figure 1-32). This accomplishes two things. First, if air is inadvertently injected, structures deep to the air will be obscured. If the initial injection is placed deep to the target, injected air may hide structures below the target although the target structure remains visible. Second, target tissues such as nerves are mobile. Deep injections may push the target nerve shallower, making secondary injections easier. It is usually easier to visualize and target needles shallower rather than deeper.

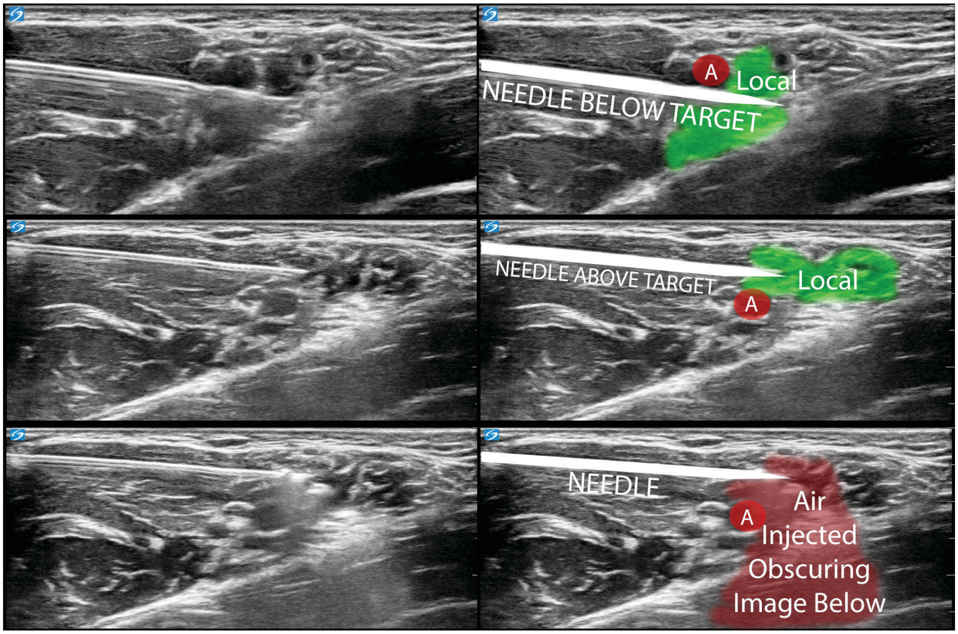


Figure 1-32 Inject deep first, and save shallow injections for later. For almost every block in which multiple injections are used, the first injection should be placed deep to the target *(top images)*. This allows the target structure to be pushed shallower, so the easier injections can be performed next. Also, if air is inadvertently injected, the structures deep to the air will be obscured *(bottom images)*. Save the shallowest injections for the end of the nerve block *(middle images)*. A, artery.

Principles of Peripheral Nerve Catheter Placement

Placement of the Catheter

Place the needle near the nerve, just as for a single injection block. The catheter can be fed in "blindly" (without using the ultrasound), or it can be placed under ultrasound guidance.

Blind Feeding

After the needle is positioned around the nerve, let go of the ultrasound probe, use one hand to hold the needle, and feed the catheter with the other hand, not visualizing the catheter insertion with ultrasound. After 1 to 2 cm of catheter length has been fed in, obtain an image of the nerve, needle, and catheter and then give a test dose (1-5 mL of the local anesthetic) under ultrasound visualization (Figure 1-33). This should reveal good perineural spread of the local anesthetic and confirm that the catheter tip is in the correct place. This technique may be necessary if one is working alone.

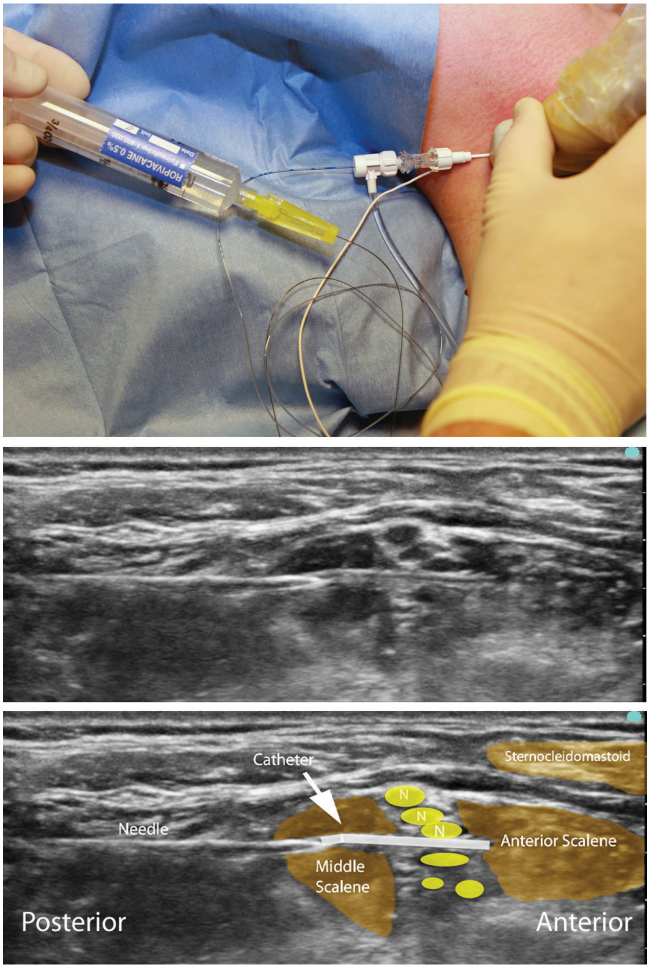


Figure 1-33 The needle is still in place *(top image)* and helps identify the catheter in this interscalene nerve block *(middle and bottom images)*. N, nerve.

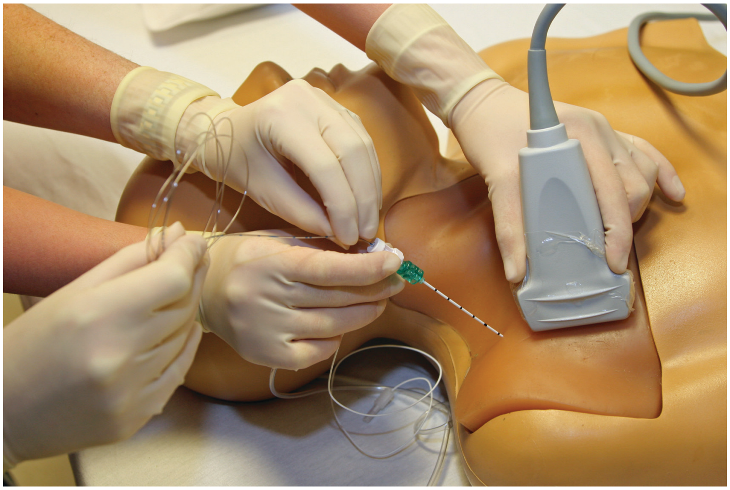


Figure 1-34 It is easier to find the catheter tip if only 1 or 2 cm of catheter length is advanced beyond the needle tip. After initial catheter placement, a check scan is performed with the needle in position. Find the needle tip, and then inject a small test dose through the catheter. Look for appropriate local anesthetic spread around the target. Once the catheter position is confirmed, the needle can be removed. It is helpful to have an assistant hold the probe and then inject a fluid bolus through the catheter while performing the check scan.

Ultrasound Guided Catheter Placement

Have an assistant hold the ultrasound probe. Usually, the assistant has less ultrasound experience, so guide the probe over the needle and then have the assistant hold the probe still. (Remind the assistant to rest his or her hand so that it is stable.) Once a good view is obtained, feed the catheter under direct visualization and place the tip perineurally. Confirm the tip position with a test injection (1–5 mL of local anesthetic) (Figure 1-34).

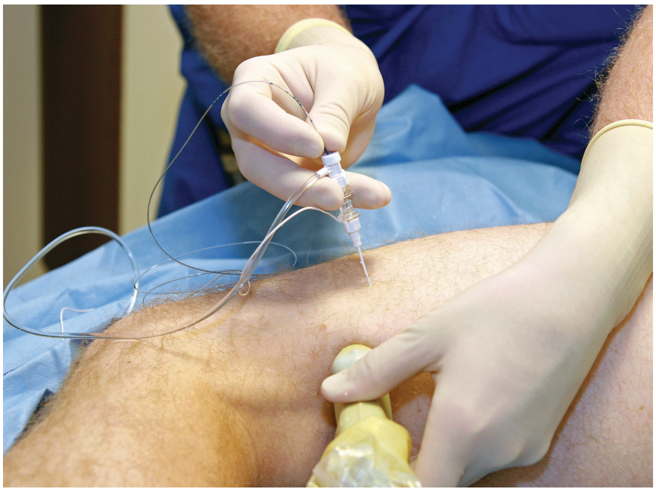


Figure 1-35 The catheter can be observed leaving the needle tip under live ultrasound imaging. The needle can be gripped between the fourth and fifth fingers and the catheter between the thumb and index finger (similar to using a set of chopsticks). The catheter can be advanced by the thumb and index finger and the needle stabilized by the third, fourth, and fifth fingers. The other hand can then be used to image catheter placement with real-time ultrasound imaging.

If you are working alone, continue to hold the probe in one hand. With the needle hand, place the needle between the fourth and fifth fingers, and use the thumb and index finger to feed the catheter. This way, the catheter can be advanced under direct vision without any assistance. This technique requires some practice and good coordination (Figure 1-35).

Confirming Local Anesthetic Spread

1. Look for a dark (anechoic) mass of local anesthetic spread whenever injecting through a needle (Figure 1-36). If no local anesthetic spread is visible, the needle may be out-of-plane or in a blood vessel. If local anesthetic spread is not visualized during injection, immediately stop the injection and reconfirm the location of the needle or catheter tip.
2. It is sometimes difficult to find the tip of a catheter. To locate the catheter, use a test dose of local anesthetic. If a dark (anechoic) area is not visualized on injection, use color Doppler

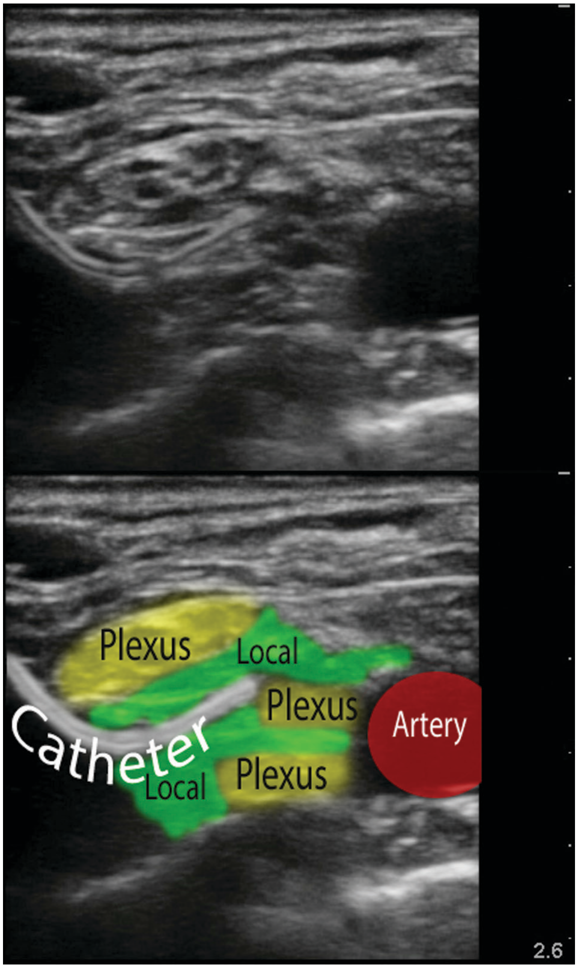


Figure 1-36 Checking catheter placement. Local anesthetic spread is identified as a growing dark mass around the nerve (the labeled bottom image identifies the structures). Because fluid is a great conductor of sound waves, there is very little or no reflection *(top image)*. Although some have advocated checking catheter placement with air, we do not routinely use this technique except as a last resort. Air can obscure future ultrasound imaging if the catheter position needs to be adjusted.

imaging. Color Doppler helps visualize the flow of local anesthetic out of the catheter and helps confirm the tip location. If Doppler does not help, consider injecting a small amount of air (1 cc) or local anesthetic with bubbles in it under Doppler visualization to make the flow more visible. Alternatively, air can be injected under normal two-dimensional imaging, and it will usually appear bright (hyperechoic) between the interface of the air and tissue.

After Successful Catheter Placement

Consider using surgical glue to secure the catheter. Surgical glue keeps the catheter from moving and also prevents leakage from the catheter. Catheter success rates are significantly improved after 2 days of continuous infusion when surgical glue is used at the catheter entry site. Patients are routinely sent home with catheters that are glued in, and they do not report difficultly removing the catheter at home themselves. The glue should be applied only around the catheter at the puncture site and not under the whole occlusive dressing.

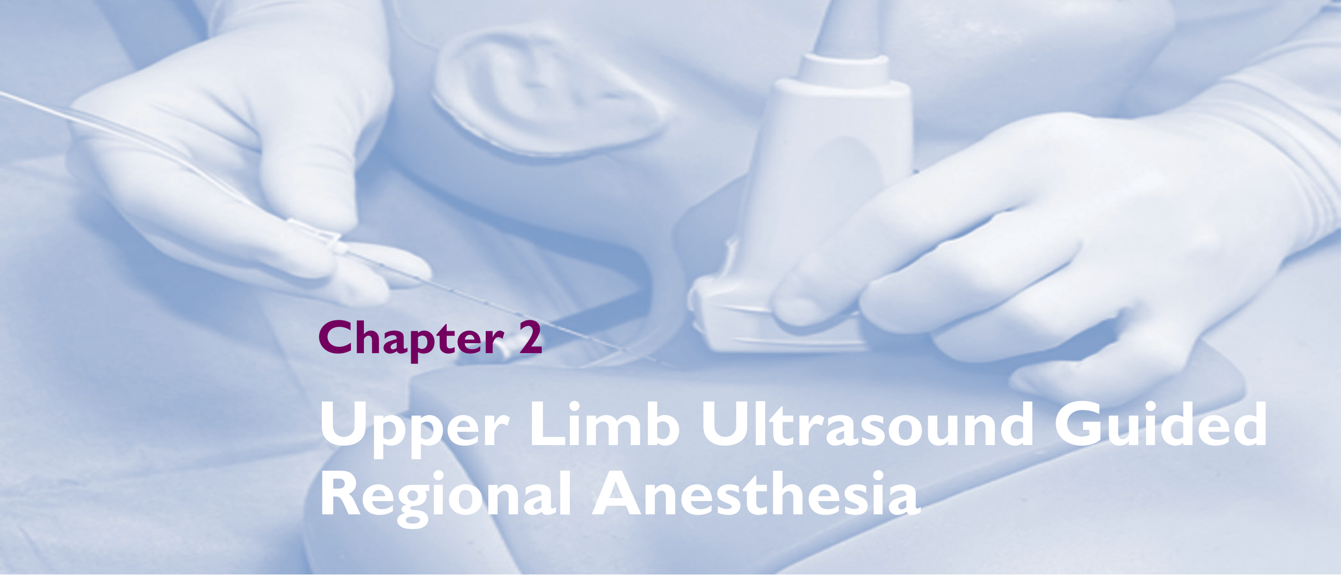
Appendix: What Block for What Surgery?

Surgery Area	Surgical Blocks for Anesthesia	Blocks for Postoperative Pain (consider a continuous catheter)	Alternative Blocks to Consider
		Upper Extremity	
Clavicle	Interscalene (concentrate injection around the top C5 nerve root) + Cervical plexus block	Interscalene	Add a Cervical plexus block for most complete coverage
Minor Shoulder (e.g., Arthroscopy)	Interscalene	Interscalene ± catheter	Supraclavicular *or* Suprascapular
Major Shoulder (e.g., Replacement)	Interscalene	Interscalene catheter	Supraclavicular *or* Suprascapular
Proximal Humerus	**Interscalene** *or* Supraclavicular	**Interscalene** *or* Supraclavicular	
Elbow	**Supraclavicular** *or* Infraclavicular	Supraclavicular *or* **Infraclavicular catheter**	
Scapula		Interscalene	Dorsal scapular
Wrist	**Supraclavicular** *or* Infraclavicular or Axillary	Supraclavicular *or* **Infraclavicular catheter**	
Hand/Finger	Supraclavicular *or* **Axillary**	Supraclavicular *or* **Infraclavicular or Axillary**	Distal arm blocks *or* Infiltration over surgical area
		Lower Extremity	
Hip Replacement	Lumbar plexus + Proximal sciatic	Femoral *or* SIFI	Lateral femoral cutaneous *and/or* Obturator
Hip Fracture		Femoral catheter	SIFI/Fascia iliaca
Femoral Shaft	Femoral + Proximal sciatic	Femoral	
Total Knee Replacement	Lumbar plexus + Sciatic	Adductor canal catheter	Femoral *and/or* Sciatic, Selective tibial *and/or* IPACK
Ambulatory Knee Surgery (e.g., ACL repair)	Femoral + Popliteal sciatic ± Obturator	Adductor canal or **Femoral** ± Popliteal sciatic	**Femoral** ± Popliteal sciatic
Above-the-Knee Amputation	Femoral + Proximal sciatic	**Femoral** + Proximal sciatic	
Below-the-Knee Amputation	Proximal *or* Popliteal sciatic + Adductor canal	**Proximal** *or* Popliteal sciatic + Adductor canal	Femoral block can replace Adductor canal block

(continued)

Surgery Area	Surgical Blocks for Anesthesia	Blocks for Postoperative Pain (consider a continuous catheter)	Alternative Blocks to Consider
Tibia/Fibula or Ankle	Popliteal sciatic + Adductor canal	**Popliteal sciatic** + Adductor canal for medial surgery	Selective tibial nerve block *or* Selective peroneal nerve block (for lateral surgery)
Foot/Toe	Popliteal sciatic + Adductor canal for medial surgery	**Popliteal sciatic** + Adductor canal for medial surgery	Ankle block
		Neck/Thoracic	
Carotid	Cervical plexus	Cervical plexus	
Thoracotomy		Paravertebral *or* **Epidural**	Intercostal
Video-Assisted Thoracic Surgery		**Paravertebral** *or* Epidural	Intercostal or Serratus plane
Breast	Paravertebral	Paravertebral	PECS I and II *or* Serratus plane
Rib Fractures		**Paravertebral** *or* Intercostal	Serratus plane
		Abdominal	
Upper Abdominal		Subcostal TAP *or* **Epidural**	Rectus sheath *or* Paravertebral *or* Intercostal
Lower Abdominal		**TAP** *or* Epidural	Quadratus lumborum
Inguinal	Iliohypogastric-ilioinguinal	Iliohypogastric-ilioinguinal	Paravertebral or TAP or quadratus lumborum

ACL, anterior cruciate ligament; IPACK, infiltration posterior to the articular capsule of the knee; PECS, pectoral nerves; SIFI, suprainguinal fascia iliaca; TAP, transverse abdominis plane.



Chapter 2

Upper Limb Ultrasound Guided Regional Anesthesia

Interscalene Nerve Block

Introduction

Blocking of the brachial plexus in the interscalene groove is performed at the level of the roots and can produce complete anesthesia of the shoulder and clavicle (Figures 2-1, 2-2, 2-3). The brachial plexus is most often formed from the C5 to T1 nerve roots. The large physical distance separating the C5 and T1 nerve roots results in ulnar sparing when local anesthetic is placed in the interscalene groove at the level of C5 or C6. With ulnar sparing, sensation and motor function will remain intact in the fourth and fifth digits. Therefore, the interscalene block is less useful for surgery distal to the midhumerus.

Anatomy

The interscalene block is performed at the level of the roots. At this level, the plexus lies between two muscles: the anterior scalene muscle and the middle scalene muscle (Figure 2-4). The most important roots to block for shoulder surgery are the C5, C6, and C7 nerve roots.

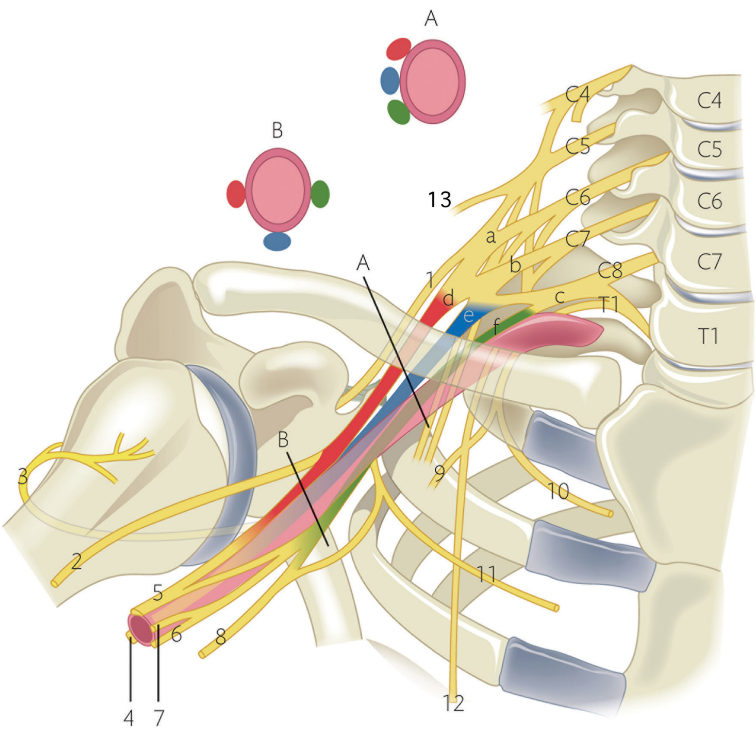


Figure 2-1 Anatomy of the brachial plexus. Key: a = superior trunk; b = middle trunk; c = inferior trunk; d = lateral cord (red); e = posterior cord (blue); f = medial cord (green); 1 = suprascapular nerve; 2 = musculocutaneous nerve; 3 = axillary nerve (from posterior cord); 4 = radial nerve; 5 = median nerve; 6 = ulnar nerve; 7 = medial antebrachial cutaneous nerve; 8 = medial brachial cutaneous nerve; 9 = intercostobrachial nerve; 10 and 11 = intercostal nerve; 12 = long thoracic nerve 13 = dorsal scapular nerve. Cross-sections A and B show the arrangement of the lateral, posterior, and medial cords at the levels shown. (Reproduced, in part, with permission from Chuan A, Scott DM. *Regional Anaesthesia: A Pocket Guide.* Oxford, UK: Oxford University Press: 2014.)

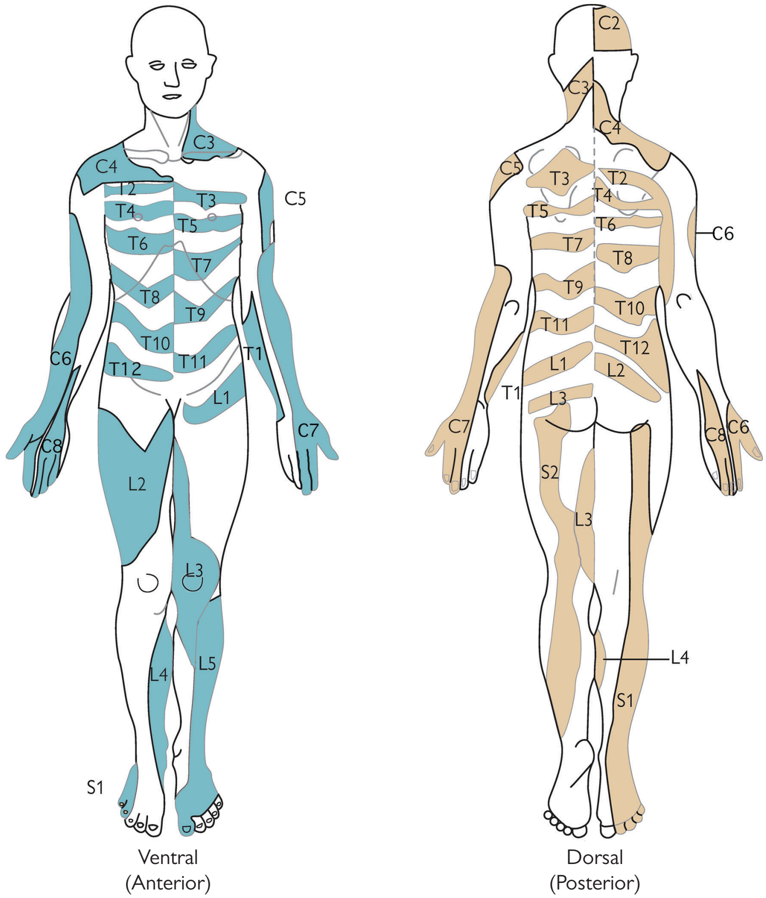


Figure 2-2 Dermatomes innervated by the spinal nerve roots.

The C5 and C6 roots form the superior trunk of the brachial plexus. The C7 nerve root forms the middle trunk. There is a natural separation between the C6 and C7 nerve roots as they form the superior and middle trunks, respectively.

The nerve roots in the interscalene groove can appear as a single hypoechoic (dark) or anechoic (black) circle or as several hypoechoic circles. Often, novice ultrasound users have the mistaken belief that each individual dark circle is an individual nerve. However, a single nerve root can be composed of several fascicles that appear as several dark circles. For instance, the C6 nerve root often appears as two fascicles (dark circles), and the C7 nerve root often appears as three or more (Figure 2-5). To identify and confirm specific nerve roots, the brachial plexus can be traced cranially to where each root emerges between the tubercles of its respective transverse process (Figure 2-6). As the transducer is moved cephalad from the classic interscalene image, the transverse process of C7 can be visualized. The C7 transverse process is easily identified because, unlike the other cervical vertebrae, it has only a posterior tubercle and no anterior tubercle. At this level, the C7 nerve root appears beside the tubercle as a single dark (anechoic) circle. Anterior to the nerve root, the vertebral artery can be visualized and confirmed with color Doppler ultrasound (Figure 2-7).

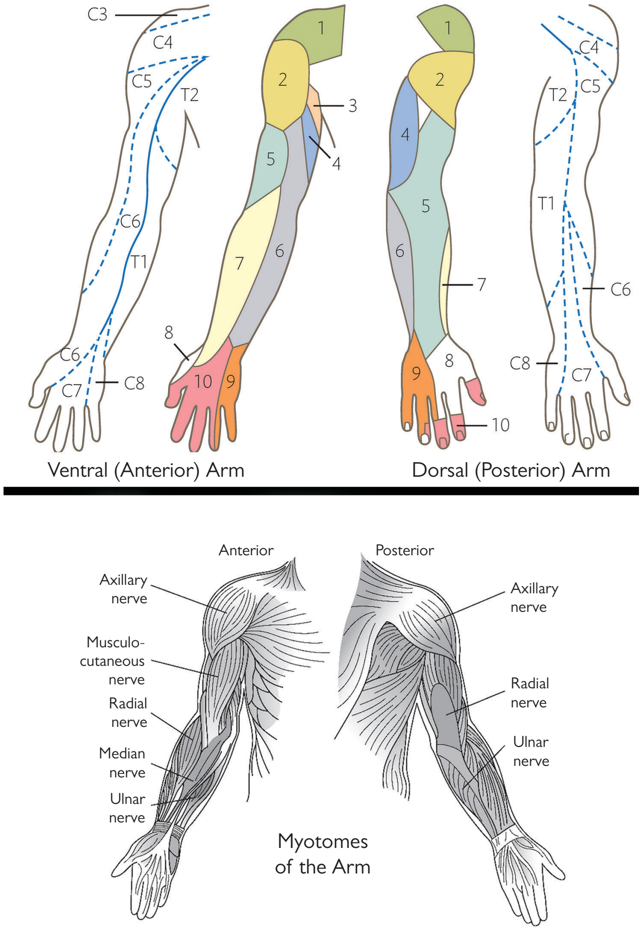


Figure 2-3 Sensory supply from nerve roots and distal nerve branches *(top)* and myotomes *(bottom)* of the upper extremity. Key: 1 = supraclavicular nerve (from cervical plexus); 2 = axillary nerve; 3 = intercostobrachial nerve; 4 = medial brachial cutaneous nerve (from medial cord); 5 = posterior antebrachial cutaneous nerve (from radial nerve); 6 = medial antebrachial cutaneous nerve (from medial cord); 7 = lateral antebrachial cutaneous nerve (from musculocutaneous nerve); 8 = radial nerve; 9 = ulnar nerve; 10 = median nerve. (Reproduced, in part, with permission from Chuan A, Scott DM. *Regional Anaesthesia: A Pocket Guide*. Oxford, UK: Oxford University Press; 2014.)

At the interscalene level, the classic appearance is the "three circles" or "stoplight" nerve root configuration. The bottom two circles are the two fascicles of the C6 nerve. If these two circles are traced more cephalad, they will be seen to combine into a single dark anechoic C6 nerve root. At that level, the anterior and posterior tubercles of the C6 transverse process are visible (Figure 2-8). Usually the C6 transverse process has a prominent anterior tubercle (the Chassaignac tubercle). Further movement of the transducer cephalad will reveal the C5 nerve root entering the spinal column at the C5 transverse process. The C5 transverse process has both anterior and posterior tubercles and appears similar to, but smaller than, the C6 transverse process (Figure 2-9).

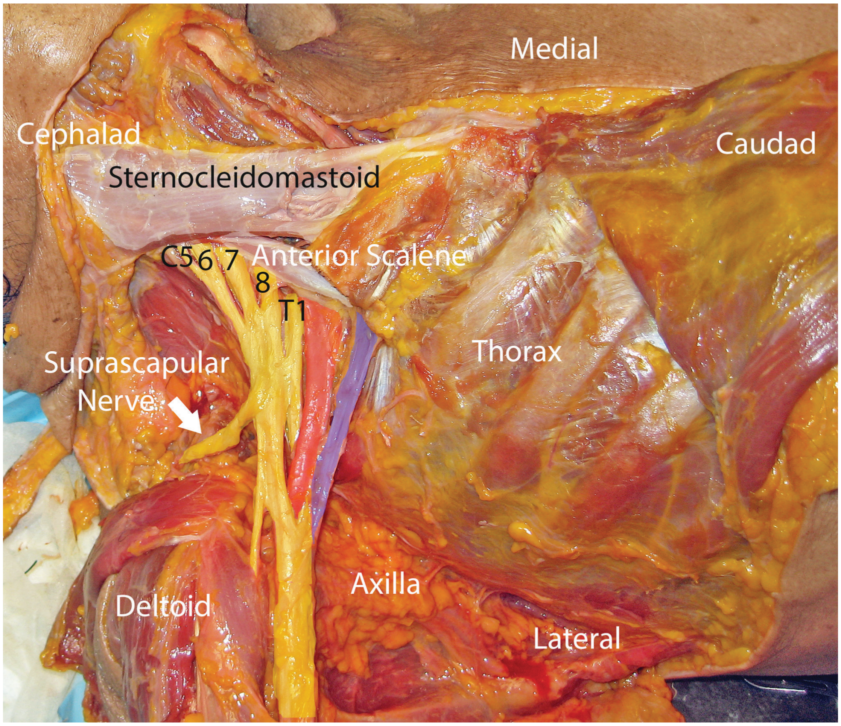


Figure 2-4 The brachial plexus (yellow) exits behind the anterior scalene muscle. The subclavian artery and vein are highlighted in red and blue, respectively.

Suprascapular Nerve

The suprascapular nerve arises from the C5 nerve root or superior trunk. It supplies some of the muscles of the rotator cuff and much of the sensory innervation of the shoulder joint. When performing an interscalene block for shoulder surgery, it is important to place a nerve block proximal to the origin of the suprascapular nerve along the brachial plexus, especially if small volumes of local anesthetic or continuous catheter techniques are being used. With large boluses of local anesthetic, there is greater spread along the brachial plexus, and identifying the branch point of the suprascapular nerve may be less important. A selective suprascapular nerve block is also possible and is described later in this chapter.

Phrenic Nerve

The phrenic nerve lies in close proximity to the brachial plexus on the anterior scalene muscle (Figure 2-10). Because the phrenic nerve lies anterior to the plexus, we recommend that all in-plane needle insertions start posterior to the plexus. Placing the needle behind the plexus avoids direct phrenic nerve injury. Most interscalene blocks, even with low volumes of local anesthetic, result in phrenic nerve paralysis and some degree of hemi-diaphragmatic paralysis. Caution should be exercised when performing interscalene blocks on patients with restrictive or severe obstructive lung disease or any significant pulmonary disease.

Dorsal Scapular and Long Thoracic Nerves

Needles that pass through the middle scalene can also cause injury to smaller nerves traversing the muscle belly, such as the dorsal scapular and long thoracic nerves (Figure 2-11). These nerves

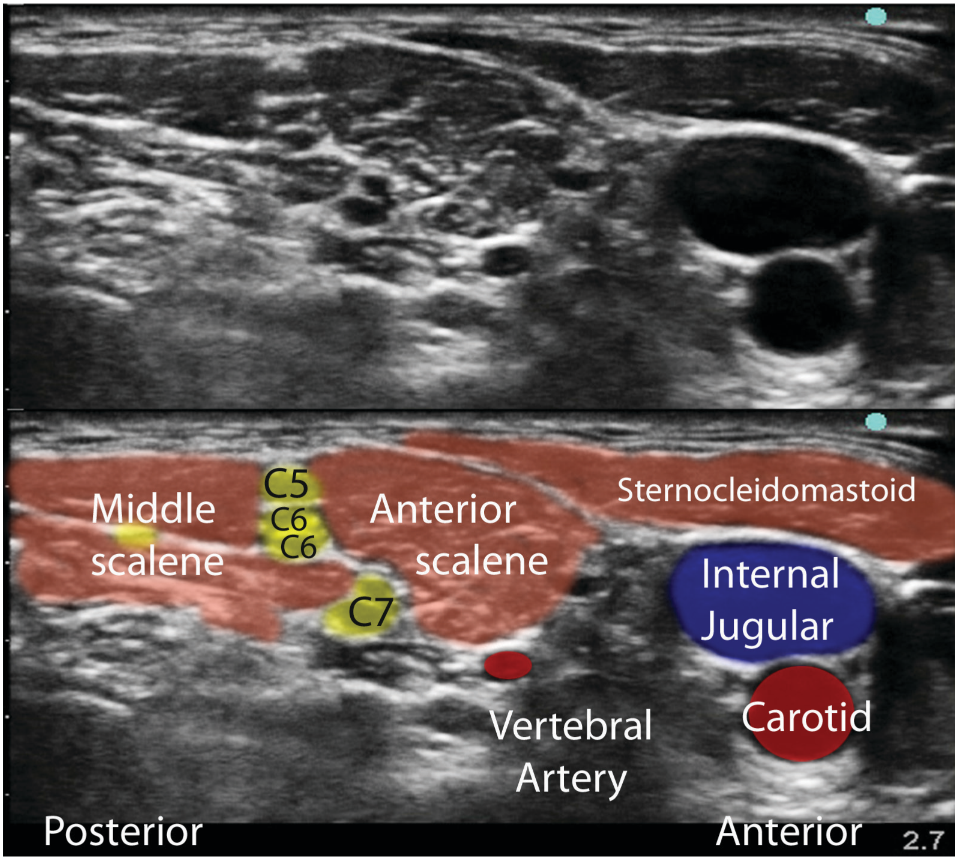


Figure 2-5 The brachial plexus at the interscalene level. The bottom image identifies the structures seen on the top image. Notice that each hypoechoic circle is not a separate nerve root. The nerve roots quickly divide after exiting from the cervical vertebrae.

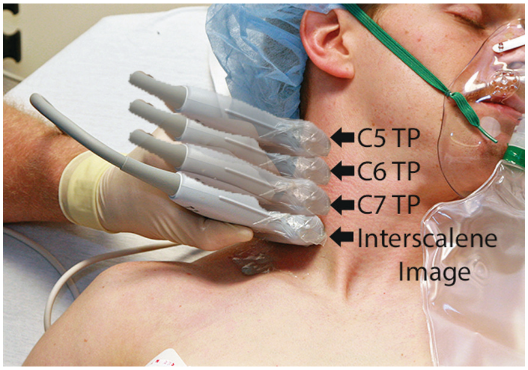


Figure 2-6 Relative ultrasound transducer positions for scanning at the interscalene level and at the C5, C6, and C7 cervical nerve roots. TP, transverse process.

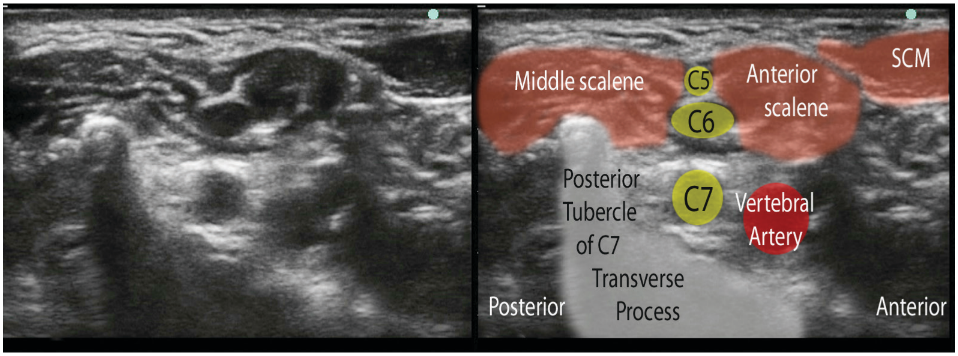


Figure 2-7 The C7 transverse process, C7 cervical nerve root, and vertebral artery. To confirm nerve root identification, the plexus can be scanned cephalad until the root enters the spinal column at the corresponding transverse process. The C7 transverse process is unique and easily identified because it has no anterior tubercle. Instead, the vertebral artery begins its ascent through the transverse foramen of the cervical vertebrae at the C7 level. Color Doppler ultrasound can be useful for confirming the vertebral artery. SCM, sternocleidomastoid.

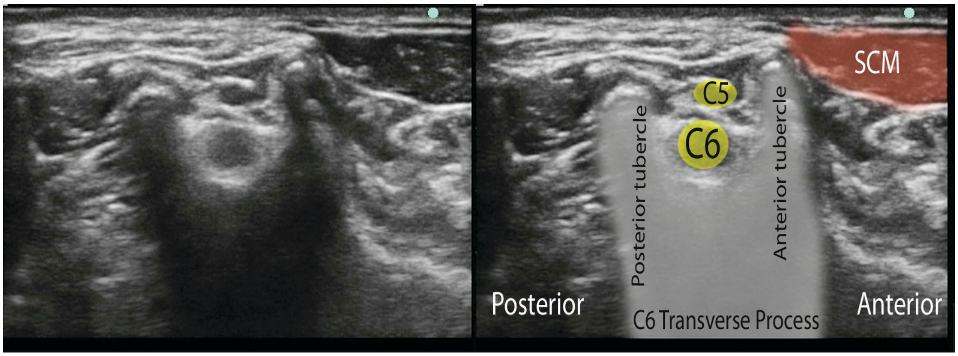


Figure 2-8 The C6 transverse process and C6 nerve root. The C6 nerve root is visible between the anterior and posterior tubercles of the C6 transverse process. The anterior tubercle (Chassaignac tubercle) is often the most shallow of any of the cervical vertebral anterior tubercles and therefore is palpable in thin adults. SCM, sternocleidomastoid.

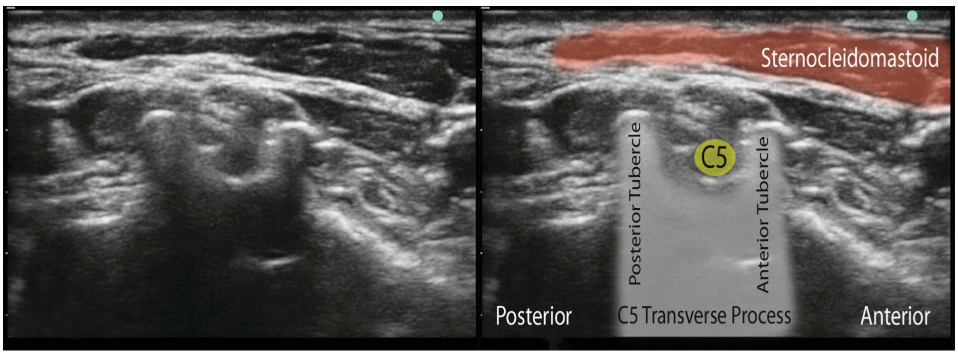


Figure 2-9 The C5 transverse process and C5 nerve root. The C5 nerve root is found entering the spine at the C5 transverse process. The C5 transverse process has obvious anterior and posterior tubercles.

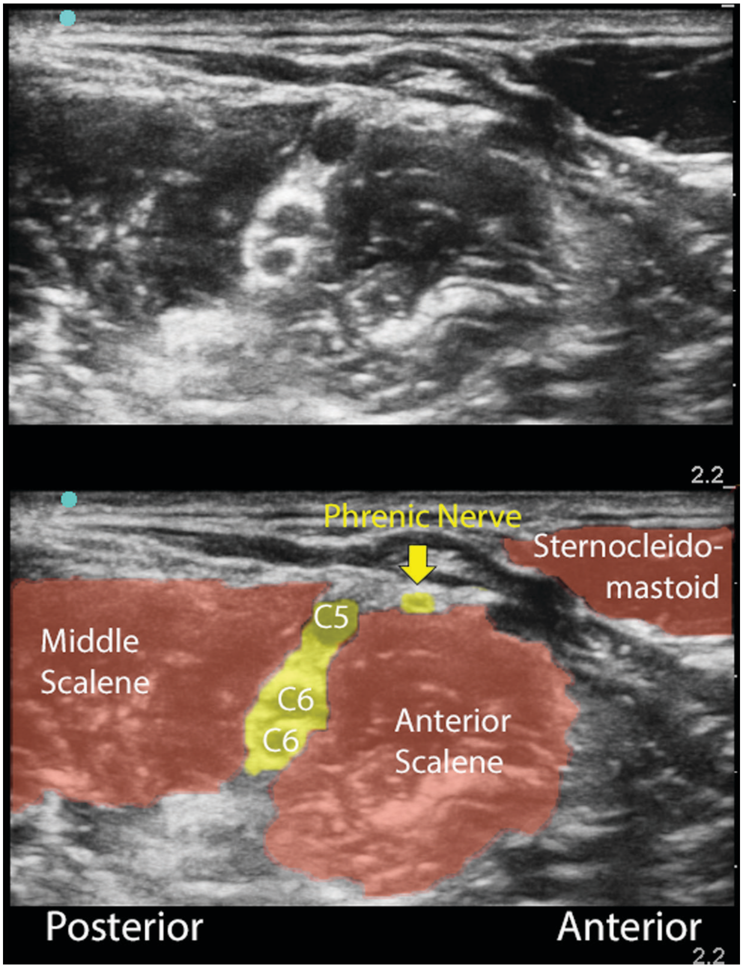


Figure 2-10 Phrenic nerve at the interscalene level. The phrenic nerve can be found on the anterior surface of the anterior scalene muscle.

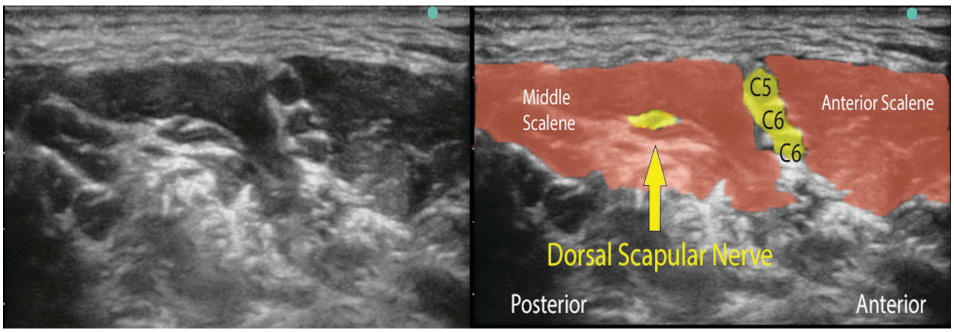


Figure 2-11 The dorsal scapular nerve is reliably located within the middle scalene muscle. Before advancing a needle through the middle scalene, evaluate this area to identify the dorsal scapular nerve and avoid direct injury to it.

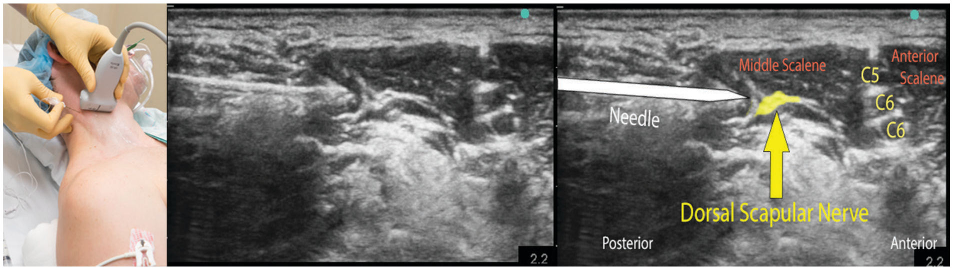


Figure 2-12 A needle is advanced from posterior to anterior for a selective dorsal scapular nerve block.

are branches of the brachial plexus and appear as bright, hyperechoic ovals with dark hypoechoic centers. To help identify these small branches, the transducer can be moved cephalad, tracing the nerves toward the brachial plexus nerve roots. The dorsal scapular and long thoracic nerves usually insert into the C5 and/or C6 nerve roots just before they enter the spinal column. When passing needles through the middle scalene muscle during interscalene or supraclavicular nerve blocks, try to identify the dorsal scapular and long thoracic nerves and avoid them.

Dorsal scapular nerve blocks are useful for surgery of the scapula. In-plane dorsal scapular nerve blocks have been described and are very similar to interscalene nerve blocks. To perform this block, advance the needle as described for an interscalene nerve block, but rather than advancing fully to the interscalene groove, deposit a small amount of local anesthetic (5 mL) near the dorsal scapular nerve in the belly of the middle scalene muscle (Figure 2-12). This block results in analgesia for scapula surgery while sparing the majority of the ipsilateral brachial plexus. If the dorsal scapular nerve cannot be individually identified for scapula surgery, consider injecting local anesthetic at the interscalene level and focusing the injection near the C5 nerve root.

Clinical Applications

Blockade of the brachial plexus at the interscalene level can be used for shoulder surgeries including shoulder arthroscopies, rotator cuff repairs, procedures involving the middle to distal clavicle, shoulder manipulations, and total shoulder arthroplasties. Continuous catheters can routinely be placed in the interscalene groove to extend analgesia for days.

Technique

Ultrasound Details

Monitors: Electrocardiogram (ECG), noninvasive blood pressure monitor (NIBP), pulse oximeter.

Skin Preparation: Chlorhexidine with alcohol.

Probe: High-frequency linear probe (10-15 MHz); expected target depth in 80-kg adult, 1 to 2 cm.

Patient Position: The patient is positioned in a sitting position of 45 degrees, head up with a pillow under the head but moved away to expose the neck on the operative side. The patient's face is rotated toward the contralateral side. A pillow or folded blanket can be placed under the ipsilateral shoulder to create more room for a needle to be advanced from the posterior side (Figure 2-13).

Local anesthetic choice: Usually, 10 to 30 mL of local anesthetic is required. To achieve surgical-level anesthesia and long-acting analgesia, ropivacaine or bupivacaine 0.5% is used.

Figure 2-13 Positioning for an above-the-clavicle nerve block with a folded towel beneath the patient's ipsilateral shoulder.

For short-duration blocks, mepivacaine 1.5% or lidocaine 2% may be employed. If the nerve block is required only for postoperative analgesia, a lower concentration of local anesthetic may be used (e.g., ropivacaine 0.2%).

Needle: 100-mm (4-inch), short-bevel nerve block needle.

Scanning Technique

1. **Use the supraclavicular ultrasound image to locate the brachial plexus.** The close proximity of the plexus to a pulsating artery (the subclavian artery) assists in locating the plexus at the supraclavicular level.
2. **Place the probe behind the midpoint of the clavicle.**
3. **The probe should be aimed acutely down the neck as if attempting to image deep into the thorax.** Do not direct the probe flat across the neck (Figure 2-14).
4. **Locate the pulsatile subclavian artery.** The artery is a hypoechoic (black) circle and will appear pulsatile. The artery sits on the hyperechoic line of the first rib or pleura. If the artery is not initially visible, slide the probe parallel to the clavicle medially or laterally. Take care not to mistake the carotid artery for the subclavian artery.
5. **The nerves are located lateral and posterior to the artery or occasionally superior to the artery.** The brachial plexus appears as "a bunch of grapes"—hypoechoic circles encased in hyperechoic fascia.
6. **Once the brachial plexus is located in the supraclavicular fossa, place the nerves in the middle of the screen and slide the probe up the neck**, **keeping the probe perpendicular to the skin.** Continue to follow the most superficial part of the brachial plexus, keeping it on the screen as the probe is moved cephalad up the neck (Figure 2-15).

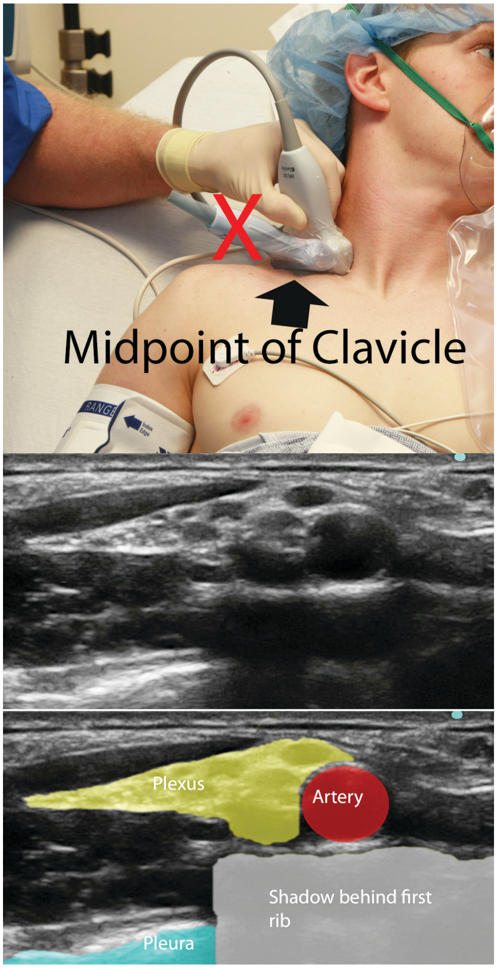


Figure 2-14 Mark the midpoint of the clavicle to quickly identify the position of the subclavian artery. Aim the probe down into the thorax to image the supraclavicular region, not across the neck. Identify the pulsating subclavian artery. The nerves will be found immediately posterolateral to the artery.

7. **As the probe is moved cephalad, the subclavian artery should drop away.** The superior part of the brachial plexus should initially appear as many small dark circles (multi-fascicular). Then, as the interscalene groove is formed, it takes on the appearance of three dark circles. These circles are usually aligned between the anterior scalene anteriorly and the middle scalene posteriorly (Figure 2-15, *bottom image*).
8. **Stop sliding the probe when the brachial plexus appears as the three dark circles surrounded by bright, hyperechoic fascia.** The three dark circles, from superior to inferior, are the C5 nerve root and two distinct C6 fascicles.
9. **Usually, the perfect image of the interscalene groove appears only a few centimeters up the neck from the supraclavicular view.** Do not be concerned that the probe may not be very far up the neck. Perform the block where the ultrasound image gives the best representation of the three dark circles within the interscalene groove.

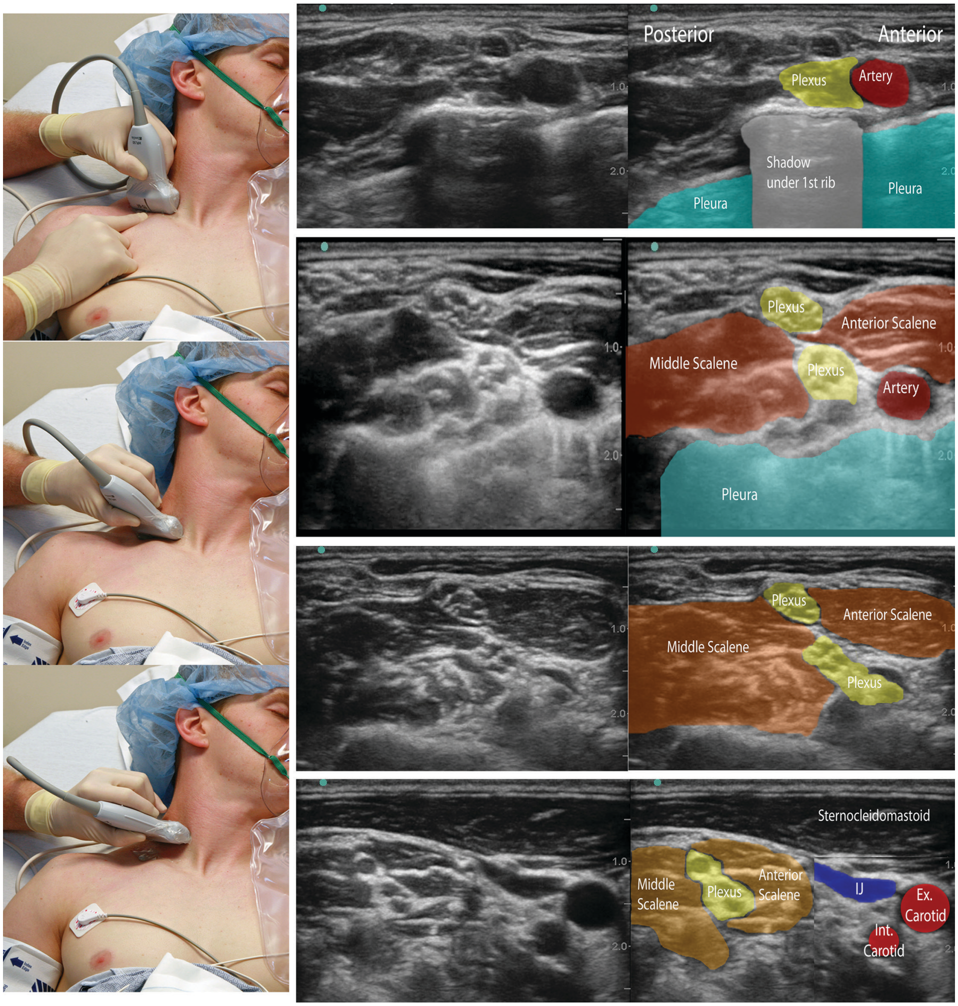


Figure 2-15 Probe positions and ultrasound images for scanning the interscalene region. The images on the left show the position of the probe as the brachial plexus is traced from the supraclavicular to the interscalene region. The probe is used to trace the multifascicular nerves up the neck, stopping when the nerves appear as three stacked circles *(bottom image)*. In the top two images, the vessel lying on the first rib is the subclavian artery. In the bottom two images, obtained further up the neck, the anteromedial vessels are the internal (Int.) and external (Ext.) branches of the carotid artery and the internal jugular vein (IJ).

10. **Insert the needle in-plane, starting lateral and posterior to the brachial plexus and aiming medially and anteriorly** (Figure 2-16).
11. **Advance the needle either to the most superficial part of the plexus (above the C5 nerve root) or to the deepest part of the plexus (below the most inferior C6 fascicle).** In other words, a good injection point is found by aiming shallow to the three circles or aiming below the three circles (Figure 2-17). We recommend aiming deep to the three circles to ensure local anesthetic spread underneath the fascia that is found shallow to the brachial plexus (pre-vertebral fascia).

Figure 2-16 Needle entry position for in-plane interscalene nerve block.

12. **For safety, the needle should not puncture between any of the hypoechoic fascicles of the brachial plexus at this level.** One should never place a needle between the two fascicles of C6. This is why we specifically highlight the nerve roots at the interscalene level.
13. The **ideal spread of local anesthetic for a single injection is anywhere next to the brachial plexus (i.e., the three circles).** Simply deposit the local anesthetic above, posterior, or deep to the three circles (Figure 2-18).
14. **The needle can be redirected if spread around the plexus is not deemed adequate.** The ultimate objective is to deposit the local anesthetic anywhere adjacent to the brachial plexus. There is no need to place local anesthetic on both the anterior and posterior sides.

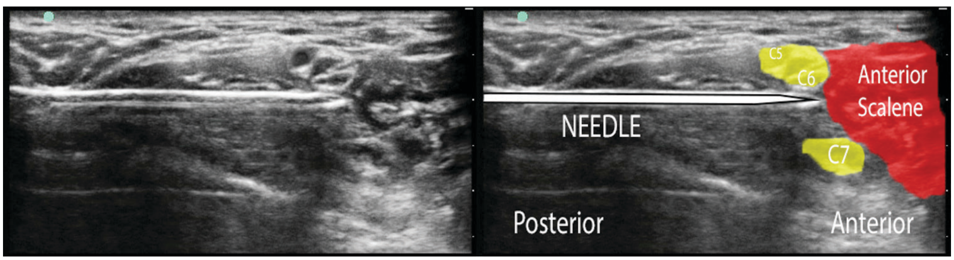


Figure 2-17 Needle advancement during interscalene nerve block. A skin puncture site 2 cm posterior to the probe will yield a flatter needle angle and allow for greater needle visibility.

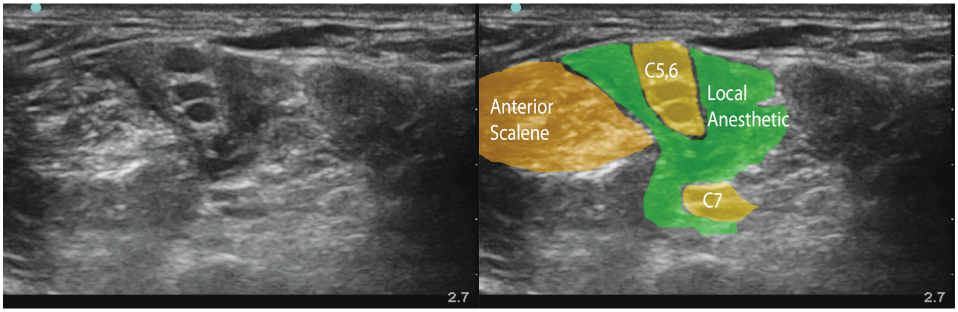


Figure 2-18 Local anesthetic spread during the interscalene nerve block. Local anesthetic is highlighted in green. Observe the marked separation between C5 and C6 nerve roots and that of C7 much lower. Local anesthetic in this image has spread anterior and posterior to the nerve roots, but this is not essential for success. Solely posterior spread of local anesthetic in the interscalene groove is adequate to achieve a working block. Do not place the needle directly into the nerve roots in this area.

Alterative Techniques

Out-of-plane approaches for the interscalene block have been described with the probe in the same position as for in the standard in-plane technique. For out-of-plane needle insertion, place the interscalene groove and brachial plexus in the middle of the ultrasound image. Then advance the needle using the techniques described in Chapter 1 ("How to Visualize Nerves and Needles"), starting in the middle of the ultrasound probe (Figure 2-19).

Catheters

Catheter placement can follow the same steps as for placement of the block but involves complete sterile technique, a larger-gauge needle, and securing the catheter after placement. Catheters can be placed using an in-plane or an out-of-plane technique. Place the tip of the needle either above C5 or below both fascicles of C6 (Figure 2-20). Again, the needle should not penetrate anywhere between the three circles of the interscalene groove. Once the needle is in place, the catheter should be fed into the interscalene groove. Because of the mobility of the superficial tissues and the shallow nature of this block, premature catheter failure is common. Securing the catheter well with surgical glue and well-placed dressings improves longevity (Figure 2-21).

Figure 2-19 Out-of-plane approach for placement of an interscalene nerve block.

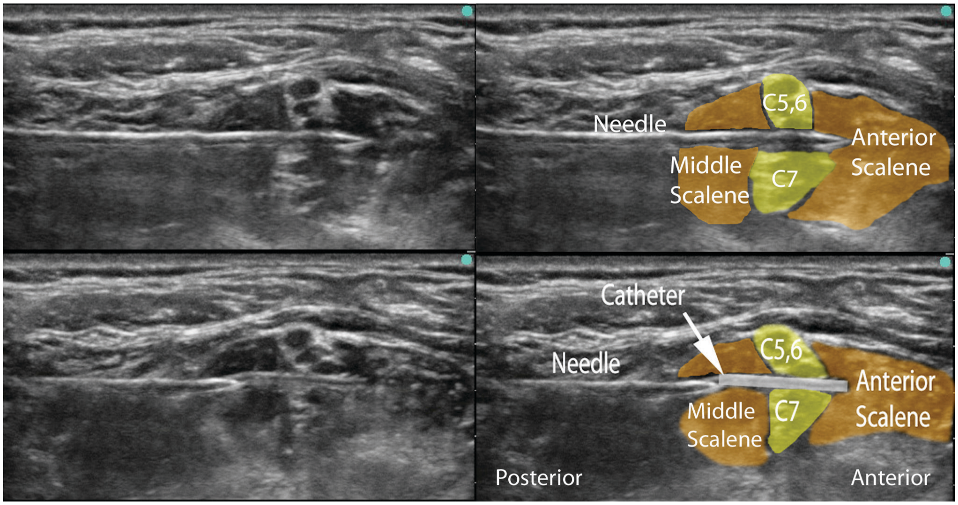


Figure 2-20 Interscalene catheter placement. In the top images, the needle has been placed for the nerve block. The bottom images show the catheter carefully placed in the anatomic gap between the C6 and C7 nerve roots.

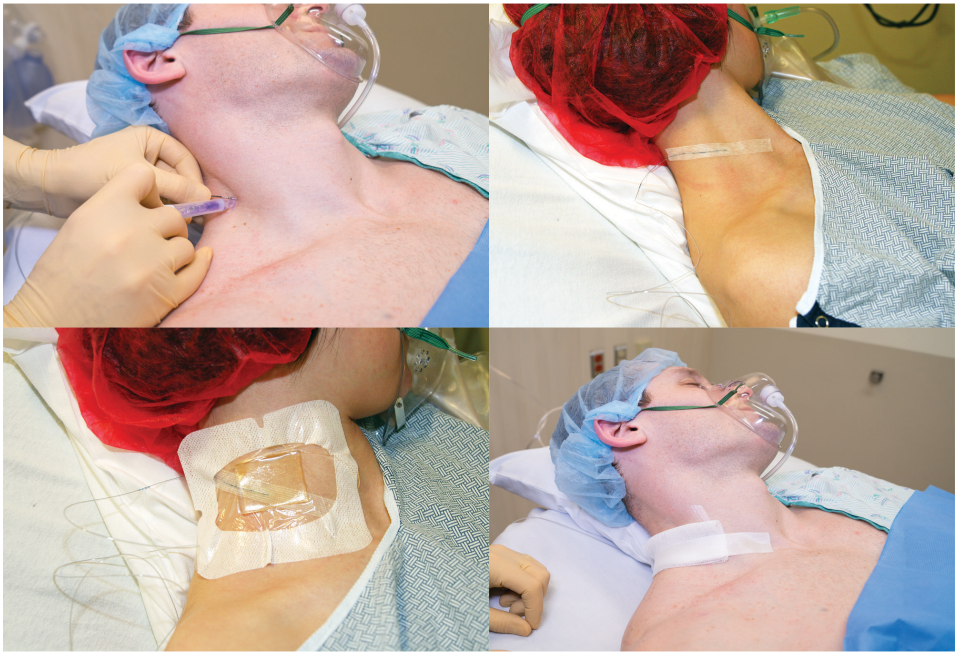


Figure 2-21 Interscalene catheter fixation. Place a drop of surgical glue at the puncture site *(upper left)*, followed by Steri-Strips *(upper right)* and then a clear occlusive dressing *(lower left)*. Occasionally, two smaller or narrower dressings may function better than one larger dressing as shown here. A practical tip is to cover the dressing with gauze or with its backing paper and tape after the dressing has been secured *(lower right)*. This prevents the surgical drapes from sticking to the dressing and pulling it off at the end of the case.

Complications

Ipsilateral hemi-diaphragmatic paralysis due to phrenic nerve blockade is a frequent side effect. Other side effects include Horner syndrome, hematoma, failed block, infection, and nerve injury.

Pearls

- If the brachial plexus at the interscalene level is difficult to identify, restart at the very beginning by finding the brachial plexus in the supraclavicular view. Then continue with the scanning process by following the plexus superiorly and sliding up the neck again.
- Low volumes (3-5 mL) of the local anesthetic may be used to decrease phrenic nerve blockade and the severity of hemi-diaphragm paralysis. However, low volumes will decrease the duration of the nerve block. Consider a suprascapular nerve block if there is significant concern that a patient may not tolerate phrenic nerve paralysis.
- In less than 5% of cases, the brachial plexus is split. This means that the C5, C6, or C7 nerve roots may not be within the interscalene groove and instead may be found within the anterior scalene muscle. If this is the case, inject the roots individually. If placing a catheter, leave it around the C5 or C6 nerve root (Figure 2-22).
- Small arteries may overlie the brachial plexus at this level. Color Doppler imaging is useful for identifying these arteries so that they can avoided during needle placement (Figure 2-23).
- Keep the catheter insertion site away from the ipsilateral shoulder and away from the surgical field. Once the brachial plexus is located, rotate the probe 10 to 20 degrees so the posterior edge moves cranially. This moves the catheter insertion site more cephalad and away from the surgical field. This rotation usually does not compromise the ultrasound image of the plexus (Figure 2-24).
- Move the pillow or headrest toward the contralateral side to maximize the area available for needle placement.
- When scanning slim patients, place a pillow or folded blanket beneath the ipsilateral shoulder to provide more room during needle insertion and manipulation (Figure 2-25).
- If the nerves of the brachial plexus at the interscalene level do not appear in the classic stacked three-circle orientation, consider scanning further cephalad to identify individual nerve roots, as described earlier. Tracing the nerves up and down from the transverse processes will help define specific parts of the brachial plexus and may aid in planning a safe, effective injection.

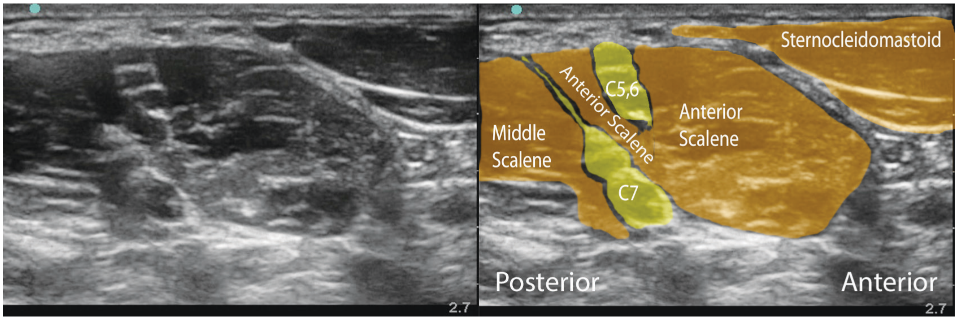


Figure 2-22 Split brachial plexus. The C5 and C6 nerve roots are found within the anterior scalene muscle, whereas the C7 nerve root is in the interscalene groove.

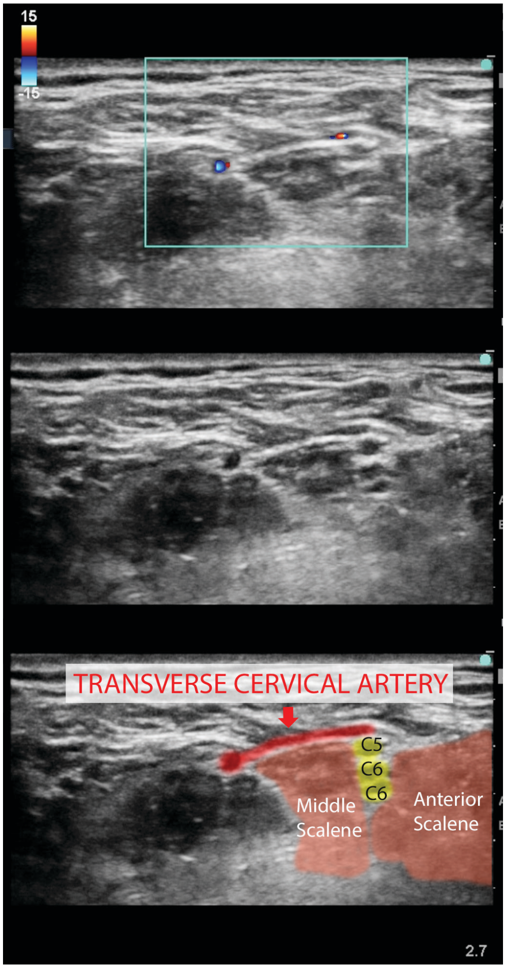


Figure 2-23 Color Doppler imaging *(top)* is used to identify one of many small blood vessels in the neck. Without color Doppler imaging *(middle)* the vessel has a similar ultrasound appearance as the brachial plexus. Labeled image of the artery, nerves, and muscles *(bottom)*.

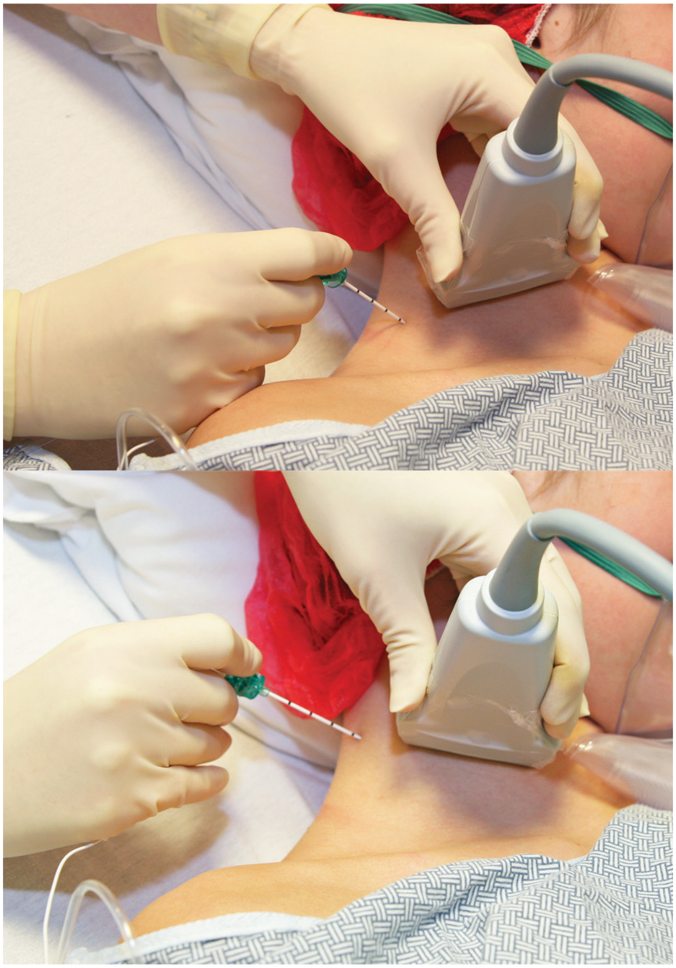


Figure 2-24 Needle insertion site for catheter placement. Rotate the probe to move the puncture site up the neck and away from the operative field. With this adjustment, the catheter can be secured outside the operative sterile field.

Figure 2-25 Patient positioning. For slim patients, fold a pillow and place it under the patient's back to create more room for needle insertion.

Suprascapular Nerve Block

Introduction

The suprascapular nerve block can be used as an alternative to the interscalene block for patients in whom phrenic nerve blockade is not desirable. A suprascapular nerve block can be combined with an axillary nerve block, as the so-called shoulder block, to provide postoperative analgesia. However, the suprascapular block alone is very useful for postoperative analgesia after total shoulder arthroplasty or rotator cuff repair and can be particularly valuable in patients with morbid obesity or preexisting lung dysfunction who cannot tolerate pulmonary compromise.

Anatomy

The suprascapular nerve is a branch of the superior trunk or C5 nerve root. It runs over or through the middle scalene muscle along the lateral edge of the superior trunk of the plexus, then courses laterally away from the brachial plexus and deep to the omohyoid muscle at the supraclavicular level (see Figure 2-4). The suprascapular nerve then runs through the suprascapular fossa, through the suprascapular notch of the scapula, and supplies a significant proportion of shoulder sensation. The nerve does not have cutaneous branches, nor does it supply the entirety of the shoulder joint.

Clinical Applications

The suprascapular nerve block is useful as an analgesic block for arthroscopic shoulder surgery or shoulder replacement. It is used primarily as an alternative block for shoulder surgery if an interscalene block is undesirable because of associated lung dysfunction.

Technique

Ultrasound Details

Monitors: ECG, NIBP, pulse oximeter.

Skin Preparation: Chlorhexidine with alcohol.

Probe: High-frequency linear probe (10-15 MHz); expected target depth in 80-kg adult, 0.5 to 1 cm. Use the transducer with the smallest footprint possible (e.g., 25-mm wide transducer, hockey-stick transducer) to avoid being physically impeded by the clavicle.

Patient Position: The patient is positioned upright in a sitting position. A pillow is placed under the ipsilateral shoulder to create space for advancement of a needle from posterior to anterior, similar to the positioning for an interscalene block (see Figure 2-25). It also helps to ask the patient to reach the ipsilateral arm caudally, as if trying to touch the contralateral thigh. This moves the clavicle inferior and anterior, which allows more space to image the suprascapular nerve (Figure 2-26).

Local anesthetic choice: Usually, 5 to 10 mL of local anesthetic is required. Because this is primarily an analgesic block, a long-acting local anesthetic (ropivacaine or bupivacaine 0.25-0.5%) is preferred. For short-duration blocks, mepivacaine 1.5% or lidocaine 2% may be employed.

Needle: 100-mm (4-inch), short-bevel nerve block needle. A shorter needle may be used if the patient cannot be adequately positioned to advance the needle from posterior to anterior.

Scanning Technique

1. **Place the probe in the supraclavicular fossa, similar to the start of a supraclavicular nerve block.** Use the supraclavicular ultrasound image to locate the brachial

Figure 2-26 The clavicle can inhibit probe movement during a suprascapular nerve block. To provide more room for nerve imaging, have the patient reach down toward the contralateral side with the ipsilateral hand.

plexus with the transducer aiming down into the thorax parallel to and behind the clavicle (Figure 2-27).

2. **Locate the nerves lateral and posterior to the pulsating artery, and find the most superior/lateral point of the brachial plexus**. The suprascapular nerve will be found at this most lateral point.
3. **To confirm the suprascapular nerve, consider scanning down the brachial plexus from the interscalene level.** With good imaging, the suprascapular nerve can be seen originating from the C5 nerve root and then followed caudal and lateral to the supraclavicular fossa.
4. **At the supraclavicular level, trace the nerve laterally.** The nerve should exit posteriorly and laterally away from the brachial plexus.
5. **Often, the clavicle inhibits further lateral transducer movement.** If so, try asking the patient to push his or her arm down toward the contralateral thigh to help move the clavicle out of the way. Then aim the ultrasound beam under the clavicle (Figure 2-28).
6. **As the nerve separates from the brachial plexus, it should be relatively shallow (<1 cm deep) and located under the omohyoid** muscle (Figure 2-29).
7. **The nerve will appear as a round hypoechoic (dark) structure with a hyperechoic (bright) cover.**
8. **The needle should be advanced from a posterolateral position in a medial and anterior** direction (Figure 2-30).
9. **Aim to place the local anesthetic just deep to the suprascapular nerve to ensure that the injection occurs beneath the fascia covering the nerve.**

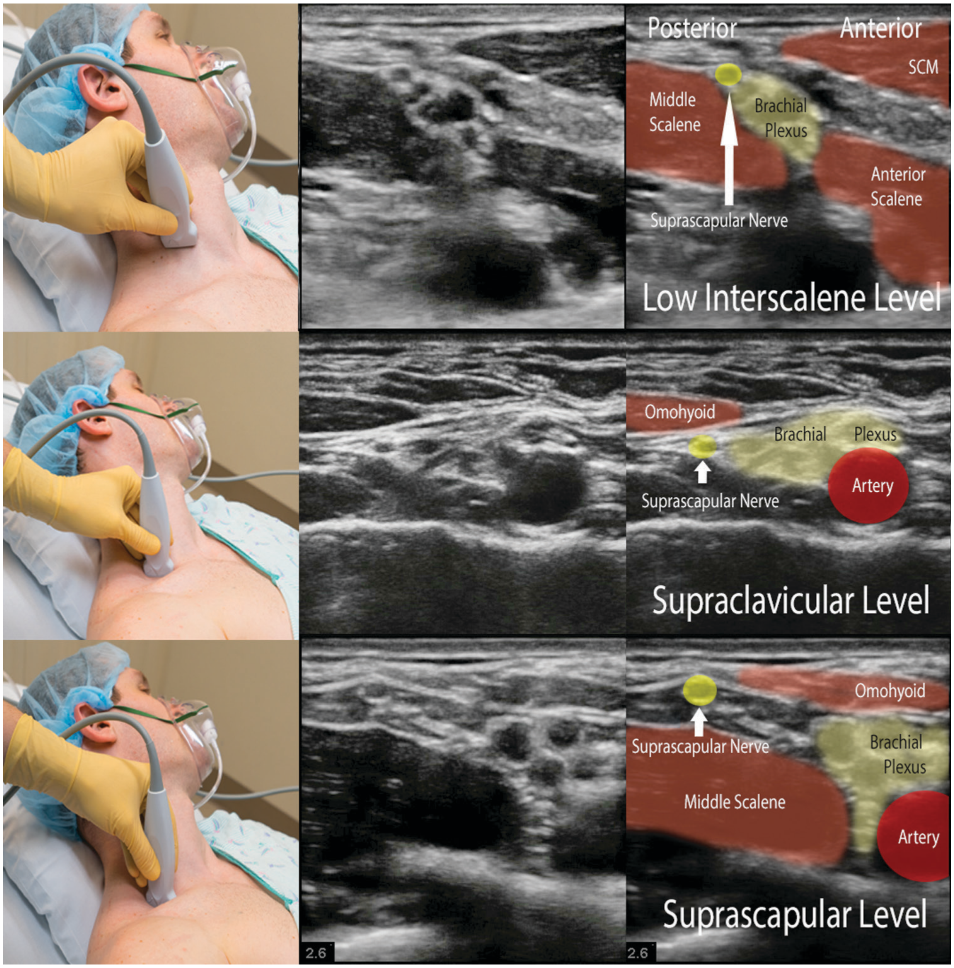


Figure 2-27 The suprascapular nerve can be identified as it exits superficially and posteriorly from the brachial plexus. At a low interscalene level, a small hypoechoic suprascapular nerve can be visualized budding from the C5 nerve root *(top images)*. By tracing further down the supraclavicular level, one can find the suprascapular nerve on the posterior edge of the brachial plexus bundle *(middle images)*. If the nerve is followed further laterally, the suprascapular nerve can be isolated from the remainder of the brachial plexus *(bottom images)*.

Alternative Techniques

The injection can also be performed posteriorly, above the spine of the scapula. For this approach, the transducer is placed above the spine of the scapula, and the suprascapular notch at the superior margin of the scapula is identified with ultrasound. The suprascapular nerve and artery run within the notch. This approach is deeper and often more difficult to image than the proximal approach detailed previously.

Catheters

Catheters can be effective when placed with a proximal approach similar to that described for the nerve block. For catheters, the insertion point is often started very posteriorly (dorsally) in order to keep the catheter insertion site out of the surgical field (see Figure 2-30, *right image*).

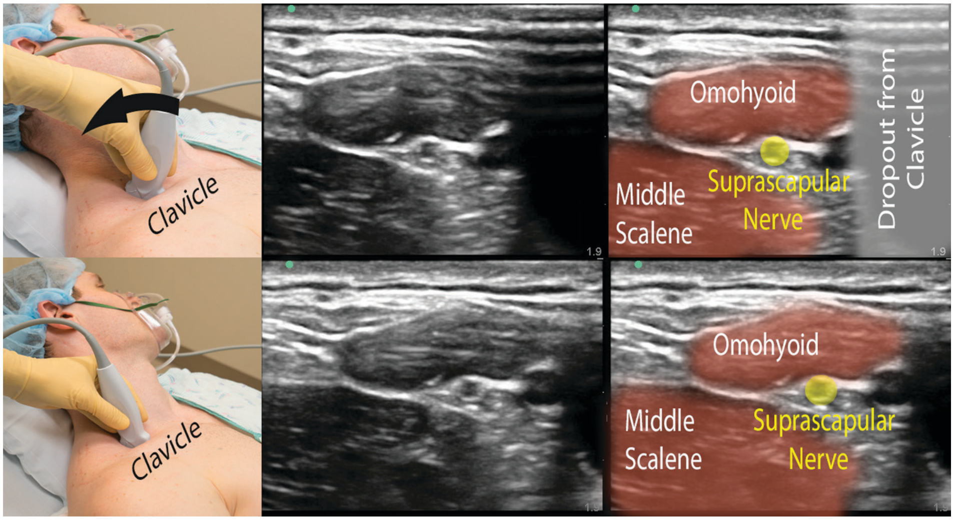


Figure 2-28 To obtain an unobstructed image of the suprascapular nerve, start with a supraclavicular image and slide the probe laterally. The clavicle inhibits lateral imaging of the suprascapular nerve *(top images)*, so tilt the transducer to aim the ultrasound beam underneath the clavicle *(bottom images)*. A small-footprint transducer is useful here.

Complications

The primary side effect of the suprascapular block is partial blockade of the brachial plexus when large injections or continuous infusions are employed. Phrenic nerve blockade still remains a risk, although the severity of diaphragmatic impairment is less than with the interscalene block.

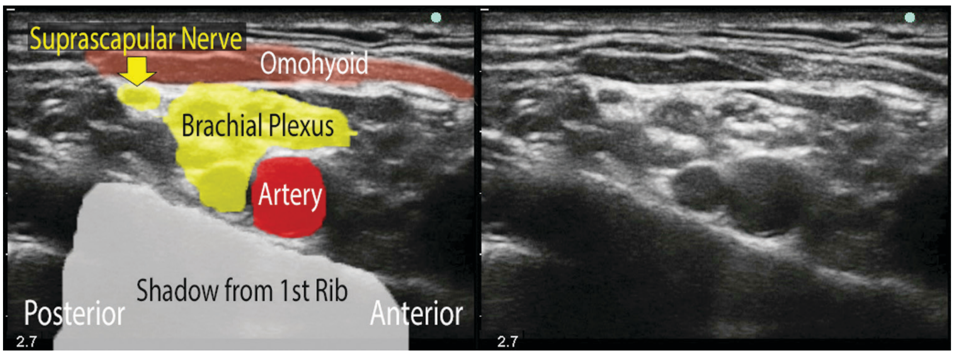


Figure 2-29 Imaging the suprascapular nerve is very similar to supraclavicular block imaging. To better isolate the suprascapular nerve, try to image as far laterally as possible.

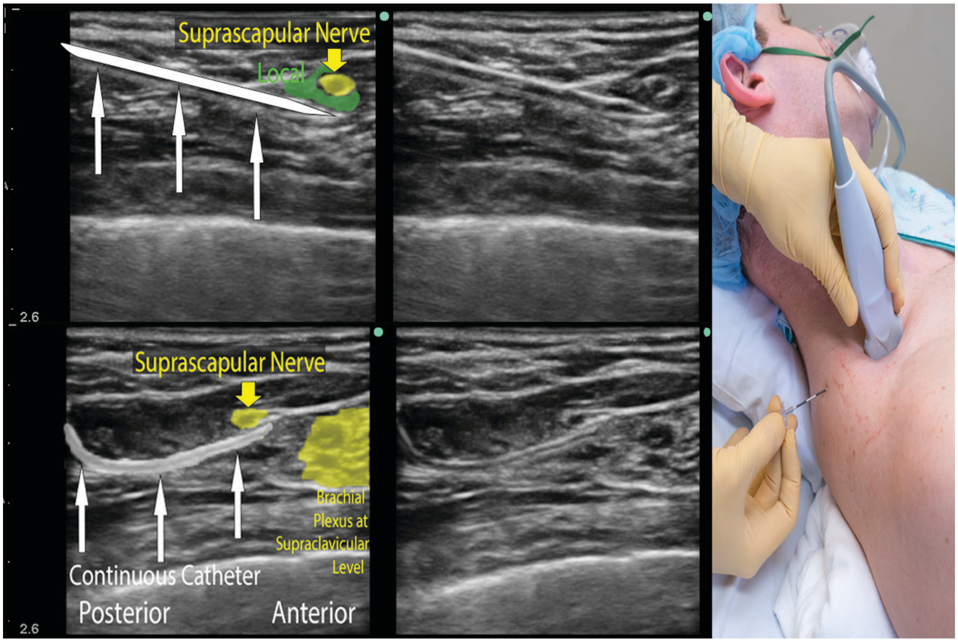


Figure 2-30 The needle is advanced from posterior to anterior. The suprascapular nerve is usually quite shallow, so keep the needle in a shallow plane *(top images)*. Target injections below the nerve to ensure needle penetration through the overlying fascia. Catheters can be left in a similar position *(bottom images)*.

Pearls

- As described earlier, ipsilateral arm positioning moves the clavicle, allowing more room to place the transducer.
- A small, high-frequency linear transducer (25 mm wide) is preferred to avoid running into the clavicle when imaging the suprascapular nerve. Tilting the probe to aim the beam underneath the clavicle helps image the nerve (see Figure 2-28).
- If the nerve cannot be traced laterally or if the clavicle prevents further movement of the transducer laterally away from the brachial plexus, consider placing the injection of local anesthetic at the superficial lateral point of the brachial plexus in the supraclavicular ultrasound view. In the supraclavicular view, the suprascapular nerve is located at the lateroposterior part of the plexus (see Figure 2-27).
- If the nerve is difficult to trace, it may be also found as a hypoechoic structure lying underneath the omohyoid muscle.
- Consider stimulating this nerve when learning this block or having difficulty locating it. The twitch obtained should be in the supraspinatus and infraspinatus muscles. With a low current, the twitch will appear as a subtle lateral movement or abduction of the arm.

Cervical Plexus Nerve Block

Introduction

The cervical plexus block was previously divided into a deep and a superficial block. Use of ultrasound now allows establishment of a complete block without the use of separate injections. In addition, needles previously were advanced blindly in close proximity to nerve roots, increasing the risk of neuraxial injection. Ultrasound permits a simple, safe injection of the cervical plexus that targets both the sensory (superficial) and muscular (deep) branches.

Anatomy

The cervical plexus is formed from the branches of the C1 through C4 nerve roots. The plexus lies on the anterior and middle scalene muscles, deep to the sternocleidomastoid. Before the advent of ultrasound-guided injections, precise placement of local anesthetic under the sternocleidomastoid was difficult, so techniques were developed to place field blocks in this area. Now, with ultrasound, the nerve roots and cervical plexus found between the scalene muscles and the sternocleidomastoid can be specifically targeted.

Clinical Applications

There are two primary uses for the cervical plexus block in the perioperative arena: carotid surgery and clavicle surgery.

Technique

Ultrasound Details

Monitors: ECG, NIBP, pulse oximeter.

Skin Preparation: Chlorhexidine with alcohol.

Probe: High-frequency linear probe (10-15 MHz); expected target depth in 80-kg adult, 0.5 to 1 cm.

Patient Position: Supine, with head elevated 45 degrees.

Local anesthetic choice: From 5 to 10 mL of local anesthetic is required. For long-acting analgesia, ropivacaine or bupivacaine 0.25% to 0.5% is used. For short-duration blocks, mepivacaine 1.5% or lidocaine 2% may be employed.

Needle: 50-mm (2-inch) or 100-mm (4-inch), short-bevel nerve block needle.

Scanning Technique

1. **Locate the C5 and C6 nerve roots at the interscalene level, as described for the interscalene nerve block.**
2. **Slide the transducer up to visualize the C6 and then the C5 transverse processes** (see Figures 2-6, 2-7, and 2-8).
3. **At the level of C5, the C3 and C4 nerve roots and the cervical plexus are reliably located between the sternocleidomastoid and the middle scalene muscle** (Figure 2-31).
4. **This is a fascial plane block, and the nerves will not always be visible.** Identification of the sternocleidomastoid muscle and the scalene muscles is all that is required.
5. **An in-plane or out-of-plane injection of 5 to 10 mL of local anesthetic placed between the sternocleidomastoid and the scalene muscles will reliably block the cervical plexus** (Figure 2-32).

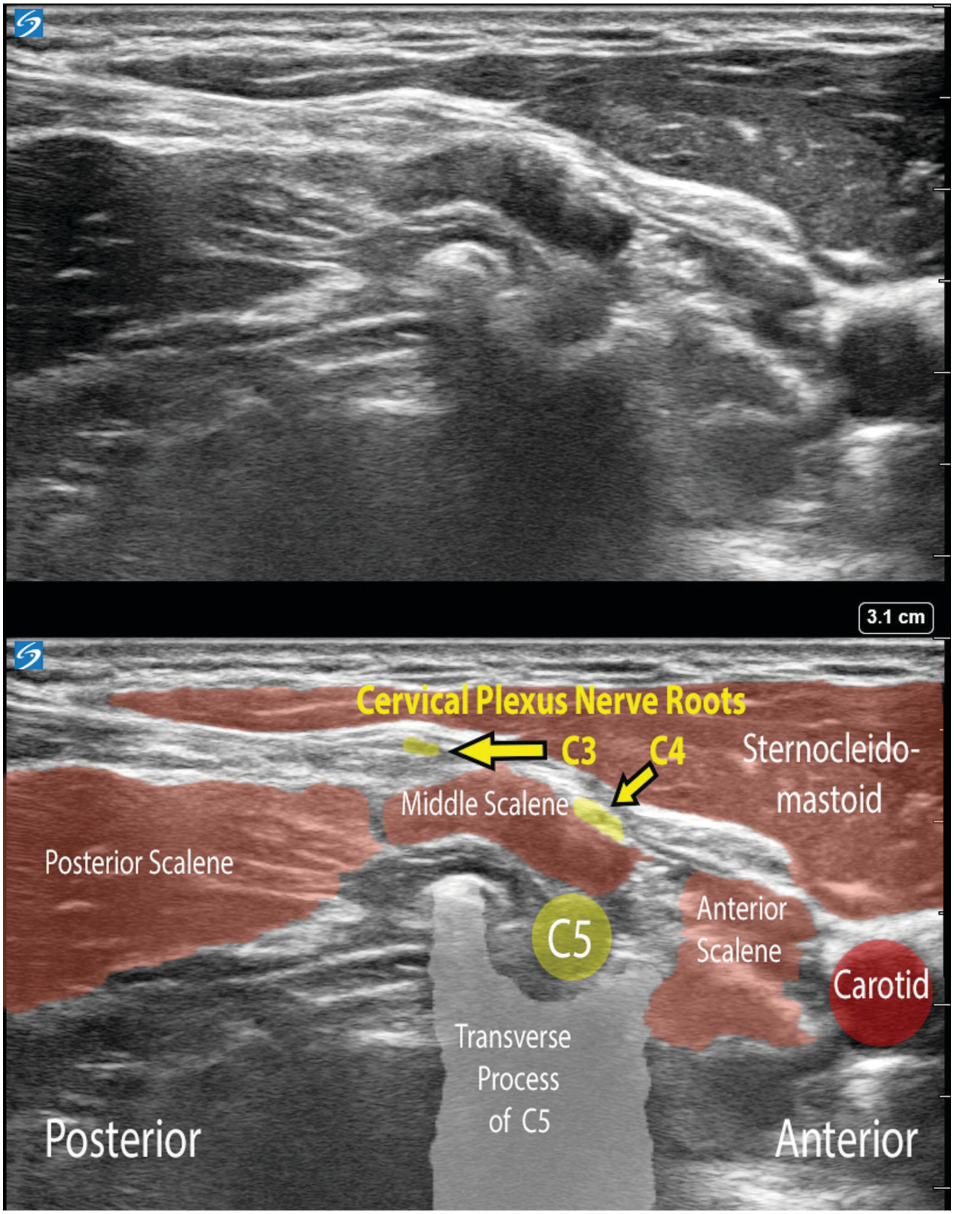


Figure 2-31 Imaging of the superficial cervical plexus at the C5 transverse process level. The cervical nerve roots of C3 and C4 are only a fraction of the size of the C5 nerve root and are not reliably visualized in all people using standard clinical ultrasound techniques. Whether visualized or not, the C3 and C4 nerve roots can reliably be found in the plane between the sternocleidomastoid and the scalene muscles.

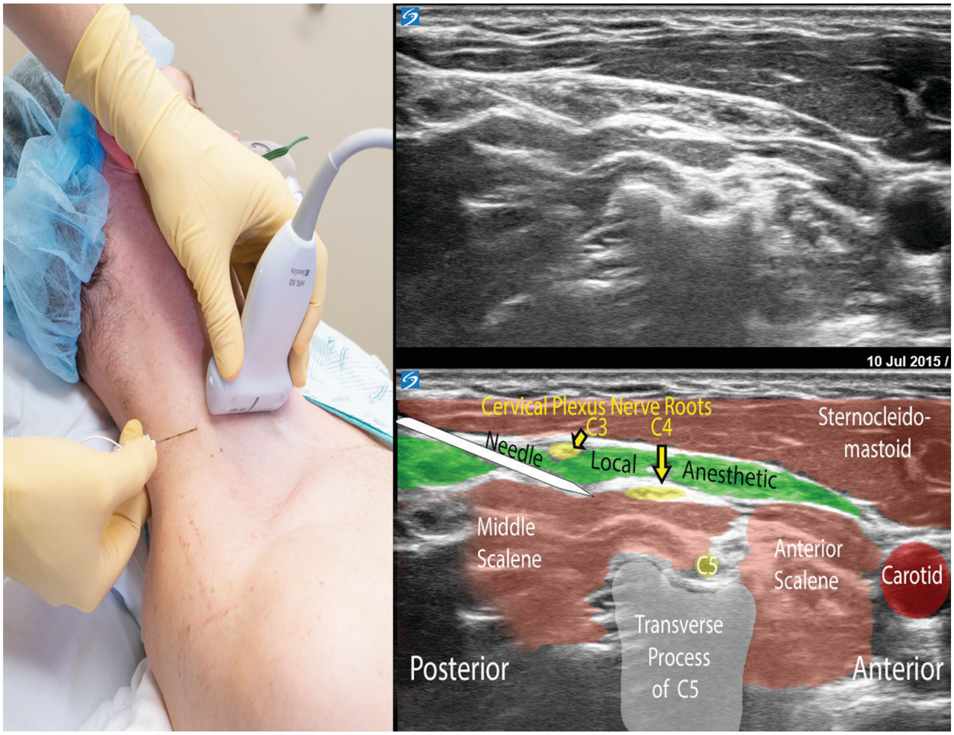


Figure 2-32 For a reliable cervical plexus block, direct the needle to inject local anesthetic between the sternocleidomastoid and the scalene muscles. Usually a posterior-to-anterior needle trajectory, similar to that used for an interscalene block, is effective.

Complications

The neck has many important structures. Needle visualization, whether in-plane or out-of-plane, is of great importance. The phrenic nerve arises from these nerve roots, so bilateral blocks of the cervical plexus are not appropriate. Hydrodissection during advancement helps to push the nerves away from the tip of the needle and potentially lessens the risk of direct nerve injury.

Pearls

- Local anesthetic should easily spread within the plane between the sternocleidomastoid and scalene muscles to cover the entire cervical plexus.
- To improve chances that the majority of nerve roots are blocked, consider advancing the needle in a slightly cephalad-to-caudad direction while injecting the bolus of local anesthetic.
- Alternatively, two injections can be made between the muscles at the C4 and then at the C3 level.
- An out-of-plane needle approach can also be an effective technique for the cervical plexus block.

Supraclavicular Nerve Block

Introduction

The supraclavicular block is effective and useful. It routinely anesthetizes the entire arm below the shoulder because the brachial plexus is very compact as this level. Before the advent of ultrasound guidance, the risk of pneumothorax caused practitioners to shy away from the classic supraclavicular nerve block. Ultrasound permits visualization of the pleura as well as the nerves, and if performed correctly, it greatly improves the safety of this block.

Anatomy

This brachial plexus block is performed at the level of the first rib (a key identifier on ultrasound). At this level, the plexus is emerging from between the scalene muscles and is made up of the trunks or divisions. The superior, middle, and inferior trunks each split into anterior and posterior divisions. The nerves are located lateral and posterior to the subclavian artery. Key landmarks from lateral to medial along the first rib are the middle scalene muscle, the brachial plexus, the subclavian artery, the anterior scalene muscle, and the subclavian vein. The first rib curves around the dome of the pleura. This curvature makes it difficult to visualize more than a section of the rib at any one time during the performance of this block.

Clinical Applications

The supraclavicular block can be used for surgeries from the shoulder to the hand. In the traditional descriptions, the supraclavicular block was thought to cover the arm from the midhumerus to the fingers. A slight variation in block injection technique (described in the "Pearls" section) can increase the likelihood that this block will cover the shoulder as well. Surgeries may include orthopedic surgery of the upper extremity as well as arteriovenous fistula creation. If the block is not performed correctly, the ulnar nerve can be missed. Exercise caution or choose an alternative (i.e., a block below the clavicle) in patients with significant restrictive or obstructive lung disease because of the higher incidence of phrenic nerve paralysis with blocks above the clavicle. The phrenic nerve (C3-5) runs along the anterior border of the anterior scalene muscle, so the needle should be advanced from the posterior side. Additionally, the proximity of the pleura needs to be recognized deep and/or medial to the first rib. There are multiple branches of the subclavian artery in this area, and ultrasound guidance will help avoid inadvertent intraarterial injection.

Technique

Ultrasound Details

Monitors: ECG, NIBP, pulse oximeter.

Skin Preparation: Chlorhexidine with alcohol.

Probe: High-frequency linear probe (10-15 MHz); expected target depth in 80-kg adult, 1 to 2 cm.

Patient Position: The patient is positioned in a sitting position of 45 degrees head up with a pillow under the head but moved out of the way to fully expose the neck on the operative side (see Figure 2-25).

Local anesthetic choice: Usually, 15 to 30 mL of local anesthetic is required. For anesthesia and long-acting analgesia, ropivacaine or bupivacaine 0.5% is used. For short-duration blocks, mepivacaine 1.5% or lidocaine 2% may be employed. If the nerve block is required only for postoperative analgesia, a lower concentration of local anesthetic can be used (e.g., ropivacaine 0.2%).

Needle: 100-mm (4-inch), short-bevel nerve block needle.

Scanning Technique

1. **Place the probe behind the midpoint of the clavicle.**
2. **The probe should be aimed acutely down the neck as if attempting to image deep into the thorax.** Do not aim with the probe flat across the neck (see Figure 2-14).

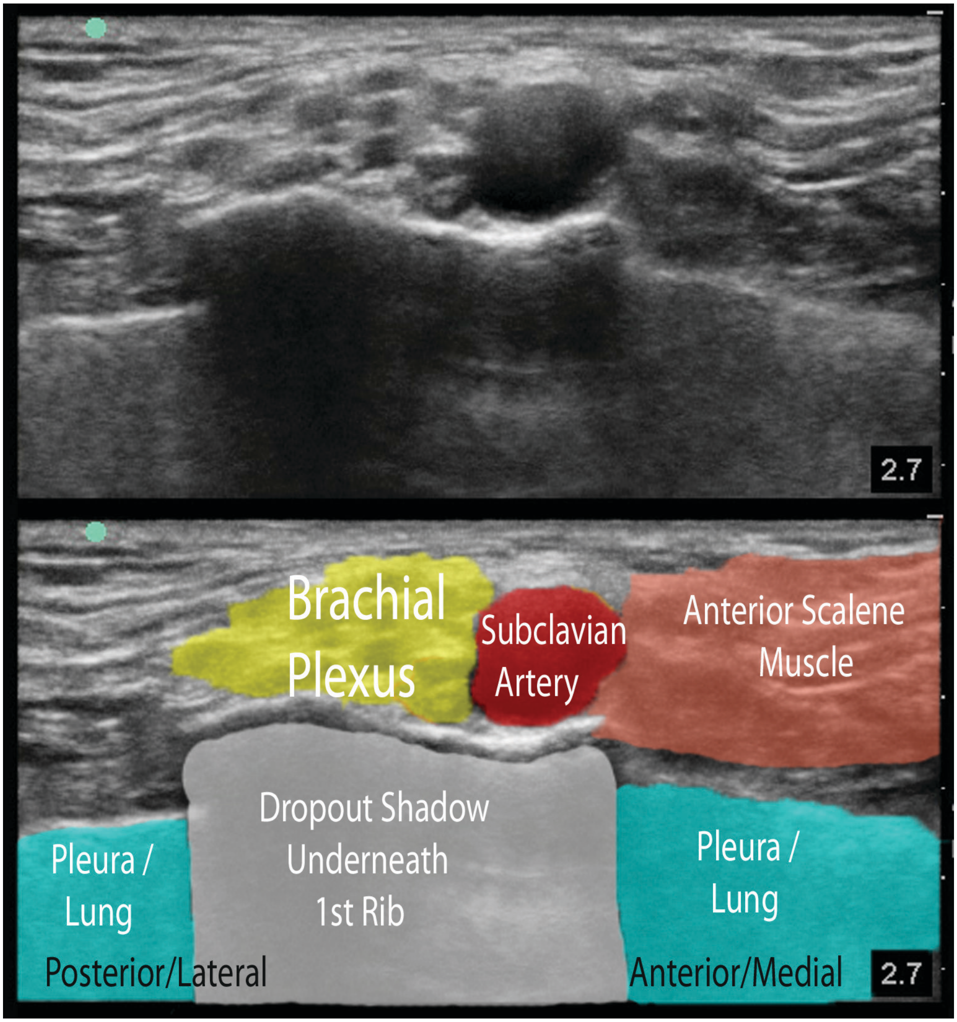


Figure 2-33 Supraclavicular image. The circular subclavian artery is central in the image; it lies on the first rib with the brachial plexus posterior. Avoid placing the probe too medial and mistaking the carotid artery or subclavian vein for the subclavian artery.

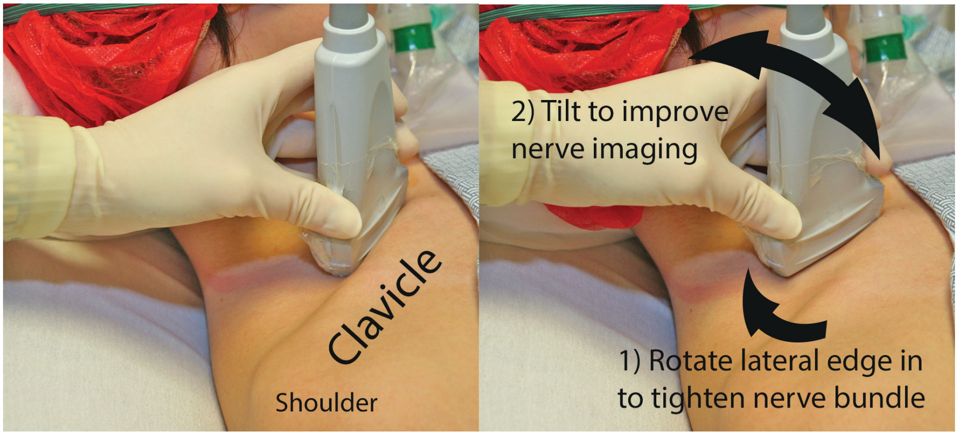


Figure 2-34 To improve visualization of the brachial plexus bundle, start with a rotation of the lateral part of the probe away from the clavicle. Next, use a tilting motion (see Figure 1-11 in Chapter 1) to further improve imaging of the nerves.

3. **Locate the pulsatile subclavian artery.** The artery is a hypoechoic or black circle and will appear pulsatile. The artery sits on the hyperechoic line of the first rib or pleura. If the artery is not initially visible, slide the probe parallel to the clavicle medially or laterally. Take care not to mistake the carotid artery for the subclavian artery (Figure 2-33).
4. **The nerves are located posterolateral to the artery or occasionally superior to the artery.** The brachial plexus appears as a "bunch of grapes"—hypoechoic circles encased in hyperechoic fascia.
5. **If the image of the nerves does not appear crisp, rotate the lateral part of the probe away from the clavicle or use a tilting motion to improve image quality.** This aids visualization by imaging the nerves more in cross section (Figure 2-34).
6. **Before needle insertion, turn on color Doppler imaging to look for blood vessels that may course through or around the brachial plexus and in the needle path** (Figure 2-35).
7. **Insert the needle in-plane, starting lateral and aiming medially** (Figure 2-36).
8. **Advance the needle, aiming for the junction of the artery and the rib**. Be cautious with this movement because identification of the pleura and rib can be confusing. For safety, ensure that the needle never advances deep to the hyperechoic line of the rib or pleura.
9. **Ideal spread of local anesthetic is beneath the brachial plexus and pushing up the plexus.** Inject half of the local anesthetic at that point (see Figure 2-36).
10. **Then redirect the needle to the most superficial aspect of the plexus,** and inject the remaining local anesthetic. The final objective is to have the plexus completely surrounded with local anesthetic (Figure 2-37).

Alternative Techniques

Placing the patient in the lateral position provides an opportunity to approach the plexus from posterior, but here the benefits of gravity pulling the shoulder inferiorly may not be appreciated. Additionally, respiratory mechanics are better with the patient in the sitting position.

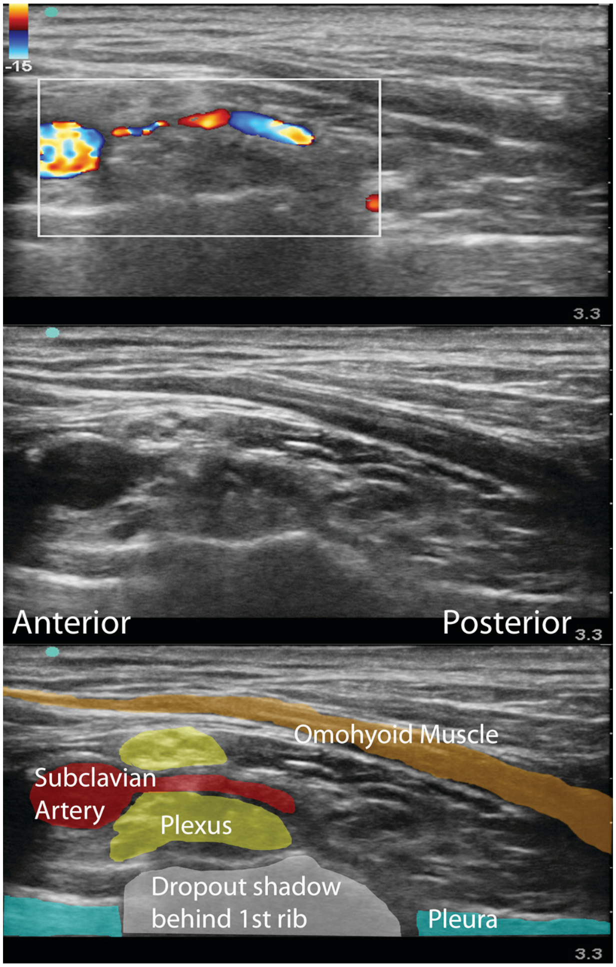


Figure 2-35 Color Doppler imaging is essential in the supraclavicular region *(top)*. There are many arteries in this area with many normal anatomic variations. Without color Doppler imaging, the artery is less obvious *(middle)*. The transverse cervical artery is seen splitting the brachial plexus as it leaves the subclavian artery *(top and bottom)*.

Catheters

Supraclavicular catheters can be placed with the same technique used for single-shot nerve blocks. The close proximity of the nerves in this location and the great success of single-shot blocks make this site seem a likely location for a successful continuous catheter placement. However, clinically and in the published literature, the infraclavicular catheter has been proven to provide better prolonged analgesia for elbow and distal arm or hand surgery. Understanding the surgical location can improve catheter placement; for example, if the surgery is in the ulnar nerve distribution, the catheter should be placed adjacent to the most inferior part of the plexus. For shoulder surgery, placement of the catheter at the upper lateral portion of the brachial plexus in the supraclavicular region is an effective means of providing extended analgesia with less phrenic involvement than occurs with an interscalene catheter (Figure 2-38). In this shallow, mobile area of the supraclavicular fossa, catheter

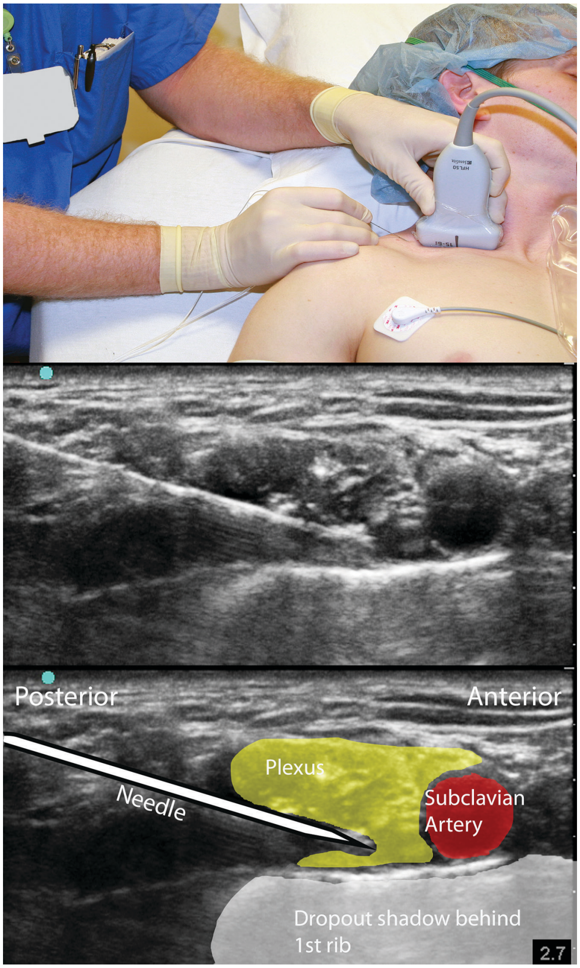


Figure 2-36 Supraclavicular needle insertion position. Make the first injection in the corner between the first rib and the subclavian artery, underneath the brachial plexus. Avoid advancing the needle to the hyperechoic border of the first rib, because there may be confusion in distinguishing between the pleura and the first rib in some patients.

fixation can be difficult. Consider using surgical glue on the puncture site to improve catheter longevity.

Complications

Complications may include phrenic nerve palsy, Horner syndrome, hematoma, pneumothorax, failed block, infection, and nerve injury.

Pearls

- Be prepared to abandon the supraclavicular approach for an alternative (e.g., infraclavicular) approach if overlying arterial branches make it unsafe. Consider other blocks in compressible areas (e.g., axillary block) if the patient is anticoagulated.

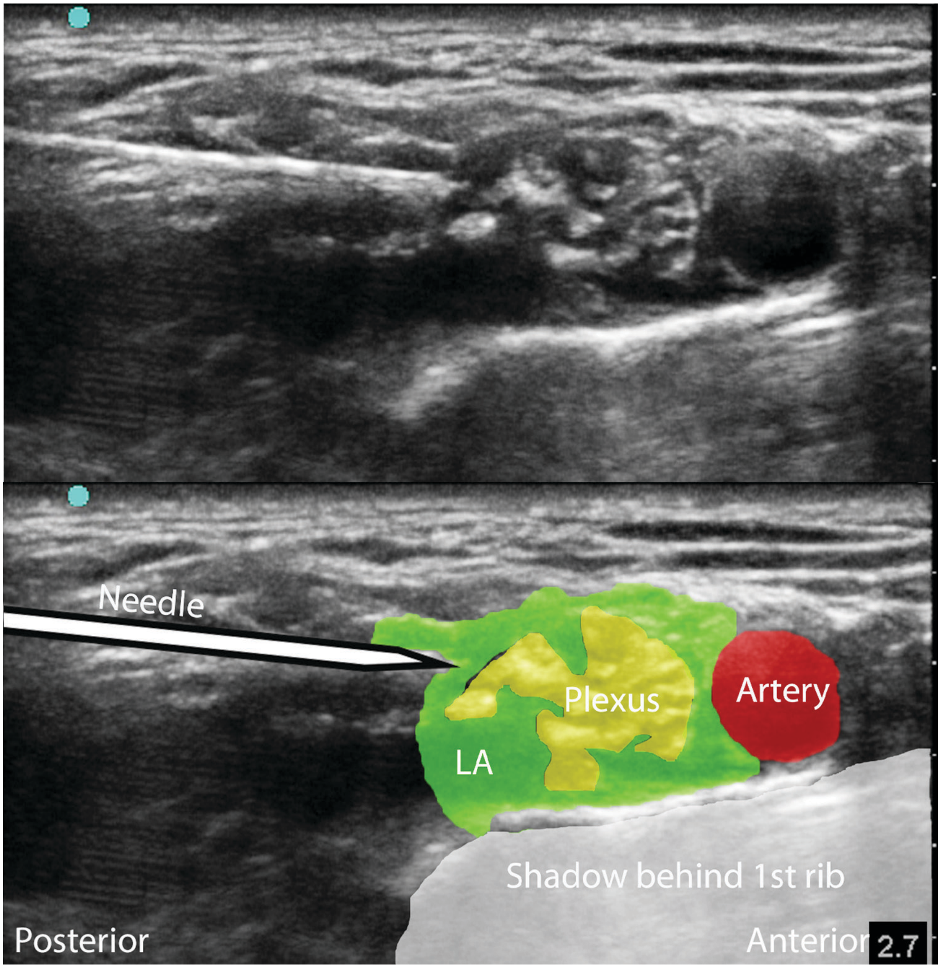


Figure 2-37 Supraclavicular ultrasound images demonstrate secondary needle position. The probe can be moved off the needle during injection and up the neck before returning to the needle. This provides a dynamic three-dimensional image of local anesthetic spread during injection (see "Step-Off Technique" and Figure 1-22 in Chapter 1).

- Move the pillow or headrest toward the opposite side to maximize the area for needle placement.
- The midpoint of the clavicle from the sternal notch to the acromioclavicular joint can be used as a starting point to begin scanning and locating the subclavian artery. Surface anatomy can be used to help identify the subclavian artery, especially for beginners. First, identify the jugular notch medially and the acromioclavicular joint laterally. The midpoint between these two landmarks and posterior to the clavicle is where the initial probe placement should be made. This approach increases the likelihood of visualizing the subclavian artery immediately (see Figure 2.14).
- Single-shot blocks and catheter placements use the same patient positioning and scanning techniques.

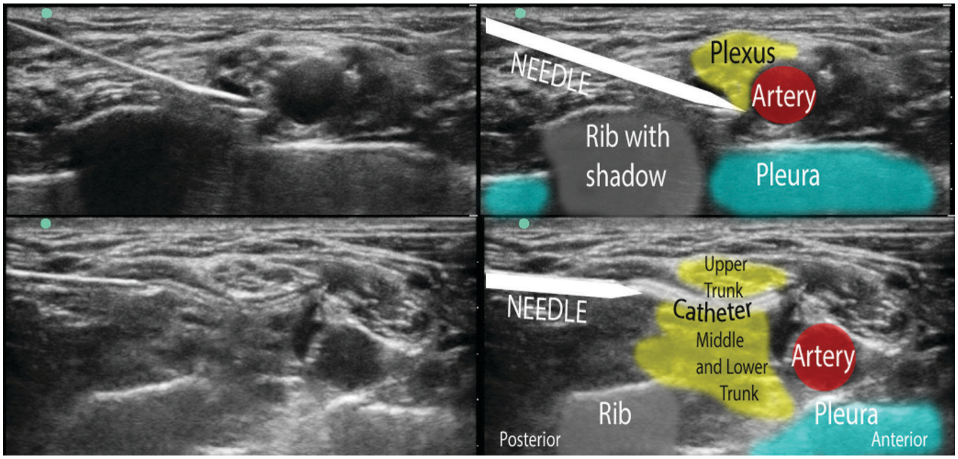


Figure 2-38 Supraclavicular catheter placement. A catheter placed in the upper part of the brachial plexus at the supraclavicular level *(bottom images)* is more effective for shoulder analgesia than catheters placed lower *(top images)*.

- As more experience is acquired, the step-off technique may be employed. This is a great aid to assess the spread of local anesthetic and improve the success of this and other nerve blocks. After injection of the first local bolus in the area between the plexus and the rib is complete, do not move the needle. With the needle still, slide the probe up the neck to look at the spread of local anesthetic surrounding the plexus. Once the spread of local anesthetic has been assessed, slide the probe back down the neck to view the needle. When the needle is visible again, more local anesthetic can be injected if required, or the needle position can be readjusted to achieve better spread. This step-off technique allows the practitioner to assess appropriate local anesthetic spread around the target nerves. For beginners, the thought of leaving the needle can be daunting. However, for more experienced users, assessing local anesthetic spread allows improved confidence about the success of the nerve block (see Figure 1-22 in Chapter 1).
- If using the supraclavicular block for a shoulder surgery, the deeper injection near the rib is not necessary. Concentrate the local anesthetic injection at the upper portion of the plexus (see Figures 2-29 and 2-38). This is where the superior trunk, including the suprascapular nerve, lies. The suprascapular nerve carries the majority of pain sensation after shoulder surgery.
- Consider an intercostobrachial nerve block supplementation for surgeries on the medial upper arm or for prolonged tourniquet times. See "Intercostobrachial Nerve Block" for full details.

Infraclavicular Nerve Block

Introduction

The infraclavicular block is effective in providing anesthesia and analgesia for the arm distal to the shoulder. This block provides coverage similar to that of the supraclavicular nerve block but has distinct benefits compared to the supraclavicular nerve block with ultrasound guidance, including decreased risk of phrenic nerve paralysis and better securing of a continuous catheter due to the needle traversing the pectoralis muscles. However, the infraclavicular block also presents distinct challenges: (1) the close proximity of the clavicle to the needle insertion site, (2) the proximity of the vessels to the corresponding cords, and (3) the increased depth of the block due to the overlying pectoralis muscles and breast tissue.

Anatomy

The infraclavicular block is performed at the level of the cords. When scanning from below the clavicle to the axilla, the cords can be located at varying orientations around the artery. There are three cords: lateral, medial, and posterior. Eventually, these cords will become the terminal branches of the brachial plexus.

The subclavian artery continues distally as the axillary artery. The change in nomenclature from subclavian to axillary begins as this artery crosses the first rib. As the artery courses deep to the pectoral muscles into the arm, it is surrounded by the brachial plexus. Lying caudad to the axillary artery is the axillary vein. Both the artery and the vein have numerous branches in the infraclavicular region. The thoracoacromial artery can often seen branching superficially to course between the pectoralis major and pectoralis minor. This branch is used as a landmark for the PECS block (see Chapter 4). The cephalic vein often can be seen as it courses over the axillary artery to join the axillary vein.

Clinical Applications

Infraclavicular nerve blocks are useful for upper limb surgeries that extend as far proximally as the elbow and as far distally as the fingers. Single-injection blocks or continuous catheters can be placed in this area.

Technique

Ultrasound Details

Monitors: ECG, NIBP, pulse oximeter.

Skin Preparation: Chlorhexidine with alcohol.

Probe: Medium- to high-frequency linear probe (6-15 MHz); expected target depth in 80-kg, patient 3 to 4 cm. In obese patients, a curvilinear, low-frequency transducer (<6 MHz) may be useful.

Patient Position: The patient is positioned supine with the arm abducted at the shoulder 90 degrees and the elbow flexed 90 degrees. Abduction of the shoulder is helpful because it makes the clavicle almost disappear posteriorly (the Houdini clavicle maneuver). Arm abduction rotates the clavicle dorsally (posteriorly) to provide more room for a flat trajectory when the needle is advanced anterior to the clavicle. In patients whose arm is immobile (e.g., extremity fracture, frozen shoulder), the arm can remain adducted at the side, but the needle approach may have to be adjusted (see "Pearls").

Local anesthetic choice: Usually, 30 to 40 mL of local anesthetic is required, in divided doses.

Needle: 100-mm (4-inch), short-bevel nerve block needle.

Scanning Technique

1. **Abduct the arm and feel the clavicle.** The clavicle should be displaced posteriorly with arm abduction. The deltoid muscle is lateral to the clavicle. The clavicle and deltoid muscle form a "V" if viewed from above.
2. **The bottom of the "V" formed by the clavicle and the deltoid muscle should be the needle insertion site.** Placement of the needle at that point allows it to be advanced with the shallowest possible angle, aiding significantly in needle visibility (Figure 2-39).
3. **Place the probe at the midpoint of the clavicle in the paramedian plane** (Figure 2-40).
4. **The key initial ultrasound landmark is the axillary artery.** The objective is to scan the artery in a short-axis view. From the initial starting position (midclavicle), slide the probe medial-to-lateral or cranial-to-caudal to locate the dark, pulsatile artery. The axillary artery is located cephalad to the vein. The axillary artery and vein should be positioned side by side on the ultrasound image (see Figure 2-40).
5. **If the artery is still not imaged, use color Doppler ultrasound to identify flow and/or deepen the ultrasound image** (Figure 2-41).

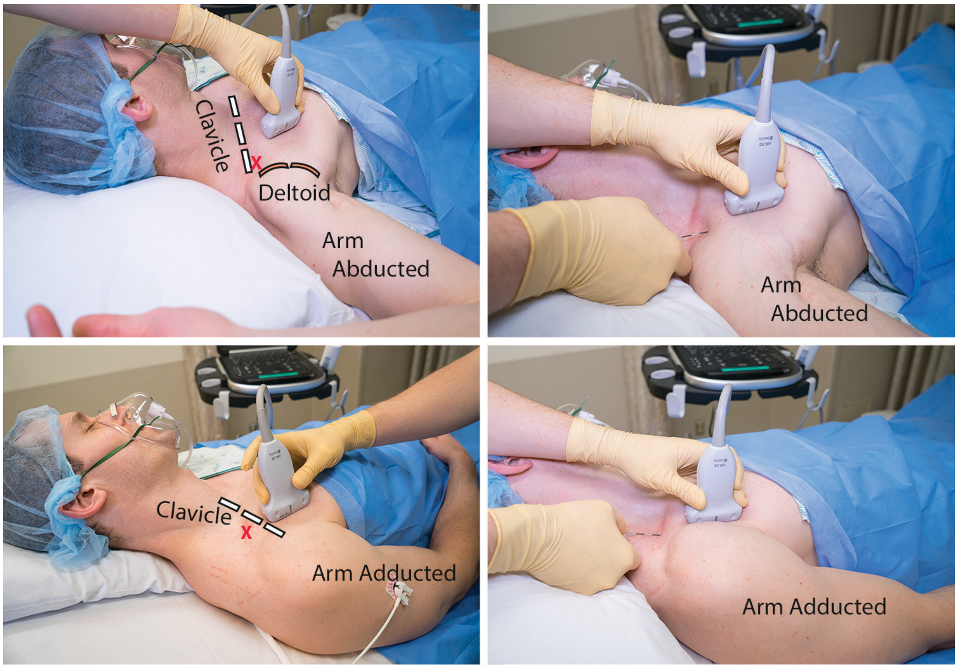


Figure 2-39 Finding the ideal needle insertion site (X) for the infraclavicular block. The top images illustrate the Houdini approach. The arm is abducted, and the displaced posteriorly clavicle and deltoid muscle are identified. These two structures form a "V." The bottom of this "V" is the best site for needle insertion because it allows advancement of the needle in a flat trajectory. The needle is inserted *anterior* to the clavicle. The bottom images show the RAPTIR approach (retroclavicular approach to plexus in the infraclavicular region). The arm is adducted, and the needle is inserted *posterior* to the clavicle. This also allows for a flat needle trajectory.

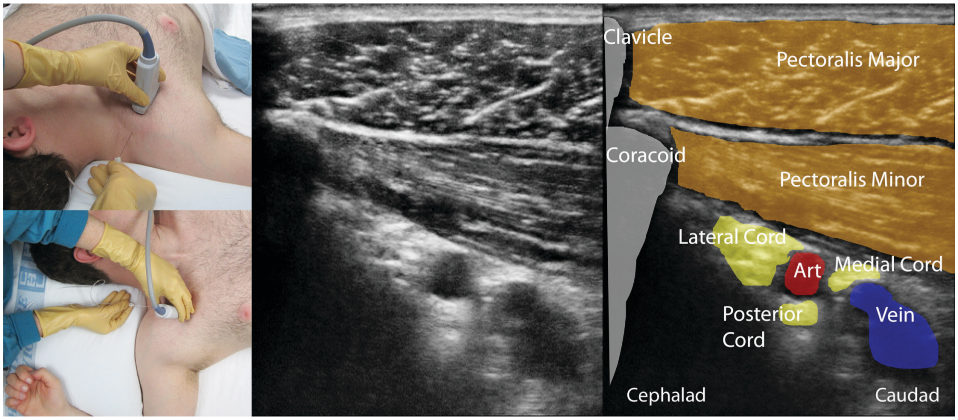


Figure 2-40 Positioning of the patient and probe for an infraclavicular block *(left)* and the initial infraclavicular ultrasound scan *(middle and right)*. Art., artery.

6. **If the axillary artery and vein cannot be located, find the superficial muscles.** Overlying the artery and vein should be two muscle layers: the pectoralis major (shallow) and the pectoralis minor (deep). Additionally, the shadow of the clavicle may be seen cephalad to the artery.
7. **The artery should be traced in cross section medially and then laterally.** Identify the ribs and the pleura deep to the artery as the probe is moved medially. Slide the probe laterally to make the pleura and ribs disappear deep. The perfect block location will not have a visible rib or lung in the image. To improve safety, it is best to be more lateral if the pleura and ribs are in the image during block performance (Figure 2-42).
8. **The nerves (cords of the brachial plexus) appear as bright hyperechoic tissue with small hypoechoic circles lying within.** The position of the nerves varies as the artery is followed from medial to lateral, so it is impossible to always accurately identify each part of the brachial plexus at all times. Medially, the nerves usually lie bunched

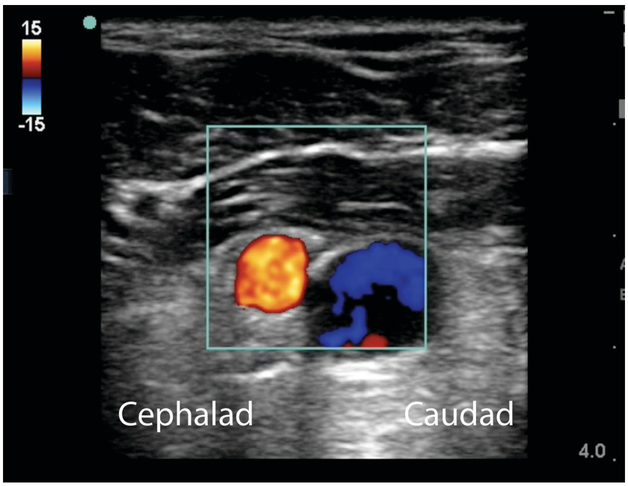


Figure 2-41 Color Doppler imaging for vessel identification in the infraclavicular area.

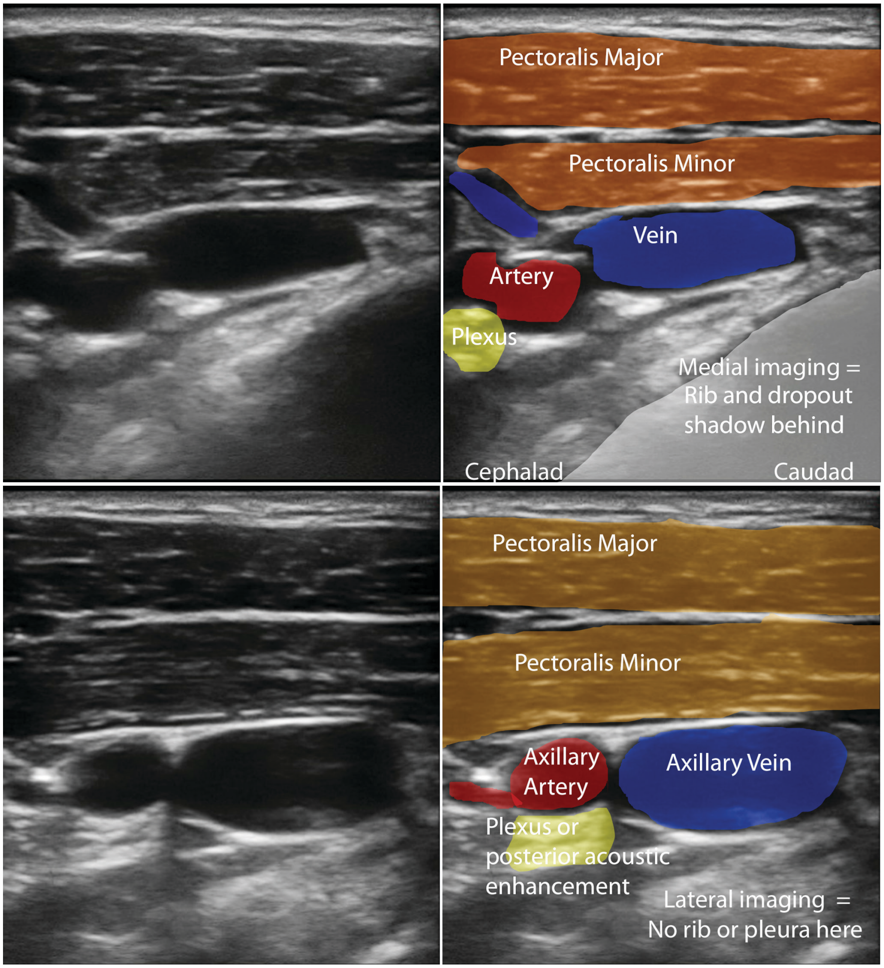


Figure 2-42 Infraclavicular images obtained medially *(top)*, demonstrating the proximity of rib and lung deep to the nerves, and laterally *(bottom)*, demonstrating no visible pulmonary structures.

together cephalad to the artery. Laterally, the nerves lie in their more classic cord positions: lateral, medial, and posterior (Figure 2-43).

9. **The posterior cord can be difficult to distinguish from artifact owing to posterior acoustic enhancement.** Posterior acoustic enhancement is the appearance of a bright echogenic area deep to a blood vessel. This bright reflection can mask or mimic the position of the posterior cord.
10. **Rotate the probe so that the needle insertion site at the bottom of the "V" (see Steps 1 and 2) is at the cephalad end of the transducer.** The perfect needle trajectory is found by aiming the needle slightly laterally. This helps to avoid aiming the needle at the lung (see Figure 2-40).
11. **The needle is advanced from the cephalad end of the probe, in-plane with the ultrasound beam.** Because the arm is abducted, the clavicle is displaced and the needle can be inserted several centimeters away from the probe, resulting in better needle visibility (Figure 2-44).

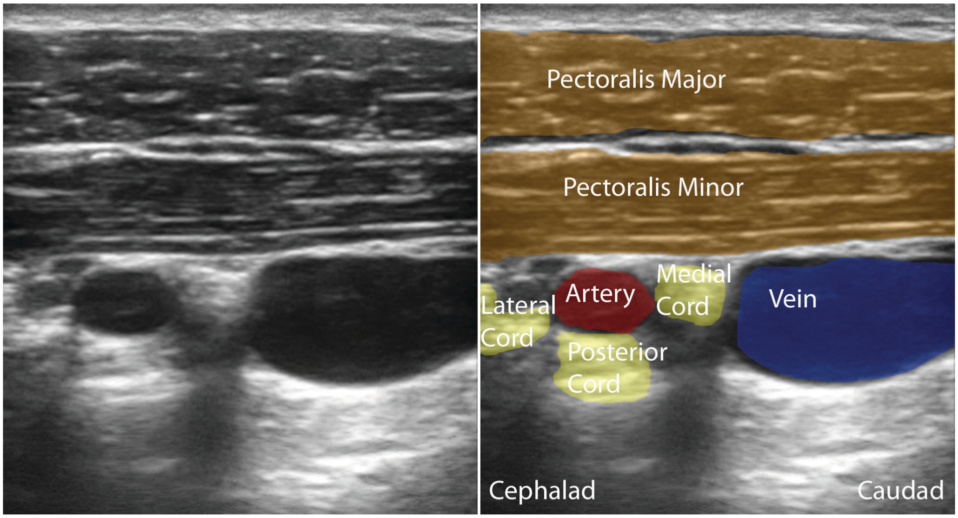


Figure 2-43 Classic infraclavicular lateral, medial, and posterior cord positions. The cord positions are variable and can change in the same patient when scanning from medial to lateral.

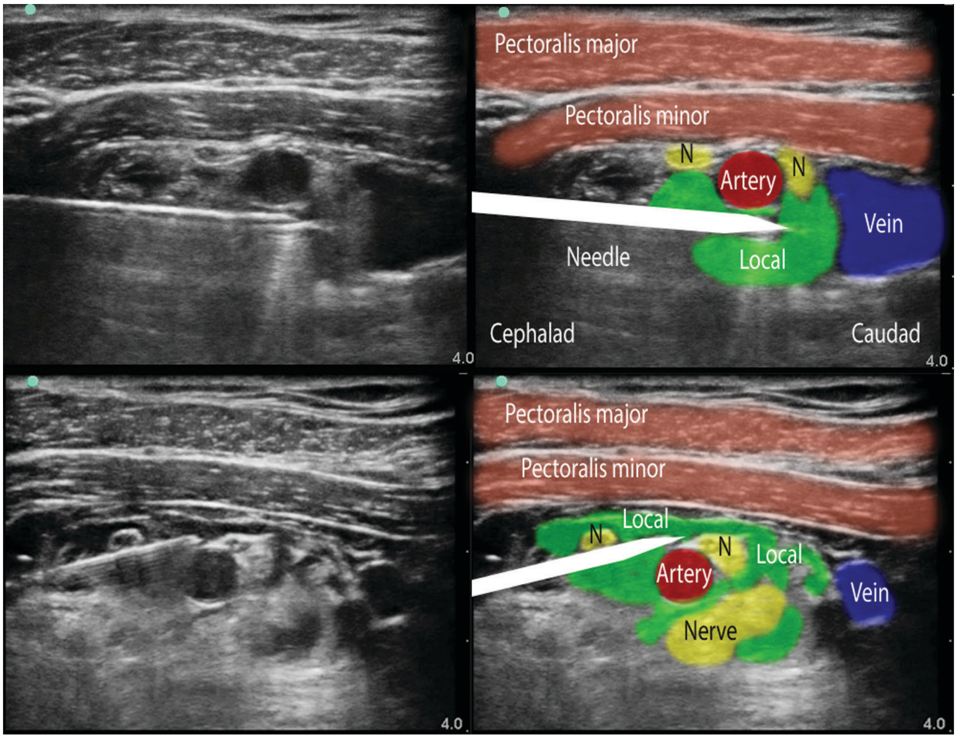


Figure 2-44 Infraclavicular needle position. Initially, the needle should be directed deep to the artery *(top images)*. To improve block quality, redirect the needle and perform a second injection above the artery *(bottom images)*.

12. **The goal is to position the needle deep to the axillary artery**. The majority of the local anesthetic should be placed deep to the axillary artery (see Figure 2-44).
13. **Local anesthetic is injected incrementally and should be observed surrounding the artery and nerves.**
14. **The needle can be repositioned as necessary to ensure spread of local anesthetic around the axillary artery.** Usually, an injection deep to the axillary artery and superficial to the axillary artery will result in adequate local anesthetic spread for this block and a high clinical success rate (see Figure 2-44).

Catheters

Catheters can be placed at the infraclavicular level using the same technique as for single shot-blocks. To obtain best analgesia of the upper limb, the catheters should be targeted for placement deep (posterior) to the axillary artery (Figure 2-45). Continuous catheters are useful here because the increased depth to the brachial plexus results in the catheter's being effectively "tunneled" in the pectoralis muscles, improving longevity. Also, one should consider using surgical glue on the puncture site to improve catheter duration. Continuous catheter infusion rates are typically 5 to 10 mL/hr for an infraclavicular catheter.

Pearls

- Abduct the patient's shoulder 90 degrees and flex the elbow. This position moves the clavicle up and away, providing more room for the needle between the clavicle and the probe.
- Start the needle at the bottom of the "V" formed by the clavicle and the deltoid muscle.
- Keep the needle as nearly perpendicular to the ultrasound beam as possible, using arm abduction to create more room and a more distant needle insertion site several centimeters away from the probe. With this technique, the needle can be advanced anterior to the clavicle.
- If arm abduction is not possible, the arm can remain at the patient's side, and the needle can be advanced posterior to (underneath) the clavicle. This is known as the RAPTIR

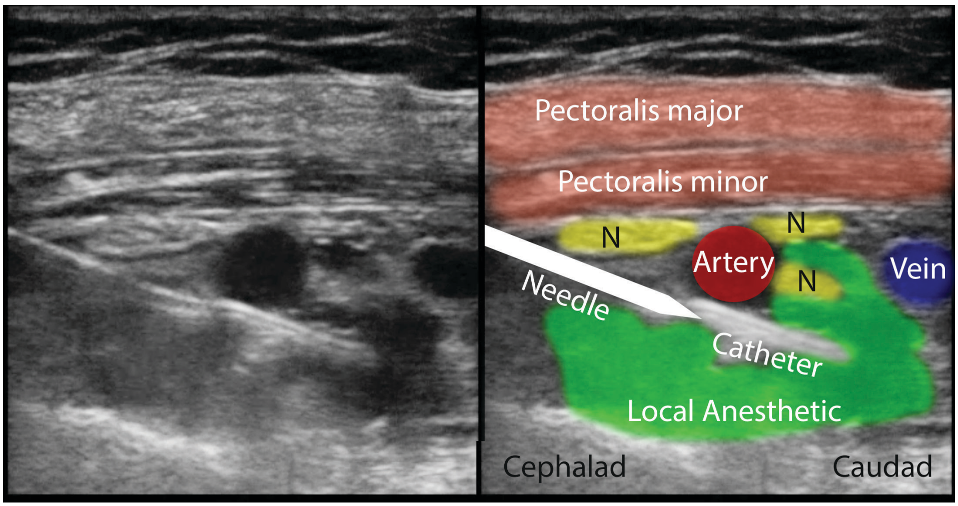


Figure 2-45 Infraclavicular catheters should be positioned deep (underneath) the axillary artery. N, nerve.

technique (retroclavicular approach to the plexus in the infraclavicular region). This is useful in patients with a frozen shoulder or fractured extremity. Placing the needle posterior to the clavicle allows good needle visualization during the nerve block, similar to abducting the arm with the Houdini maneuver. No matter what positioning technique is used, the goal is to advance the needle with a flat trajectory, allowing for good needle visualization throughout the infraclavicular nerve block procedure (see Figure 2-39).

- Although this block was initially described as using low-frequency curvilinear probes, it can be accomplished as described here, with a standard high-frequency linear transducer, in most patients weighing less than 100 kg. For heavier patients, a low-frequency curvilinear probe should be considered.
- Inject the local anesthetic deep to the axillary artery first. This way, the local anesthetic will push the relevant anatomic structures more superficial, resulting in better needle visibility due to a more shallow needle insertion angle. Injecting superficially first can result in the opposite situation, in which the local anesthetic pushes structures deeper and it is therefore more difficult to visualize the needle during subsequent imaging and needle advancement. Also, superficial injections may introduce air bubbles, making structures located deep to the air more difficult to visualize.
- The nerve block should be placed laterally in the infraclavicular region. Medially, the pleura is closer to the posterior wall of the axillary artery, making the potential for pneumothorax greater. In addition, medial probe positions result in less room between the clavicle and the underlying plexus. Laterally, the nerves are usually slightly deeper but there is more room for needle insertion away from the clavicle. We recommend a slightly lateral approach to keep as much distance as possible between the pleura and the needle. Rib or lung should not be visible in the deeper portion of the infraclavicular ultrasound image. If either of those structures is visible, slide or rotate the probe laterally.
- Understanding of the anatomy of the plexus and the relationship of the cords to the terminal nerves and sensory supply of the upper limb allows the regional anesthesiologist to make an informed choice about where to deposit the majority of the local anesthetic. For example, if most of the surgery will occur on the ulnar (medial) aspect of the arm, a larger volume of local anesthetic should be placed on the medial cord (between the artery and vein).
- Consider intercostobrachial nerve block supplementation for surgeries on the medial upper arm and for prolonged tourniquet times. See “Intercostobrachial Nerve Block” for full details.

Axillary Nerve Block

Introduction

The axillary block is performed at the level of the terminal branches of the brachial plexus. At the axillary level, the plexus is located around the axillary artery, but a single injection does not reliably cover all branches. Therefore, visualization of both the axillary artery and the branches of the brachial plexus is important for axillary block success. The lung and pleura are nowhere near an axillary block injection site, so the risk of a pneumothorax is negligible. Other benefits of the block include no risk of phrenic nerve paralysis (unlike blocks above the clavicle), the overall shallow nature of the block, and easy compressibility of the site. For these reasons, the axillary block is useful in obese or even anticoagulated patients.

Anatomy

The brachial plexus in the axilla has separated into its terminal branches: the median, ulnar, radial, axillary, and musculocutaneous nerves. The plexus lies adjacent to the axillary artery and veins. This area is highly vascularized, with several branches from both the axillary artery and the axillary vein. The veins are easily compressed with an ultrasound probe, and gentle relaxation with the probe off the skin often reveals these veins. The nerves lie between the biceps/coracobrachialis muscle laterally and the triceps/teres major muscle medially. The nerves are superficial here, and the initial key anatomic landmark is the axillary artery. The nerves can be in a variety of positions in relation to the axillary artery, and there is no exact place where each nerve is always found. The traditional positions of the nerves are described as follows: (1) median nerve lying superolateral to the axillary artery, (2) ulnar nerve lying medial to the artery, (3) radial nerve lying posterior or posteromedial to the artery, (4) musculocutaneous nerve lying distal and lateral to the artery and running through the coracobrachialis or biceps muscles. These nerve locations are variable and can even change relative to the artery when pressure is exerted by an ultrasound probe.

To best confirm the location of specific nerves, it is useful to scan the nerves in real time along their course distally down the arm. The median nerve runs adjacent to the axillary artery, down the upper arm to the antecubital fossa. The ulnar nerve starts beside the axillary artery or vein and then separates into medial and superficial branches approximately halfway down the upper arm. It then courses over the triceps muscle, making its way toward the ulnar groove between the medial epicondyle and olecranon process on the medial side of the elbow. The position of the radial nerve is usually posterior or posteromedial to the axillary artery. As the nerve courses distally, the radial nerve separates from the plexus deep, entering the spiral groove of the humerus. The humerus appears as a hyperechoic crescent reflection with dark dropout deep. This is a key characteristic that can be used to identify the radial nerve as it leaves the spiral groove and ascends between the heads of the triceps, coursing proximally to join the rest of the plexus.

At the level of the axilla, the musculocutaneous nerve has usually already left the brachial plexus and is found lateral to the artery in the fascial plane between the biceps and the coracobrachialis muscle or piercing the coracobrachialis. When the musculocutaneous nerve is traced distally, it often appears as an oval or triangle. As the probe is moved proximally toward the axilla, the nerve will usually slide closer to the axillary artery and the remainder of the brachial plexus. If the scan is continued even more proximally, high into the axilla, the musculocutaneous nerve can often be found still attached to the rest of the plexus.

Nerves can be identified distally along the upper arm and then traced back to the axilla to confirm their location for the axillary nerve block.

Clinical Applications

The axillary nerve block is useful for upper limb surgeries extending as far proximally as the elbow and far as distally as the fingers. This block is performed in a compressible area, so if there are concerns about bleeding due to anticoagulation or coagulopathy, the axillary block would be preferred over a block in a noncompressible area (e.g., supraclavicular block, infraclavicular block). Also, because this portion of the brachial plexus is remote from the phrenic nerve, there is essentially no chance for hemi-diaphragmatic paralysis with the axillary nerve block.

Technique

Ultrasound Details

Monitors: ECG, NIBP, pulse oximeter.

Skin Preparation: Chlorhexidine with alcohol.

Probe: High-frequency linear probe (10-20 MHz); expected target depth in 80-kg patient, less than 2 cm.

Patient Position: The patient is positioned supine with the arm abducted at the shoulder 90 degrees and the elbow flexed.

Local anesthetic choice: Usually, 20 to 30 mL of local anesthetic is required, in divided doses.

Needle: 100-mm (4-inch), short-bevel nerve block needle. Although a shorter needle can reach the target nerves, a longer needle (100 mm) allows easier alignment of the probe and needle.

Scanning Technique

1. **Place the probe in the transverse plane in the axilla** (Figure 2-46).
2. **Identify the axillary artery as a superficial, dark, pulsatile circle.** If the artery is not visualized, slide the probe cephalad or caudad in the axilla to identify the vessel.
3. **Deep to the artery is the triceps muscle or the teres major.** The teres major muscle is usually oval shaped and forms a bright stripe deep to the axillary artery. If the teres major is not identified, slide the probe proximally, more into the armpit. The teres major is a reliable structure to find and helps make this block reproducible. Injections performed on the fascia of the teres major allow the local anesthetic to reliably spread medially underneath the axillary artery. The teres major muscle is often wrongly labeled as the "conjoint tendon." Tendons are the insertions muscle into bone, not the coverings of muscle (see Figure 2-46).
4. **The nerves appear as hyperechoic oval structures with a bright border (epineurium) and a honeycomb appearance.** Occasionally, the nerves appear hypoechoic instead. Look immediately next to the artery to identify the median and ulnar nerves, which are often located at the same level or just shallow to the axillary artery. Again, realize that there is often great variation in the positions of the nerves, and they may or may not visible in this exact area (Figure 2-47).
5. **After identification of the median and ulnar nerves, look medial and deep or posterior to the artery to identify the radial nerve.** The radial nerve can be difficult to identify and can sometimes be confused with posterior acoustic enhancement, an ultrasound artifact that makes the area deep to the artery appear bright.
6. **Once the artery is identified, scan proximal and distal to evaluate the needle path for small arterial or venous braches.** Also, press down with the probe and then relax the pressure to identify corresponding veins. Color Doppler imaging may be useful to identify any vessels in the area of the anticipated needle path (see Figure 2-47).

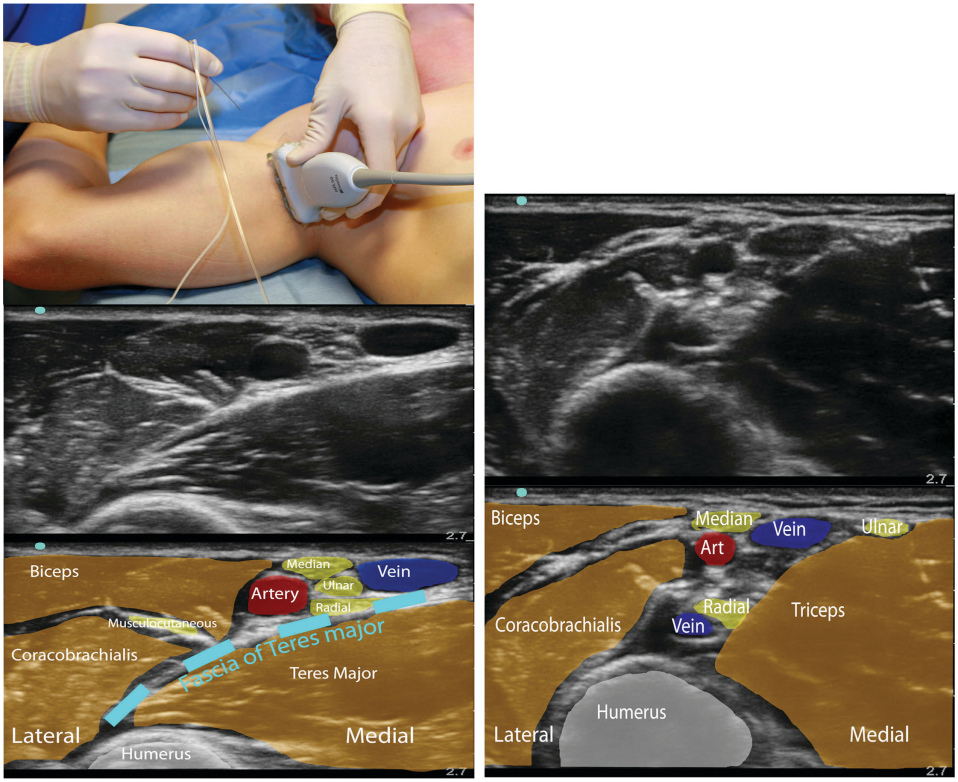


Figure 2-46 For an axillary nerve block, the patient is positioned supine with the arm abducted *(top image)*. The brachial plexus and axillary artery should be imaged medially so that the teres major muscle and fascia are visible *(left images)*. If the arm is imaged even slightly too far laterally, the teres major muscle and fascia will not be visible and the anatomy will be less reproducible *(right images)*.

7. **The block can be performed anywhere in the axilla, provided the teres major muscle is identified deep to the artery.**
8. **Slide the probe slightly lateral to identify the coracobrachialis muscle and the musculocutaneous nerve.** The musculocutaneous nerve usually appears as an oval or triangular structure within the coracobrachialis muscle.
9. **If the specific nerves cannot be identified, injecting deep to the axillary artery and then superficial to the axillary artery usually results in reliable clinical block success.**
10. **After the nerves and vessels are identified, the needle should be inserted in-plane from the lateral (superior) edge of the probe.** The needle should pass through the coracobrachialis and should be directed initially toward the musculocutaneous nerve (Figure 2-48).
11. **The needle should be advanced until the tip is located just adjacent to the musculocutaneous nerve.** Inject 3 to 5 mL of local anesthetic and observe the spread around the nerve.
12. **Usually, the needle can simply be redirected medially to target the area underneath the axillary artery without any additional needle insertions**

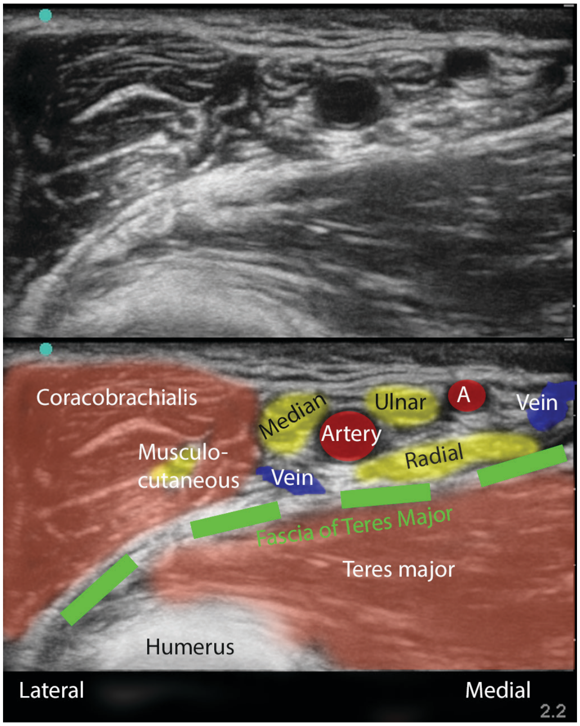


Figure 2-47 Sonoanatomy for the axillary brachial plexus block. The axillary artery and the fascia of the teres major muscle are the primary identifiers. Also notice the many blood vessels in this region. Vascular anatomy is variable in this region. A, artery.

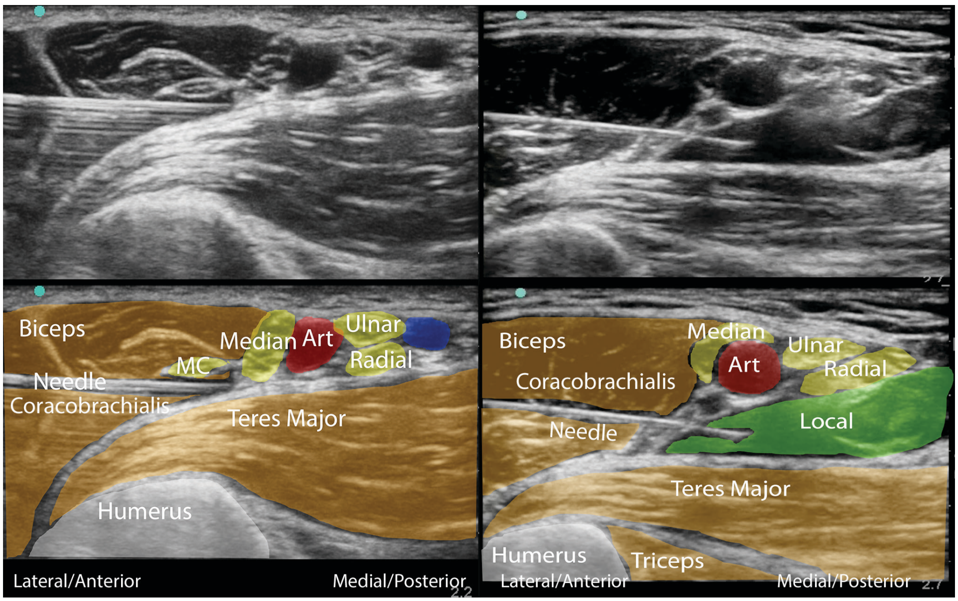


Figure 2-48 Axillary nerve block needle advancement toward the musculocutaneous (MC) nerve *(left images)*. Further needle advancement results in injection deep to the axillary artery but above the teres major fascia *(right images)*.

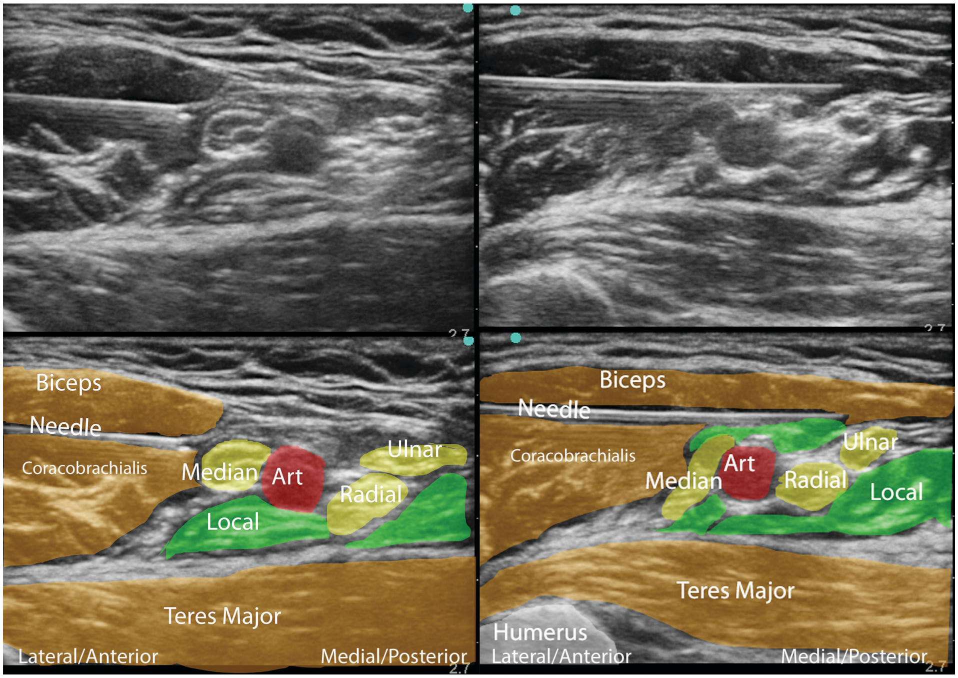


Figure 2-49 Axillary nerve block needle advancement *(left)* and injection superficial to the artery *(right)*.

through the skin. A small redirection of the needle posterior to the artery will target the radial nerve. Inject 5 to 10 mL underneath the axillary artery to reach the radial nerve. This volume, when injected on the teres major, will continue to spread medially to reach the ulnar nerve as well. If the spread is inadequate, continue to advance the needle underneath the artery to the medial side of the vessel. As the needle moves past the artery, relax pressure on the probe to identify the axillary vein, which often runs immediately posterior to the artery (see Figure 2-48).

13. **Next, the needle is withdrawn and then advanced toward the median and ulnar nerves lying on the anterior (superficial) aspect of the axillary artery.** The nerve positions are variable, but the objective is to have local anesthetic spread around the nerve tissue lying anterior (superficial) to the artery. There is often a large vein located on the medial side of the artery, so be cautious during needle advancement and injection of the local anesthetic.
14. **Once the needle is positioned above (superficial) to the artery, inject another 5 to 10 mL of the local anesthetic and observe the spread around the median and ulnar nerves** (Figure 2-49).

Out-of-Plane Approaches

For an out-of-plane approach, the needle may be inserted perpendicular to the probe. Although in-line needle orientation allows for visualization of the needle tip at all times, a perpendicular orientation may allow for technically easier block placement, especially for practitioners who do not have much ultrasound experience and have difficulty viewing an in-plane needle.

Follow the steps already described to identify the axillary artery and the branches of the brachial plexus.

1. **Position the axillary artery in the middle of the ultrasound screen.**
2. **Insert a 2-inch (50-mm) needle about 2 cm away from the probe.** With this technique, the entire needle will not be visualized. Only a cross section of the needle, which appears as a white dot, will be seen during needle advancement.
3. **One may slide the probe in small increments or make small angulations of the probe in attempting to identify the actual location of the needle tip, rather than just observing a static cross section of the needle as described for the interscalene nerve block.**
4. **The needle tip should be advanced just deep to the axillary artery on both sides, and incremental injections should be made as the needle is withdrawn**. The objective is circumferential deposition of local anesthetic around the artery.
5. **Aim lateral or medial to the artery; the needle can often be advanced just to the side of the artery to avoid cannulation of the artery.**
6. **First, aspirate for blood.** If no blood is aspirated, inject approximately 15 to 30 mL of local anesthetic in 5-mL aliquots.
7. **A hypoechoic "donut" of local anesthetic should appear surrounding the axillary artery and the nerves.** Adjust the needle and inject small boluses until local anesthetic is visualized surrounding the artery and nerves.

Catheters

Placement of an indwelling catheter should be performed with the same technique as for single-shot injections. The catheter is placed beside the nerve that supplies the majority of the surgical wound. Since the nerves are usually spread apart in the axillary region, other catheter insertion sites are preferred (e.g., infraclavicular) to get more effective long-term analgesia.

Pearls

- The various arteries and veins lie in variable positions, and color Doppler ultrasound imaging is very valuable to identify all blood vessels.
- The nerves lie in variable positions as well. For reliable axillary blocks, deposit half of the local anesthetic just above the artery and half just below the artery. This technique is similar to transarterial techniques, but ultrasound allows the local anesthetic to be placed without puncture of the artery.
- In most clinical cases, it is not important to know exactly which nerve is which—for example, the median and ulnar nerves can swap positions. For most surgeries, all four branches need to be covered. In rare cases, it is advantageous to place the majority of local anesthetic only in the distribution of one particular nerve.
- To identify the median nerve, follow the axillary artery down to the skin crease of the elbow. The median nerve accompanies the axillary artery all the way to the elbow (Figure 2-50).
- To identify the ulnar nerve, either start at the ulnar groove of the elbow and scan proximally until the nerve joins the plexus in the axilla or, alternatively, scan from the axilla distally down the arm and trace the ulnar nerve as it moves medially, away from the artery, to

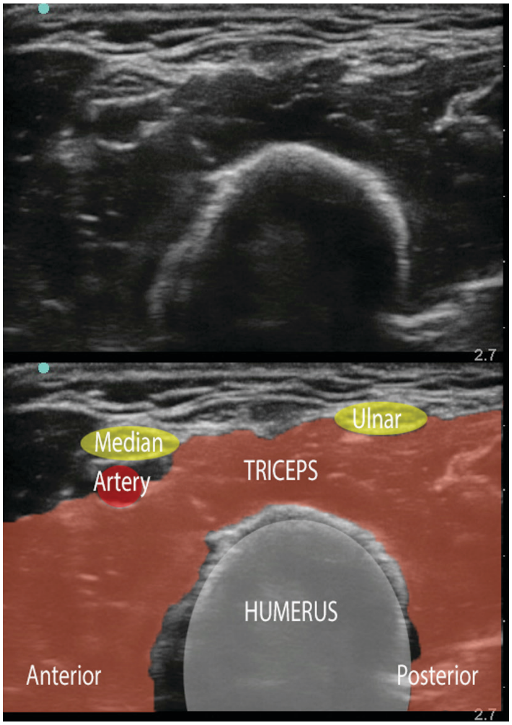


Figure 2-50 Axillary scanning distally along the arm to confirm the nerves. By sliding the probe down the arm, the ulnar nerve can be located medial to the artery shallow to the triceps muscle. The median nerve continues distally and is reliably located next to the axillary artery.

start its journey toward the ulnar groove. The nerve courses superficially over the triceps muscle (see Figure 2-50).

- The radial nerve is the most difficult nerve to identify reliably. If it is not easily visible, deepen the view on the ultrasound machine until the cross section of the humerus is visible beneath the artery. Slide the probe medially, keeping it in the transverse plane on the arm until the medial border of the humerus is in the center of the screen. Scan up and down the medial border of the humerus, looking for the take-off of the radial nerve as it leaves the spiral groove. The radial nerve can then be followed proximally as it ascends between two heads of the triceps to its usual position adjacent to the axillary artery high in the axilla (Figure 2-51).
- Be wary of small blood vessels, especially collapsible veins, near the nerve targets and the axillary artery. Slow incremental injections and intermittent aspirations for blood are important.
- Keep the injection below the brachial fascia for axillary blocks but above the brachial fascia for intercostobrachial blocks (Figure 2-52).

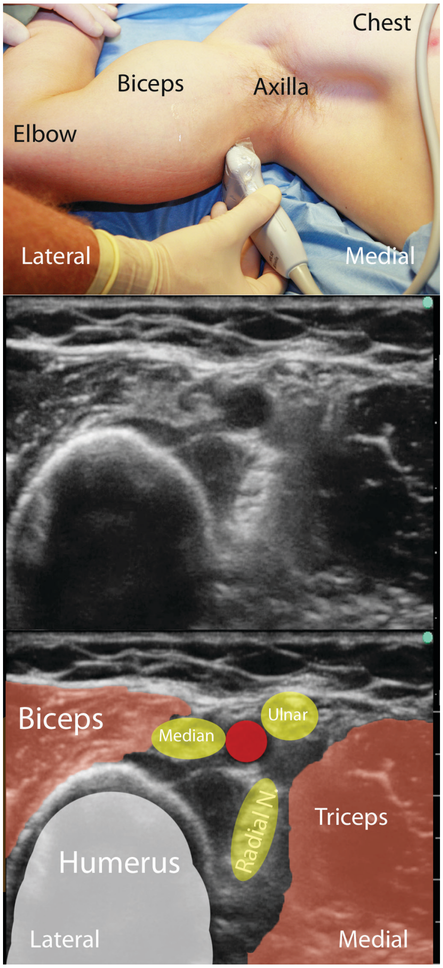


Figure 2-51 Probe position and ultrasound images used to identify the radial nerve coming out of the spiral groove of the humerus when scanning toward the axilla.

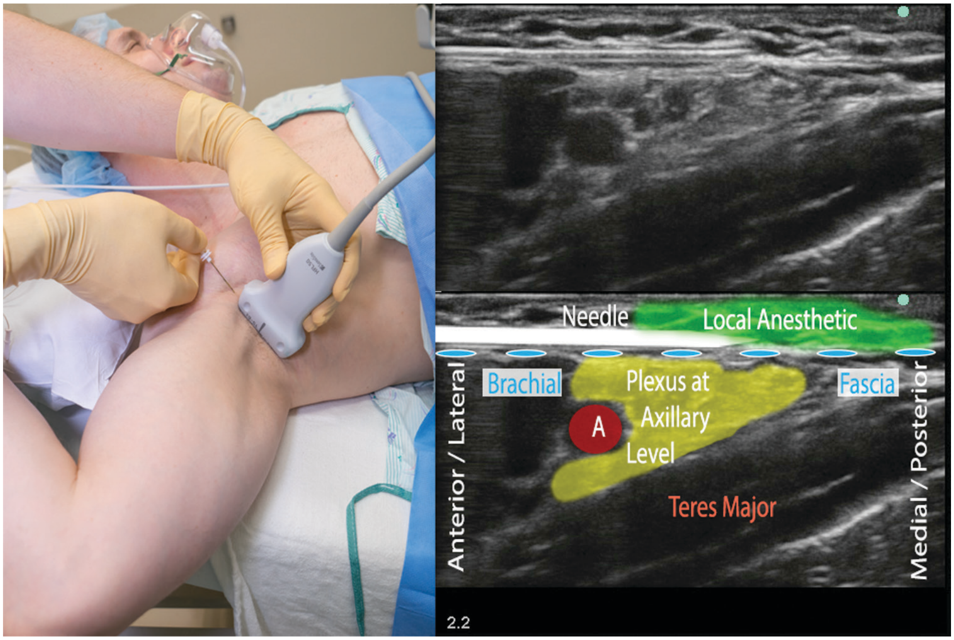


Figure 2-52 Intercostobrachial nerve block. The needle is directed above the axillary artery and brachial plexus. Keep the needle and injectate above the brachial fascia that covers the neurovascular bundle and muscles.

Intercostobrachial Nerve Block

Introduction

The intercostobrachial nerve supplies sensation to the skin of the medial upper arm. This block is rarely performed alone but usually in conjunction with other upper extremity blocks. There is significant anatomic variability with this nerve, and the clinical benefit of blocking the intercostobrachial nerve can sometimes mean the difference between success and failure of an upper extremity regional anesthetic. Blockade of this nerve is most important for medial elbow surgery (e.g., ulnar transposition) or for extended surgeries that require prolonged upper arm tourniquet times. When performing this block one does not aim to identify the actual nerve (it is small); rather, one places anesthetic within the correct plane where the nerve is typically located. The block is traditionally performed as a skin wheal in the axilla, and the use of ultrasound here is debatable. However, because this is a supplemental block for other ultrasound-guided nerve blocks, the ultrasound equipment will already be available, so it seems appropriate to use ultrasound guidance to ensure injection in the correct plane.

Anatomy

The intercostobrachial nerve is most commonly described as having contributions from the T2 and T3 intercostal nerves, but more recent studies have shown contributions from T1 and T4 in some cadaver specimens. These superficial branches from the intercostal nerves join and supply the skin of the axilla and medial upper arm.

Clinical Applications

The intercostobrachial nerve block is used for surgery of the elbow, especially the medial elbow. It is also helpful for upper arm surgeries, such as arteriovenous fistulas or grafts. This block is most often used in conjunction with a supraclavicular, infraclavicular, or axillary nerve block to provide sensory blockade. It may be employed for upper arm tourniquet applications with duration longer than 10 minutes in patients who are not sedated. For heavily sedated patients, this block may be used for surgeries with extended tourniquet times (>30 min).

Technique

Ultrasound Details

Monitors: ECG, NIBP, pulse oximeter.

Skin Preparation: Chlorhexidine with alcohol.

Transducer: High-frequency linear probe (10-20 MHz); expected target depth in 80-kg patient, less than 1 cm.

Patient Position: The patient is positioned supine with the arm abducted 90 degrees at the shoulder and the elbow flexed. This is the same position as for an axillary nerve block.

Local anesthetic choice. Usually, 5 to 10 mL of local anesthetic is required for infiltration. Because this is a purely sensory block, a long-acting local anesthetic such as ropivacaine 0.5% or bupivacaine 0.25% to 0.5% can be used.

Needle: 100-mm (4-inch), short-bevel nerve block needle.

Scanning Technique

1. **The patient is placed supine with the arm abducted 90 degrees.** The ultrasound transducer is placed over the axillary artery in the crease of the axilla.
2. **The needle is placed on the cephalad side of the transducer with an in-plane technique, aiming posteriorly** (see Figure 2-52).

3. **The needle should stay superficial to the brachial fascia that overlies the muscle and axillary blood vessels.**
4. **The needle is advanced in the superficial adipose tissue with intermittent injection of about 1 mL of local anesthetic to spread locally in the plane above the brachial fascia.**
5. **Continue advancing the needle and injecting local anesthetic for 3 to 5 cm posterior to the axillary artery to ensure good coverage.**
6. Because **this nerve is small and often has several branches, the goal is not to locate the nerve itself but rather to infiltrate local anesthetic (5–10 mL) in the superficial tissues where the nerve is thought to be located.**

Pearls

- This block is not performed for every upper extremity surgery but only when necessary (see "Clinical Applications").
- The needle insertion site can be the same site as that used when performing an axillary block.
- This block is used most often used in conjunction with a supraclavicular, infraclavicular, or axillary nerve block.

Nerve Blocks of the Elbow and Forearm

Introduction

The terminal branches of the brachial plexus are accessible for nerve blocks, rescue blocks, or postoperative analgesia in the elbow region and forearm. The innervation of the forearm and hand is complex and includes cutaneous nerves that may exit from the brachial plexus proximal to the axilla. Additionally, normal anatomic variation from person to person makes it more difficult to achieve complete anesthesia for a specific area of the forearm or hand solely by blocking the terminal branches at this level. However, these blocks can be used for less invasive surgeries (e.g., carpal tunnel release) and for motor-sparing analgesia.

Anatomy

At the level of the elbow, the ulnar nerve lies medial and deep. Take care to avoid the ulnar nerve where it is tightly constrained by the ligaments of the elbow. The nerve exits from the ulnar groove between the medial epicondyle and olecranon process. It then passes between the two heads of the flexor carpi ulnaris and lies on the flexor digitorum profundus muscle. Further down the forearm, the nerve is found in close proximity (medial) to the ulnar artery. The close relationship of the ulnar artery and ulnar nerve in the forearm makes the artery a useful tool to locate the nerve for a nerve block.

Key landmarks at the elbow to help identify the medial and radial nerves are the skin creases in the antecubital fossa and the tendon of the biceps muscle. The position of the brachial artery is variable, but it is usually located medial to the biceps tendon. Visualization of the artery approximately 2 cm medial to the biceps tendon helps to identify the median nerve (Figure 2-53). The median nerve usually runs medial to the brachial artery as it enters the forearm and subsequently runs between the two heads of pronator teres. It continues distally

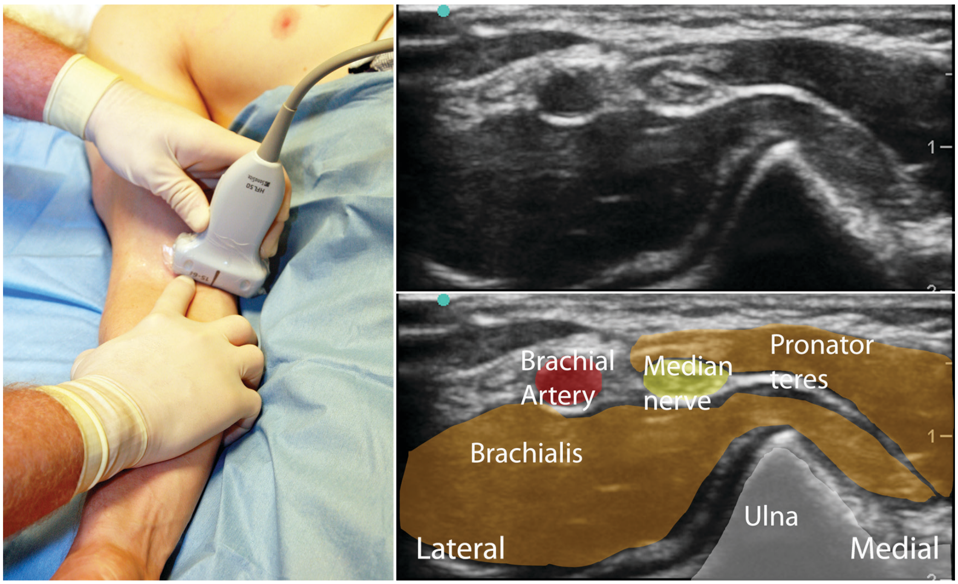


Figure 2-53 Identify the biceps tendon, and place the probe just above the antecubital fossa, slightly on the medial side of the arm *(left image)*. The brachial artery and median nerve (medial to the artery) are easily identified *(right images)*.

in the middle of the forearm, deep to the superficial flexors of the forearm (flexor digitorum superficialis). The lack of vessels beside the median nerve in the forearm makes this an ideal place to block the nerve. A key feature of the median and ulnar nerves in the midforearm is that they both lie deep to the superficial flexors in the same fascial plane. The ulnar artery can be used to trace the ulnar nerve to the midforearm; from there, the probe can be moved laterally in the same fascial plane to locate the median nerve.

The radial nerve wraps posteriorly around the humerus in the spiral groove. As it exits the lateral side of the upper arm, it immediately splits into superficial and deep branches. These branches run between the brachioradialis and brachialis muscles. Ideally, the radial nerve should be traced proximally and blocked before it splits into the two branches.

Clinical Applications

Elbow and forearm blocks are used as rescue blocks for missed nerves after more proximal attempts at brachial plexus blocks. They are also used to provide long-lasting single-injection nerve block after hand surgery without the concomitant motor block associated with more proximal approaches. If surgery is combined with a general anesthetic, there is no need to cover upper arm tourniquet pain, so these single-branch blocks can be used to provide good analgesia with low volumes of local anesthetic.

Technique

Ultrasound Details

Monitors: ECG, NIBP, pulse oximeter.

Skin Preparation: Chlorhexidine with alcohol.

Probe: High-frequency linear probe (10–15 MHz); expected target depth in 80-kg patient, less than 2 cm.

Patient Position: The patient is positioned supine with the arm extended at the shoulder and externally rotated.

Local anesthetic choice. Usually, 3 to 5 mL of local anesthetic is required at each nerve.

Needle: 50-mm (2-inch), short-bevel nerve block needle.

Scanning Technique for the Median Nerve

1. **The probe is placed on the flexor crease of the elbow just medial to the biceps tendon insertion** (see Figure 2-53).
2. **The brachial artery is identified as a hypoechoic circle usually less than 1 cm deep.** Color Doppler imaging can be used to assist identification (see Figure 2-53).
3. **Use minimal pressure on the ultrasound probe to avoid collapsing the veins, which usually lie in close proximity to the artery.**
4. **Medial to the brachial artery is the median nerve** (see Figure 2-53). The nerve appears as an oval structure, usually hyperechoic and in close proximity to the artery. If the probe is moved distally from the antecubital fossa to the forearm, the artery and nerve separate (Figure 2-54).
5. **The median nerve can be blocked anywhere it is visible.** Just proximal to the antecubital fossa, the nerve is shallow and lies in close proximity to the artery. The nerve can also be blocked just distal to the antecubital skin crease, where it has separated from the artery. In some patients, it can be difficult to follow the nerve as it descends between the muscles.
6. **Advance a needle in-plane from the medial end of the probe** (Figure 2-55).

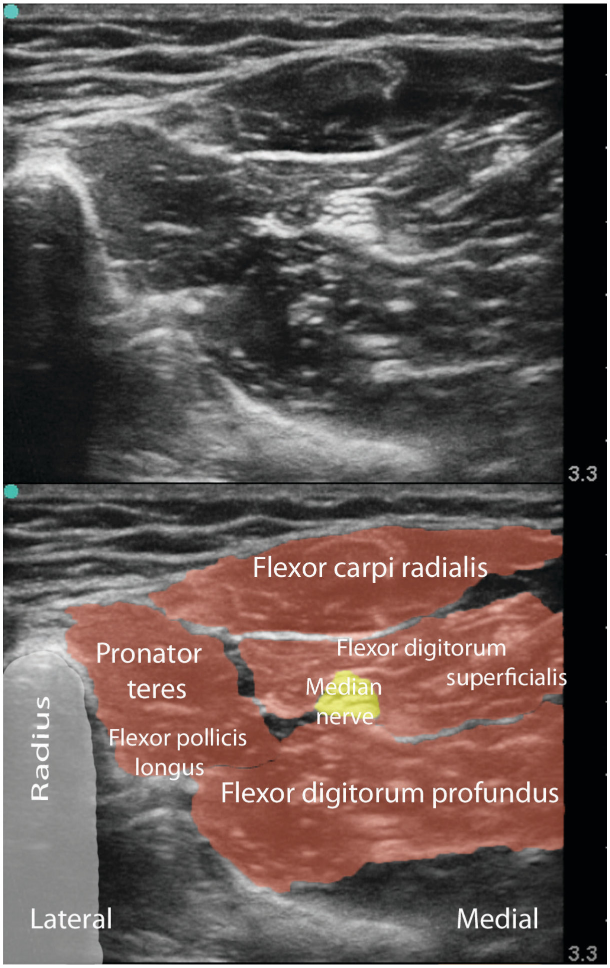


Figure 2-54 Image of the median nerve distal to the antecubital fossa. At this level, the brachial artery is no longer associated with the median nerve.

7. **The needle should target the fascial plane that contains the nerve.** Aim the needle tip toward the tissue just deep or shallow to the nerve. Do not aim for the nerve itself. Inject 3 to 5 mL of local anesthetic.
8. **The median nerve can be located and traced proximally from the wrist as well.** Start with the probe at the wrist and identify the nerve, which has a honeycomb appearance. There are many tendons here that appear hyperechoic and similar in structure to the nerve. As the probe is moved proximally, the tendons will disappear as they become muscles, and the only remaining structure will be the median nerve. Block the nerve anywhere it is visible, taking into account that distal nerve blocks have less effect on motor function (Figure 2-56).
9. **After injection of the median nerve distal to the forearm is complete, the probe can be moved medially to identify the ulnar nerve lying in the same fascial plane**. See "Scanning Technique for the Ulnar Nerve" and Figure 2-57.

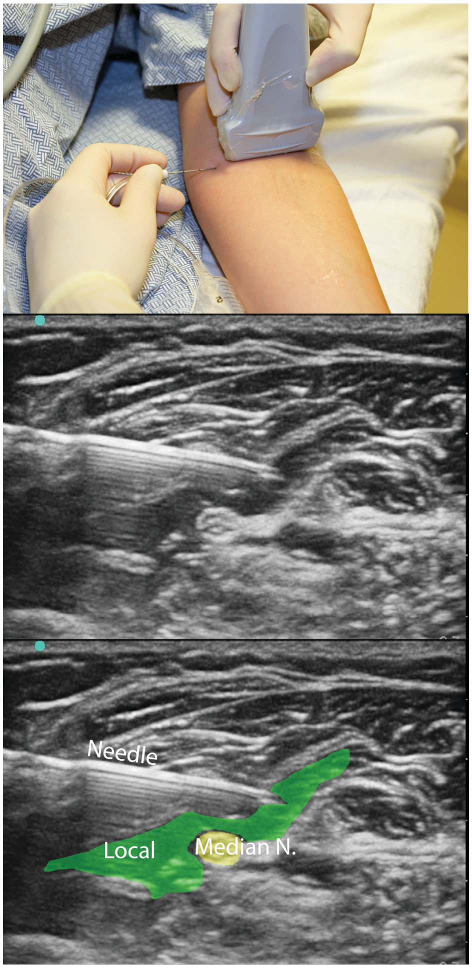


Figure 2-55 Needle position for median nerve block just distal to the antecubital fossa *(top)* and the ultrasound image obtained *(middle and bottom)*. N., nerve.

Scanning Technique for the Radial Nerve

1. **The probe is placed on the flexor crease of the elbow 2 cm lateral to the biceps tendon insertion** (Figure 2-58).
2. **Find the hyperechoic image of the radial nerve sandwiched between the brachioradialis and the brachialis muscles** (see Figure 2-58).
3. **To confirm the nerve, scan proximally up the arm.** The nerve will be located beneath the brachioradialis, and as it is traced proximally, it will become more closely associated with the humerus. As the nerve enters the spiral groove of the lateral humerus, it will disappear deep to this bone.
4. **As the nerve is followed distally from the spiral groove of the humerus, it can be visualized splitting into two branches (superficial and deep)**.
5. **The nerve can be blocked anywhere it is visible.** To ensure the most complete block, plan to inject local anesthetic proximal to the split above the elbow. Although the

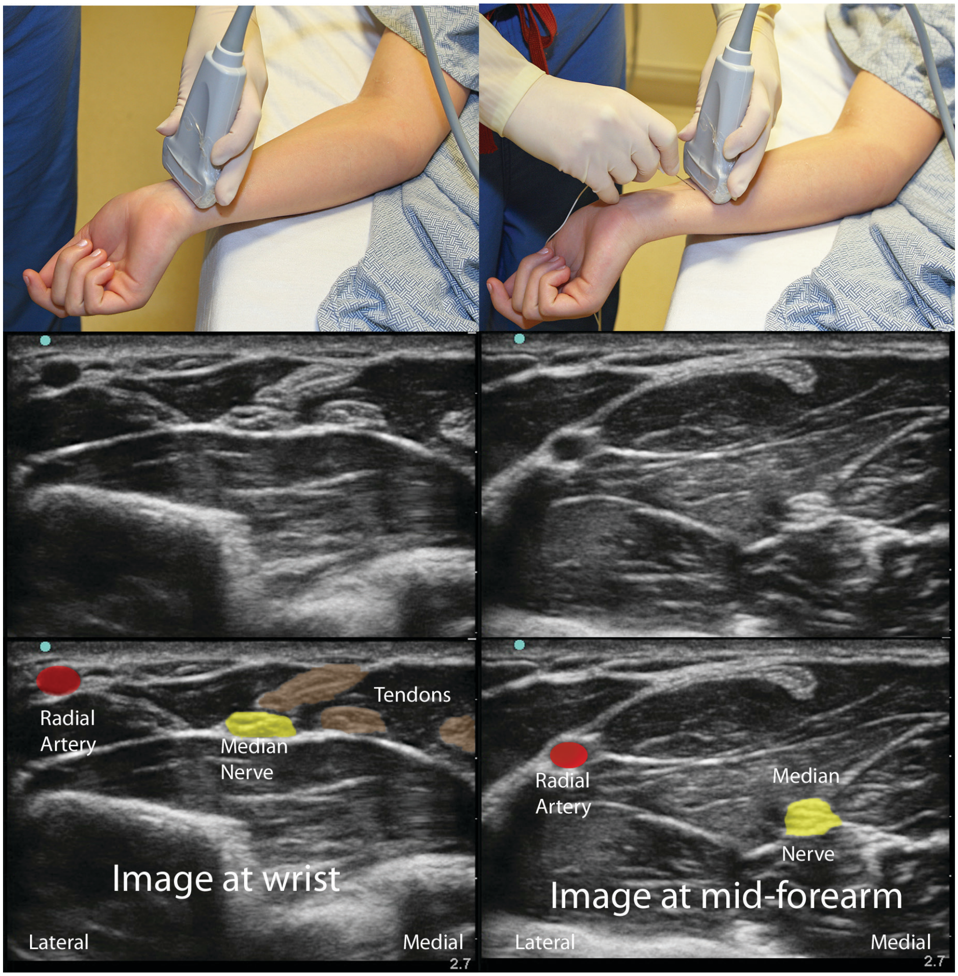


Figure 2-56 Alternative method for tracing the median nerve. Identify the nerve at the wrist, and slide the probe back to the midforearm *(top images)*. At the level of the wrist, the nerve will appear hyperechoic, similar to the tendons *(left)*. As the probe is slid proximally, the tendons disappear, leaving only the hyperechoic median nerve *(right)*.

radial nerve can be traced all the way to the wrist (it is located lateral to the radial artery), distal blocks provide less complete analgesia, so we recommend that this nerve be blocked above the elbow.

6. **Approach the nerve with the needle from either the medial or the lateral end of the probe in an in-plane approach** (Figure 2-59).
7. **Aim for the fascial plane beside the nerve, and slowly inject 3 to 5 mL of local anesthetic, looking for spread around the n**erve.

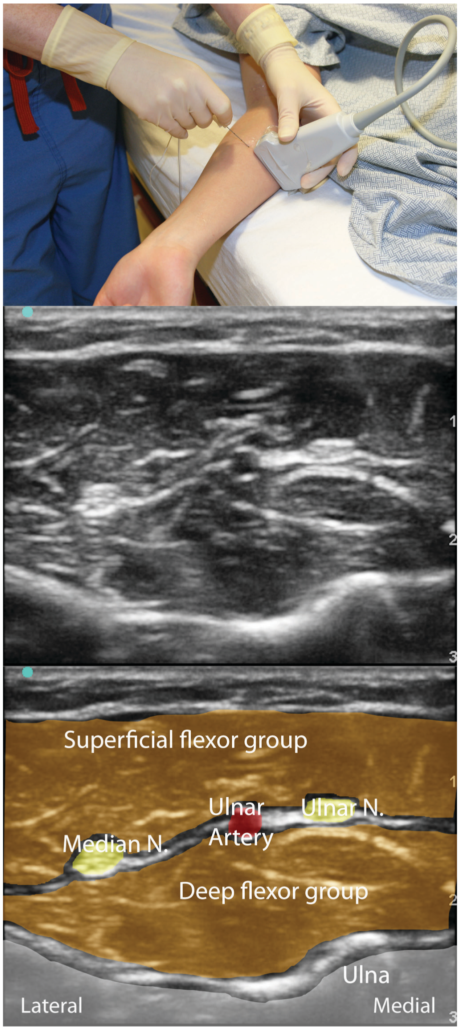


Figure 2-57 In the proximal forearm, the median nerve and ulnar nerve can be found lying within the same plane. Often at this level, both a median and an ulnar nerve block can be performed using the same needle insertion site.

Scanning Technique for the Ulnar Nerve

1. **The ulnar nerve can be reliably located at the elbow.** At the elbow, the ulnar nerve exits distally from between the medial epicondyle and the olecranon process. Here, it lies deep in the proximal forearm and is at risk of compression. Follow the ulnar nerve more distally before blocking it.
2. **Use surface anatomy to help locate the ulnar nerve.** The nerve lies in the groove between the bony prominences of the elbow, the olecranon and the medial epicondyle of the humerus (Figure 2-60). Place the probe just distal to this point, on the medial elbow.

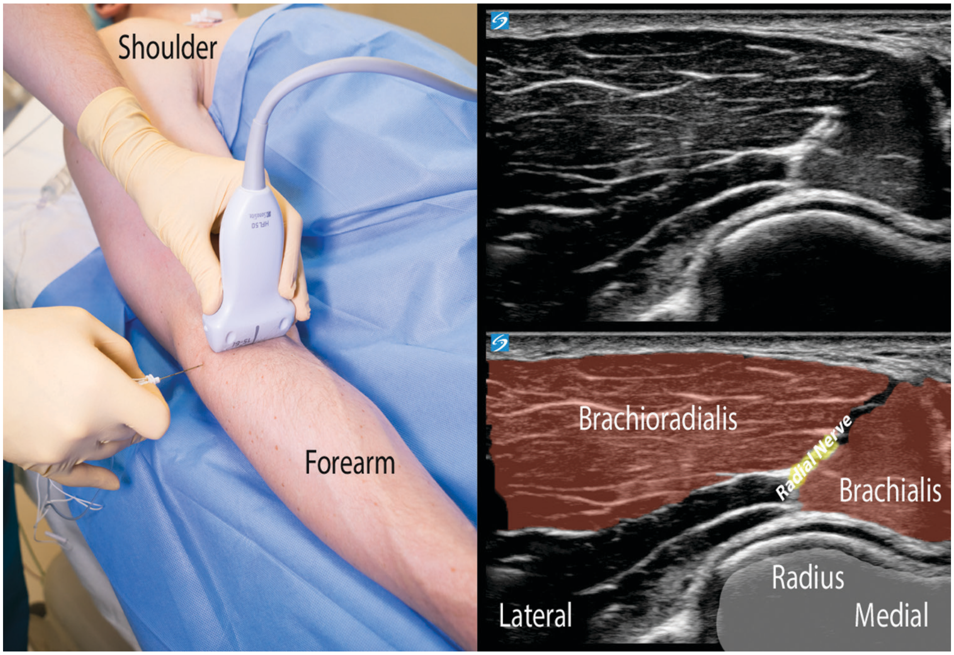


Figure 2-58 Probe position for radial nerve block at the elbow. Identify the biceps tendon at the elbow and slide the probe 2 cm laterally. The radial nerve above the elbow is best identified as it exits the lateral humerus and as it emerges from the spiral groove. Then it can be followed distally.

3. **First, identify the flexor carpi ulnaris and then scan distally from the elbow to identify the overlying flexor muscles and flexor digitorum profundus** (Figure 2-61).
4. **Between those muscles, locate the ulnar nerve.** The circular or oval nerve has a hyperechoic rim of epineurium around it. It is important to follow the nerve distal to the elbow before attempting to stabilize the image for injection.
5. **The needle is advanced, from lateral and anterior to medial and posterior, to the tissue plane in which the nerve is located.**
6. **Inject 3 to 5 mL of local anesthetic slowly, observing the spread around the nerve** (see Figure 2-61).
7. **Alternatively, locate the ulnar nerve at the wrist.** Find the ulnar nerve at the wrist lateral to the ulnar artery. Trace the nerve proximally as the ulnar artery and ulnar nerve split, making the nerve easier to visualize. The ulnar nerve has a triangular or oval, honeycomb appearance and is found underneath the superficial flexor muscles. The separation of the artery and nerve also makes inadvertent arterial puncture less likely. This is a good place for an ulnar nerve block (Figure 2-62).

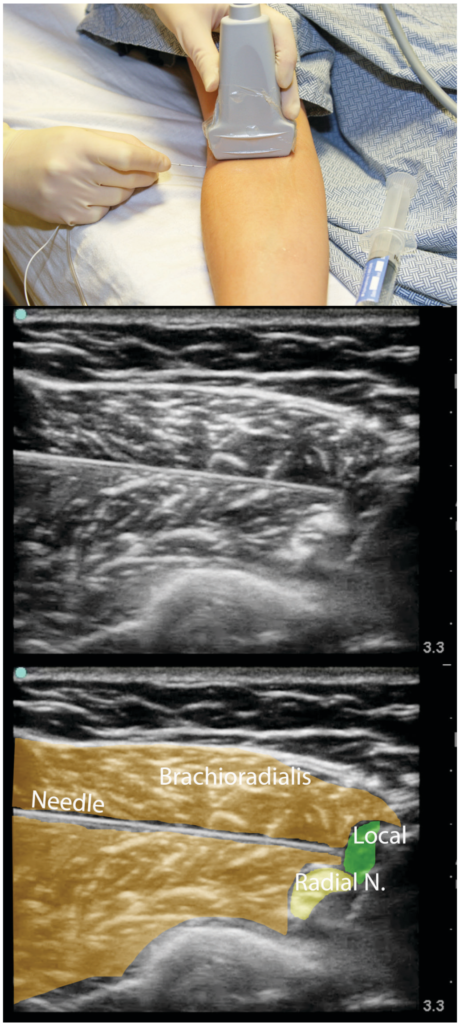


Figure 2-59 Needle advancement and injection of local anesthetic around the radial nerve above the elbow.

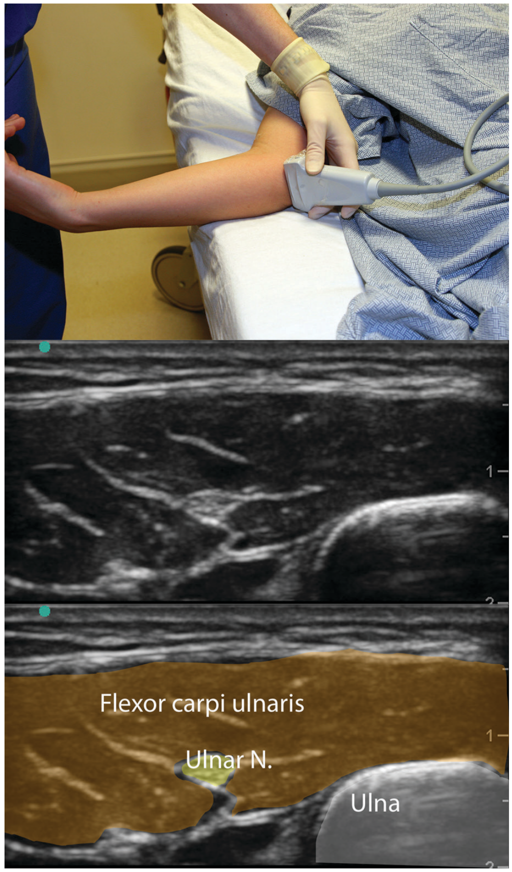


Figure 2-60 Identification of the ulnar nerve just distal to the medial elbow.

Pearls

- It is difficult to obtain complete anesthesia with distal arm blocks because of the variable nature of distal arm innervation and the numerous nerves that cover a single region. One of the main benefits of distal arm blocks is that they preserve motor function while still providing analgesic benefit. Use more complete plexus blocks (axillary) for anesthesia, and save distal blocks for specific analgesic purposes.

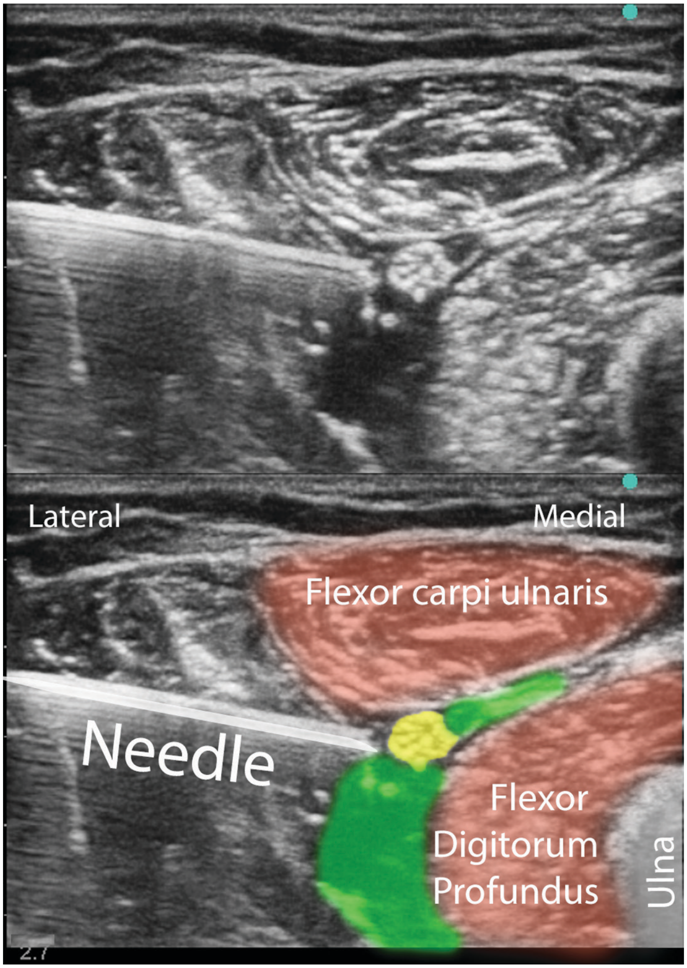


Figure 2-61 Needle advancement and injection of the ulnar nerve location just distal to the elbow.

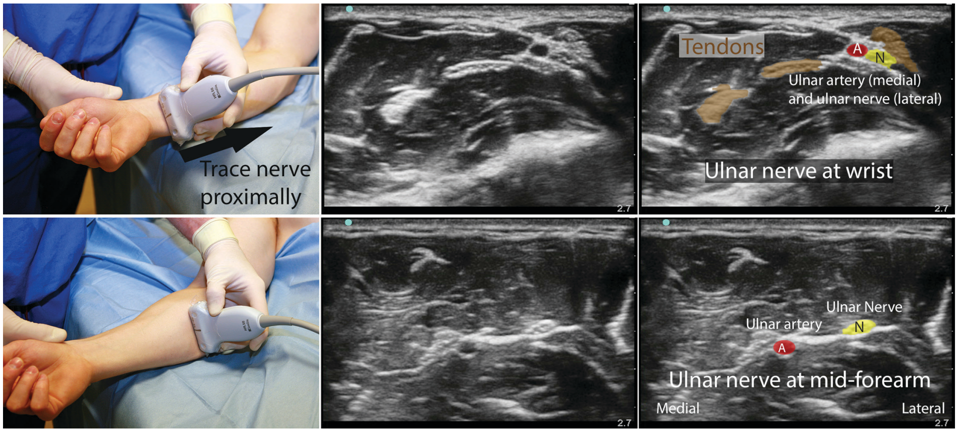
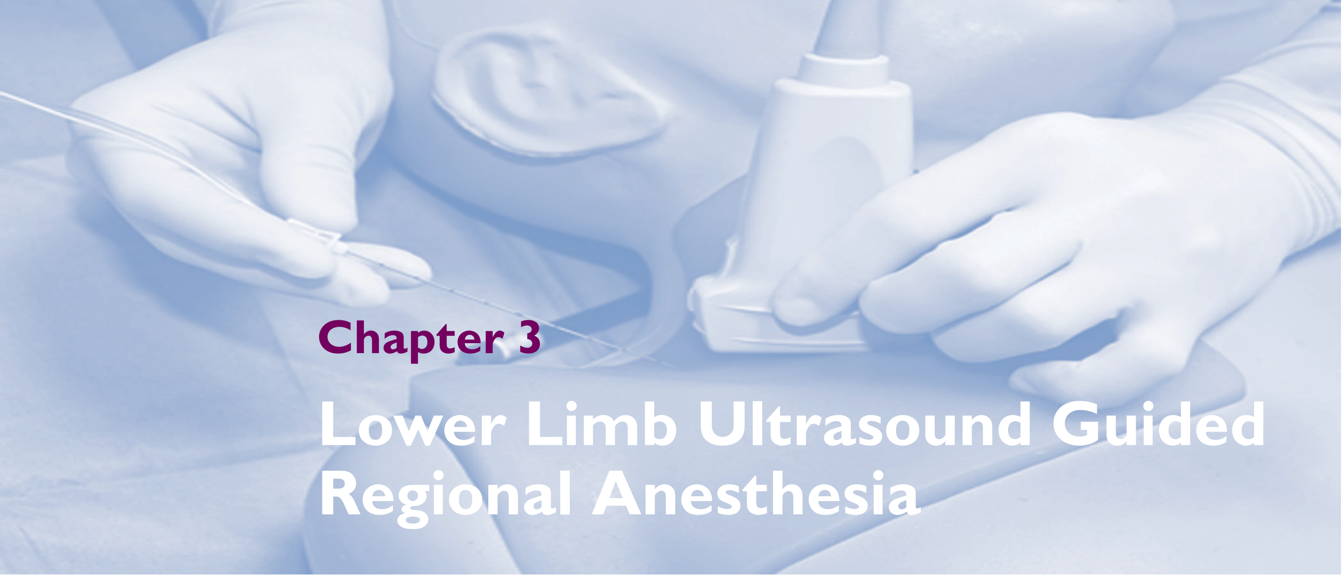


Figure 2-62 Probe positions for scanning the ulnar nerve at the wrist and forearm. Start at the wrist *(top images)*, and follow the ulnar artery up the forearm to where the artery and nerve split *(bottom images)*. The ulnar nerve can be injected anywhere it is visible in the forearm. A, artery; N, nerve.

- In the forearm, the nerves often appear hyperechoic over a narrow range of probe tilt. Be patient and systematic as you move the probe. Slide the probe, stop, then tilt through a wide range of motion to improve nerve visualization.
- If planning to place an elbow or forearm block in combination with a general anesthetic for postoperative analgesia, consider using a low concentration of local anesthetic (e.g., 0.2% ropivacaine instead of 0.5%, 0.25% bupivacaine instead of 0.5%). The analgesia is equivalent and the impact on duration is minimal.
- If a tourniquet will be applied during surgery, further anesthesia will be needed to cover the cutaneous nerves of the medial upper arm (intercostobrachial) for intraoperative anesthesia.



Chapter 3

Lower Limb Ultrasound Guided Regional Anesthesia

Introduction

The innervation of the lower extremity is derived from the lumbar and the sacral plexuses (Figure 3-1). In contrast to the peripheral nerves of the upper extremity, which are contained entirely within the brachial plexus, the nerves of the lower extremity are not as conveniently organized for the regional anesthesiologist. As a result, at least two peripheral nerve blocks are required to provide complete anesthesia or analgesia to the entire lower extremity (Figure 3-2). Both single-injection nerve blocks and continuous peripheral nerve catheters may be used to provide analgesia or anesthesia. The sites of injection along the course of the nerves of the lumbosacral plexus are determined by the operative site and result in varying distributions of sensory and motor blockade (Figures 3-3 and 3-4).

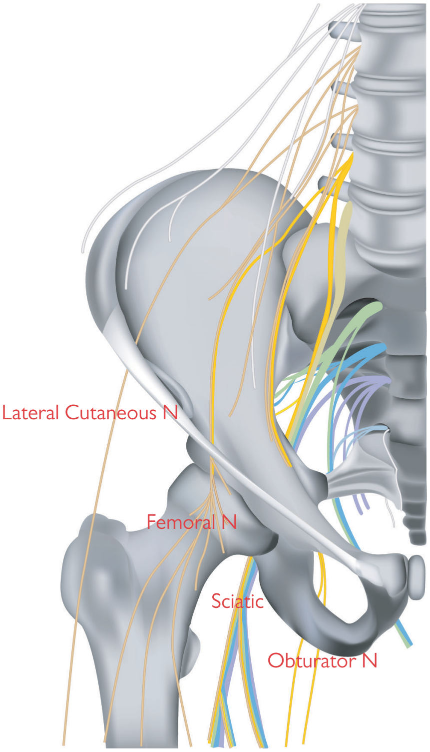


Figure 3-1 Nerves that make up the lumbosacral plexus. N, nerve.

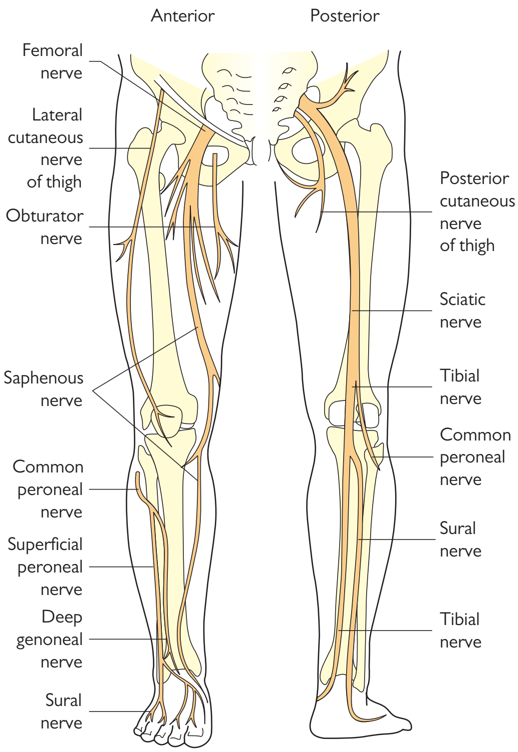


Figure 3-2 Main nerves of the lower limb.

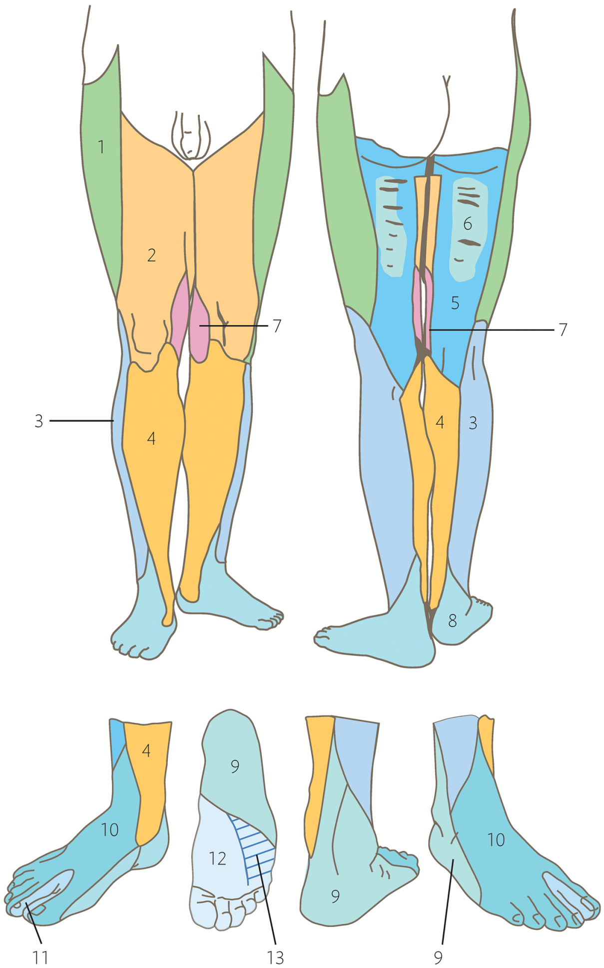


Figure 3-3 Sensory supply of the lower extremities. Area of sensory distribution are shown for the femoral nerve and its branches *(yellow)*, the sciatic nerve and its branches *(blue)*, the lateral femoral cutaneous nerve *(green)*, and the obturator nerve *(red)*. Key: 1 = lateral femoral cutaneous nerve; 2 = femoral nerve; 3 = peroneal nerve; 4 = saphenous nerve; 5 = sciatic nerve; 6 = posterior femoral cutaneous nerve; 7 = obturator nerve; 8 = posterior tibial nerve; 9 = sural nerve; 10 = superficial peroneal nerve; 11 = deep peroneal nerve; 12 = medial plantar nerve (tibial nerve); 13 = lateral plantar nerve (tibial). (Reproduced with permission from Chuan A, Scott DM. *Regional Anaesthesia: A Pocket Guide*. Oxford, UK: Oxford University Press; 2014.)

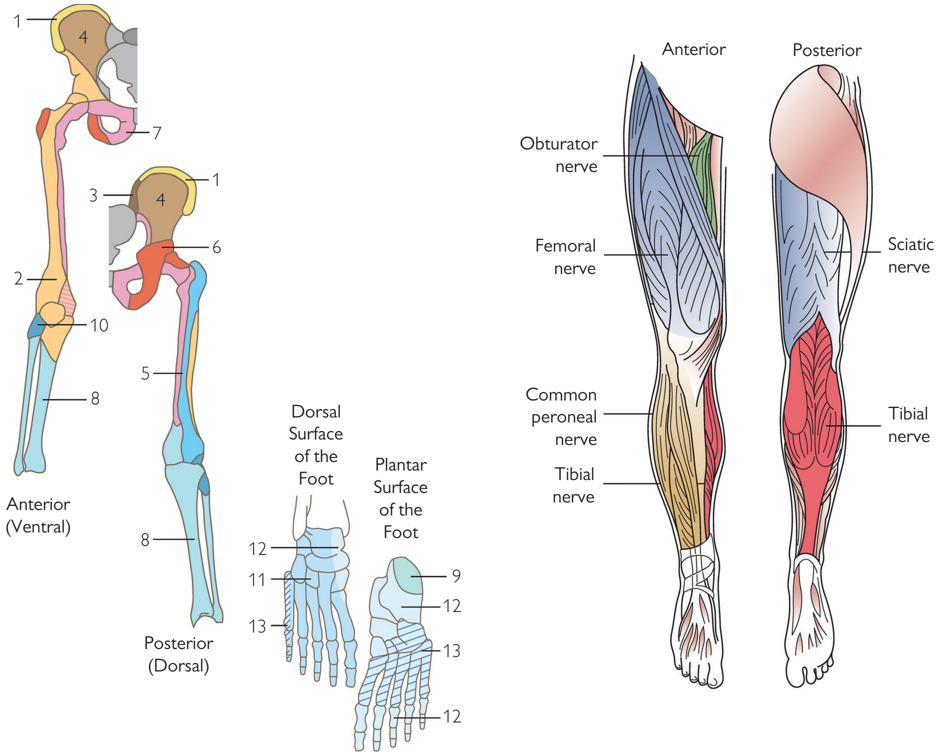


Figure 3-4 Sensory supply of bony structures *(left)* and myotomes *(right)* of the lower extremity. Key: 1 = collateral branch of the femoral nerve; 2 = femoral nerve; 3 = superior gluteal nerve; 4 = inferior gluteal nerve; 5 = sciatic nerve; 6 = sacral nerves; 7 = obturator nerve; 8 = tibial and posterior tibial nerves; 9 = sural nerve; 10 = common peroneal nerve; 11 = deep peroneal nerve; 12 = medial plantar nerve (tibial), 13 = lateral plantar nerve (tibial). (Reproduced with permission from Chuan A, Scott DM. *Regional Anaesthesia: A Pocket Guide*. Oxford, UK: Oxford University Press; 2014.)

Femoral Nerve Block

The femoral nerve block is commonly performed to provide analgesia to the hip, knee, and thigh. Although finding the femoral artery and vein is straightforward, practitioners new to ultrasound often have difficulty identifying the femoral nerve itself. A systematic approach to identifying the nerve and understanding the common pitfalls encountered during this block improve overall success.

Anatomy

The femoral nerve is the largest terminal branch of the lumbar plexus. After its origin from the ventral rami of the L2-4 nerve roots, the femoral nerve exits the pelvis under the inguinal ligament on top of the iliacus muscle. Almost immediately after passing under the inguinal ligament, the femoral nerve starts to divide. When divided, the femoral nerve is more difficult to visualize with ultrasound. At this level, the orientation of the neurovascular structures can be remembered by the mnemonic NAVEL (from lateral to medial, the order of the structures is femoral Nerve, Artery, Vein, Empty space, and Lymphatics).

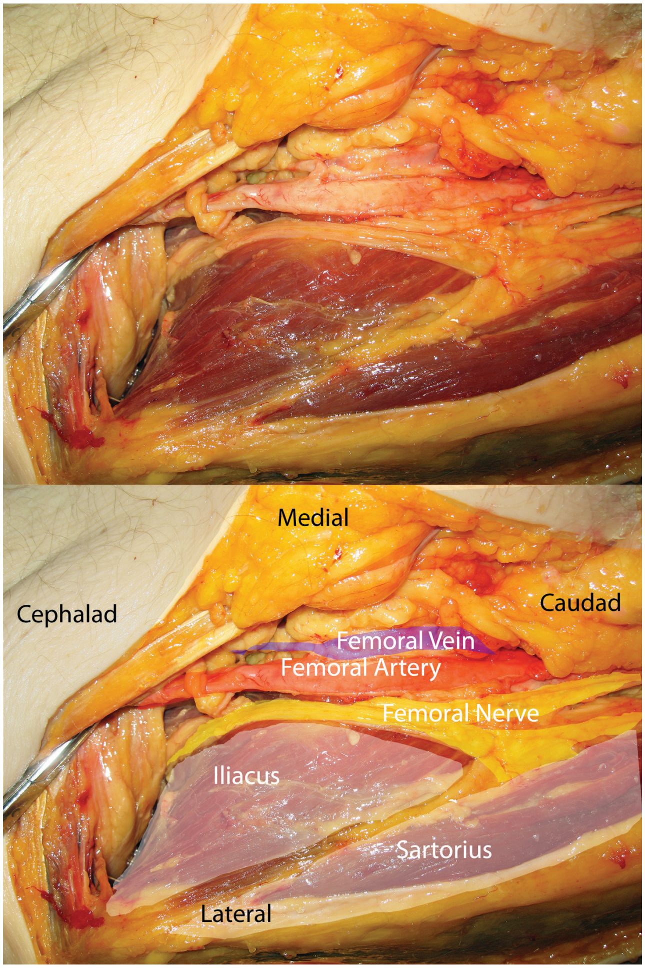


Figure 3-5 Femoral nerve anatomy on fresh tissue cadaver.

The femoral nerve lies under two fascial planes, the fascia lata and the fascia iliaca. The nerve is often described as being located 1 to 2 cm lateral to the artery, although there is some variability that can be appreciated under ultrasound. The ligamentum iliopectineus separates the nerve from the artery medially. The femoral nerve is located at the bottom of the triangle formed by the ligamentum iliopectineus medially, the fascia lata superficially, and the iliacus muscle deep to the nerve. The femoral nerve is located only at the bottom of this triangular boundary, underneath the fascia iliaca and on top of the iliacus muscle. It is important to understand this concept when performing ultrasound-guided femoral nerve blocks (Figure 3-5).

Clinical Applications

A femoral nerve block provides anesthesia and analgesia to the anterior thigh, hip, femur, knee, and medial lower leg and foot. Anesthesia of the entire lower leg can be achieved when this block is combined with a sciatic and obturator nerve block. The femoral nerve block is a relatively basic technique with a high success rate, a low incidence of complications, and broad clinical utility for both surgical anesthesia and postoperative analgesia. As such, it is no surprise that it is one of the most common lower extremity nerve blocks performed. The femoral nerve block may be used for knee surgeries including knee arthroscopy, anterior cruciate ligament repair, and total knee arthroplasty. Femoral nerve blocks can provide surgical anesthesia for thigh tourniquets and for medial lower leg, ankle, and foot surgeries. The femoral nerve provides a significant amount of innervation to the hip, so a femoral nerve block

Figure 3-6 Probe and ultrasound screen position for femoral nerve block.

can also be used to provide posttraumatic analgesia for patients with hip fracture. A sciatic nerve block is often used in conjunction with a femoral nerve block to provide anesthesia or analgesia to the posterior part of the knee.

Technique

Ultrasound Details

Monitors: Electrocardiogram (ECG), noninvasive blood pressure monitor (NIBP), pulse oximeter, and additional monitors as deemed necessary.

Skin Preparation: Chlorhexidine with alcohol.

Probe: High-frequency linear probe (10-15 MHz).

Patient Position: Supine.

Local Anesthetic Choice: Depends on the surgical indication. For long-lasting nerve blocks, use ropivacaine 0.5% or bupivacaine 0.25% to 0.5%. For short-duration blocks (e.g., ambulatory patient, intraoperative tourniquet coverage), mepivacaine 1.5% or lidocaine 1.5% may be employed.

Needle: 100-mm (4-inch), short-bevel nerve block needle or Tuohy needle for catheter placement.

Scanning Technique

1. **Position the patient completely supine with the legs extended and the ultrasound machine positioned opposite the side to be blocked.**
2. **Place a high-frequency linear probe on the operative leg in the inguinal crease** (Figure 3-6).
3. **Locate the femoral vein and artery, with the artery lateral to the vein.** Color Doppler imaging and occlusion of the vein by application of additional pressure with the probe can help in identifying the femoral vessels (Figure 3-7).
4. **Scan proximally and distally on the leg to identify the division of the common femoral artery into the superficial femoral artery, profunda femoral artery, and/or lateral circumflex femoral artery** (Figure 3-8).
5. **Scan cephalad to above the arterial division.** There should be a single femoral artery and a single femoral vein in the image (see Figure 3-8).
6. **The femoral nerve lies approximately 1 to 2 cm lateral to the artery and is best visualized cephalad to the arterial division.**
7. **The nerve is a wide, flat hyperechoic structure lying on the iliacus muscle.** It may contain dark hypoechoic circles that represent the nerve fascicles (see Figure 3-8).
8. **Blindly aiming into the hyperechoic triangle that lies laterally to the artery frequently results in block failure.** This is fascia and lymphatic tissue. The nerve (only the bottom portion of the hyperechoic triangle) lies deep to the fascia iliaca and should be sought through careful scanning.
9. **A 4-inch (100-mm) block needle should be inserted in-plane with the ultrasound beam.**
10. **The needle is advanced under the fascia iliaca toward the femoral nerve.**
11. **Target the initial injection just deep and lateral to the nerve.** This ensures that the needle tip will be below the fascia iliaca (Figure 3-9).
12. **Approximately 15 to 30 mL of local anesthetic is injected in 5-mL aliquots following aspiration for blood. As the local anesthetic is injected, it should**

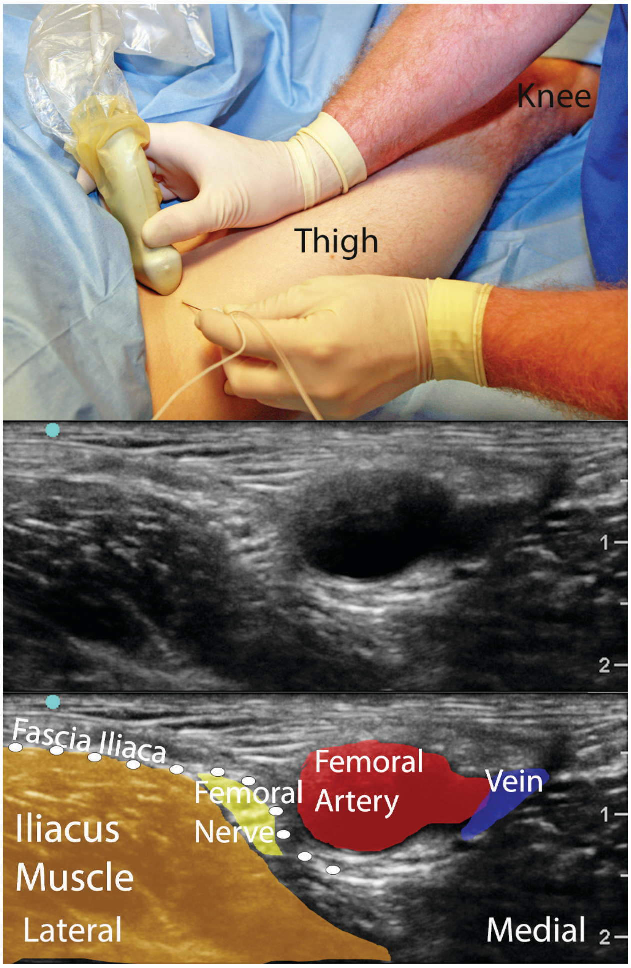


Figure 3-7 Ultrasound image of the femoral nerve *(middle and bottom images)* with the probe positioned in the inguinal crease *(top image)*. Although it is not obvious, the fascia iliaca covers the femoral nerve.

track below the femoral artery. This ensures that the anesthetic is injected beneath the fascia iliaca. If spread is not visualized under ultrasound, the injection should be halted and needle tip position reconfirmed (Figure 3-10).

Alternative Techniques

Out-of-Plane Needle Approach

Alternatively, the needle may be inserted perpendicular to the probe in an out-of-plane approach. Although in-plane needle orientation allows for visualization of the needle tip at all times, a perpendicular orientation may allow for technically easier block placement, especially for practitioners who do not have much ultrasound experience and have difficulty viewing an in-plane needle.

1. Follow steps 1 through 8, as listed for the in-plane approach, to identify the femoral vessels and the femoral nerve.

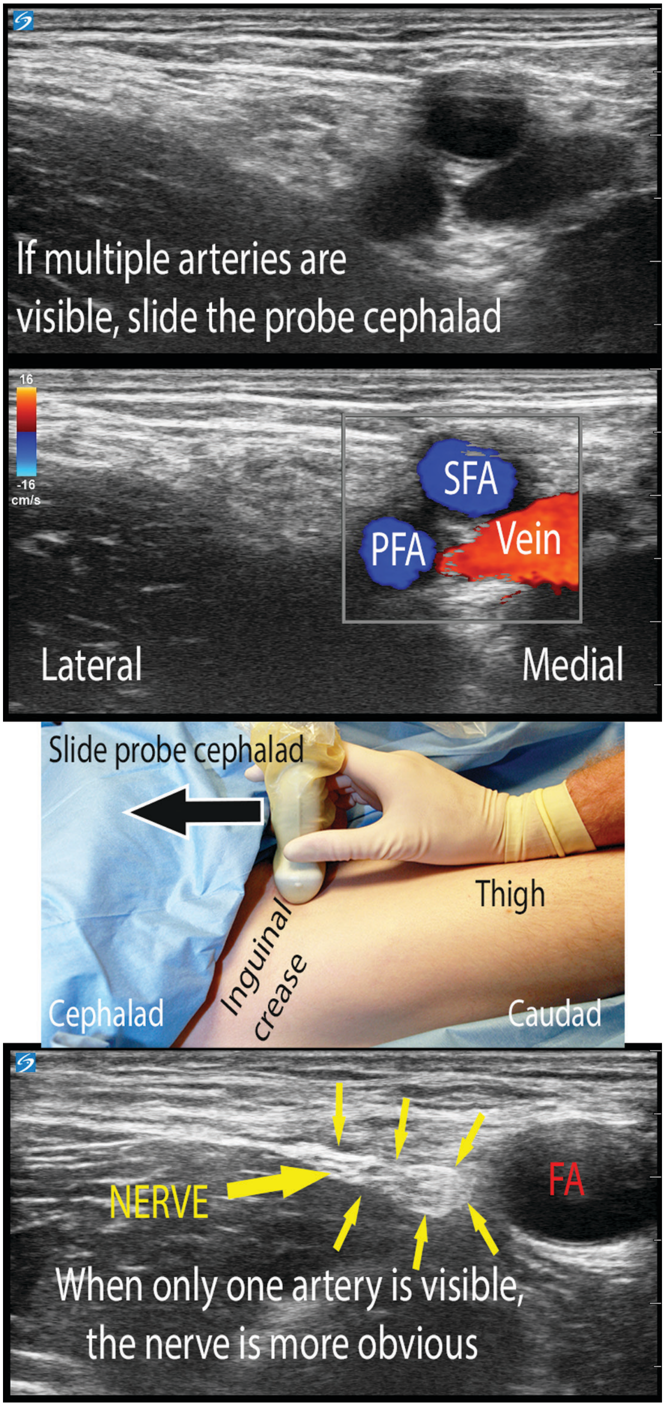


Figure 3-8 Femoral nerve block image with and without color Doppler *(top two images)*. More than one artery is present in the image. The use of color Doppler confirms the superficial femoral artery (SFA) and the profunda femoral artery (PFA). This branch point of the femoral artery (FA) is an important landmark. For successful identification of the femoral nerve, the femoral artery should be imaged proximal to the femoral artery's branch point *(bottom two images)*. The nerve is significantly more visible when imaged at the level of the single common femoral artery.

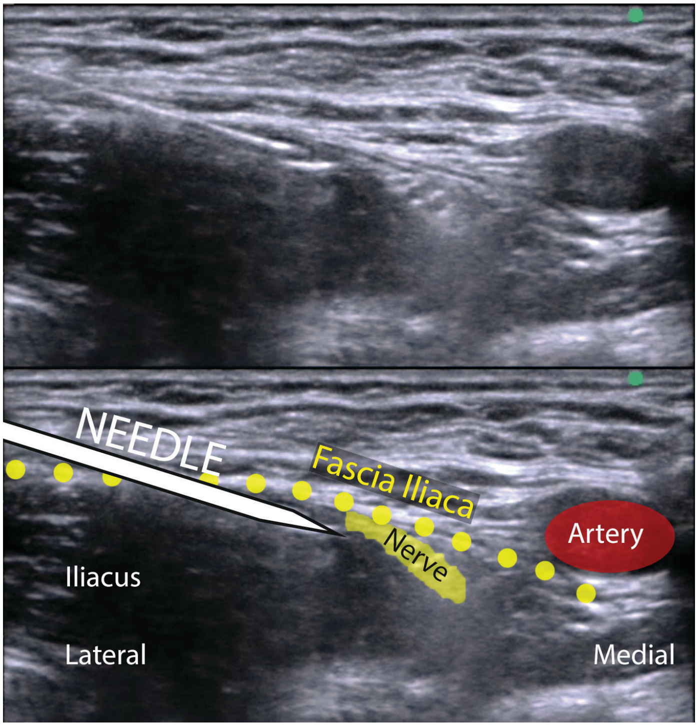


Figure 3-9 Initial needle trajectory for a femoral nerve block. The needle should be aimed lateral and just deep to the femoral nerve to ensure puncture of the fascia iliaca.

2. Position the femoral nerve in the middle of the ultrasound screen. In this position, the nerve will lie directly underneath the middle of the probe.
3. Insert a 2-inch (50-mm) needle perpendicular to the ultrasound probe and beam. With this technique, the entire needle will not be visualized. Only a cross section of the needle, which will appear as a white dot, will be seen during needle advancement (Figure 3-11).
4. Rather than just observing a static cross section of the needle, one may slide the probe in small increments or make small angulations of the probe to identify the actual location of the needle tip (see "How to Visualize Nerves and Needles" in Chapter 1).
5. The needle tip should be advanced medially or laterally, as needed, to approach the femoral nerve.
6. Electrical stimulation may be used in conjunction with ultrasound to confirm proper placement of the needle tip.
7. Approximately 20 to 30 mL of local anesthetic is injected in 5-mL aliquots after aspiration for blood.
8. Local anesthetic should be seen spreading under the fascia iliaca and femoral artery, as in the in-plane view.

Catheters

A continuous femoral nerve catheter may be placed to provide extended postoperative analgesia after surgeries such as total knee arthroplasty or anterior cruciate ligament

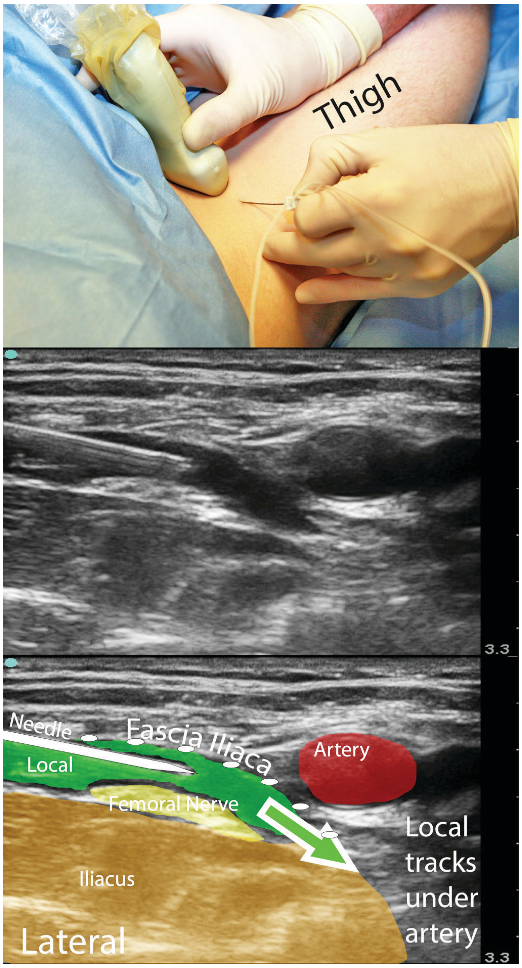


Figure 3-10 Final needle position for a femoral nerve block. Needle positions anterior to (above) or posterior to (below) the femoral nerve are equally successful. The key for a successful femoral nerve block is that the needle tip must be beneath the fascia iliaca. Local anesthetic can be seen spreading underneath the fascia iliaca in the image. A key identifier is to confirm that the local anesthetic spreads underneath the artery during injection. If local anesthetic spread is limited to the area above the artery, the needle is not deep to the fascia iliaca.

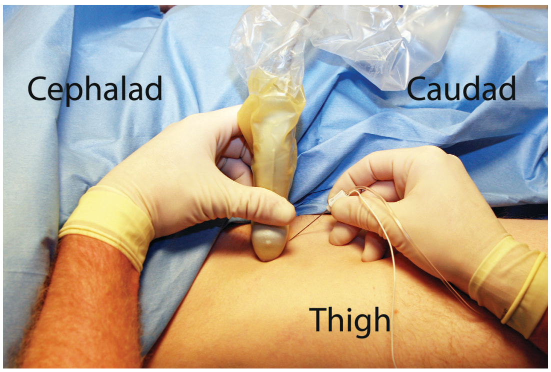


Figure 3-11 Out-of-plane needle entry for a femoral nerve block.

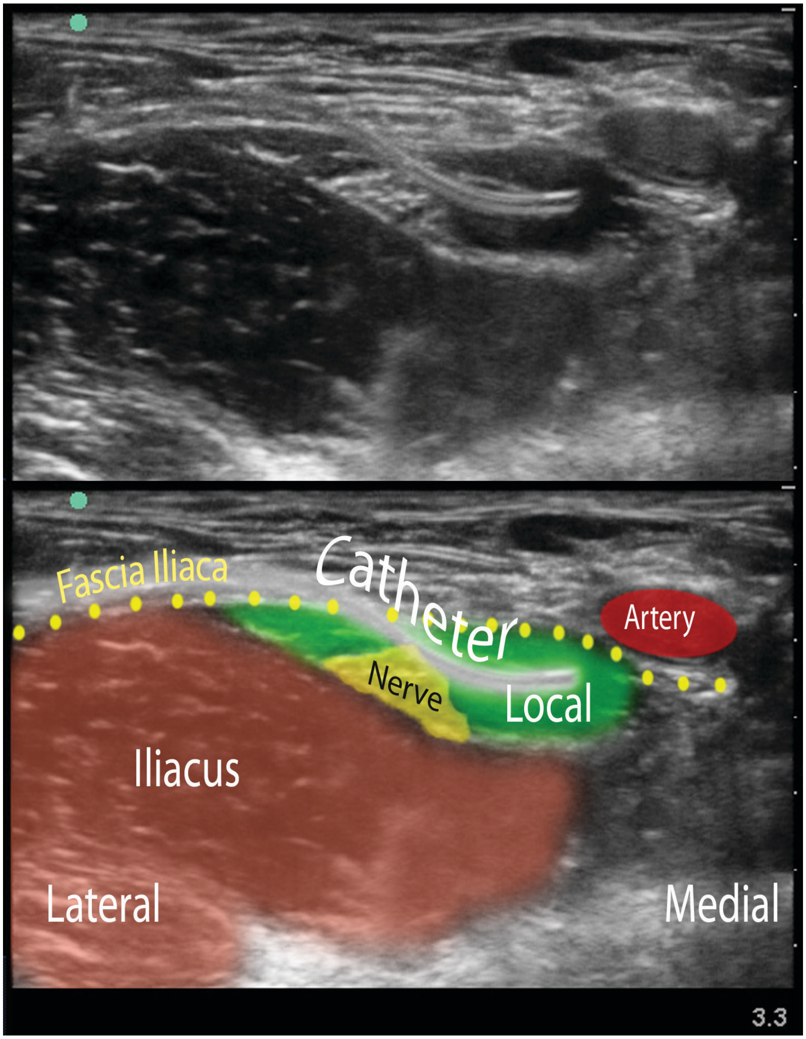


Figure 3-12 Continuous femoral nerve block with a catheter lying directly above the nerve. The spread of local anesthetic above the nerve is acutely demarcated by the overlying fascia iliaca.

repair (Figure 3-12). Femoral catheters have resulted in improved and prolonged analgesia, decreased opioid requirements, reduced incidence of side effects, decreased hospital stay, and improved postoperative rehabilitation and joint mobilization. In-plane catheters may be placed above or below the femoral nerve with similar analgesic effect (Figure 3-13). The actual location of the catheter is far less important than ensuring that the catheter is below the fascia iliaca, as described for the single-injection techniques. See Chapter 1 for specific details on catheter insertion.

Complications

As with all peripheral nerve blocks, complications such as nerve injury and local anesthetic toxicity have been associated with the femoral nerve block. However, the compressibility

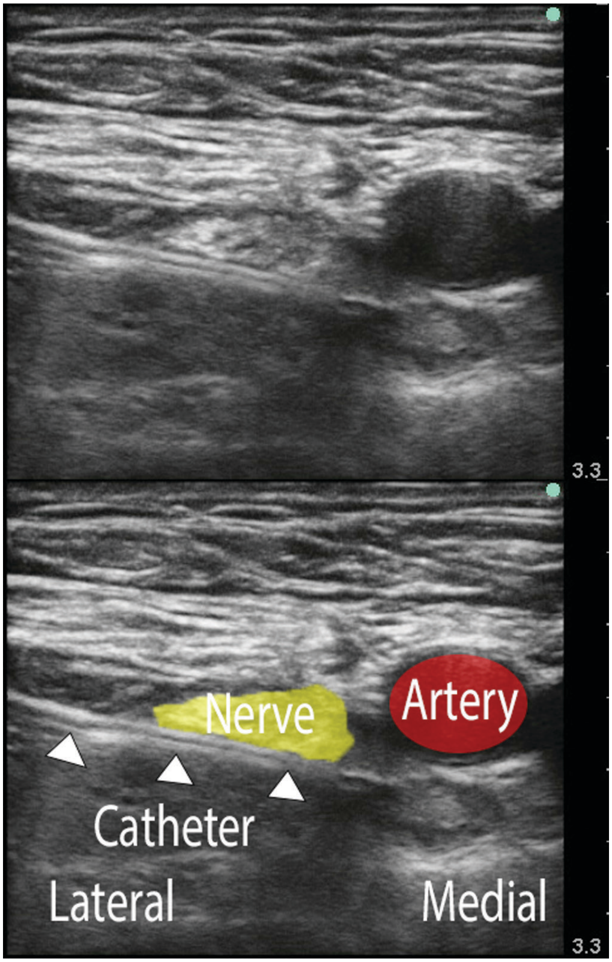


Figure 3-13 Continuous femoral nerve catheter placed below the nerve.

of the nearby vessels, the superficial location of the femoral nerve in the inguinal crease, the distance from the spinal cord and vital organs, and the applicability of ultrasound guidance make this a very safe peripheral nerve block with few complications. One of the most common concerns with a continuous femoral nerve block is the possibility of infection due to its close proximity to the groin. Although bacterial colonization is common, especially in catheters that remain in place for longer than 48 hours, the incidence of local inflammation is low, and serious infectious complications are very rare. There is also a risk of falling with femoral nerve blocks due to a weak or insensate limb. This risk of falls had led to the popularity of the selective femoral nerve block, otherwise known as the adductor canal block (see later discussion).

Pearls

- Remember "NAVEL" in reference to the orientation of the neurovascular structures from lateral to medial.

- It is important to optimize patient positioning and ensure adequate exposure of the inguinal crease. In obese patients, the pannus can be retracted superiorly out of the field and held in place with several large pieces of tape attached to the contralateral bed rail if necessary.
- The inguinal crease is a good starting point for initial probe placement. In obese patients, the inguinal crease is usually distal to the split of the common femoral artery, so the probe needs to be slid cephalad.
- Use the femoral artery to help guide visualization to the femoral nerve. The femoral artery branches at the same level at which the femoral nerve splits into its more distal components. Once the femoral nerve has branched, it is more difficult to see. If the artery is imaged proximally as a single artery, the nerve will more likely be found as a large single nerve and will be more visible on the ultrasound image.
- Ensure the spread of local anesthetic below the fascia iliaca by observing its spread deep to the artery.
- The femoral nerve may be variable in its location relative to the artery. Occasionally it lies adjacent to the artery, and at times it may be far lateral to the artery. With experience, scanning proximally and distally, and adjusting the angle and pressure of the probe, the femoral nerve can be reliably identified as a hyperechoic, wide structure on top of the iliacus muscle. Nerve stimulation may help confirm the position of the nerve if uncertainty remains.
- A common anatomic structure that may be mistaken for the femoral nerve is an inflamed lymph node. These are found above the fascia iliaca and therefore should not be confused with the nerve.

Fascia Iliaca Block

The term *fascia iliaca block* was first used to describe an anterior lumbar plexus block. The landmark-based fascia iliaca block afforded a low-tech alternative approach to the more traditional lumbar plexus block and used fascial pops or clicks as guidance for local anesthetic placement. With the fascia iliaca block, the femoral nerve and possibly the lateral femoral cutaneous nerve (LFCN) can be blocked without bringing the needle into close proximity to the nerves. Use of ultrasound for the performance of a femoral nerve block requires identification of the fascia iliaca; this has led to confusion regarding what represents a fascia iliaca block and what represents a femoral nerve block. For most operators, use of ultrasound guidance for either block is anatomically the same thing. Depending on the concentration used and the total dose, there is a potential for the local anesthetic to spread and involve other branches of the lumbar plexus. Practically speaking, in obese patients, the fascia iliaca nerve block is performed more distally, closer to the inguinal skin crease, and is identical to the femoral nerve block described earlier.

Anatomy

The relevant anatomic description is similar to that for femoral nerve block. The fascia iliaca covers the iliacus muscle. The femoral nerve lies deep to the fascia and sits on the iliacus muscle in the groin region. More proximally and laterally, the LFCN lies deep to the fascia iliaca before it crosses the inguinal ligament on its course to the lateral thigh. The other main branch of the lumbar plexus, the obturator nerve, exits the psoas muscle medially, high in the posterior pelvis, and is not blocked by this approach. The spread of local anesthetic to the LFCN depends on the initial injection position and the volume of local anesthetic used.

Clinical Applications

A fascia iliaca block provides anesthesia and analgesia to the anterior and lateral thigh, hip, femur, knee, and medial lower leg and foot. Anesthesia of the entire lower leg can be achieved when this block is combined with a sciatic and obturator nerve block. The fascia iliaca block is a relatively basic technique and has a high success rate when ultrasound is used. Additionally, an ultrasound fascia iliaca block has a low incidence of complications and is commonly used to provide perioperative analgesia for hip surgery. A fascia iliaca block can provide analgesia after hip arthroplasty or hip fracture surgery. The terms fascia iliaca block and femoral nerve block can be used interchangeably depending on the exact position of local anesthetic injection and the total volume and concentration of local anesthetic used.

Technique

Ultrasound Details

Monitors: ECG, NIBP, pulse oximeter, and additional monitors as deemed necessary.

Skin Preparation: Chlorhexidine with alcohol.

Probe: High-frequency linear probe (10-15 MHz).

Patient Position: Supine.

Local Anesthetic Choice: Depends on the surgical indication. For long-lasting nerve blocks, use ropivacaine 0.5% or bupivacaine 0.25% to 0.5%. For short-duration blocks (e.g., ambulatory patient, intraoperative tourniquet coverage), mepivacaine 1.5% or lidocaine 1.5% may be employed.

Needle: 100-mm (4-inch), short-bevel nerve block needle or Tuohy needle for catheter placement.

Scanning Technique

1. **Position the patient completely supine with the legs extended and the ultrasound machine positioned opposite the side to be blocked.**
2. **Place a high-frequency linear probe on the operative leg in an axial plane at the level of the inguinal crease, similar to the initial probe position for a femoral nerve block** (see Figure 3-6).
3. **Locate the femoral vein and artery, with the artery lateral to the vein.** Color Doppler imaging and occlusion of the vein by application of additional pressure with the probe can help to identify the femoral vessels (see Figure 3-7).
4. **Identify the fascia iliaca lying on the iliacus muscle.** Often, the fascia is easier to identify more laterally, underneath the sartorius muscle. The fascia can be followed medially to the femoral artery. Underneath the fascia, the femoral nerve can be identified but this is not necessary for block success. Identification of the femoral nerve does improve success of the block but an injection laterally away from the nerve can enhance block safety by making inadvertent intraneural injection less likely (Figure 3-14).
5. **The target for injection is deep to the fascia iliaca, just caudad to the inguinal ligament.** The position for injection will be greatly affected by the body habitus of the

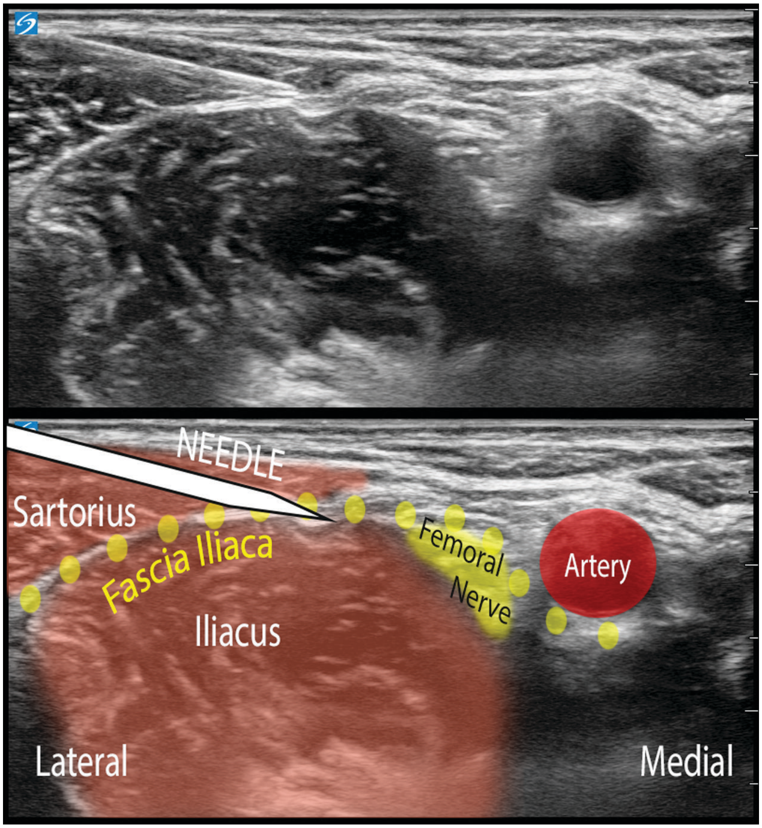


Figure 3-14 An in-plane fascia iliaca block aims to place the needle and local anesthetic below the fascia that is found between the sartorius muscle (shallow) and the iliacus muscle (deep). The femoral artery and nerve are visualized more medial to the injection site.

patient. In obese patients with a large pannus, the injection site will be much more caudad, making the proximal spread of local anesthetic less likely. Often, the injection is similar to that used for a femoral nerve block.

6. **A 4-inch (100-mm) block needle should be inserted in-plane with the ultrasound beam, beginning laterally and aimed medially** (see Figure 3-14).
7. **The needle is advanced under the fascia iliaca.** Stop just deep to the fascia iliaca. Ideal spread of local anesthetic is achieved by hydrodissection of local anesthetic between the fascia iliaca and the iliacus muscle.
8. **Inject incrementally up to 30 mL of local anesthetic with aspiration after every 5 mL.** Use ropivacaine 0.25% for a long-lasting analgesic block. If spread of the local anesthetic is not visualized under ultrasound, the injection should be halted and the needle tip position reconfirmed.

Alternative Techniques

An alternative approach to the standard fascia iliaca block is the suprainguinal fascia iliaca (SIFI) block. Early descriptions of this block, the operator attempted to advance the needle in a cephalad direction underneath the inguinal ligament. The long needle entry path and difficulty imaging the correct fascial plane, particularly in obese patients, made this approach challenging. Described here is an ultrasound-guided, out-of-plane SIFI block that is more simple to perform and provides successful postoperative analgesia after hip surgery.

1. Place one hand on the anterior superior iliac spine (ASIS). Place the probe in the inguinal crease. Scan laterally from the femoral artery and nerve in the inguinal crease to identify the sartorius muscle (see Figure 3-14).
2. Place the sartorius muscle in the middle of the screen, and follow it cephalad to the ASIS. As the probe moves up the thigh, the muscle appears to shrink and eventually disappears where it originates on the ASIS.
3. The shadow of the bony iliac crest will then appear. The flat shape of the iliacus muscle will be seen medial to the shadow of the iliac crest and lying on the bone. Medial and superficial to the iliacus muscle, the transversus abdominis muscle (deep) and the internal oblique muscle (superficial) can be located. The external oblique muscle is an aponeurosis at this point of the lower abdomen and is not identifiable (Figure 3-15).
4. Once the ASIS and the iliacus muscle are identified, the probe is rotated slightly to point at the umbilicus.
5. The needle is inserted out-of-plane from either the cephalad or the caudad side of the probe, based on the handedness of the operator (see Figure 3-15).
6. The end point for needle injection is deep to the fascia iliaca and above the iliacus muscle in the lateral part of the iliacus muscle. This is also the most superficial part of the muscle (Figure 3-16).
7. Inject 30 mL of local anesthetic incrementally, aspirating after every 5 mL. If local anesthetic is not seen spreading under the fascial plane, stop injecting and reposition the needle. Ropivacaine 0.25% will provide a long-acting block.

Catheters

Fascia iliaca catheters can be placed preoperatively in hip fracture patients. A catheter insertion site close to the incision often necessitates removal before surgery, but one should consider a local anesthetic bolus before removal. The technique for catheter placement is identical to that for a single-injection block.

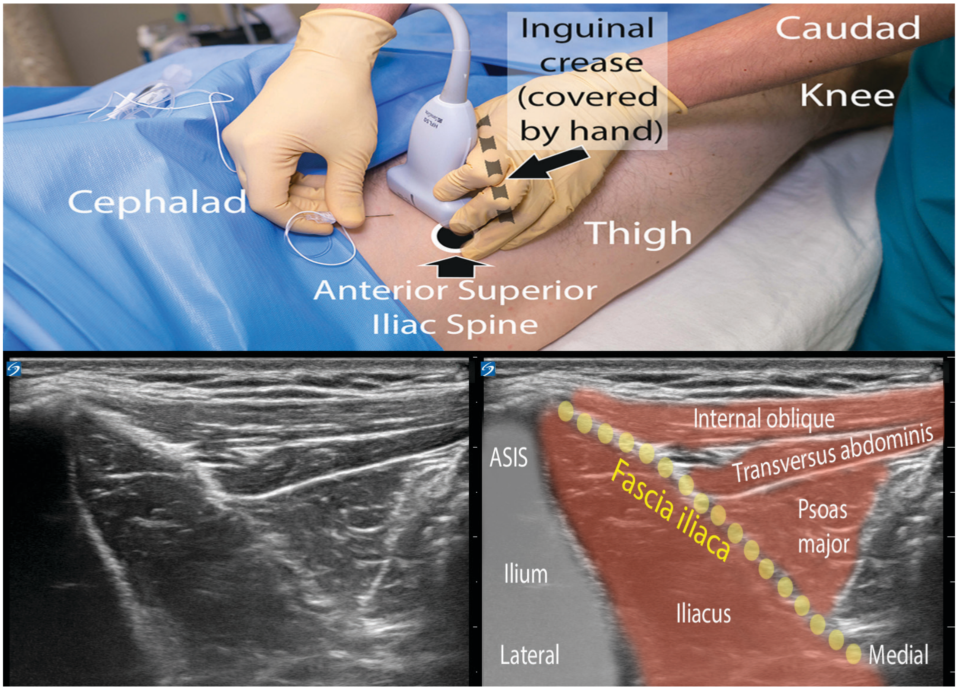


Figure 3-15 The upper image shows the probe and needle position for an out-of-plane suprainguinal fascia iliaca (SIFI) block. Notice that the lateral margin of the probe is placed over the anterior superior iliac spine (ASIS). The ultrasound images *(bottom)* reveal the ASIS on the lateral side and the iliacus muscle in close association with the bone. The fascia *(yellow dots)* that must be pierced with the needle is found covering the iliacus muscle.

Complications

As with all nerve blocks, systemic toxicity is a potential problem. Calculate a total safe dose carefully. If this block is used for hip arthroplasty, a high volume along with a high concentration of local anesthetic can delay ambulation due to quadriceps or hip flexor weakness. Consider a lower concentration of local anesthetic if using the block for postoperative analgesia.

Pearls

- The fascia iliaca block should be performed in a fascial plane between the muscle and nerve, but if there is uncertainty about the anatomy, a nerve stimulator should be attached to ensure that no major nerves are within the path of the needle.
- Use clinical judgment when choosing a nerve block approach based on the body habitus of the patient. More cephalad blocks around the inguinal crease often are inhibited by pannus in large patients.
- Be realistic about the expected spread of local anesthetic—the obturator nerve is never reliably blocked with this approach. If complete coverage of the lumbar plexus is desired (i.e., femoral, LFCN, and obturator nerves) consider using a classic (posterior) lumbar plexus block or blocking the obturator nerve separately.

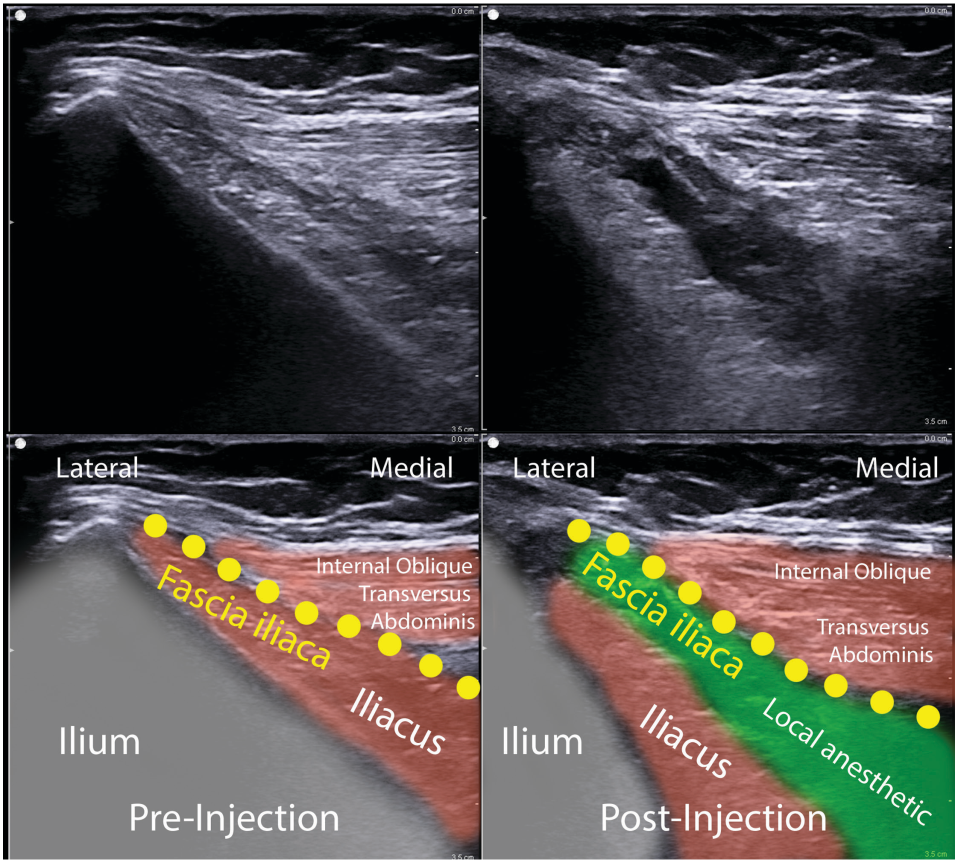


Figure 3-16 Before *(left)* and after *(right)* images of a suprainguinal fascia iliaca block. With proper needle placement, the injected local anesthetic spreads along the iliacus muscle beneath the fascia iliaca.

- If a fascia iliaca block is for hip arthroplasty, understand that the innervation of the hip is complex. The sources of pain after hip surgery include the femoral nerve and the LFCN. Additionally, the obturator, sciatic, and subcostal nerves contribute to pain, and a fascia iliaca block will affect none of these. Plan accordingly for supplemental postoperative analgesia.

Lateral Femoral Cutaneous Nerve Block

Blockade of the LFCN, also called the lateral cutaneous nerve of the thigh, should be considered during a lateral approach to hip surgery and for any incision on the lateral part of the thigh. The nerve can be blocked individually or as part of a lumbar plexus technique. This block is similar to the SIFI block except that it is performed more distally. If the LFCN is blocked near the femoral crease, there is almost no chance of quadriceps muscle weakness from local anesthetic spread to the femoral nerve. The technique for imaging and blocking of the LFCN stems from the chronic pain experience, in which isolated sensory blockade of this nerve is performed for patients with meralgia paresthetica.

Anatomy

The anatomy of the LCFN is variable in the leg. This nerve is a branch of the L2 and L3 dorsal divisions of the lumbar plexus. The nerve runs on the iliacus muscle in the pelvis between two fascial layers. Then, at the inguinal ligament and below, the nerve's location becomes quite variable. It usually runs 1 to 2 cm medial to ASIS and can be found coursing either beneath, through, or above the inguinal ligament. The LCFN can include up to three divisions as it enters the thigh and crosses the lateral border of the sartorius muscle, up to 10 cm distal to the ASIS. Lateral to the sartorius muscle is the tensor fasciae latae muscle. As many as three branches of the LCFN may pass over or through sartorius muscle and can be identified in the fascia between sartorius and tensor fasciae latae.

Clinical Applications

The LCFN block is used for analgesia after surgery following trauma to the lateral thigh or hip joint. Even with a complete block of the LCFN, patients may still complain of pain in the top of their hip surgery incision. In these patients, the upper part of a hip surgery incision may be in the distribution of the subcostal nerve and not the lumbar plexus. The LCFN block is also used for the diagnosis and treatment of meralgia paresthetica.

Technique

Ultrasound Details

Monitors: ECG, NIBP, pulse oximeter, and additional monitors as deemed necessary.

Skin Preparation: Chlorhexidine with alcohol.

Probe: High-frequency linear probe (10-15 MHz).

Patient Position: Supine.

Local Anesthetic Choice: Depends on the surgical indication. For long-lasting nerve blocks as part of an anesthetic technique, ropivacaine 0.5% or bupivacaine 0.5% may be used. For only postoperative analgesia, use ropivacaine 0.25% or bupivacaine 0.25%.

Needle: 50- to 100-mm (2- to 4-inch), short-bevel nerve block needle.

Scanning Technique

1. **Place the probe in the inguinal skin crease at the top of the thigh, as for a femoral nerve block** (see Figure 3-6).
2. **Slide the probe laterally from the femoral vessels to find the sartorius muscle.** The sartorius muscle is an oval structure lying lateral to the femoral artery, above the iliacus muscle and fascia iliaca (Figure 3-17; see also Figure 3-14).
3. **Once the sartorius muscle is identified, slide the probe more laterally to locate the tensor fascia latae muscle.** The tensor fascia latae muscle can be identified

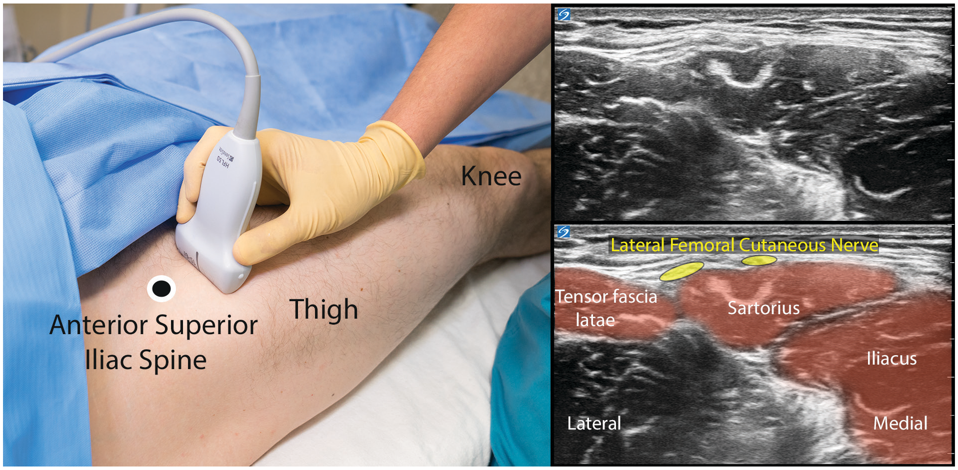


Figure 3-17 For a lateral femoral cutaneous nerve (LFCN) block, position the transducer at the inguinal crease and then slide it laterally until the sartorius muscle is imaged shallow to the iliacus muscle. Follow the sartorius by sliding the probe cephalad until the muscle starts to decrease in size. It eventually becomes a tendon as it inserts into the anterior superior iliac spine (ASIS). The nerve should be located in close proximity to the sartorius muscle and laterally located tensor fascia latae muscle, which are found distal to the ASIS.

because it is lateral to the sartorius muscle and of similar size. When the probe is slid proximally, both the sartorius and the tensor fascia latae will shrink in size as the probe reaches the ASIS. If the tensor fascia latae muscle is traced distally, it shrinks and then disappears before the midthigh is reached (see Figure 3-17).

4. **Search between the medial portion of tensor fasciae late muscle and the sartorius muscle for the LCFN or its multiple branches.**
5. **The LCFN can appear as a single hyperechoic oval lying between the fascial planes that separate the muscles or on the sartorius muscle.** The nerve can also exist as multiple circles (see Figure 3-17).
6. **The nerve can be difficult to visualize due to normal anatomic variations.** If the nerve cannot be found with ultrasound, consider infiltrating local anesthetic in several tissue planes, on the sartorius and between the sartorius and tensor fascia latae muscles. Alternatively, consider performing this block with one of the alternative approaches described later.
7. **Once the nerve is identified, insert the needle in-plane or out-of-plane.** We find this superficial nerve is a good place to use an out-of-plane technique. The target for the needle is within the fascial plane that contains the nerve.
8. **Inject local anesthetic (5-10 mL) until adequate spread is visualized** (Figure 3-18).

Alternative Techniques

1. In the inguinal crease, the transducer can be moved laterally and cephalad until the ASIS is identified. At this point, local anesthetic is infiltrated in multiple fascial planes both above and below the sartorius tendon or muscle and on the iliacus muscle. An in-plane or out-of-plane approach can be used. We recommend infiltrating in multiple fascial planes because of the variability of nerve location.

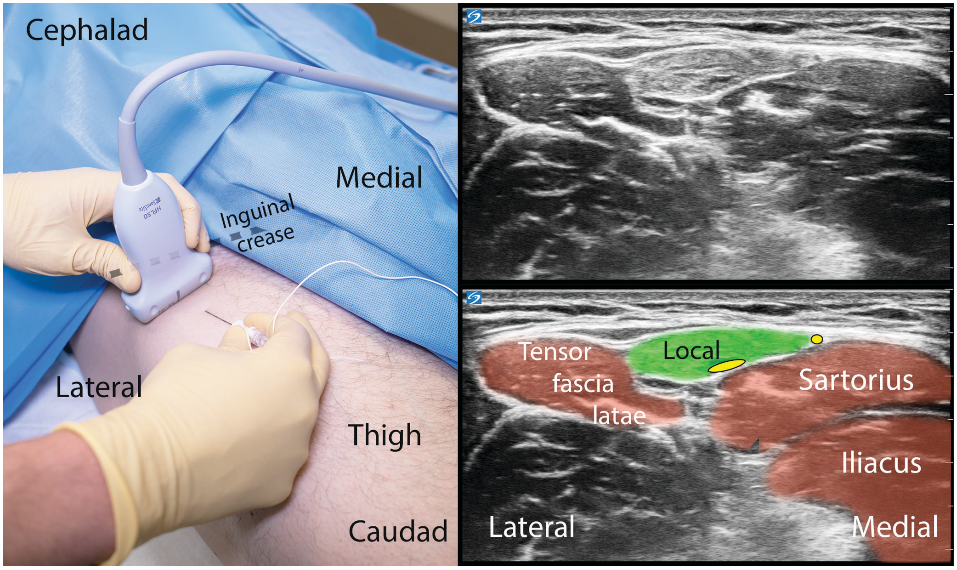


Figure 3-18 Out-of-plane lateral femoral cutaneous nerve (LFCN) block. The needle is directed cephalad to inject local anesthetic between the sartorius and the tensor fascia latae. Local anesthetic can be visualized spreading within that plane and surrounding the nerves.

2. If the nerve cannot be visualized, another approach is infiltration of local anesthetic along the lateral border of the sartorius muscle between the fascial layers. This approach is best performed slightly distal to the ASIS and distal to the level of the inguinal crease. At this level, the sartorius is an obvious muscle, rather than a tendon inserting into the ASIS.
3. A third approach, if there is no concern about motor weakness from a femoral nerve block, is to use a SIFI block. This approach can block both the LFCN and the femoral nerve.

Pearls

- If the nerve or its branches are not as obvious as in Figures 3-17 and 3-18, consider infiltration within several planes to improve success rates.
- Large volumes of local anesthetic are not required; a maximum total of 20 mL should be used for all injections). Even with small volumes (5 mL), good spread within the fascial planes will be visualized.

Adductor Canal Block (Selective Femoral Nerve Block)

The adductor canal block provides pain relief for knee, leg, and ankle surgeries without causing weakness of the anterior thigh muscles. This allows for rapid and active rehabilitation after joint surgery and improved mobility for patients discharged to home. The adductor canal block has increased in popularity because it has been shown to provide good analgesia for knee surgery, in both major joint replacement and smaller surgeries such as arthroscopy of the knee. Studies have shown that the adductor block can decrease opioid use, improve participation in physical therapy, improve strength after surgery, and improve discharge times.

Anatomy

The selective femoral nerve block at the adductor canal anesthetizes one of the largest branches of the femoral nerve. After its origin from the femoral nerve, this branch is located in close proximity to the superficial femoral artery at the midthigh. At this level, the artery and nerve enter the adductor canal. Anatomically, several muscles bound the adductor canal: the vastus medialis *anterolaterally*, the adductor longus and adductor magnus *posteromedially*, and the sartorius *anteromedially*. The proximal boundary of the adductor canal is located where the sartorius muscle crosses over the adductor longus, approximately 15 cm inferior to the inguinal ligament. The distal boundary is the adductor hiatus, an opening in the tendon of the adductor magus muscle. Although the adductor canal contains the saphenous nerve, nerve to vastus medialis, and sometimes branches of the obturator nerve, local anesthetics delivered at this level avoid significant motor weakness of the quadriceps muscles. Needle approaches to the selective femoral block at the adductor canal must traverse through or between the sartorius and vastus medialis at the midthigh. The vastoadductor membrane, a fascial layer connecting the vastus medialis to the adductor muscles, covers the nerve at this level. Injections must be placed deep to the vastoadductor membrane for optimal efficacy (Figure 3-19).

Clinical Applications

The adductor canal block (selective femoral nerve block) is effective in providing analgesia to the knee and is a good way to reproducibly block the saphenous nerve. The primary benefit of this block is that it allows for good analgesia after surgery of the knee and lower leg while maintaining strength of the majority of the quadriceps muscles. This block is effective for surgeries distal to the thigh including knee arthroplasty, knee arthroscopy, knee tendon repair (anterior or posterior cruciate ligament), and surgery of the lower leg, foot, and ankle. When compared with the femoral nerve block, the adductor canal block may offer similar pain relief after most of these surgeries.

Technique

Ultrasound Details

Monitors: ECG, NIBP, pulse oximeter, and additional monitors as deemed necessary.

Skin Preparation: Chlorhexidine with alcohol.

Probe: High-frequency linear probe (10-15 MHz) for most patients. In larger patients (>100 kg), lower-frequency probes, including curvilinear probes, are sometimes indicated.

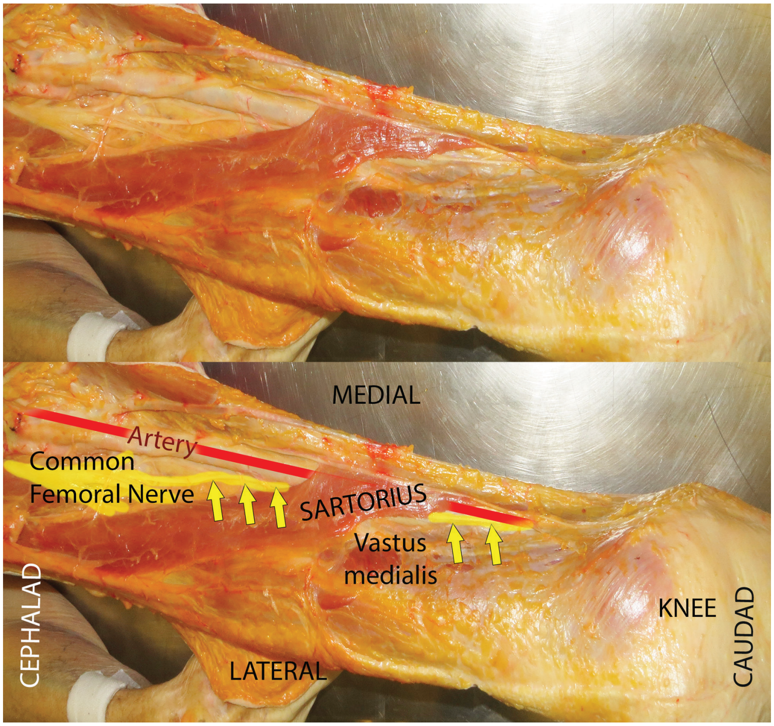


Figure 3-19 Adductor canal dissection of the midthigh. The superficial femoral artery can be seen on the anterior leg. The sartorius muscle crosses the leg from lateral to medial as it runs distally down the thigh. The important branch of the femoral nerve that eventually becomes the saphenous nerve joins the artery as it courses underneath the sartorius muscle.

Patient Position: Supine, with the leg externally rotated. A frog-leg position can facilitate block performance.

Local Anesthetic Choice: Depends on the surgical indication. For long-lasting nerve blocks, ropivacaine 0.2% to 0.5% or bupivacaine 0.25% to 0.5% may be used. Because this block is employed primarily for analgesia of the knee, long-acting agents are usually preferred. A maximum volume of 20 mL for the bolus is recommended.

Needle: 100-mm (4-inch), short-bevel nerve block needle or Tuohy needle for catheter placement.

Scanning Technique

1. **Position the patient completely supine with the surgical leg externally rotated.** Another good position for the block is with the patient's knee bent in a frog-leg position. The ultrasound machine should be positioned opposite the operative or block side.
2. **Place a high-frequency linear probe on the operative leg in a transverse plane at the level of the midthigh** (Figure 3-20).
3. **Locate the superficial femoral artery on the medial thigh by moving the probe in a lateral to medial direction.** If the artery cannot be located, move the probe more medially. The artery is often located more medial / posterior than anticipated. Color Doppler imaging can help to identify the femoral artery (see Figure 3-20).

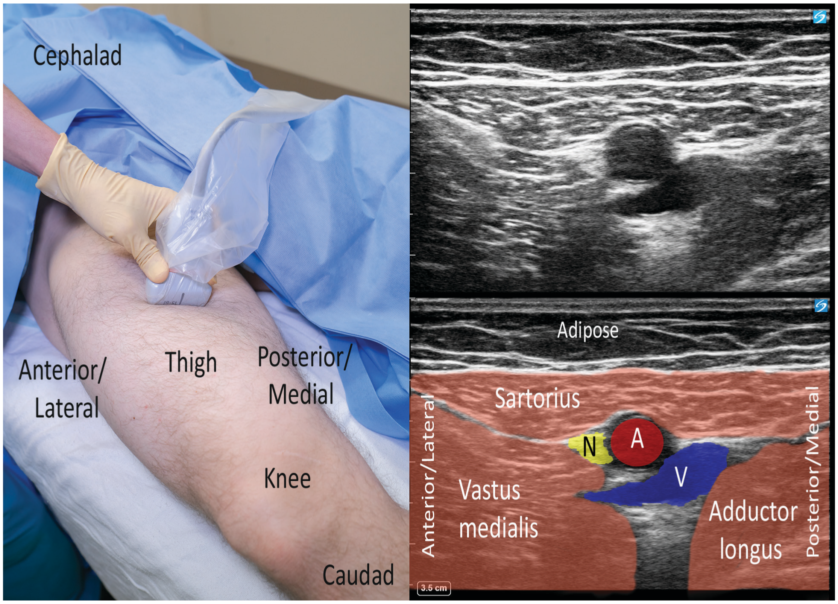


Figure 3-20 Adductor canal probe position and ultrasound image. Externally rotate the leg or place the patient in a frog-leg position to make probe and imaging placement easier. The ultrasound transducer is placed on the medial leg. The nerve is located on the anterolateral side of the artery. A, artery; N, nerve; V, vein.

4. **Scan proximally and distally on the leg to identify the sartorius muscle superficial to the artery.** The optimal place to perform this block is where the superficial femoral artery is located directly below the sartorius muscle. If the artery is not located underneath the sartorius muscle, move the probe proximally or distally until the artery is located below the sartorius (Figure 3-21).
5. **Locate the femoral vein at this level.** The femoral vein is often deep to the artery at this level and is easily compressed during scanning in patients. It is important to identify the vein to avoid inadvertent intravascular injection during the block. Relax pressure on the probe before needle injection to verify vein position.
6. **The nerves of the adductor canal lie lateral and anterior to the superficial femoral artery and often appear bright (hyperechoic).** These nerves are located just adjacent to, and usually attached to, the superficial femoral artery (see Figures 3-19 and 3-20).
7. **A 4-inch (100-mm) block needle should be inserted in-plane with the ultrasound beam.**
8. **The needle needs to be advanced under the vastoadductor membrane for the block to be successful.** The vastoadductor membrane is not visible. The needle should target the area almost below the artery (5 o'clock or 7 o'clock position) to consistently and successfully pierce the vastoadductor membrane (Figure 3-22).
9. **The end point for needle positioning is next to the superficial femoral artery, under the nerve, with care taken to avoid the femoral vein** (see Figure 3-22).
10. **During injection of local anesthetic, the hyperechoic nerve lying in close approximation to the superficial femoral artery should be pushed**

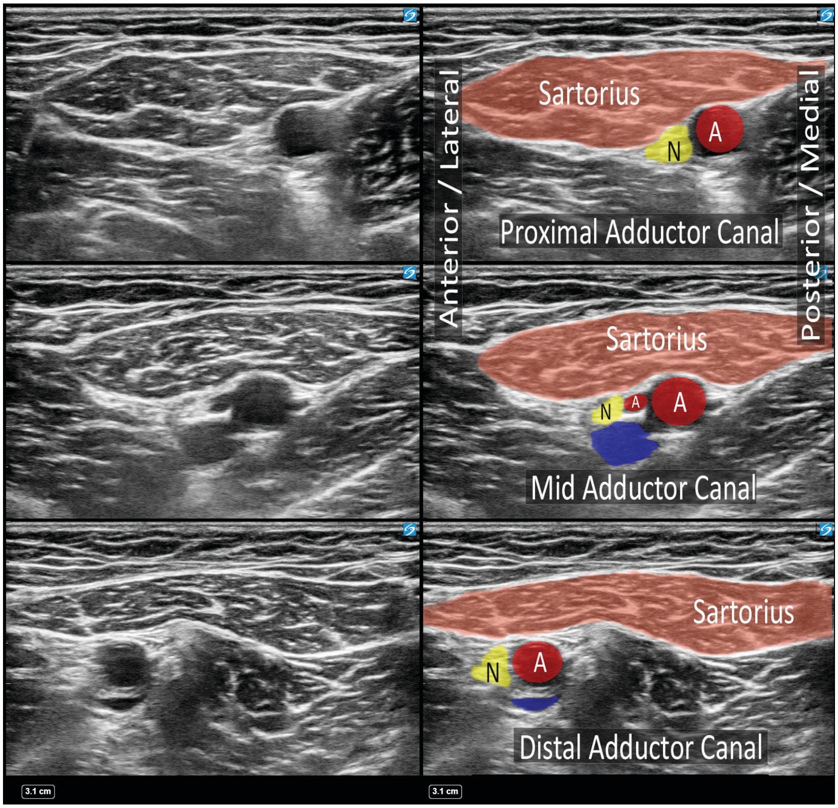


Figure 3-21 Adductor canal imaging from proximal to distal. Proximal adductor canal blocks are performed where the sartorius is more lateral to the artery *(top)*. Mid-adductor canal blocks are performed where the artery is located directly under the center of the sartorius muscle *(middle)*. Distal adductor canal blocks are performed where the sartorius muscle is mostly posterior and medial to the artery. In this patient, a small branch of the artery is located in close proximity to the nerve in the mid-adductor canal, making a proximal or distal block preferred. Compare these ultrasound images with the dissection in Figure 3-19. A, artery; N, nerve.

superficially. This will be a good sign that the needle has traversed the vastoadductor membrane (Figure 3-23).

11. **Approximately 10 to 20 mL of local anesthetic is injected in 5-mL aliquots after aspiration for blood.**

Catheters

A continuous selective femoral nerve catheter at the adductor canal provides extended postoperative analgesia after surgeries such as total knee arthroplasty or anterior cruciate ligament repair (Figure 3-24). Adductor canal catheters are especially valuable in improving postoperative outcomes after knee replacement surgery. If an adductor canal catheter is placed before knee surgery, the catheter may be in the way of the tourniquet or sterile field. Consider rotation of the probe so that the needle insertion site is higher up the leg (Figure 3-25). This rotation will not change the ultrasound image significantly, but it will allow the needle insertion site to be moved further away from the surgical field. See Chapter 1 for specific details on peripheral nerve catheter insertion.

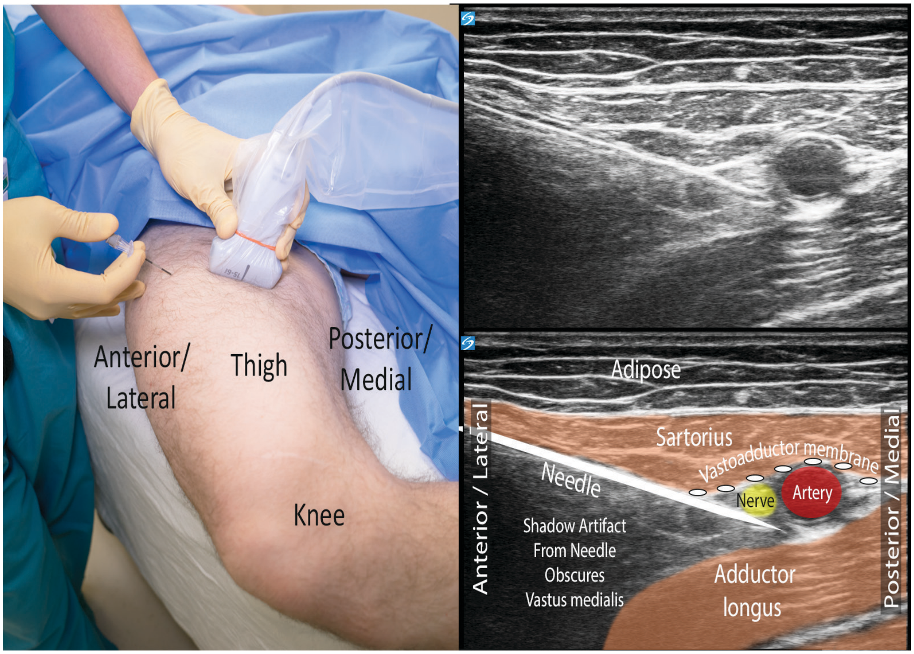


Figure 3-22 Adductor canal nerve block with the needle trajectory underneath the nerve. Advancing the needle deep to the nerve ensures local anesthetic spread beneath the vastoadductor membrane.

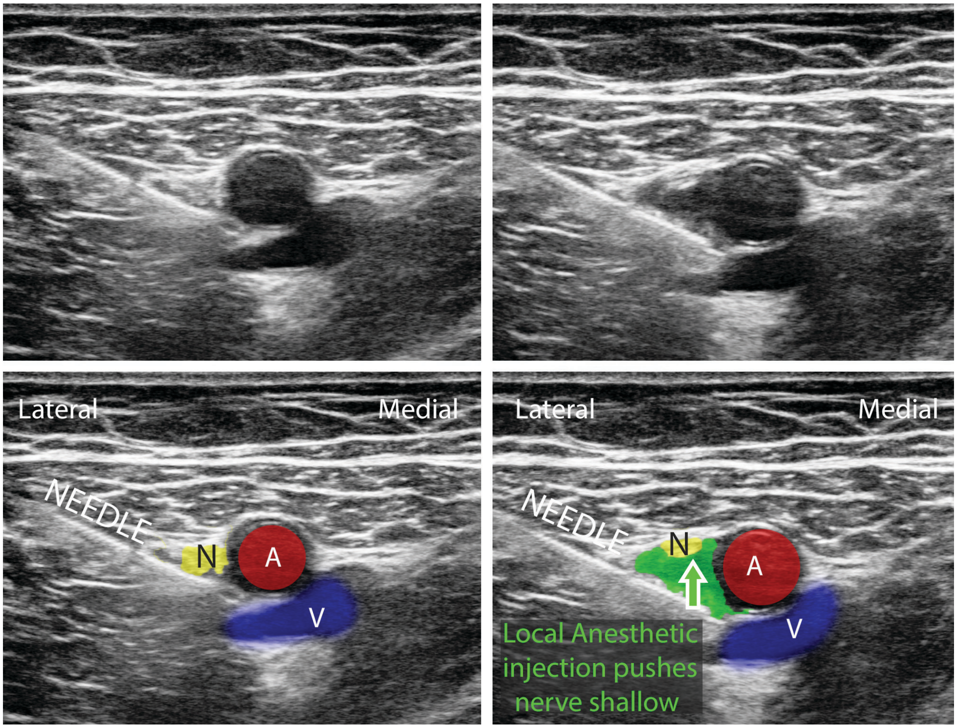


Figure 3-23 A key point in performance of the adductor canal block is to look for the nerve to be pushed superficially during injection of the local anesthetic. This is a good clinical sign to ensure correct local anesthetic placement underneath the vastoadductor membrane. A, artery; N, nerve; V, vein.

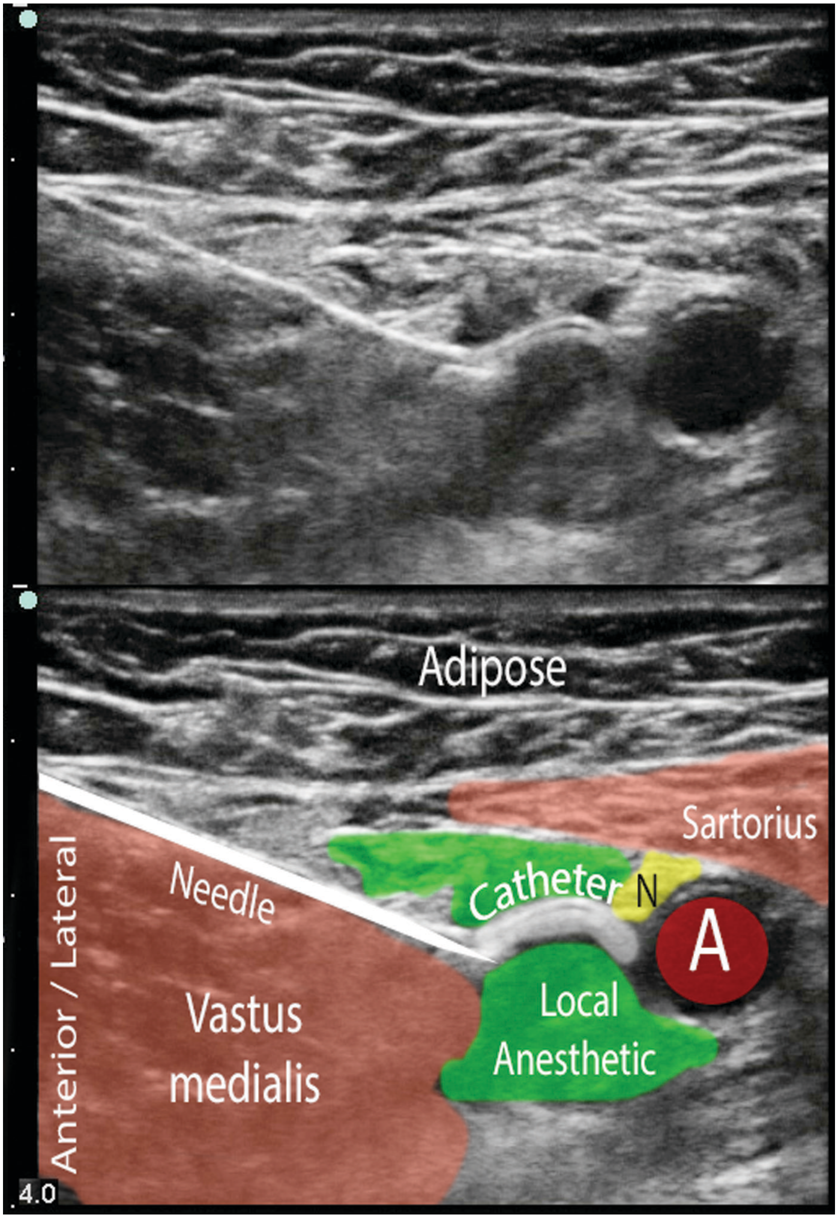


Figure 3-24 Adductor canal continuous catheter placement. As with single-injection blocks, catheters should be placed underneath the nerve. A, artery; N, nerve.

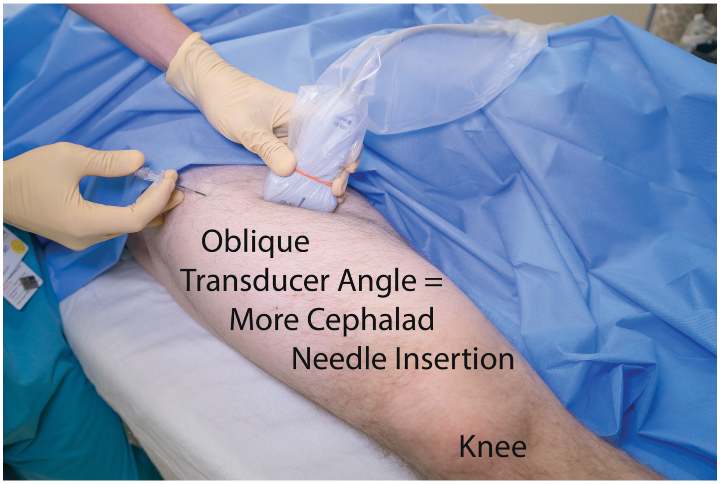


Figure 3-25 To move the continuous catheter insertion site away from the surgical field, rotate the transducer obliquely. This allows the needle puncture site to be moved more cephalad and several centimeters away from the transducer.

Complications

As with all peripheral nerve blocks, complications such as nerve injury and local anesthetic toxicity can be associated with the selective femoral nerve block at the adductor canal. Therefore, it is best to direct the needle under the hyperechoic nerve located next to the superficial femoral nerve, rather than through it. Additionally, the femoral vein at this level often can be located lateral to the artery, making needle advancements for this block more difficult. Color Doppler imaging and probe compression can help to identify the vein. Imaging with color Doppler while squeezing the thigh can augment venous flow through the femoral vein and help improve visualization of the vein. Occasionally, leg weakness or even foot drop has been described as a possible complication after this block. Local anesthetic can spread proximally to the common femoral nerve or posteriorly to the sciatic nerve. For this reason, we recommend a low-pressure injection of not more than 20 mL for this block. It is important to assess lower limb strength after this block before the patient stands or ambulates.

Pearls

- For consistency of insertion point, first scan distally to where the artery dives deep (and becomes the popliteal artery). Then, slowly scan proximally to where the artery is found under the middle sartorius muscle. This helps place the block as distally as possible, potentially decreasing the risk of quadriceps weakness.
- Conversely, if placing a catheter, slide the transducer more cephalad and rotate it to an oblique angle to move the catheter insertion point farther away from the surgical site (see Figure 3-23).
- Abduct the legs or place the leg on the block side in frog-leg position so that the ultrasound transducer can be positioned on the medial thigh (see Figure 3-22).
- Initially, aim the needle under the nerve, aim towards the 6 o'clock position on the artery. Small injections during needle advancement will help to identify the appropriate needle position. When the injection displaces the nerve superficially or away from the artery,

stop needle advancement and inject the majority of the local anesthetic at that point (see Figure 3-23).

- There are often hyperechoic regions on both sides of the artery. With the technique described here (i.e., finding the sartorius and superficial femoral artery stacked), the sensory nerve will be reliably blocked if the needle is placed beside the hyperechoic region, lateral and anterior to the artery.
- If it is difficult to locate the superficial femoral artery at the adductor canal, consider finding the artery at the femoral crease, where it is shallower. Then slide the transducer distally, tracing the artery to the point at which it is located under the sartorius muscle.
- The reason the superficial femoral artery–sartorius muscle combination is a good landmark for the adductor block is that the sartorius muscle crosses over the artery from lateral to medial as the structures move distally down the leg. The adductor canal is reliably located at the level where the artery is found directly underneath the sartorius muscle. Most of the research that shows improved outcomes with this block use the approach described in this chapter.
- Use of a large volume of local anesthetic or high injection pressure can result in either proximal spread to the femoral triangle with resulting quadriceps weakness or dorsal spread to the sciatic nerve with foot drop. Limit injections to a maximum of 20 mL in total.

Saphenous Nerve Block

The saphenous nerve block has been used as an adjunct to the popliteal sciatic block (discussed later) to provide complete regional anesthesia coverage below the knee. The saphenous nerve is a continuation of the femoral nerve below the knee; it supplies the knee, medial lower leg, ankle and foot. The saphenous nerve block described here is effective, but the anatomy at the adductor canal may be more reproducible from patient to patient. Therefore, the adductor canal approach can also provide a reliable saphenous nerve blockade. The saphenous nerve may also be targeted at the level and of the ankle and this approach is described later in the this chapter under the ankle block section.

Anatomy

The saphenous nerve is a terminal branch of the femoral nerve. It is a purely sensory nerve and innervates the medial leg and foot with variable innervation to the great toe. Branches from the saphenous nerve also innervate the knee. In the proximal thigh, the saphenous nerve lies anterior to the femoral artery. The nerve descends on the medial side of the leg, lying underneath the sartorius muscle (Figure 3-26). In the distal thigh, the saphenous nerve exits the adductor canal with the descending genicular artery. At the medial knee, the nerve emerges between the tendons of the sartorius and gracilis muscles and becomes a subcutaneous nerve. It runs adjacent to the saphenous vein from the knee to the ankle. Prior techniques of blocking this nerve included ring blocks (field blocks) and techniques that depended on fascial "clicks." Typical success rates for such techniques were poor. Ultrasound allows for visualization of this nerve and surrounding structures and therefore has the potential to greatly improve success rates.

Clinical Applications

The saphenous nerve block may be used in conjunction with a sciatic nerve block to provide anesthesia or analgesia of the lower leg and foot. Because the saphenous nerve has no motor

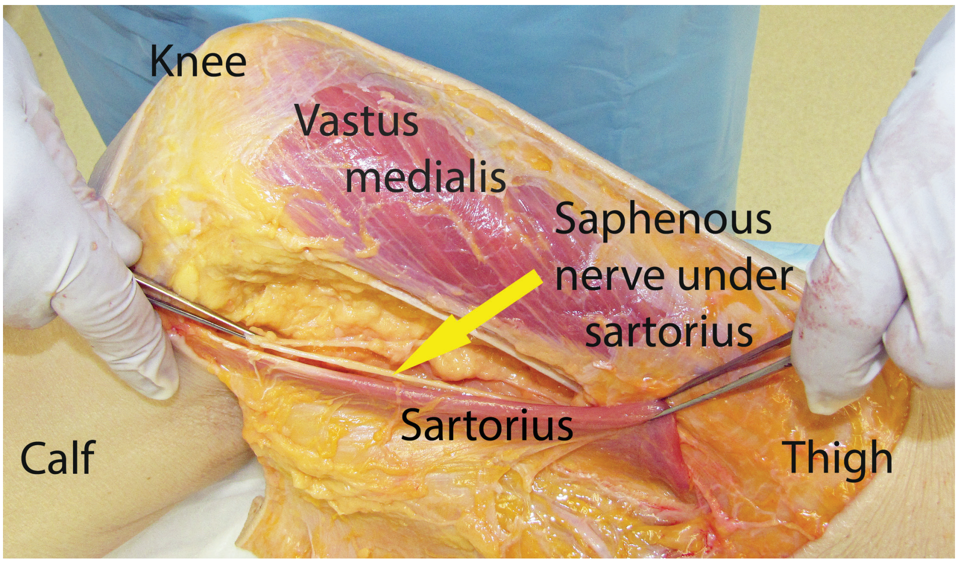


Figure 3-26 Saphenous nerve position. The saphenous nerve lies deep to the sartorius muscle in a fresh tissue cadaver.

innervation, there may be less risk for postoperative falls with a saphenous nerve block compared to a femoral nerve block. For this reason, the saphenous nerve block is well suited for use in outpatients having knee, foot, or ankle surgery.

Technique

Ultrasound Details

Monitors: ECG, NIBP, pulse oximeter.

Skin Preparation: Chlorhexidine with alcohol.

Probe: High-frequency linear probe (10-15 MHz); expected depth in an 80-kg person, 3 to 4 cm.

Patient Position: The patient is positioned supine with the leg externally rotated and bent at the knee (frog-leg position).

Local anesthetic choice: Usually, 10 mL of local anesthetic is required. Because this is a purely sensory block, longer-duration local anesthetic is usually used (e.g., bupivacaine 0.25-0.5%, ropivacaine 0.25-0.5%).

Needle: 100-mm (4-inch), short\-bevel nerve block needle.

Scanning Technique

The saphenous nerve may be blocked just above the knee, where it lies deep to the sartorius muscle. Or, it may be blocked with the adductor canal block technique in the proximal thigh near the femoral artery. The technique for a saphenous nerve block in the distal thigh is described here.

1. **Position the patient supine with the leg externally rotated in frog-leg position.** Consider some abduction of the leg, because the ultrasound probe eventually is placed on the medial leg.
2. **The ultrasound probe is placed in the transverse plane on the anterior medial thigh, approximately 10 cm (4 inches) above the knee** (Figure 3-27).
3. **Anteriorly, the femur can be visualized as a hyperechoic semicircle.**
4. **Located superficially and lying on the femur anteriorly is the vastus medialis.**
5. **Side the probe medial and posterior until the vastus medialis terminates.** Medial to the vastus medialis is the sartorius muscle, a much smaller muscle.
6. **The saphenous nerve lies either in the fascial plane between the vastus medialis and the sartorius or deep to the sartorius muscle** (see Figure 3-27).

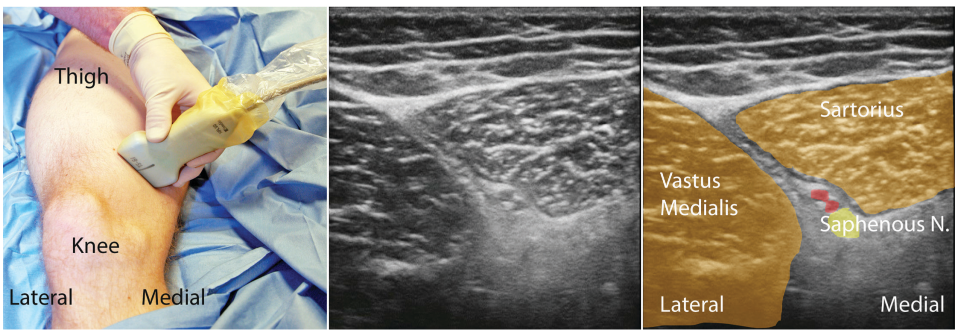


Figure 3-27 Probe position for saphenous nerve scanning in the distal thigh *(left image)* and standard ultrasound image of the saphenous nerve, vastus medialis, and sartorius *(middle and right images)*. N., nerve.

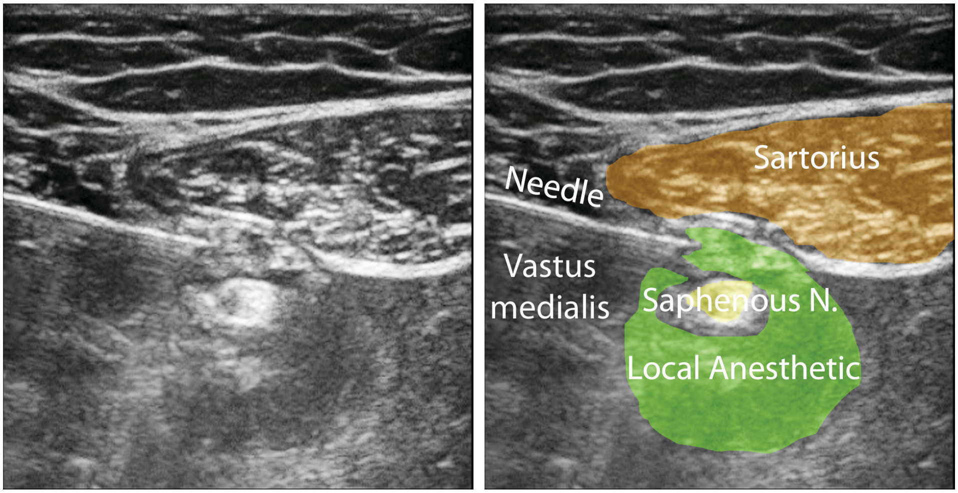


Figure 3-28 Needle advancement in-plane through the vastus medialis muscle toward the saphenous nerve. Local anesthetic injection is visualized around the saphenous nerve. N., nerve.

7. **The nerve can be visualized as a hyperechoic structure but often is not easily visible.** Frequently, a small artery, the saphenous branch of the descending genicular artery, accompanies the nerve. If the nerve is not visible, this artery can be a good marker for it. Also, take care not to inject local anesthetic into the artery. Color Doppler imaging can be used to help visualize this artery.
8. **The nerve and the artery are small and not easily visible in all patients, but use of the muscle landmarks (vastus medialis and sartorius) alone will result in reliable nerve blocks.**
9. **Using an in-plane needle approach, a 4-inch (100-mm) needle is inserted from the anterior side of the probe, aiming posteriorly and medially** (Figure 3-28).
10. **The needle is directed toward the nerve or deep to the sartorius muscle if the nerve is not visible.** Spread of local anesthetic should be observed around the hyperechoic nerve (if visible) and underneath the sartorius muscle as well as between the fascial planes of the vastus medialis and sartorius.

Alternative Techniques

For an alternative technique, the adductor canal block may be used (see earlier discussion). For foot surgery, the saphenous nerve may be blocked at the ankle.

Out-of-Plane Needle Approach

Alternatively, an out-of-plane approach may be used with the needle perpendicular to the probe.

1. Follow the same steps described earlier to locate the vastus medialis and sartorius muscles (distal).
2. Insert a 4-inch (100-mm) needle perpendicular to the ultrasound transducer and beam. Use the techniques described in Chapter 1, "How to Visualize Nerves and Needles."
3. Advance the needle tip so that it is adjacent to the saphenous nerve.

4. A small amount of local anesthetic may be injected to help determine the position of the needle tip.
5. Inject 5 to 10 mL of local anesthetic around the nerve and between the fascial planes of the vastus medialis and sartorius muscles.

Catheters

A continuous saphenous nerve catheter may be used in conjunction with a popliteal sciatic nerve catheter to provide more complete extended postoperative analgesia for surgeries involving the medial aspect of the ankle or foot or the great toe. A low infusion rate (2-4 mL/hr) is usually sufficient to provide good analgesia in the saphenous distribution. Also consider an adductor canal catheter when extended postoperative analgesia is required. See chapter 1 for specific details on peripheral nerve catheter insertion.

Complications

Nerve injury, bleeding, and local anesthetic toxicity are risks involved with this block.

Pearls

- Many times the nerve itself cannot be visualized. It is important to see the spread of local anesthetic in the fascial plane underneath the sartorius muscle and between the muscles (vastus medialis and sartorius) and not within the muscles themselves.
- After performance of a saphenous nerve block, ensure adequate quadriceps strength before ambulation. The motor nerve to vastus medialis runs with the saphenous nerve in the midthigh and can be blocked with this approach.

Obturator Nerve Block

The obturator nerve innervates the adductor muscles, medial thigh, knee, and hip. Nerve blocks of the obturator nerve may therefore be beneficial in providing anesthesia and analgesia for surgeries in these areas.

Anatomy

The obturator nerve is formed from the ventral rami of L2-4. The nerve descends through the psoas major muscle, where it may be blocked as part of a posterior approach to the lumbar plexus. The nerve enters the thigh through the obturator foramen, where it divides into anterior and posterior divisions. The nerve runs deep to the pectineus muscle as it exits the obturator foramen. Most commonly, the anterior division courses in the fascial plane between the adductor longus and adductor brevis muscles, whereas the posterior division lies in the fascial plane between the adductor brevis and adductor magnus muscles. The anatomic course of the obturator nerve is highly variable and the nerve itself is not always visible under ultrasound. Careful scanning to identify medial braches of the femoral artery is important when performing an obturator nerve block. The medial circumflex femoral vessels run in close proximity to the obturator nerve.

Clinical Applications

The obturator nerve provides innervation to the hip joint as well as variable sensory innervation to the medial thigh and knee. The obturator provides motor innervation of the adductor muscles of the lower extremity. Because of variability in innervation of these areas, the obturator block can be used as a rescue block if other nerve blocks (i.e., femoral and/or sciatic) are not providing adequate analgesia.

Technique

Ultrasound Details

Monitors: ECG, NIBP, pulse oximeter.

Skin Preparation: Chlorhexidine with alcohol.

Probe: High-frequency linear probe (10-15 MHz); expected target depth in 80-kg patient, 2 to 3 cm.

Patient Position: Supine with the leg externally rotated.

Local anesthetic choice. Usually, 10 to 20 mL of local anesthetic is required.

Needle: 100-mm (4-inch), short-bevel nerve block needle.

Scanning Technique

1. **The patient is positioned supine with the leg externally rotated.**
2. **Exposure of the groin, inguinal crease, and medial aspect of the proximal thigh is similar to that for the femoral nerve block.** The pannus may be taped to the opposite bed rail, if necessary. The leg can be slightly abducted or placed in the frog-leg position to allow for more adequate exposure of the proximal medial thigh.
3. **A high-frequency linear transducer is placed on the proximal thigh, in line with the inguinal crease** (Figure 3-29). A starting depth of 4 cm on the ultrasound screen is often appropriate.
4. **The femoral vessels are identified, as for a femoral nerve block, with the vein medial to the artery.**

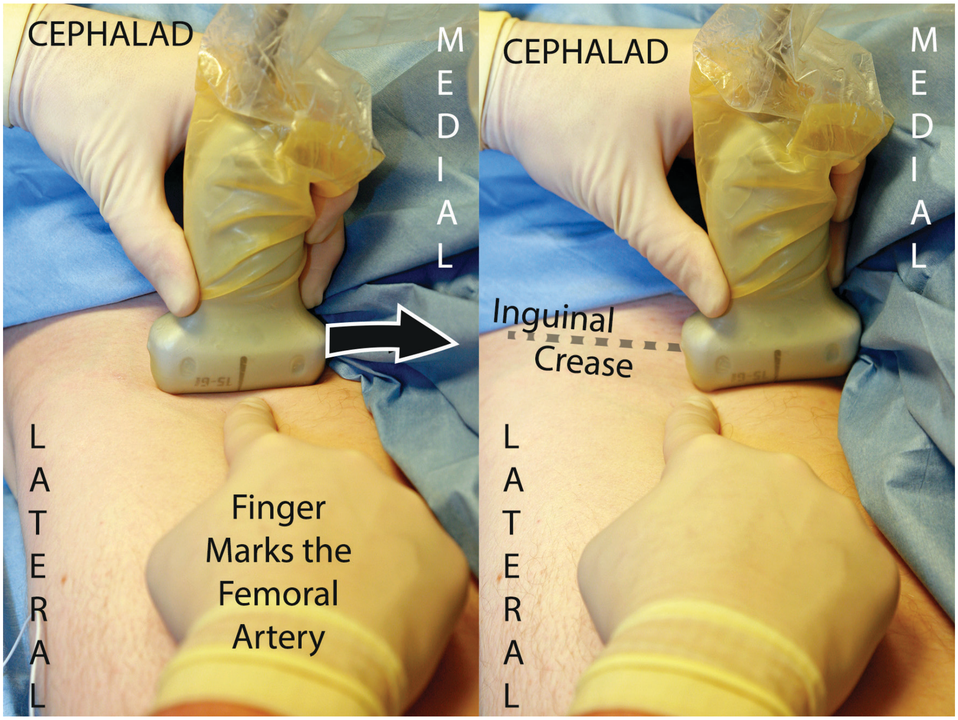


Figure 3-29 Probe position for obturator nerve block. The probe is placed in the inguinal crease and moved medially until the femoral artery is identified *(left)*. The probe is then advanced even more medially to the final position for an obturator nerve block *(right)*.

5. **By sliding the probe medially across the proximal thigh, one can identify the confluence of the pectineus muscle and the adductor muscles medially** (Figure 3-30).
6. **The adductor muscles are stacked vertically on each other, with the adductor longus most superficial.** The muscle in the middle is the adductor brevis, and the deepest and largest muscle is the adductor magnus (Figure 3-31).
7. **The anterior division of the obturator nerve is expected to lie within the plane between the adductor longus and the adductor brevis.** It may be seen as a hyperechoic structure lying within this fascial plane (see Figure 3-31).
8. **The posterior division of the obturator nerve is found in the plane between the adductor brevis and the adductor magnus.** It also appears as a hyperechoic structure within the fascial plane (see Figure 3-31).
9. **The nerves may be traced proximally and distally to help confirm that they are indeed continuous structures.**
10. **Using an in-plane approach, a 4-inch (10-cm) needle is directed from lateral to medial toward the posterior division first, followed by the anterior division of the obturator nerve** (Figure 3-32).
11. **If the nerves cannot be visualized, direct the needle toward the plane between the adductor brevis and adductor magnus first, then finally to the fascial plane between the adductor longus and adductor brevis muscles** (i.e., perform the deep injection first).

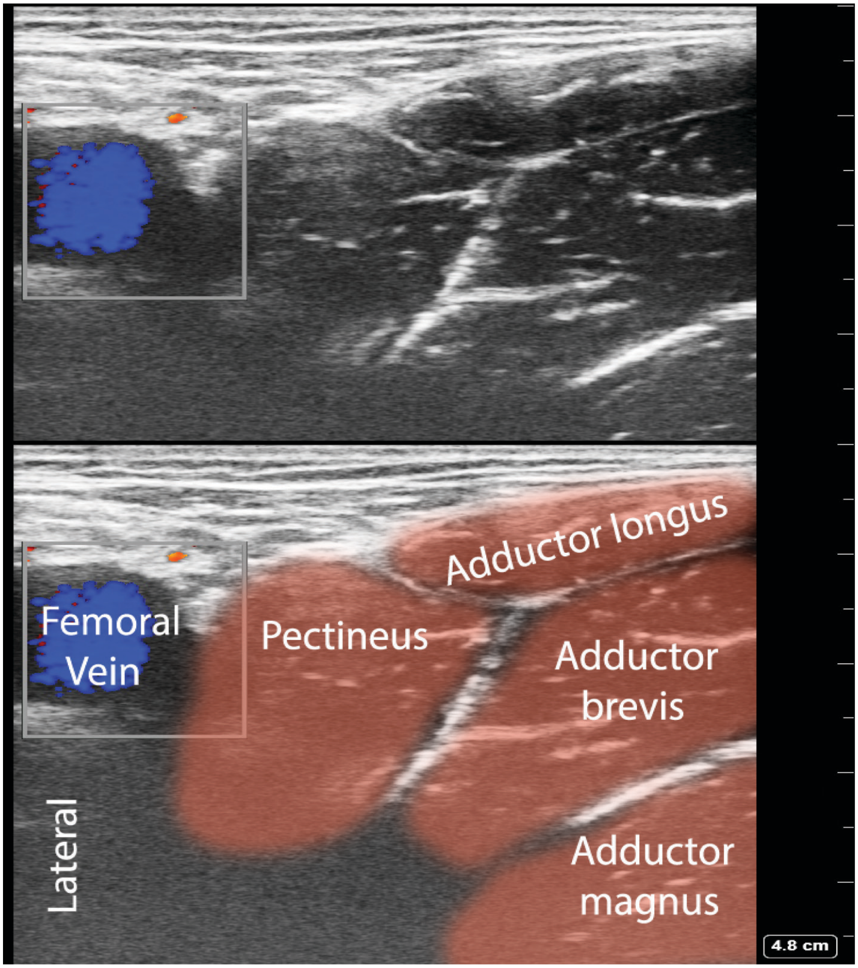


Figure 3-30 Ultrasound image of the pectineus muscle lying medial to the femoral vein. The pectineus muscle and the confluence of the adductor muscles are labeled.

12. **If the nerves cannot be identified, it is satisfactory to inject in the appropriate fascial planes.** Nerve stimulation may be used to help confirm the location of the nerve, but this is not necessary. Stimulation will result in adductor muscle contraction.
13. **Injection of 5 to 10 mL of local anesthetic around each nerve or in each plane is usually sufficient to achieve obturator blockade** (Figure 3-33).

Alternative Techniques

Alternative In-Plane Needle Approach

Position the patient and complete steps 1 through 5 as described for the standard scanning technique.

1. **Once the vein is identified, look medially for the pectineus muscle** (see Figure 3-30), which lies immediately medial to the vein.

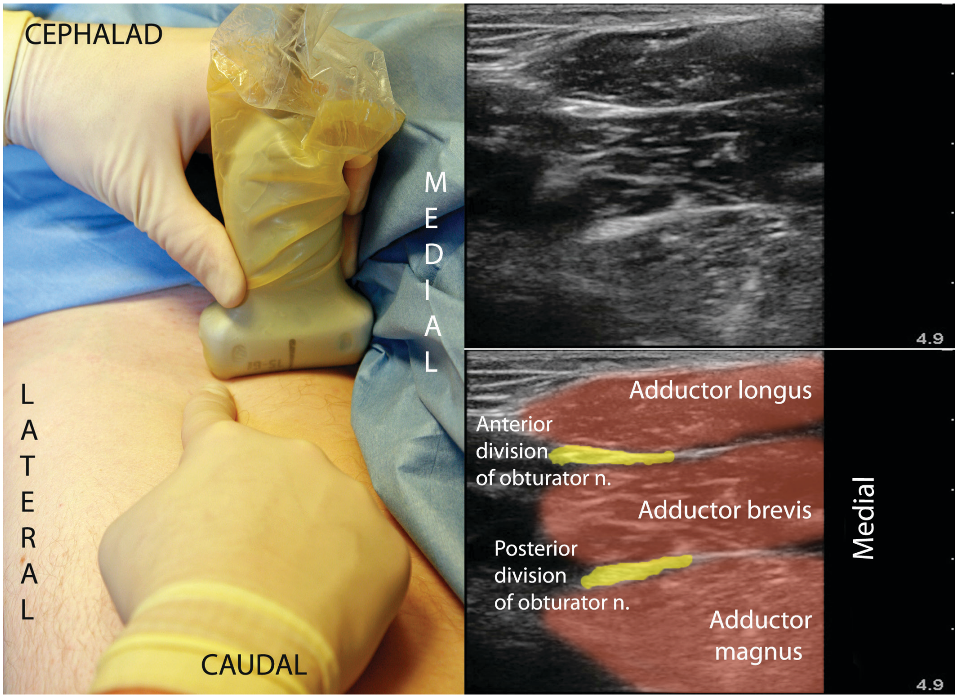


Figure 3-31 Image of the adductor muscles (labeled). This image is taken slightly more distally in the thigh than Figure 3-30. In this image, the anterior and posterior divisions of the obturator nerve are identified. n., nerve.

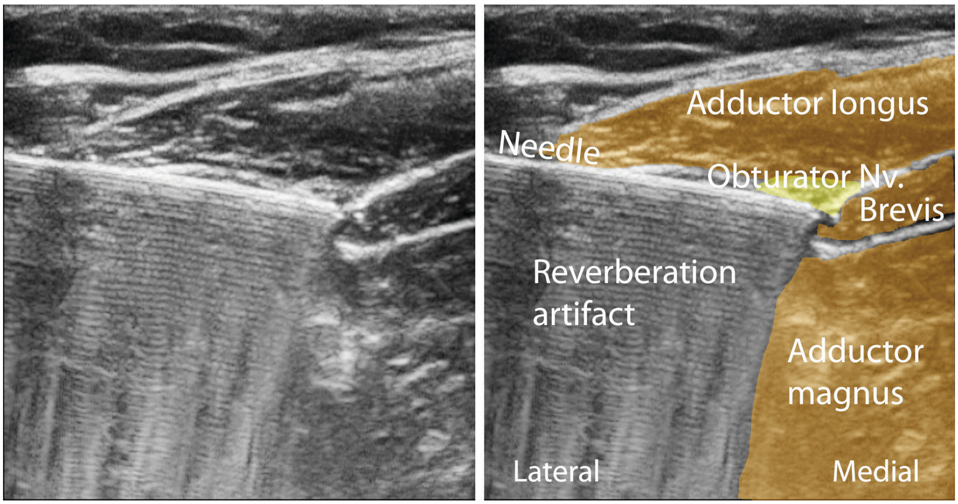


Figure 3-32 Needle approach for in-plane obturator nerve block. This needle is targeting the anterior division of the obturator nerve. The reverberation artifact obliterates the image beneath it. Nv., nerve.

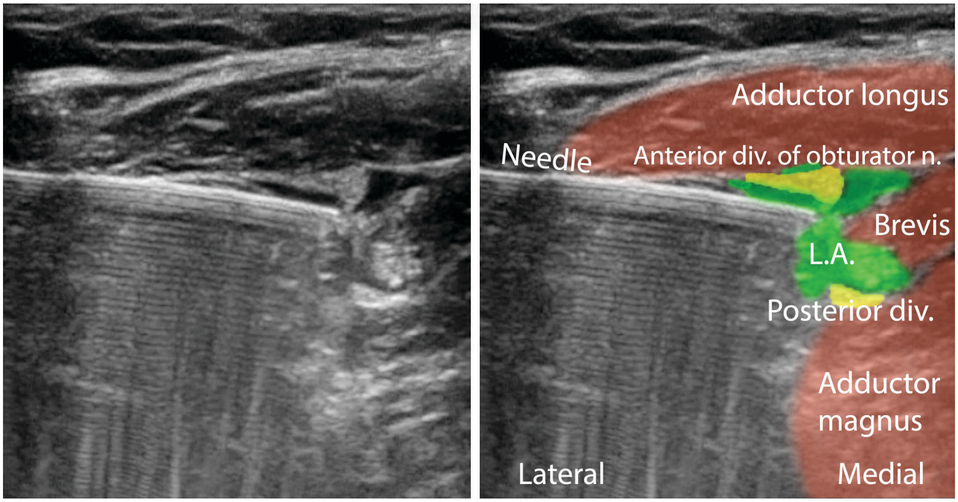


Figure 3-33 Needle injecting local anesthetic (L.A.) around both divisions of the obturator nerve.

2. **Move the probe over the center of the pectineus muscle, and rotate the probe 90 degrees.** The probe should now lie in the sagittal plane over the middle of the pectineus muscle (Figure 3-34).
3. **Slide the probe cephalad until the hyperechoic line of the superior pubic ramus is seen with the shadow of attenuation behind it.** The pectineus muscle should be seen inserting into the superior surface of the pubic ramus. This is usually occurs about 2 cm medial to the femoral vein.
4. **Identify the superficial and deep boundaries of the pectineus muscle. The obturator externus lies deep to the pectineus. These two muscles are separated by a thick fascial band, and within this fascial band lies the obturator nerve** (Figure 3-35). The nerve often cannot be identified. It splits into anterior and posterior divisions, and the split can be variable, occurring before or after the nerve exits the obturator foramen.
5. **Once the fascial layer deep to pectineus is identified, the needle is inserted in-plane from the caudad end of the ultrasound transducer, aiming cephalad.**

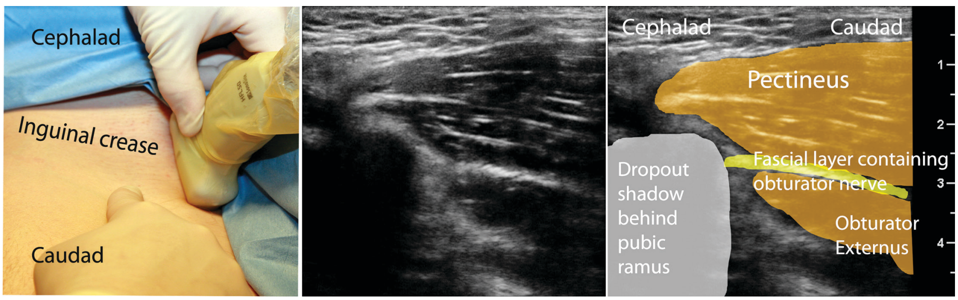


Figure 3-34 Probe position for performing the obturator nerve block with alternative technique. Once the femoral vein is identified (marked by the index finger in the left image), the probe is slid medially over the pectineus muscle and then rotated 90 degrees. The middle image shows the pectineus muscle inserting into the pubic ramus. The fascial plane containing the obturator nerve is identified underneath *(right image)*.

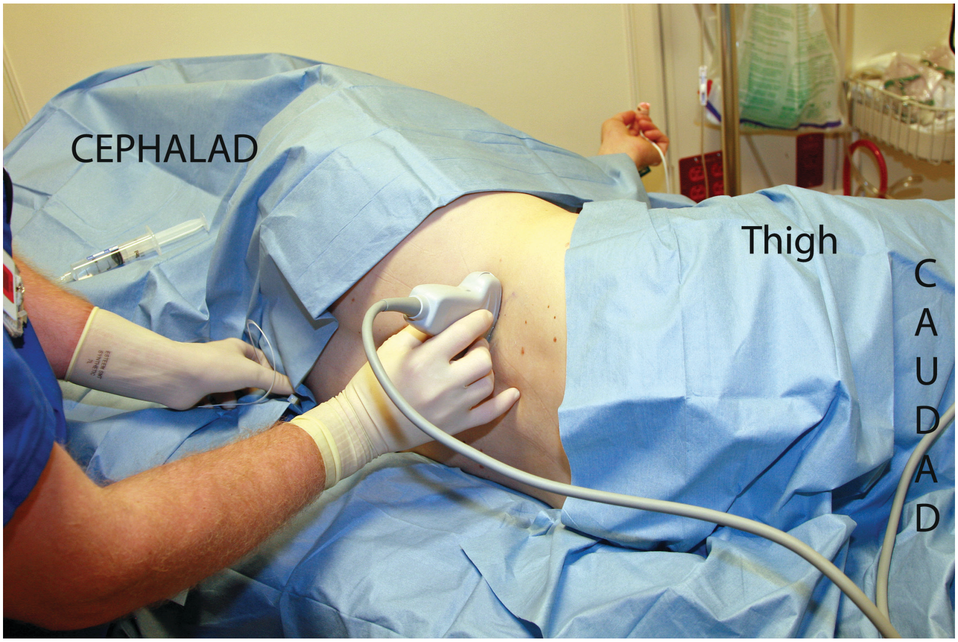


Figure 3-35 Patient and probe positioning for the posterior lumbar plexus nerve block.

6. **The final position for the needle is within the fascial layer deep to the pectineus muscle.**
7. **Inject local anesthetic after aspiration. Carefully inject 5-mL increments to a total of 10 to 15 mL.**

Alternative Out-of-Plane Needle Approach

An out-of-plane approach may be used with the needle perpendicular to the probe.

1. Follow steps 1 through 9 of the standard approach to identify the anterior and posterior divisions of the obturator nerve.
2. Insert a 50-mm (2-inch) needle perpendicular to the ultrasound transducer and beam.
3. Advance the needle to the deeper posterior branch first. If the nerve is not visualized, advance to the fascial plane between the adductor brevis and adductor magnus.
4. Inject 5 to 10 mL of local anesthetic around the nerve or between the fascial planes of the muscles.
5. Pull the needle back and redirect it toward the more superficial anterior division. If the nerve cannot be visualized, position the needle tip between the planes of the adductor longus and adductor brevis muscles.
6. Inject 5 to 10 mL of local anesthetic around the nerve or within the fascial plane.

Complications

Nerve injury, bleeding, and local anesthetic toxicity are risks involved with this block. With lateral to medial in-plane approaches, the femoral artery and vein must be identified to avoid puncture during needle insertion.

Pearls

- The obturator nerve block is often not necessary to provide adequate analgesia for knee surgery, but it can be a useful rescue block for patients who have had femoral and sciatic nerve blocks but are still experiencing significant pain in the distribution of the obturator nerve postoperatively.
- It is often easier to block the posterior division of the obturator nerve first, and injection of local anesthetic at this level does not greatly affect visualization of the anterior division. However, if the anterior branch is blocked first, injection of the local anesthetic may actually push the posterior division deeper, making it more difficult to visualize. If air is inadvertently injected, it may also obscure visualization of the deeper posterior division.
- With a lateral to medial needle approach, do not puncture the femoral artery or vein during needle insertion.
- If the nerves cannot be visualized well, it is important to see the spread of the local anesthetic within the fascial plane between the muscles and not directly within the muscles themselves.

Posterior Lumbar Plexus Block (Psoas Compartment Block)

The limits of current ultrasound technology and the relatively deep location of the lumbar plexus often make visualization of nerves of the lumbar plexus difficult. In pediatric patients and slim adults, visualization can readily be achieved. However, in obese patients, the depth of the lumbar plexus limits visualization significantly. For this reason, no single approach is suitable for patients of all sizes, and several approaches to the lumbar plexus are described here. The first technique, the paramedian transverse approach, is similar to the transverse abdominis plane (TAP) or quadratus lumborum blocks. The second technique, known as the shamrock technique, may be preferred if optimal needle visibility is desired. Because of limitations in imaging, especially in obese patients, real-time ultrasound-guided lumbar plexus blocks are not as widely used as many of the other ultrasound-guided techniques. However, by using the low-frequency probe, one can often visualize important surrounding structures, including the vertebral bodies, spinous processes, transverse processes, and kidney. These structures can provide a guide for appropriate needle insertion site selection and help in estimating the expected depth of the transverse process and lumbar plexus.

Anatomy

The lumbar plexus is formed from the ventral rami of the L1-4 nerve roots. The nerves emerge from the vertebral foramen and run anterior to the transverse processes of the lumbar vertebral bodies and into the posterior portion of the psoas muscle. The lumbar plexus block is the only technique that provides consistent blockade of the femoral, LFCN, and obturator nerves resulting in complete anesthesia or analgesia to the region of the lower extremity innervated by the lumbar plexus. Blockade of the ilioinguinal, iliohypogastric, and genitofemoral nerves—the more proximal branches of the lumbar plexus—is more variable with this technique.

Clinical Applications

When the psoas compartment block is used in conjunction with a sciatic nerve block, anesthesia and analgesia of the entire leg is achieved. The clinical applications of this block include surgery on the hip, anterior thigh, and knee. Because of its significant clinical utility, the posterior lumbar plexus block is heavily use in some practices, particularly for procedures involving the hip or knee. Although it is clear that a lumbar plexus block can be beneficial for patients undergoing surgery of the hip or knee, one must also be mindful of the risks and benefits associated with this block. The main benefit is complete coverage of the area innervated by the lumbar plexus. Risks associated with the lumbar plexus block include noncompressible bleeding, needle injury to the viscera or kidney, epidural spread and subsequent hypotension, increased pain or difficulty during block placement, and complete motor blockade of the hip flexors and quadriceps muscles.

Technique

Ultrasound Details

Monitors: ECG, NIBP, pulse oximeter.

Skin Preparation: Chlorhexidine with alcohol over the lower back. Ensure that the prep extends sufficiently lateral to cover the needle insertion site.

Probe: Low-frequency curvilinear probe (2-5 MHz); expected target depth, greater than 6 cm. A high-frequency linear ultrasound probe will not provide enough penetration.

Patient Position: The patient is positioned with the operative side up in the lateral decubitus position with a slight forward rotation. The hips and knees are flexed, and the leg on the side to be blocked should be easily visible so that twitches of the quadriceps and the resulting patellar tendon snap can be easily observed (see Figure 3-35).

Local Anesthetic Choice: Usually, 30 mL of local anesthetic is required. This is a compartment block, and local anesthetic needs to spread within the psoas muscle. As always, be cautious about the potential for toxicity from intravascular injection or absorption.

Needle: 100-mm (4-inch), short-bevel nerve block needle. Occasionally, a 6-inch needle may be necessary.

Technique 1: Paramedian Transverse–Intertransverse Space Approach

Use this technique if you already have experience with TAP or quadratus lumborum blocks. This technique also has a bony backstop (vertebral body) to help prevent needle overadvancement.

1. **Start with the probe in a paramedian plane, immediately lateral to midline. Identify the facet joints or articular processes as bright echogenic reflections.**

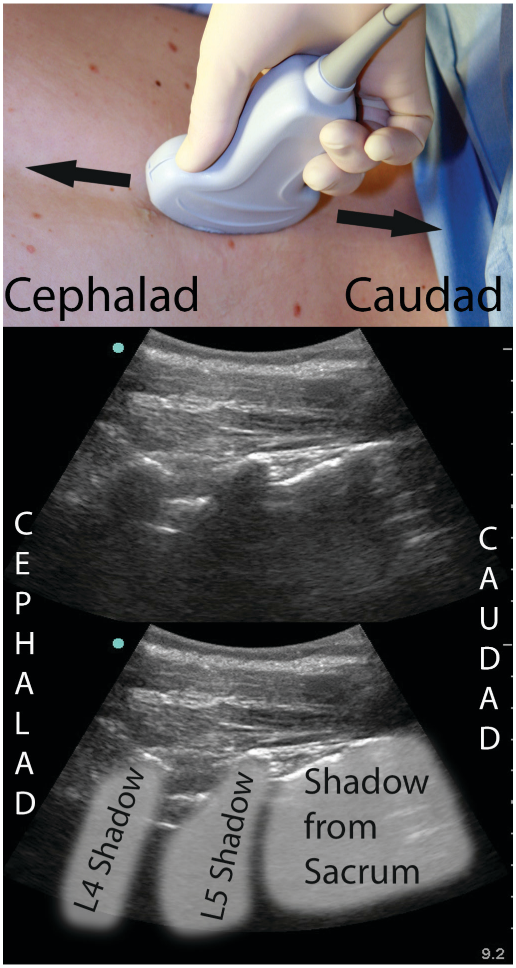


Figure 3-36 Lumbar Plexus Block, Step 1: Place the probe in a paramedian orientation, a few centimeters away from midline toward the side to be blocked. Find the facet joints and the shadow beneath them. Slide down to the sacrum (continuous hyperechoic line), and then count the vertebral levels cephalad until the L4 level is identified.

These will appear as raised echogenic bumps. Count the levels down to the sacrum, and then count back up to L4 (Figure 3-36).

2. **At L4, rotate the probe 90 degrees to a transverse position.**
3. **With the transverse process visible, slide the probe laterally for a wide paramedian image.** The objective is to place the vertebral body at the side of the screen and have the transverse process with the psoas muscle in the center of the image. The psoas muscle may be shadowed by the transverse process. The hyperechoic reflection of the transverse process will shadow the image deep to it, and the image will appear black (Figure 3-37).
4. **In this transverse view, slide the probe caudad or cephalad.** The objective is to place the probe between the transverse processes of L3-4 or L4-5. As the probe is slid

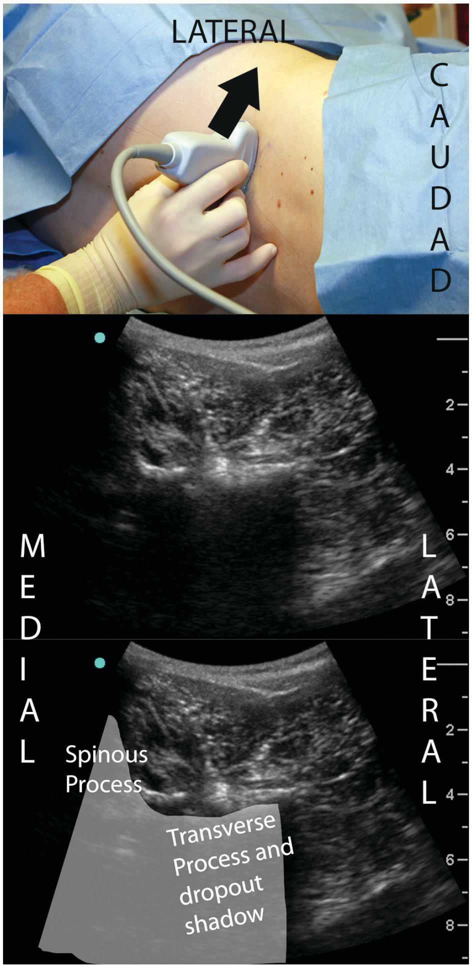


Figure 3-37 Lumbar Plexus Block, Step 2: Once the L4 facet joint has been located, slide the transducer a few centimeters laterally *(top)*. Identify the transverse process and the ultrasound shadow beneath *(bottom)*.

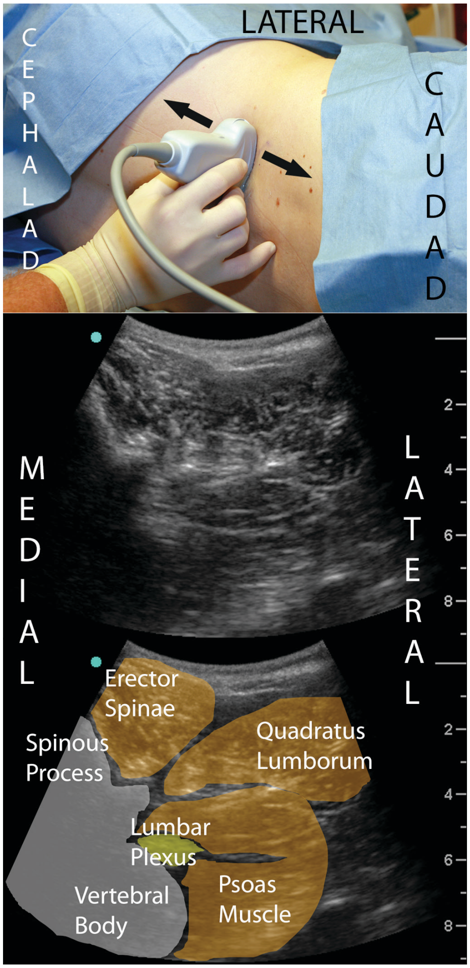


Figure 3-38 Lumbar Plexus Block, Step 3: Slide the probe in a caudad or cephalad direction to identify an intertransverse space *(top)*. These spaces between the transverse processes will allow imaging of the deeper psoas muscle. The lumbar plexus is located within the psoas muscle.

cephalad off the transverse process, the psoas muscle is seen deep to the level of the transverse process. Other muscles that appear are the quadratus lumborum laterally and the erector spinae muscles posteriorly (Figure 3-38).

5. **It is often possible to identify the lumbar plexus within the psoas muscle.** The lumbar plexus appears as a white, hyperechoic region within the muscle. The nerve root can often be identified more medially, at the edge of the vertebral body (see Figure 3-38).
6. **The needle entry point starts lateral to the probe, in-plane, and aims medially.** With a lateral insertion, the needle runs through the quadratus lumborum into the psoas muscle itself. The combination of ultrasound guidance and nerve stimulation assists in placement of the local anesthetic.
7. **The twitch that should be obtained is a patellar snap of the patellar tendon.** An adductor twitch (obturator) suggests that the needle position is too medial. A hamstring twitch (sciatic) suggests that the needle position is too caudal (Figure 3-39).

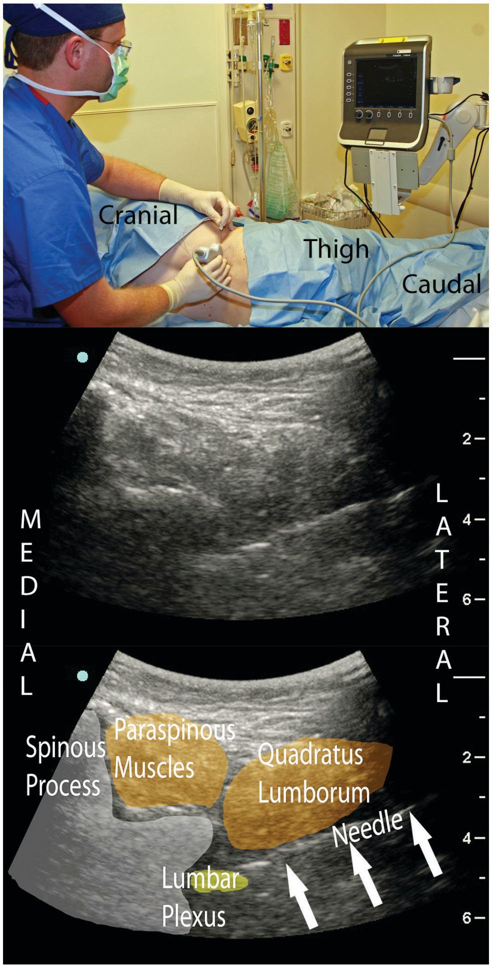


Figure 3-39 The needle is inserted in-plane from lateral to medial *(top)*. Target the hyperechoic lumbar plexus within the psoas muscle *(bottom)*. The arrows show the location of the needle.

8. **Slow injection of local anesthetic, with careful aspiration after the injection of every 5 mL, is important.** Observation of local anesthetic spreading in the psoas muscle is a key safety feature.
9. **If the needle is positioned on the identified target and no twitch is obtained, partially withdraw the needle and readvance it in-plane with the ultrasound beam, slightly shallower or slightly deeper**. If no twitches are obtained after several passes in the plane of the ultrasound, slide the probe either cephalad or caudad, searching for another target within the psoas muscle.

Technique 2: Shamrock Method

A second feasible approach to the lumbar plexus under real-time ultrasound guidance uses a needle advancement that is perpendicular to the ultrasound beam, resulting in good needle visualization as it is advanced to the target. Use this technique if you have prior experience with lumbar plexus blocks guided by nerve stimulation only, because the needle is advanced in a similar direction. Although the needle may be brighter when it is actually in-plane with the ultrasound beam, obtaining good visualization of the target structures can be problematic because of the depth of the target and the close proximity of the iliac crest to the transducer.

1. **Start with the patient in the same lateral decubitus position as described for the paramedian transverse–intertransverse space approach** (see Figure 3-35).
2. **Place the probe in a transverse plane on the patient's flank immediately cephalad to the iliac crest** (Figure 3-40). If the iliac crest (caudal) and the rib cage (cephalad) make uninhibited probe movements difficult, consider placing a folded towel under the contralateral side, on the bed, to open the space between the rib cage and the iliac crest.
3. **The ultrasound image should demonstrate the muscles of the abdominal wall superficially.** The probe is moved posteriorly until the quadratus lumborum is identified.

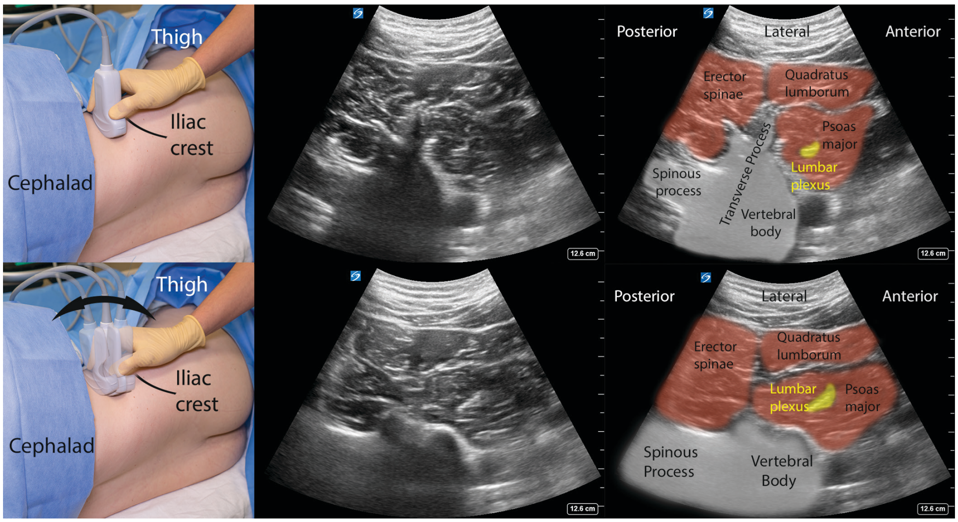


Figure 3-40 Shamrock lumbar plexus approach. Start by placing the transducer in a transverse plane, just above the pelvis. Slide the probe anterior and posterior to best image the transverse process, quadratus lumborum, psoas, and erector spinae *(top)*. Next, tilt the transducer to find an intertransverse space (where the transverse process disappears), which will allow needle advancement in-plane from anterior to posterior *(bottom)*.

4. **Sliding or tilting the probe in a cranial-to-caudal direction should reveal the transverse process of L4**.
5. **The position of the erector spinae muscles (posterior), the quadratus lumborum (lateral), and the psoas muscle (anterior) in relation to the transverse process of L4 should visually appear like the leaves of a shamrock (cloverleaf)** (see Figure 3-40).
6. **The probe can be tilted in a cephalad-to-caudad direction with the goal of making the transverse process of L4 disappear**.
7. **The view between transverse processes permits needle visualization and a clear view of the psoas muscle and the lumbar plexus contained within** (see Figure 3-40, *bottom*).

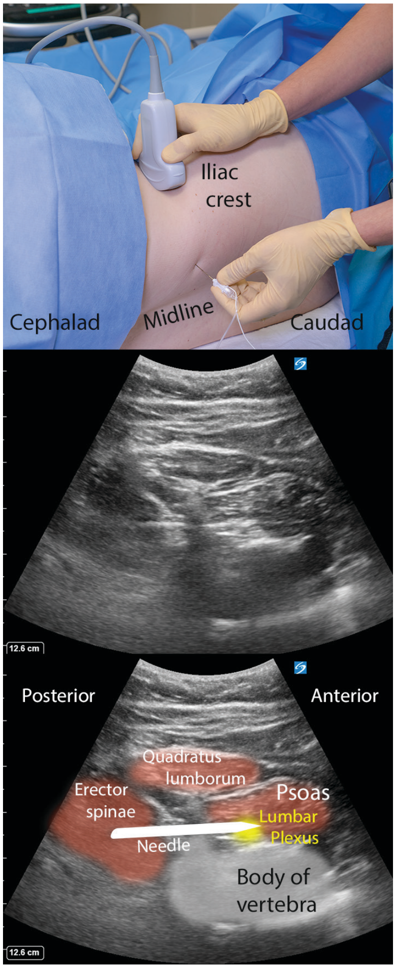


Figure 3-41 Shamrock lumbar plexus approach with needle position. The needle is advanced from anterior to posterior, about 4 to 5 cm away from midline *(top)*. This needle advancement should be 90 degrees perpendicular to the ultrasound beam. Aim for the hyperechoic lumbar plexus found within the psoas muscle *(bottom)*. Use nerve stimulation to confirm correct needle tip location.

8. **The needle is inserted approximately 4 to 5 cm from the midline in a paramedian plane** (Figure 3-41).
9. **The end point of needle advancement is a quadriceps twitch of the patellar tendon, which should disappear when local anesthetic is injected. Spread of anesthetic should be seen within the psoas muscle on the ultrasound image.**

Alternative Techniques

Preprocedure Scan and Identification of Landmarks

In obese patients with very deep structures and in those in whom imaging is difficult, a lot of valuable information can be obtained from the use of ultrasound. The midline (Figure 3-42), the transverse process of L4, and its depth from the skin can all be identified. Once these points are marked on the skin, the ultrasound probe can be put away and a traditional nerve stimulator–guided posterior lumbar plexus block can be performed.

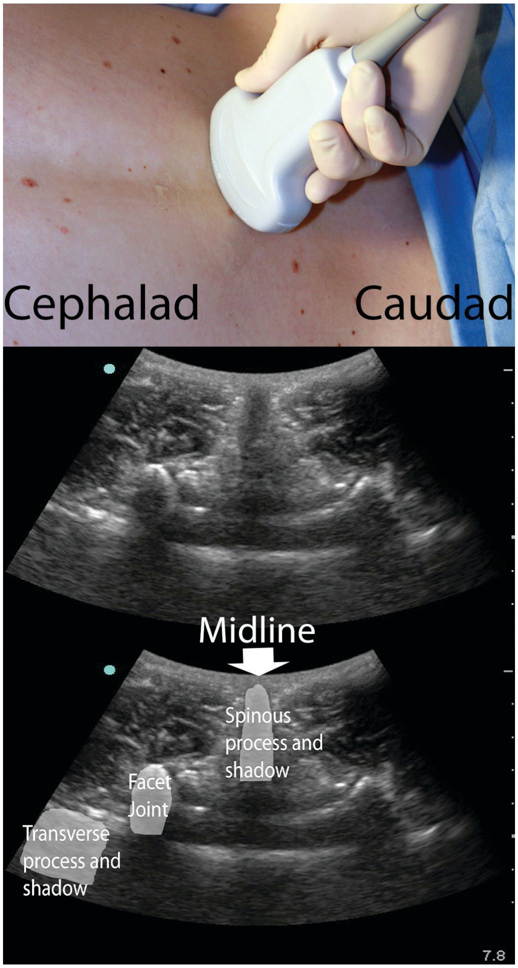


Figure 3-42 The probe is placed transversely in the midline *(top)*. The corresponding ultrasound image demonstrates the anatomy of the lumbar vertebrae *(bottom)*.

In-Plane Parasagittal Approach

Instead of the lateral-to-medial approach described earlier (see "Paramedian Transverse–Intertransverse Space Approach"), it is possible to advance the needle in a paramedian plane under direct ultrasound guidance in a cephalad-to-caudad direction.

1. Complete step 1 of the paramedian transverse–intertransverse space approach to find L4. In this paramedian view, the transverse processes are seen in cross section and appear as bright echoes with dropout shadows beneath them. The psoas muscle can be seen between the transverse process shadows (Figure 3-43).
2. With the probe in the paramedian position and transverse processes in view, advance the needle from the caudad end of the probe. The plexus is occasionally visible as a bright hyperechoic structure within the psoas muscle.

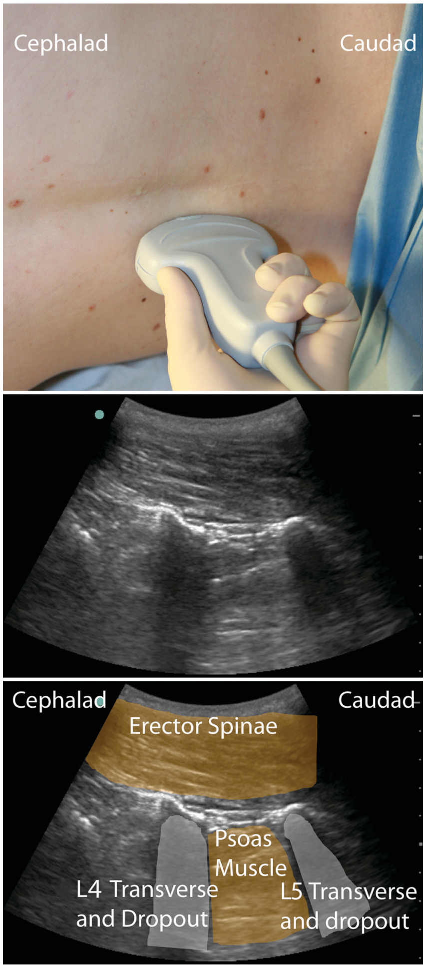


Figure 3-43 The parasagittal scan of the transverse processes of L4 and L5. Place the ultrasound probe lateral to the midline, parallel to the spine. The psoas muscle can be visualized in the acoustic window between the transverse processes. The needle can be advanced in-plane to identify the lumbar plexus within the psoas muscle.

3. The needle is advanced until it enters the psoas muscle. A nerve stimulator can be attached to aid identification of the lumbar plexus. The injection technique is identical to that described earlier.

Catheters

Stimulating or nonstimulating catheters may be placed via a Tuohy needle. The catheter should be advanced several centimeters past the tip of the needle.

Complications

There is a lack of mainstream enthusiasm for the lumbar plexus block, probably because it is a deep block that is technically more challenging to perform than many of the other peripheral nerve blocks. In the average patient, it may indeed be more difficult to perform a real-time ultrasound-guided lumbar plexus block. Therefore, the lumbar plexus block is a technique that should be employed only after one has gained appropriate training and experience with more basic nerve blocks.

Because of the deep needle placement into the body of the psoas muscle, there is a risk for vascular puncture and hematoma. There have been case reports of large retroperitoneal hematomas with this block. The bleeding risk is further amplified by the deep, noncompressible location of the plexus; the close proximity to the spinal cord; and aggressive prophylaxis against venous thromboembolism. Larger volumes of local anesthetic are typically used, and this, in combination with the vascularity of the area, increases the potential for local anesthetic systemic toxicity. The close relationship of the roots of the lumbar plexus to the epidural space and the extension of dural sleeves out along the nerve roots lead to a risk of epidural or subarachnoid spread of local anesthetic. Spread of local anesthetic to the epidural space occurs in up to 15% of patients. Epidural spread results in predictable bilateral lower extremity motor and sensory block and sympathectomy with resultant hypotension. These risks necessitate careful selection of the patient, the local anesthetic dose, and the location of injection for lumbar plexus blocks.

Pearls

- Good patient positioning improves the ease of the procedure. Ensure that the spine is properly aligned and not overrotated.
- For the Shamrock method, widen the space between the iliac crest and the ribcage by placing a pillow or towel roll under the contralateral side, between the bed and the patient.
- No matter what approach is used, be patient. Often, needles are advanced to the identified target but no twitch is obtained with stimulation. Make several passes very near the intended target to determine whether a patellar twitch can be elicited before moving to an alternative target.
- Appropriate sedation is necessary, because this procedure can be uncomfortable. Needle contact with the periosteum, needle passage through muscles, and nerve stimulation can all be uncomfortable for the patient. Sedation is best started after the patient has been positioned but before the anatomic landmarks are marked.
- If hamstring twitches are obtained, the needle is in contact with the sacral plexus. The needle should be withdrawn and angled more lateral or more cephalad to target the lumbar plexus.
- The presence of muscle stimulation after injection of the local anesthetic likely represents intravascular injection or misplacement of the needle tip within a dural sleeve. The injection should be stopped and the needle repositioned.
- Avoid fast injection of local anesthetic or injection under high pressure, both of which have been associated with nerve injury and epidural spread of local anesthetic.

Sciatic Nerve Block

Despite being the largest nerve in the body, the proximal sciatic nerve can be challenging to locate and block. Several approaches to the sciatic nerve are described in this and the following sections, and the nerve may be blocked wherever the best ultrasound image can be obtained.

Anatomy

The sciatic nerve is formed by the ventral rami of the L4-S3 nerve roots. These roots begin to merge on the anterior surface of the lateral sacrum and come together to form the sciatic nerve on the anterior surface of the piriformis muscle. The sciatic nerve is the main terminal branch of the sacral plexus. It is the largest nerve in the human body, approximately the size of the thumb at its origin. Shortly after its formation, the sciatic nerve exits the pelvis through the sciatic foramen, then gives rise to the posterior cutaneous nerve of the thigh. The main component of the nerve then descends between the greater trochanter of the femur and the ischial tuberosity. Descending deep to the biceps femoris, the nerve splits to form the tibial nerve and the common peroneal nerve several centimeters above the popliteal crease. The sciatic nerve also gives off various articular and muscular branches along its course (Figure 3-44).

Clinical Applications

A sciatic nerve block provides anesthesia and analgesia to the posterior thigh and knee and most of the lower leg, ankle, and foot. The sciatic nerve can be blocked at a variety of locations, both proximally and distally. Ultrasound guidance can be used to block the sciatic nerve proximally from a posterior approach at the gluteal or subgluteal level or from an anterior approach in the proximal thigh. More distally, the sciatic nerve may be blocked in the popliteal fossa near its division into the common peroneal and tibial nerves. Proximal sciatic nerve blocks are often used in conjunction with the femoral nerve block to provide analgesia in a posterior distribution for surgery on the knee (e.g., anterior cruciate ligament repair, total knee arthroplasty).

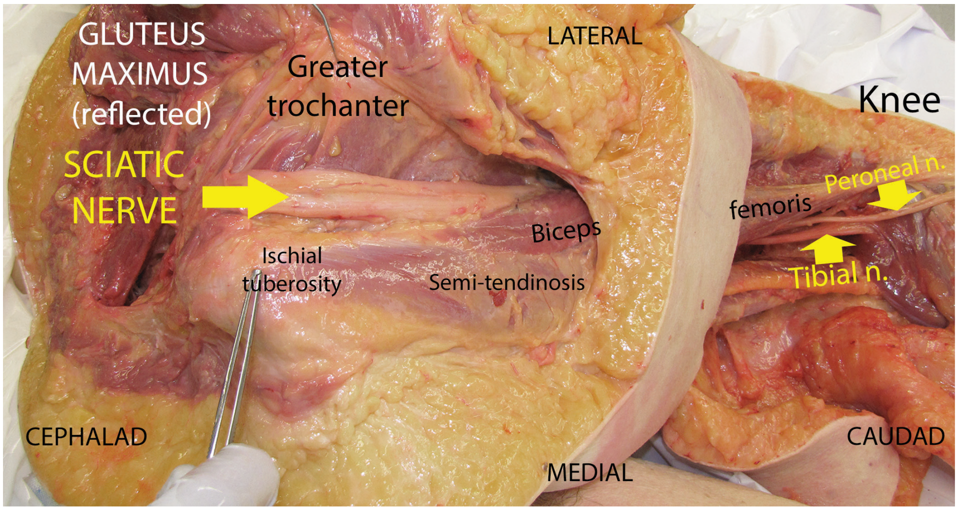


Figure 3-44 Dissection of the posterior aspect of the leg from the gluteal region to the popliteal region at the back of the knee. n., nerve.

Technique

The *proximal sciatic approach* is described first.

Ultrasound Details

Monitors: ECG, NIBP, pulse oximeter, and additional monitors as deemed necessary.

Skin Preparation: Chlorhexidine with alcohol.

Probe: Low-frequency curvilinear probe (2-5 MHz).

Patient Position: Lateral decubitus.

Local Anesthetic Choice: Depends on the surgical indication. For long-lasting nerve blocks, use ropivacaine 0.5% or bupivacaine 0.5%. For short-duration blocks (e.g. ambulatory patients), mepivacaine or lidocaine may be employed.

Needle: 100-mm (4-inch), short-bevel nerve block needle or Tuohy needle for catheter placement.

Scanning Technique

1. **Place a low-frequency ultrasound probe transversely over the posterior thigh to identify the femur** (Figure 3-45).
2. **Slide the probe proximally up the femur to the greater trochanter** (see Figure 3-45).
3. **Slide the probe medially off the greater trochanter to place the gluteus maximus in the center of the image**. At this point, the greater trochanter should be at the edge of the screen.

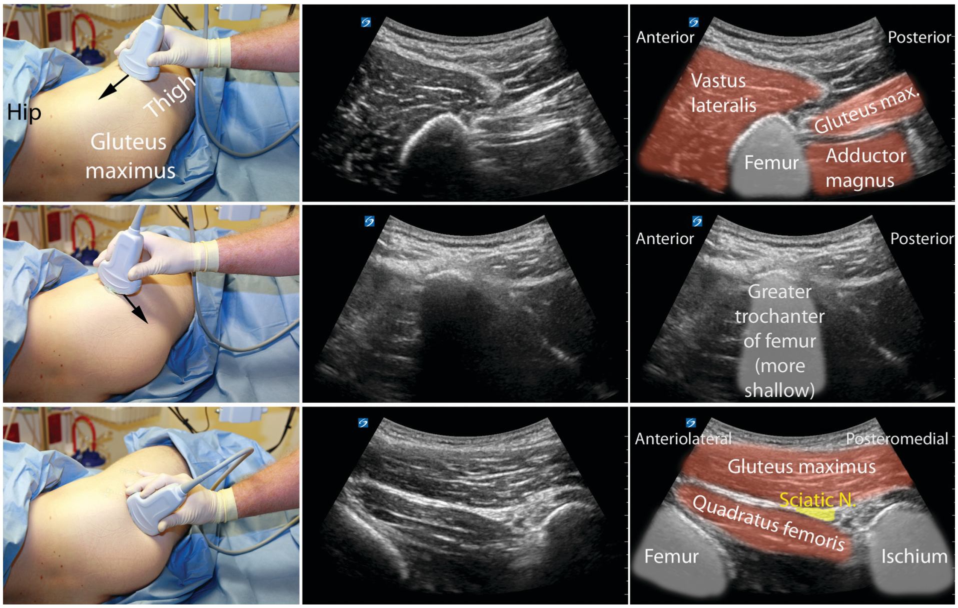


Figure 3-45 Identifying the sciatic nerve at the subgluteal region. First, place the transducer on the lateral leg and identify the hyperechoic femur (top). Next, slide the transducer cephalad until the greater trochanter is identified (middle). The greater trochanter will be shallower than the shaft of the femur. Finally, slide the transducer medially over the gluteus maxiumus (bottom). The nerve is located deep to the gluteus maximus and between the bony femur and ischial tuberosity.

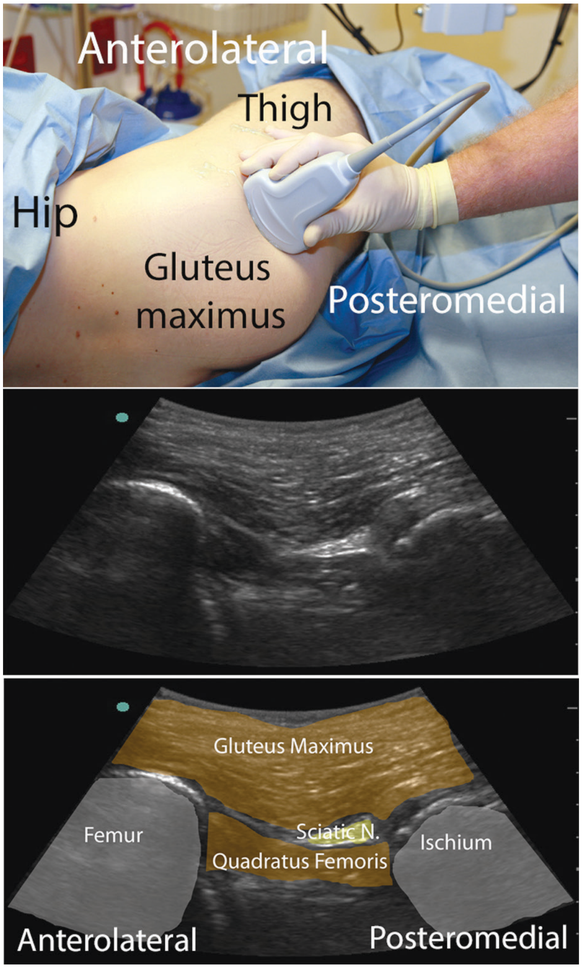


Figure 3-46 Probe position and ultrasound image for a proximal sciatic block at the subgluteal level.

4. **The sciatic nerve lies deep to the gluteus maximus and superficial to the quadratus femoris muscle.** It appears as a hyperechoic oval or triangular-shaped density (see Figure 3-46).
5. **If the nerve is not immediately visible, scan more distally in the thigh looking beneath the gluteus maximus and biceps femoris for the hyperechoic nerve. Use a tilting motion of the probe to improve nerve visibility** (Figure 3-47).
6. **Distally in the upper thigh, the sciatic nerve can be found between the biceps femoris and the adductor magnus.** Here, the nerve will be more shallow (and many times easier to image) and will be located just a few centimeters distal to the gluteal fold (Figure 3-47).
7. In **the upper or middle thigh, a good marker for the depth of the sciatic nerve is the femur.** Start the probe on the lateral side of the leg to identify the femur. Then, slide the probe posteriorly around the back of the thigh. The nerve at this level will likely be found at approximately same depth as the femur (Figure 3-48).
8. **The needle should be inserted in-plane from lateral to medial.**

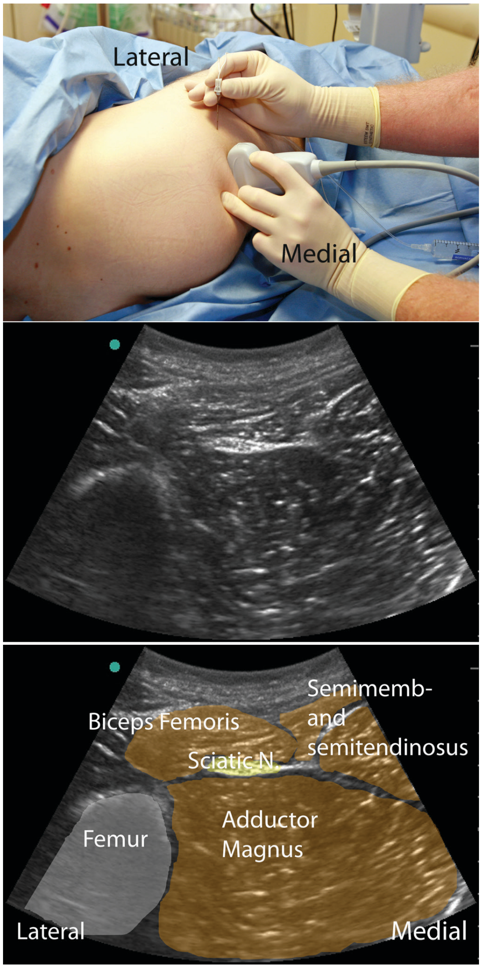


Figure 3-47 Needle insertion site and shallow location of the sciatic nerve distal to the gluteal crease.

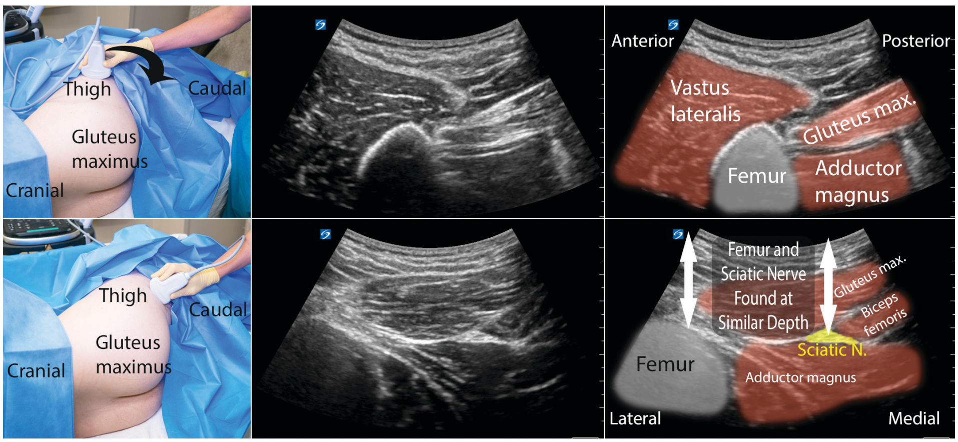


Figure 3-48 Identification of the sciatic nerve in the midthigh or proximal thigh can be aided by first identifying the depth of the femur *(top images)*. Slide the probe around the posterior aspect of the thigh. The sciatic nerve should be found at a similar depth as the femur *(bottom images)*.

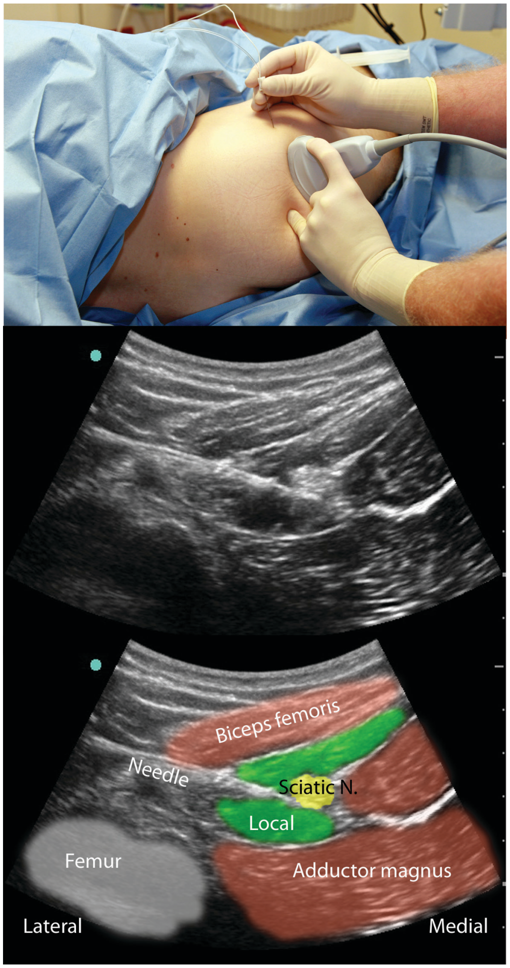


Figure 3-49 Advance the needle from lateral to medial. Aim underneath the nerve to ensure adequate penetration through the surrounding fascia.

9. **The target needle tip position should initially be lateral and just deep to the nerve**. Inject local anesthetic and observe the spread across the posterior aspect of the nerve (Figure 3-49).
10. **The needle can be slowly withdrawn into the fascial plane containing the nerve. Then, redirect the needle medially to inject around the tibial portion of the sciatic nerve.** The tibial portion of the nerve is larger, so nerve blocks tend to be more complete if the medial (tibial) portion is surrounded with local anesthetic (Figure 3-50).

Alternative Techniques

The most proximal approach to the sciatic nerve is a *parasacral approach*. This is very difficult in obese patients, and there is no bony backstop to prevent needle entry into the pelvis.

1. Place the patient in the lateral decubitus position with the lower leg straight and the upper, blocked leg bent (Figure 3-51).

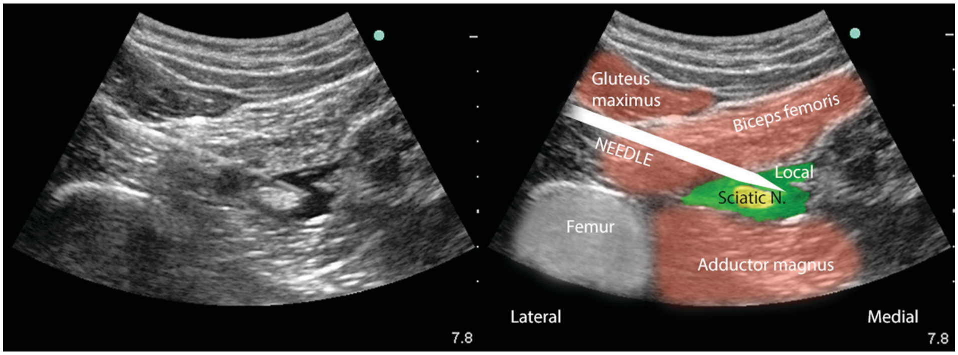


Figure 3-50 To ensure the highest chance of success, advance the needle toward the medial side of the sciatic nerve and deposit the majority of local anesthetic on that side.

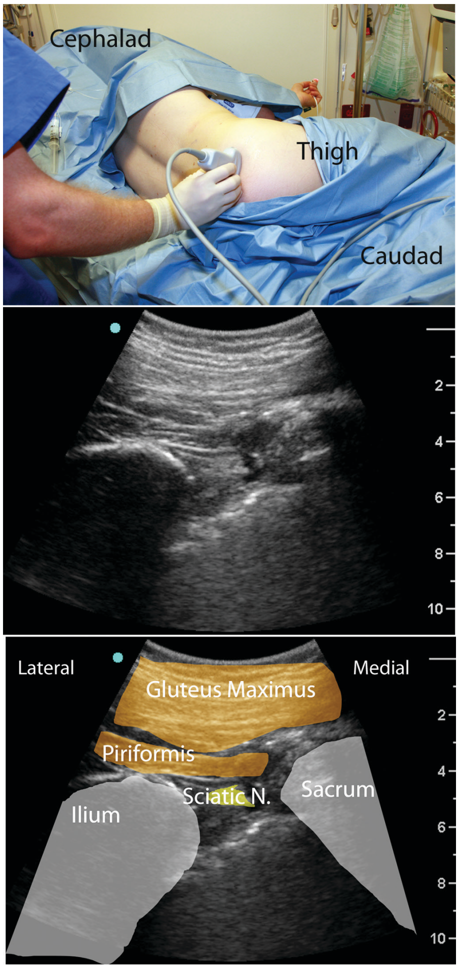


Figure 3-51 Probe position and ultrasound anatomy for the parasacral sciatic block. Ultrasound landmarks are the ilium and the sacrum. Identify the sciatic nerve deep to the gluteus maximus and piriformis muscles.

2. Place the probe cephalad to the greater trochanter in a transverse plane, and slide it medially (see Figure 3-51).
3. Beneath the probe, the hyperechoic reflection of the ilium is visible. Medial to the ilium is a gap and a hypoechoic area, the greater sciatic foramen. Medial to this foramen is the sacrum.
4. The sciatic nerve lies in the gap between the ilium and the sacrum, usually underneath the piriformis muscle. The sciatic nerve appears as an oval, hyperechoic structure.
5. Advance the needle from lateral to medial, and inject local anesthetic around the nerve.
6. The danger of this block is that the interior of the pelvis and all its viscera and vessels are deep to the sciatic nerve.

Catheters

A sciatic nerve continuous catheter can be used to provide extended analgesia after surgeries on the lower leg, ankle, and foot. A disadvantage of the gluteal approach, as opposed to the popliteal approach, for surgeries below the knee is that there will likely be some degree of motor block of the hamstrings with the gluteal approach, making ambulation more difficult. This increases the risk for falls. However, proximal sciatic catheters, however, may be used as an adjunct to femoral nerve catheters for complex surgeries on the knee or amputations of the lower extremity. For better efficacy, catheters should be left on the medial side of the sciatic nerve (near the tibial component), because this is the larger component of the nerve. See Chapter 1 for a detailed discussion of peripheral nerve catheter insertion.

Pearls

- It is often a humbling experience to identify and block the proximal sciatic nerve, even for experts. Scanning proximally and distally along the course of the nerve helps confirm the proper structure. The nerve is shallowest and often most visible 5 to 10 cm distal to the gluteal fold (skin crease).
- Spread of local anesthetic around the medial (tibial) component of the sciatic nerve is critical for success of the block. Final placement of a continuous catheter on the medial side of the nerve also improves success.
- Identification of the nearby vessels is sometimes helpful in determining the location of the sciatic nerve and avoiding vascular puncture. The inferior gluteal artery is found medial to the nerve at the subgluteal level.
- If the posterior cutaneous nerve of the thigh needs to be blocked, ensure good medial spread around the sciatic nerve when performing a proximal sciatic nerve block.
- Insert the needle a few centimeters away from the edge of the probe to allow for a shallower needle–probe angle and better needle visualization. However, if the needle is started too far laterally, the femur can interfere with the needle path to the nerve.
- The sites available for sciatic nerve blockage occur on a continuum, and with the use of ultrasound, local anesthetic can be placed anywhere along the nerve pathway from the popliteal fossa to the greater sciatic foramen. Try to choose a block site where a tourniquet will not be placed over the nerve.
- To help confirm that a potential target is the sciatic nerve, attempt to trace it with the ultrasound probe along its course down the leg into the popliteal fossa. Nerves will be continuous, whereas other structures (e.g., fascial planes, tendons) will disappear.
- The sciatic nerve is difficult to image if the ultrasound transducer is not at the correct angle to get the ultrasound beam to reflect off the nerve. To improve imaging of this nerve, tilt the ultrasound probe slightly back and forth in a cephalad-to-caudad direction.

Anterior Sciatic Nerve Block

The anterior sciatic nerve block using ultrasound is an advanced technique because of the depth of the nerve in the upper thigh. As in the posterior approach, identification of the anterior sciatic nerve can be difficult. The major benefit of the anterior approach is the ability to block the sciatic nerve without turning the patient lateral or prone.

Anatomy

The sciatic nerve descends in the thigh medial to the femur, between the adductor muscles anteriorly and the biceps femoris posteriorly. When imaged with ultrasound from the anterior thigh, the nerve will usually be located a few centimeters deeper than and medial to the hyperechoic femur. The superficial femoral artery and vein and the profunda femoral artery and vein are located superficial to the nerve and should also be recognized before needle insertion.

Clinical Applications

A sciatic nerve block from the anterior approach provides anesthesia and analgesia to the knee, the majority of the lower leg, ankle, and foot. The sciatic nerve can be blocked at a variety of locations, both proximally and distally (see "Sciatic Nerve Block" and "Popliteal Sciatic Nerve Block"). Clinically, the main benefit of an anterior sciatic nerve block is that it blocks most of the knee and leg without the need to turn the patient lateral or prone. The anterior sciatic nerve block can be performed in conjunction with the femoral block on a supine patient with a similar skin preparation site (within a few centimeters).

Technique

Ultrasound Details

Monitors: ECG, NIBP, pulse oximeter, and additional monitors as deemed necessary.

Skin Preparation: Chlorhexidine with alcohol.

Probe: Low-frequency curvilinear probe (2-5 MHz); expected depth in 80-kg patient, 6 to 8 cm.

Patient Position: Supine, with the operative leg in frog-leg position (with external rotation and a bent knee).

Local Anesthetic Choice: Depends on the surgical indication. For long-lasting nerve blocks, ropivacaine 0.5% or bupivacaine 0.5% is used. For short-duration blocks (e.g., ambulatory patient), mepivacaine or lidocaine may be employed.

Needle: 100-mm (4 inch) or 150-mm (6 inch) short-bevel nerve block needle or Tuohy needle for catheter placement.

Scanning Technique

1. **Place the patient supine with the leg externally rotated and bent at about 90 degrees** (Figure 3-52).
2. **Place a low-frequency ultrasound probe transversely over the medial thigh to identify the femur, approximately 5 to 10 cm distal to the inguinal crease.** The femur appears as a hyperechoic half-circle (see Figure 3-52).
3. **Slide the probe medially from the femur to visualize the muscles of the medial leg**.
4. **Identify the adductor muscles inserting on the medial femur.** Usually, this is the adductor magnus. Deep to the adductor magnus, one should find the hyperechoic sciatic

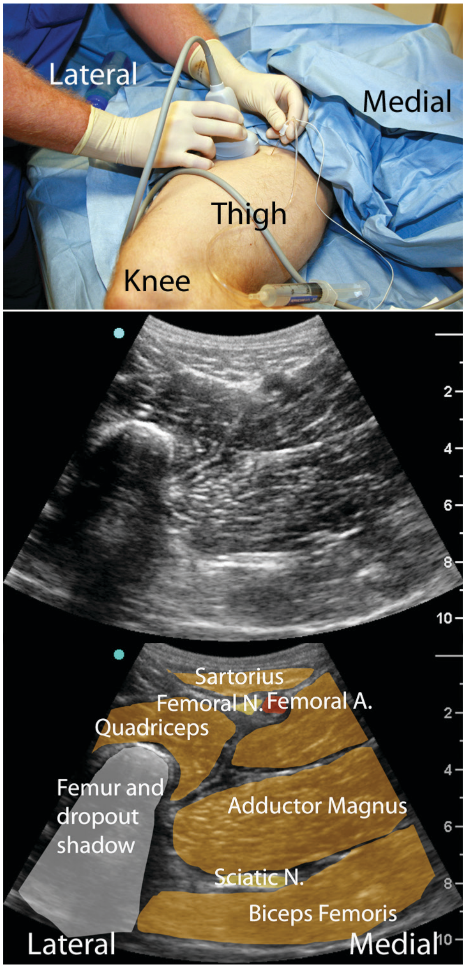


Figure 3-52 Probe position and ultrasound anatomy for the anterior sciatic nerve block. The sciatic nerve is identified between the adductor magnus muscle and the hamstrings. A., artery; N., nerve.

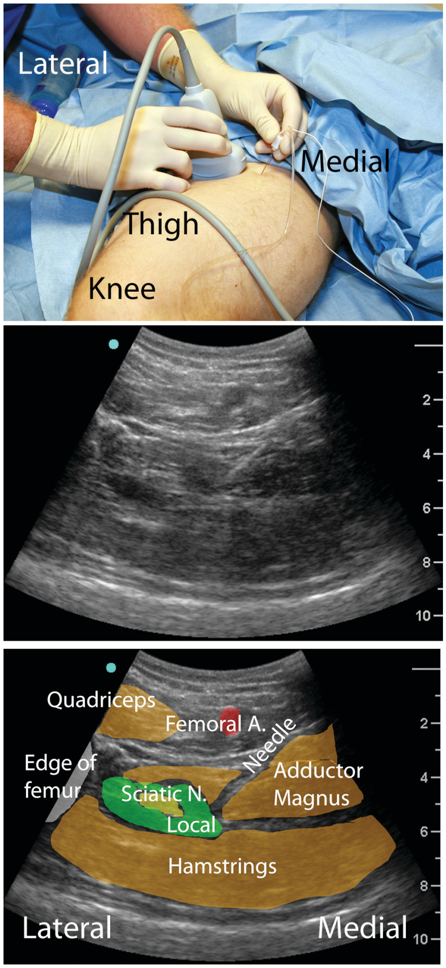


Figure 3-53 Anterior sciatic nerve block. The needle is advanced from medial to lateral. Target the medial side of the sciatic nerve with the injection. The femoral artery and nerve are imaged superficially. Care must be taken to avoid these structures during needle insertion.

nerve, which is approximately 1 cm in width at this level. Deep (posterior) to the sciatic nerve is one of the hamstring muscles, the biceps femoris (see Figure 3-52).

5. **A good marker for nerve depth is the femur.** The sciatic nerve should be a little deeper than the top of the femur at this level.
6. **If the nerve is not immediately visible, tilt the probe, aiming cranial or caudal to make the nerve more visible on the ultrasound image.** Once the nerve is located, follow it cranial or caudal to confirm its identity. If the nerve becomes less bright, tilt the probe again to improve the image. The nerve should remain hyperechoic as the probe slides over it cranially and caudally.

7. **Evaluate superficial structures that may be located in the path of the needle, including the femoral artery and vein along with their branches** (see Figure 3-52).
8. **The needle should be inserted in-plane from medial to lateral.** A nerve stimulator may be used to provide confirmation that the needle is within close proximity to the sciatic nerve.
9. **The needle tip position should initially be medial and just deep to the nerve.** Inject local anesthetic and observe the spread across the posterior aspect of the nerve (Figure 3-53).
10. **One should attempt to surround the nerve with local anesthetic, but the majority of the local anesthetic should be injected on the medial portion of the nerve (the tibial portion) because this is the larger component of the nerve.** Preferential concentration of local anesthetic on the medial portion of the nerve results in more reliable blockade.

Alternative Techniques

Out-of-Plane Approach

The needle can be advance in an out-of-plane approach using the techniques described in the section on "How to Visualize Nerves and Needles" in Chapter 1. Track the needle tip as it advances just medial to the nerve. This is a deep nerve block so often small boluses of saline or local anesthetic will help confirm depth of the needle tip. For the greatest reliability with out-of-plane approaches, inject just medial and lateral to the sciatic nerve.

Catheters

Catheters can be placed in this location, but the depth to the target makes accurate placement difficult. If a sciatic catheter is to be placed, we recommend using one of the other sciatic nerve approaches described unless the patient cannot be turned lateral.

Pearls

- It is often difficult to visualize the sciatic nerve using the anterior approach because of its depth. Make sure to use a low-frequency (1-5 MHz) ultrasound probe and to make adequate adjustments (i.e., frequency, gain, and focus) to optimize the imaging.
- Slide the transducer proximally and distally if the nerve is not initially recognized. The nerve may be better visualized at other locations.
- Identify the lesser trochanter of the femur (a medial step on the round cross section of the femur). Often, the sciatic nerve is more clearly visualized distal to the lesser trochanter. The adductor muscles are also easier to identify distal to the lesser trochanter.
- To confirm the identity of the nerve, consider sliding the probe medially and then distally, tracing the nerve down to the popliteal fossa, where it is closely associated with the popliteal artery and vein.
- Spread of local anesthetic around the medial (tibial) component of the sciatic nerve is critical for success of this block. Final placement of a continuous catheter on the medial side of the nerve also improves success.
- Insert the needle several centimeters medial from the edge of the probe to allow for a more shallow needle–probe angle and better needle visualization.

Popliteal Sciatic Nerve Block

Introduction

The popliteal approach to the sciatic nerve targets the nerve at one of its most superficial points, the popliteal fossa. With proper technique, the block involves one of the most visible needle approaches to a nerve because the needle can be advanced perpendicular to the ultrasound beam. Additionally, this block should provide almost complete anesthesia and analgesia below the knee if both the tibial and common peroneal components are targeted.

Anatomy

The sciatic nerve descends on the back of the leg between the hamstrings. The semimembranosus and semitendinosus muscles lie medial and the biceps femoris muscle lies lateral to the sciatic nerve. The sciatic nerve has a fascial covering called the paraneurium. This additional nerve covering, which is distinct from the epineurium, must be punctured with the needle to ensure a complete, rapid-onset nerve block. At a variable distance above the popliteal skin

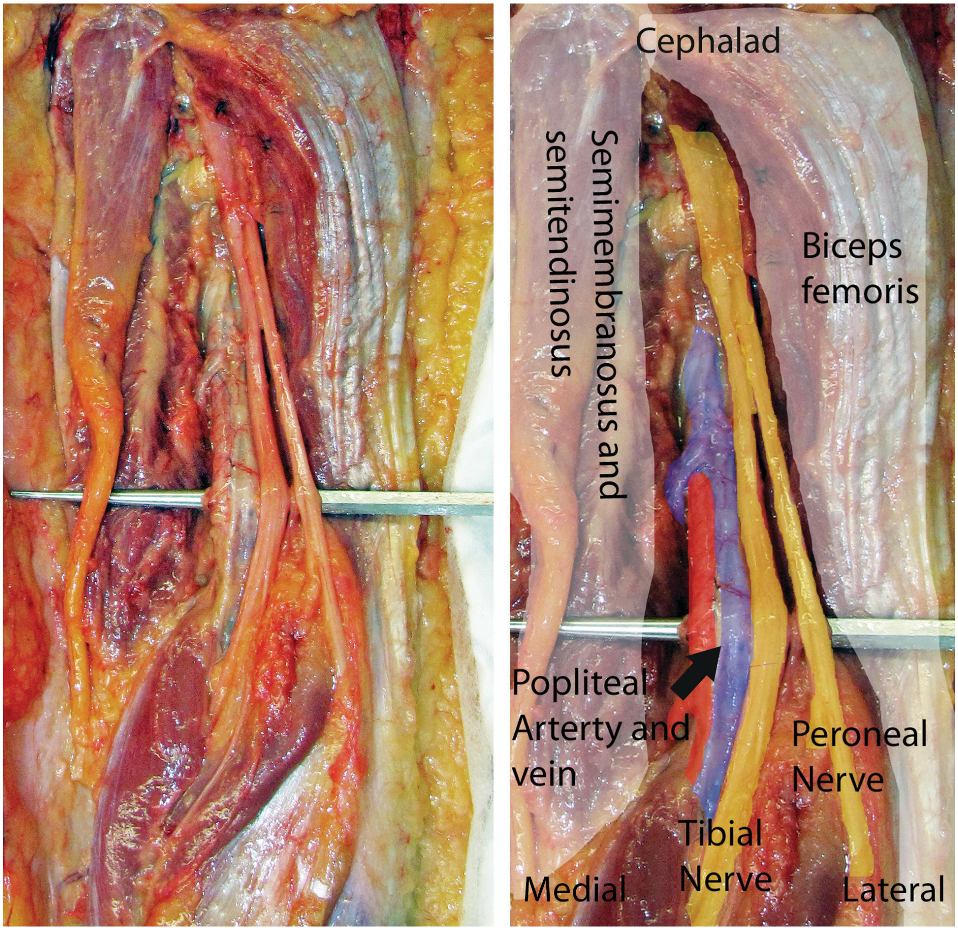


Figure 3-54 Dissection of the popliteal region of the posterior knee. The instrument marks the posterior crease of the knee and is inserted underneath the important structures in the popliteal fossa.

crease, the sciatic nerve separates into the tibial and peroneal nerves (Figure 3-54). The common peroneal nerve moves laterally away from the tibial nerve and courses just posterior to the fibular head. The tibial nerve descends into the lower leg with the popliteal artery and vein. At the level of the popliteal crease, the tibial nerve is the most superficial structure, followed by the tibial vein and, lastly, the tibial artery. This relationship between the tibial artery, vein, and nerve is an important landmark for identifying the nerve at this level.

Technique

Ultrasound Details

Monitors: ECG, NIBP, pulse oximeter, and additional monitors as deemed necessary.

Skin Preparation: Chlorhexidine with alcohol.

Probe: High-frequency linear probe (10-15 MHz); expected depth in an 80-kg patient, 2 to 3 cm.

Patient Position: Lateral.

Local Anesthetic Choice: Depends on the surgical indication. For long-lasting nerve blocks, use ropivacaine 0.5% or bupivacaine 0.5%. For short-duration blocks (e.g., ambulatory patient), mepivacaine or lidocaine may be employed.

Needle: 100-mm (4-inch), short-bevel nerve block needle or Tuohy needle for catheter placement.

Scanning Technique

1. **Position the patient in lateral decubitus position** with the operative side up and the knee bent slightly at 10 to 20 degrees (Figure 3-55).
2. **Place a linear, high-frequency ultrasound probe transversely in the popliteal crease.** Aim the probe at the patella of the knee.
3. **Locate the popliteal artery, which appears as a pulsatile, anechoic circle.**
4. **The popliteal vein lies superficial to the artery on the image**. Color Doppler and occluding pressure applied with the probe can be used for vessel confirmation (Figure 3-56).
5. **Identify the tibial nerve superficial and slightly medial to the popliteal vein. It often appears as a hyperechoic circle with hypoechoic "honeycomb" fascicles** (Figure 3-57).
6. **The common peroneal nerve is located lateral to the tibial nerve.** If the nerve is not visible initially, it will become visible as the probe is moved up the leg.
7. **Tilt the ultrasound probe, aiming distally, to improve the imaging of the nerve** (Figure 3-58).
8. **Once they are located, trace these nerves proximally up the leg.** The two components of the sciatic nerve, the tibial component and the peroneal component, will join to become a single sciatic nerve (Figure 3-59).
9. **The ideal site for injection is just distal to the branch point, where there is just enough room to place a needle between the two nerves without damaging either nerve.**
10. **A 4-inch (100-mm) needle is introduced from the lateral aspect of the thigh, in-plane with the ultrasound beam.** Assess the depth of the nerve, and insert the needle at the same depth. This permits easy visualization of the needle because it will enter exactly perpendicular to the ultrasound beam (Figure 3-60).
11. **Advance the needle between the two nerves, aspirate, then inject 20 to 30 mL of local anesthetic in incremental doses.** The needle can be repositioned

Figure 3-55 Positioning for the popliteal sciatic nerve block. The patient can be positioned facing the operator *(top)*. This allows good stabilization of both the probe hand and the needle hand. Alternatively, the patient can be positioned facing away from the operator *(bottom)*. In either position, a pillow or folded blanket placed between the legs can improve the comfort of the patient.

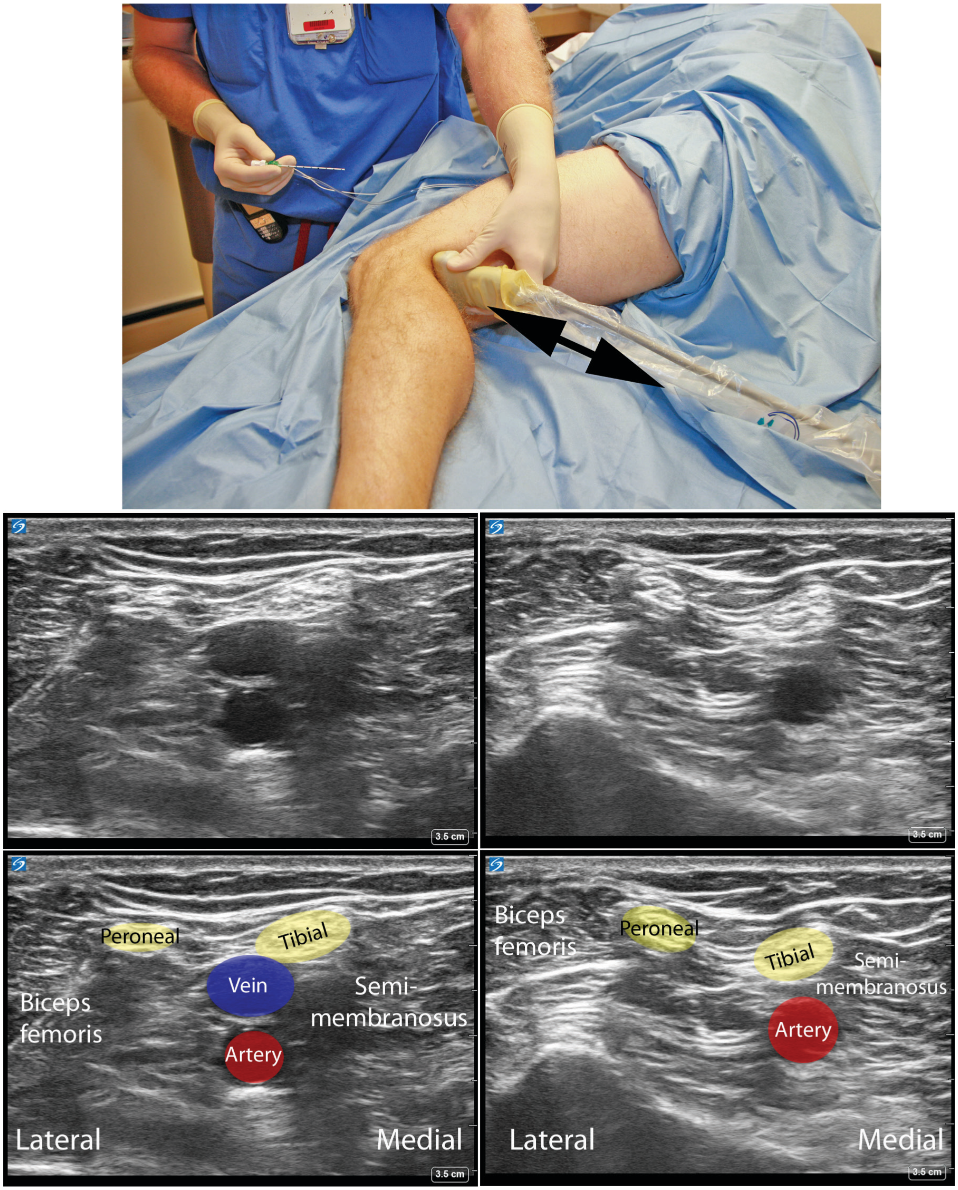


Figure 3-56 Identification of the popliteal artery and vein helps to confirm the location of the popliteal sciatic nerve. On the left, light pressure is applied by the probe to make the popliteal vein more visible. On the right, heavy pressure is applied by the probe, and the vein is not visible. The tibial nerve lies immediately superficial to the vein at the level of the popliteal crease. Use caution when advancing a needle under the tibial component, because lack of visualization of the vein due to occlusive pressure makes inadvertent needle puncture of this vascular structure more likely.

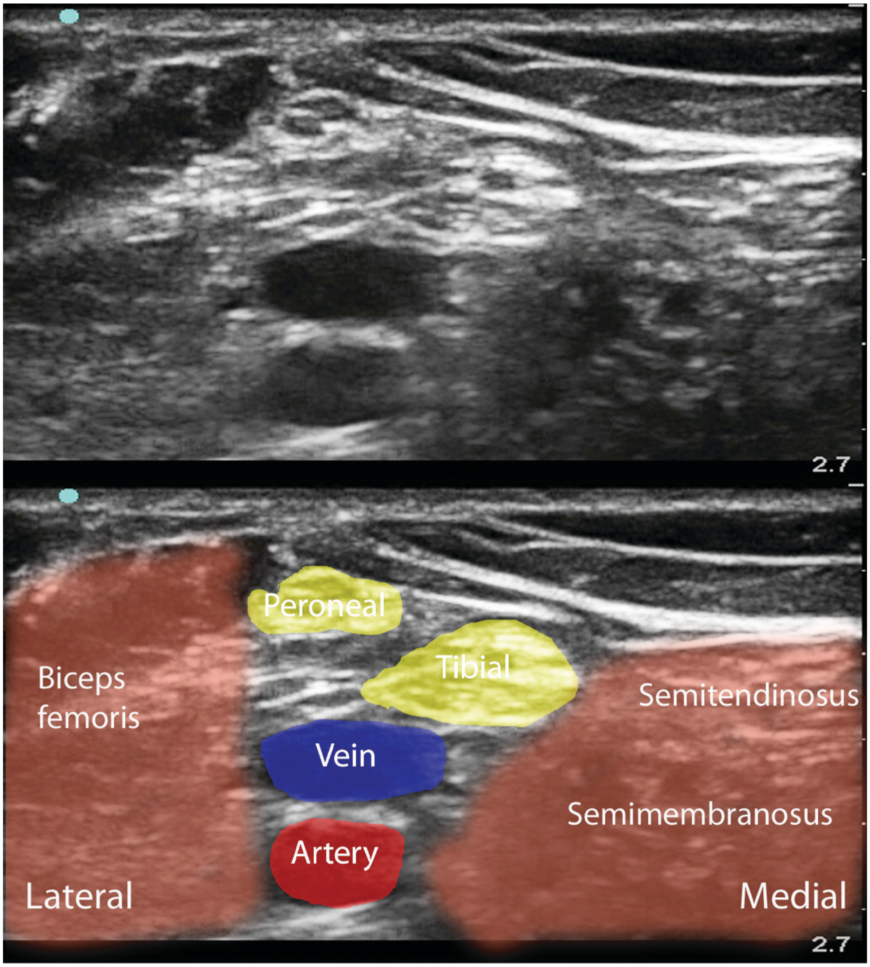


Figure 3-57 Relationships of the popliteal nerve, vein, and artery. The nerve is found superficial to the blood vessels.

to ensure circumferential spread of local anesthetic around the nerves, improving block onset time (Figure 3-61).

12. **If the needle cannot be advanced safely between the nerves, place more local anesthetic around the medial side (tibial component), which is responsible for the majority of sensation in the foot** (Figure 3-62).

Alternative Techniques

Out-of-Plane Needle Approach

The out-of-plane approach to the popliteal sciatic nerve block resembles traditional nerve stimulation approaches. For out-of-plane approaches, it is best to position the patient prone on the bed.

1. Follow the steps described earlier to identify the sciatic nerve.
2. Insert a 4-inch (100-mm) needle perpendicular to the ultrasound transducer and beam.

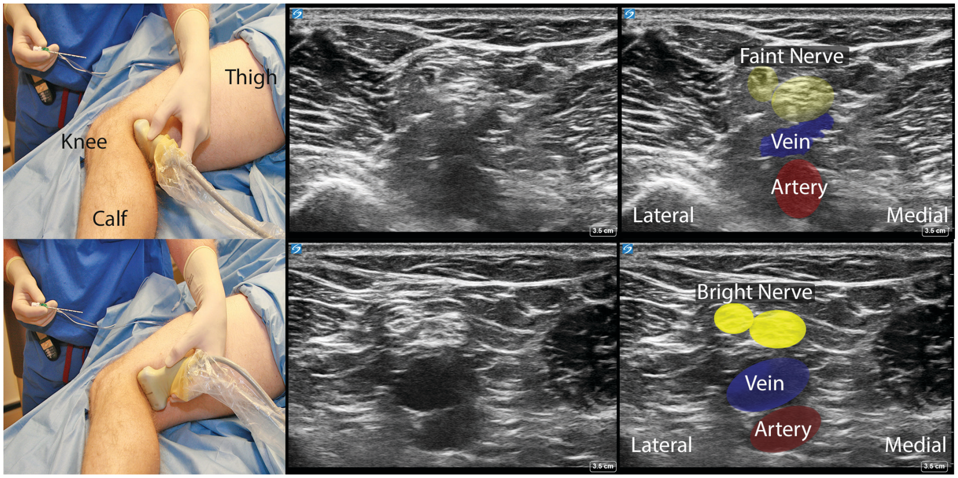


Figure 3-58 Probe position is critical for nerve identification in the popliteal fossa. Aiming the ultrasound beam perpendicular to the skin usually results in a suboptimal image of the nerve *(top images)*. Aiming the beam distally, toward the foot, improves imaging of the components of the popliteal sciatic nerve *(bottom images)*.

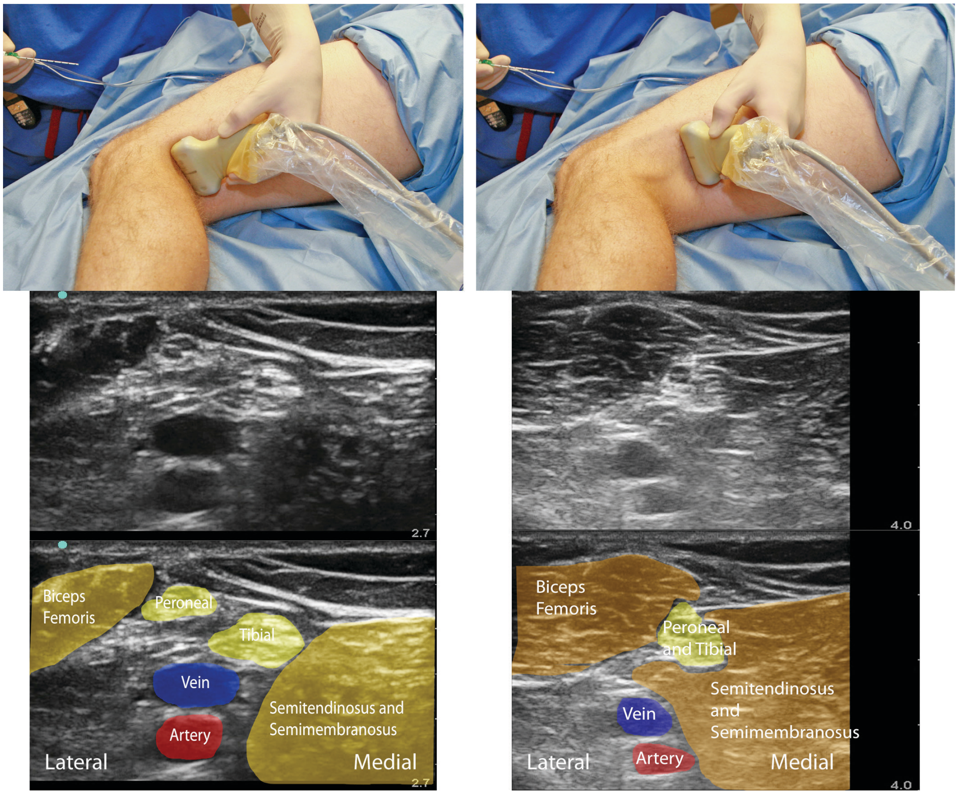


Figure 3-59 Ultrasound image demonstrating the convergence of the peroneal and tibial nerves as they are traced from the popliteal crease *(left images)* proximally up the leg *(right images)*. The ideal site to inject is just after the split, between the tibial and peroneal components.

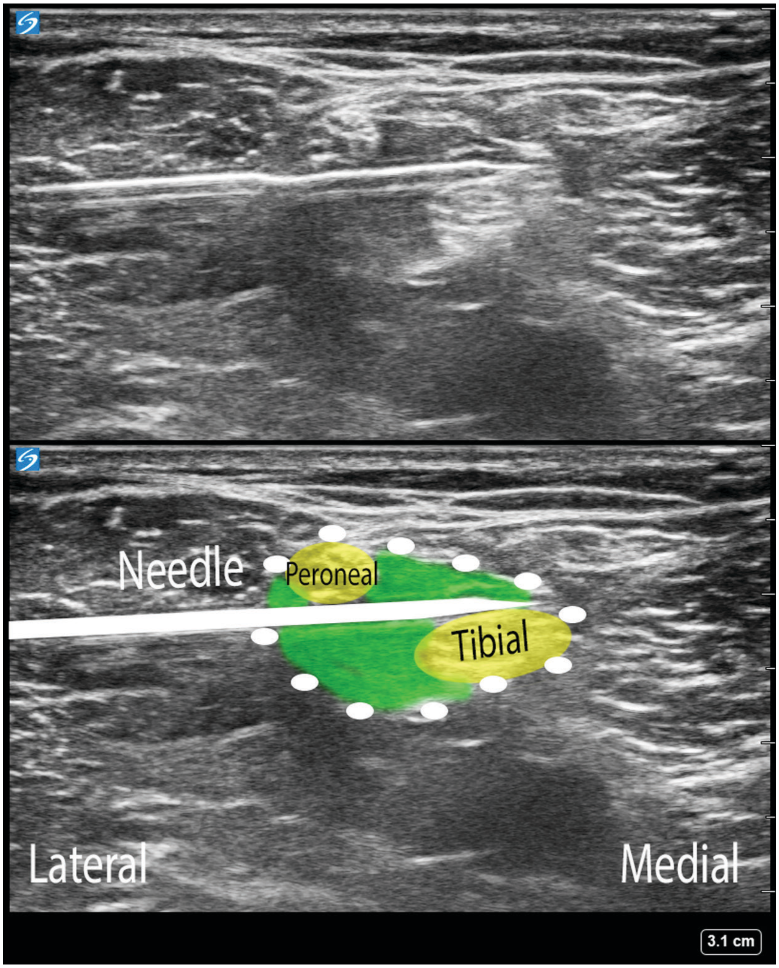


Figure 3-60 In-plane view of the needle and injection of local anesthetic between the peroneal and tibial components. The white dots signify the paraneural sheath. Although it is not visible in most ultrasound images, injection under this sheath improves block quality and onset. Ensure injection under the paraneural sheath by injecting between the two components, tibial and peroneal.

3. Use the techniques described in Chapter 1 to advance the needle out-of-plane.
4. Advance the needle tip so that it lies between the two parts of the sciatic nerve (peroneal and tibial). It is best to try to inject where the sciatic nerve is splitting and to watch the local anesthetic push the tibial and peroneal components further away from each other. This ensures that the injection is subparaneural.
5. Electrical stimulation may be useful to confirm the needle tip position.
6. Inject 20 to 30 mL of local anesthetic around the nerve. The needle may be repositioned to allow for optimal spread of local anesthetic.

Selective Tibial Nerve Block

An alternative to a full popliteal block is a selective tibial nerve block. The patient positioning and probe position are identical to those use for the standard popliteal sciatic nerve block.

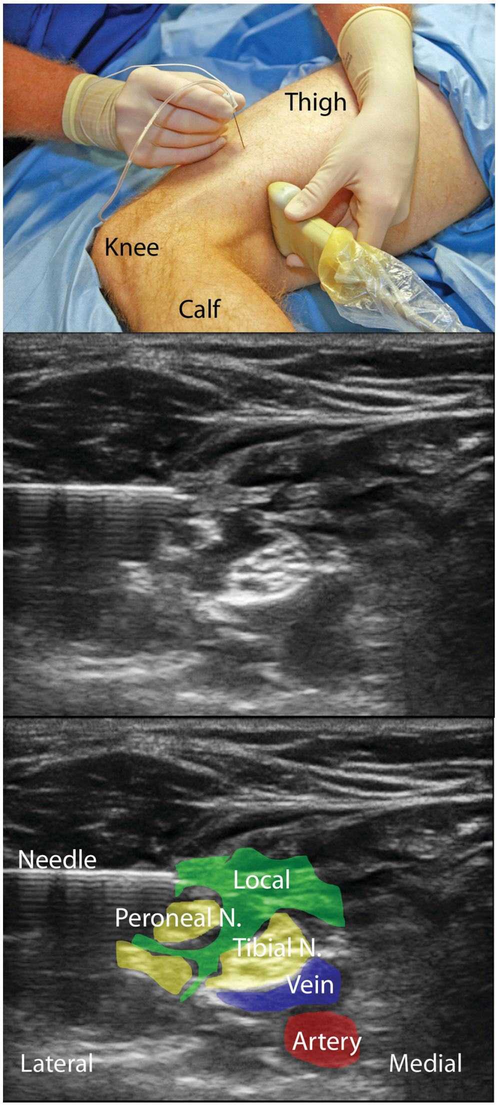


Figure 3-61 Postinjection images show good local anesthetic spread around and between both components of the sciatic nerve. N., nerve.

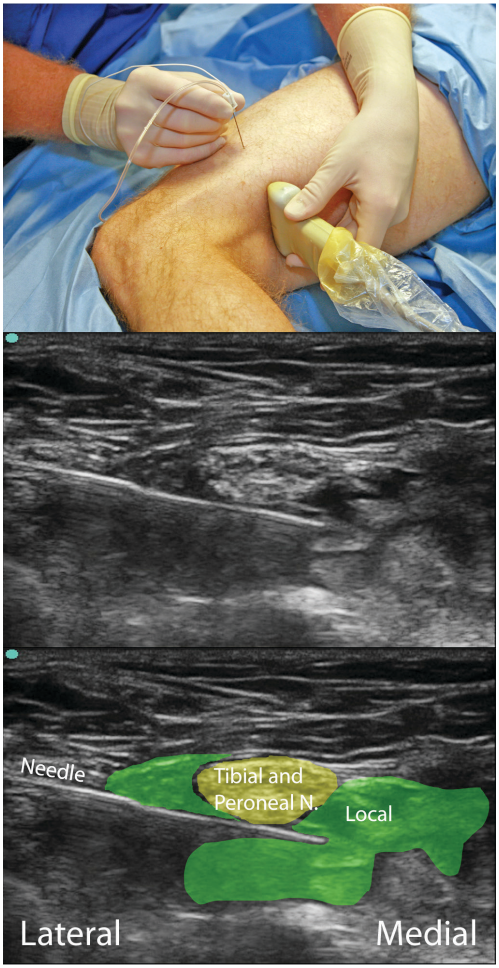


Figure 3-62 If injection between the two components of the nerve (tibial and peroneal) cannot be accomplished, then concentrate the majority of the injection on the medial side of the nerve (near the tibial component) to improve block success.

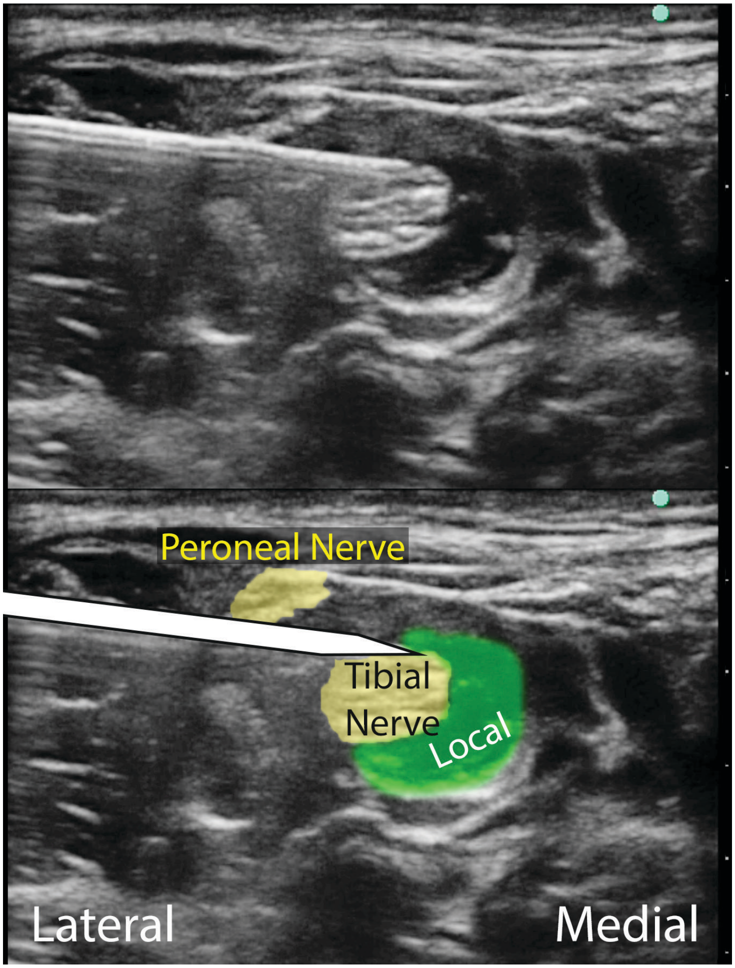


Figure 3-63 In a selective tibial nerve injection, local anesthetic spreads around only the tibial component of the sciatic nerve.

Follow steps 1 through 7 as described, but instead of tracing up the leg, place the probe just above the popliteal crease, where the nerves lie separate, and use a low-volume injection of 5 mL to block only the tibial (medial) nerve (Figure 3-63).

This block is performed to provide analgesia to the knee but prevent foot drop after knee surgery. Since the peroneal nerve is not blocked, the patient should be able to evert or dorsiflex the foot. Sparing the peroneal nerve allows assessment of peroneal nerve injury post-operatively. It also makes mobilization with crutches easier as the operative foot can be dorsiflexed and not drag on the ground. However, the tibial nerve is still responsible for motor innervation to the leg and for sensation of the foot. Altered foot sensation and motor compromise resulting from tibial nerve block can make ambulation difficult.

iPACK Block

The problem of ambulation difficulty after a sciatic or selective tibial nerve block for knee surgery led to the development of the iPACK approach (Infiltration Posterior to the Articular

Capsule of the Knee). As an alterative to blind surgical infiltration of the knee, which can have varying success, an ultrasound-directed iPACK by the anesthesiologist can reduce posterior knee pain. The iPACK block, when combined with an adductor canal catheter, can improve ambulation after total knee arthroplasty. The objective of this block is to infiltrate the small genicular branches that innervate the back of the knee without blocking larger nerves that supply the muscles of the leg.

1. Position the patient in a frog-leg position with a medium- or low-frequency probe centered in the popliteal crease and aimed at the patient's patella. In this position, both an adductor canal block and an iPACK block can be performed (Figure 3-64).
2. The objective is to approach the block from a medial to lateral direction. In elderly patients who have severe hip arthritis, start with flexion of the knee and place the probe behind in the popliteal crease. This alternate approach can be performed with the needle advanced in a lateral-to-medial direction.
3. Set the depth on the ultrasound screen at 6 cm for an 80-kg patient, and identify the lower end of the femur as a hyperechoic (bright) line.
4. Tilting the probe cephalad and caudad allows identification of the proximal tibia and distal femur.
5. Once the distal femur is identified, slide the probe slightly proximal on the femur until the bony bulges of the lateral and medial condyles are visible (see Figure 3-64).
6. At that point, identify the popliteal artery. Often, the tibial nerve is visible shallow to the artery.
7. The target for needle insertion is to place the needle between the midpoint of the pulsating artery and the hyperechoic posterior femur (see Figure 3-64).
8. Additionally in knee arthroplasty patients, a knee effusion or a dark, hypoechoic Baker cyst (popliteal cyst) can be identified behind the knee. If a Baker cyst is visible, slide the probe proximally up the femur until it is above the dark cyst.
9. Advance a 100-mm (4-inch), short-bevel nerve block needle to the midpoint between the artery and the posterior capsule of the knee. To improve needle visibility, insert the needle an appropriate (often large) distance from the probe (Figure 3-65).
10. After negative aspiration, inject 20 mL of ropivacaine 0.2% in intermittent boluses. Between boluses, advance or retract the needle to deposit the local anesthetic over a

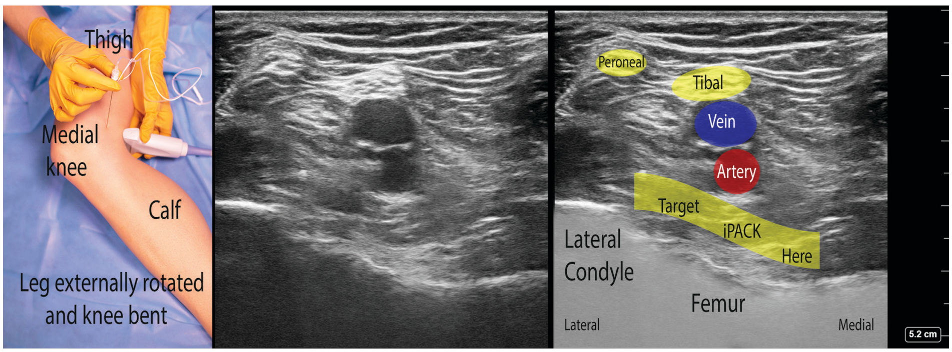


Figure 3-64 Positioning with the leg externally rotated with the knee bent (frog-leg position) for performance of the iPACK block (left image). This same position can be used to perform an adductor canal block. The sonograms show the important landmarks of the popliteal artery and femur *(middle and right images)*. iPACK, infiltration posterior to the articular capsule of the knee.

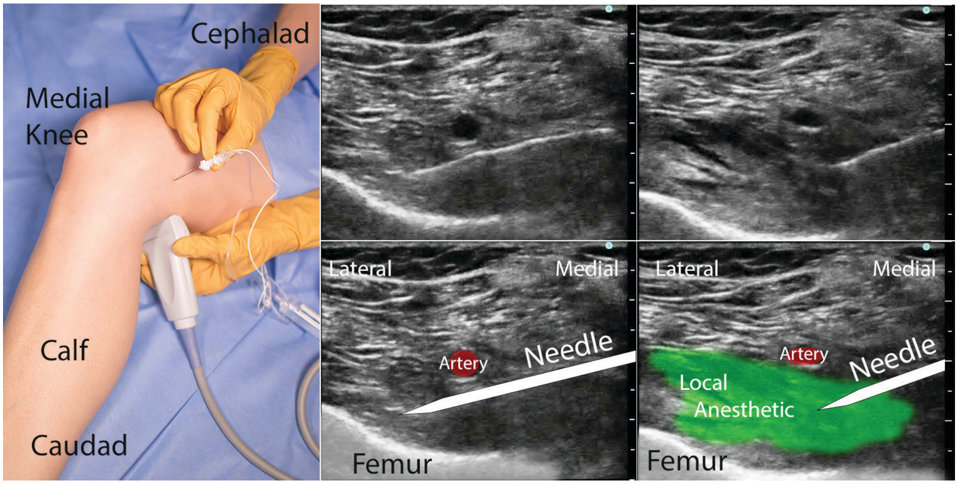


Figure 3-65 Patient positioning and probe and needle placement for the iPACK block *(left)*. Preinjection images *(middle)* show the femur (deep) and the popliteal artery. Postinjection images *(right)* show the wide deposition of local anesthetic between the artery and femur.

wide area. Keep the volume and concentration low to avoid motor block and possible foot drop. The local anesthetic should be seen spreading though the tissues between the artery and the posterior aspect of the knee.

Catheters

Catheter technique is often used with the popliteal approach and is similar to the technique described for single-shot popliteal nerve blocks. Ideal positioning of the catheter is between the tibial and peroneal nerves or on the medial (tibial) side of the nerve (Figure 3-66). See the discussion in Chapter 1 on peripheral nerve catheter placement.

Complications

Many of the complications encountered with other nerve blocks hold true for the sciatic nerve block as well. These include infection, vascular puncture, hematoma, local anesthetic

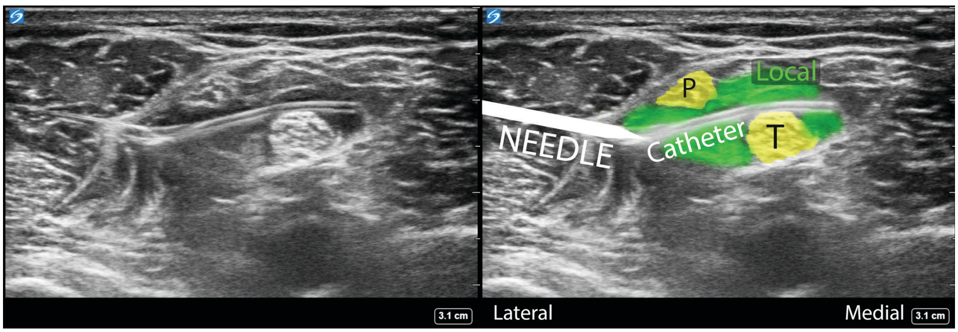


Figure 3-66 Continuous catheters can be left between the two components of the sciatic nerve, as in single-injection blocks. P, peroneal nerve; T, tibial nerve.

toxicity, and nerve injury. The popliteal artery and vein are in close proximity at the popliteal sciatic block level. Risks more specific to the sciatic nerve block include postoperative fall resulting from foot drop and associated gait disturbances. Patients should be carefully evaluated and given specific instructions before receiving a sciatic nerve block to help avoid postoperative complications.

Pearls

- The key to reproducible blocks at this level is injection of the local anesthetic subparaneurally. The paraneurium is a fascial layer that covers the sciatic nerve. The best place to ensure injection underneath this layer is to inject between the tibial and peroneal components just after they branch from the sciatic nerve. An obvious balance needs to be achieved here between success and safety, because the injection should not be made within the common sciatic nerve.
- Squeezing the lower leg while using color flow Doppler may aid visualization of the popliteal vein. This is useful in diabetic patients and those with vascular conditions who have little or no arterial blood flow.
- Even with the use of ultrasound and confirmation of full circumferential spread of local anesthetic around the sciatic nerve, onset of this block may be slow. Improve onset speed by placing local anesthetic just distal to the split of the two nerves rather than where they are joined together.
- An ultrasound artifact can make the needle look bent. This is called the bayonet effect (see Figure 1-19 in Chapter 1). If this is visualized, continue to follow the tip of the needle closely as it is positioned around the nerve.

Ankle Block

Introduction

The ankle block has been a staple of regional anesthesia for decades. Whereas superficial ring blocks (skin infiltrations) mainly target the superficial peroneal and saphenous nerves, ultrasound may facilitate injection of the deeper structures of the ankle (deep peroneal and tibial) and may also be more useful for targeting specific nerves. Surgical anesthesia and analgesia of the ankle can be achieved by the blocks described earlier in this chapter (e.g., adductor canal/subsartorial saphenous blocks and popliteal/mid-thigh sciatic block) However, if less leg and calf muscle involvement is desired, the ankle block remains a solid, reproducible nerve block, and it can be facilitated with ultrasound guidance.

Anatomy

A complete ankle block requires blockade of five nerves: posterior tibial, saphenous, deep peroneal, superficial peroneal, and sural. At the level of the ankle, the posterior tibial nerve is found posterior to the medial malleolus, next to the posterior tibial artery. The deep peroneal nerve is found near the anterior tibial artery as it approaches the dorsum of the foot. It can be reliably found lateral to the extensor tendon of the big toe. The superficial peroneal and saphenous nerves are traditionally described as superficial nerves found on the anterior and medial parts of the ankle, respectively. The sural nerve supplies the lateral part of the foot and is found at the ankle, posterior to the lateral malleolus.

Technique

Ultrasound Details

Monitors: ECG, NIBP, pulse oximeter, and additional monitors as deemed necessary.

Skin Preparation: Chlorhexidine with alcohol.

Probe: High-frequency linear probe (10-15 MHz); smaller transducer size (25 mm width) if possible. The expected scan depth in an 80-kg patient is 1 to 2 cm. The target depth for all nerves is less than 1 cm.

Patient Position: Lateral.

Local Anesthetic Choice: Depends on the surgical indication. For long-lasting nerve blocks, ropivacaine 0.5% or bupivacaine 0.5% is used. For blocks with faster onset (e.g., ambulatory patients), mepivacaine or lidocaine may be employed with the understanding that there will be a decrease in block duration.

Needle: 50-mm (2-inch), short-bevel nerve block needle.

Scanning Technique

Consider performing the blocks in the order described here because the injections will move from the medial side of the lower leg and ankle, over to the anterior side, and finish on the lateral side.

Posterior Tibial Nerve Block

1. **Position the patient supine with the leg externally rotated, and place the transducer posterior, on the medial malleolus** (Figure 3-67).
2. **Locate the posterior tibial artery posterior to the medial malleolus.** Color Doppler imaging may be useful to identify this small vessel. The posterior tibial nerve is located posterior and lateral to the artery. The nerve should appear as a honeycomb with multiple small fascicles.

Figure 3-67 Position of the needle and probe and sonoanatomy of the posterior tibial nerve at the ankle. A, artery; n., nerve.

3. **The exact location of the nerve can vary, but it will be found in very close proximity to the posterior tibial artery.**
4. **To confirm the nerve, trace it proximally.** Scanning proximally also allows the transducer to sit more evenly against the skin above the ankle without being disturbed by the bony medial malleolus.
5. **This block can be performed in-plane or out-of-plane.** We prefer to advance the needle from posterior to anterior because the vessels are usually located anteriorly (see Figure 3-67).
6. **On injection, local anesthetic (5 mL) should surround the posterior tibial nerve.**

Saphenous Nerve Block

1. **Start with the patient supine and the leg externally rotated. A frog-leg position may also be useful.**

Figure 3-68 Position of the needle and probe and sonoanatomy of the saphenous nerve at the ankle.

2. **Position the transducer on the medial lower leg, a few centimeters above the medial malleolus** (Figure 3-68).
3. **With only light pressure, or using a tourniquet, identify the great saphenous vein.** (For a description of how to use a "gel mound" to assist in vein identification, see the "Pearls" section.)
4. **The saphenous nerve is located next to the saphenous vein and appears as a hyperechoic honeycomb structure.** The nerve is variable in location but is usually found posterior (dorsal) to the vein (see Figure 3-68).
5. **Local anesthetic (3-5 mL) can be injected with either an in-plane or an out-of-plane technique.**
6. **If the nerve cannot be found, inject on both sides of the great saphenous vein in the same plane as the vein.**

Deep Peroneal Nerve Block

1. **With the patient supine, place the transducer on the anterior part of the lower leg** (Figure 3-69).
2. **Locate the anterior tibial artery** (see Figure 3-69). This small artery can be found pulsating just superficial to a hyperechoic bone, the tibia. Color Doppler imaging may be useful to help locate the artery.
3. **If the artery cannot be found, move the transducer down the leg, closer to the ankle.**
4. **The nerve usually can be found just next to the artery and superficial to the tibia.** It is a small, hyperechoic, honeycomb-like structure. The location of the nerve may vary in relation to the artery (lateral, medial, or superficial).

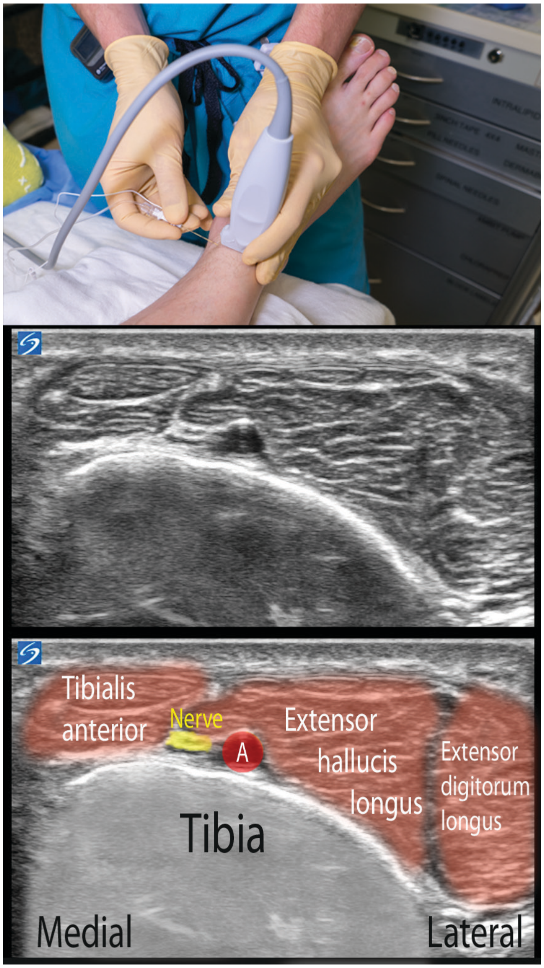


Figure 3-69 Position of the needle and probe and sonoanatomy of the deep peroneal nerve at the ankle. A, artery.

5. **There are many tendons in this area that often appear similar to nerves on ultrasound. The nerve will most likely lie in very close proximity to the artery.**
6. **Advance the needle from lateral to medial or from medial to lateral to surround the nerve with local anesthetic (5 mL).** The needle approach will depend on where the nerve is in relation to the artery and is chosen to avoid puncturing the artery.
7. **If the nerve cannot be found, inject on both sides of the anterior tibial artery.**
8. **There are several veins in this area. Be cautious of venous puncture when advancing needles in this area.**

Superficial Peroneal Nerve Block

1. **With the patient supine, start by placing the transducer on the anterior part of the lower leg, as for the deep peroneal block.**
2. **Slide the probe laterally until the tibia disappears; the next bone on the lateral side is the fibula.** The fibula is shallow (just underneath the skin) and appears hyperechoic (very bright).
3. **Once the fibula is located, slide the probe proximally up the leg, keeping the bright fibula in the center of the image.** The probe should now be on the lateral aspect of the lower leg.
4. **As the probe is moved, a muscle will start to cover the fibula on the lateral side. This is the peroneus brevis.** The muscle anterior and medial to the fibula is the extensor digitorum longus. These muscles and the fibula form the main landmarks to locate the superficial peroneal nerve.
5. **The superficial peroneal nerve is located at the junction of the peroneus brevis laterally and the extensor digitorum longus medially, just shallow to the fibula.** The nerve should be located just under the skin and less than 1 cm deep on an 80-kg patient.
6. **The superficial peroneal nerve is a very shallow nerve.** This nerve is small and difficult to see. It usually appears hyperechoic and located between the two muscles. Scan proximally and distally to trace and confirm the nerve.
7. **If the nerve is not identified, it can sometimes be found further anteromedial, superficial to the extensor digitorum longus (the muscle medial to the fibula).**
8. **Inject 3 to 5 mL of local anesthetic around the nerve. The needle can be advanced in-plane or out-of-plane from anterior or posterior.** We find an anteromedial to posterolateral in-plane approach to be easiest (Figure 3-70).
9. **If the nerve is not visible, infiltrate local anesthetic on top of the extensor digitorum longus, between the two muscles, superficial to the fibula, just underneath the skin and subcutaneous adipose.**

Sural Nerve Block

1. **With the patient supine, target the sural nerve by placing the transducer on the lateral ankle, just above the lateral malleolus.**
2. **Slide the probe posteriorly to image the space between the Achilles tendon and the peroneus brevis.**
3. **Attempt to identify a small (short) saphenous vein. An tourniquet may also help to distend the vein for easier identification.** This vein is often located in the depression between the Achilles tendon and the peroneus brevis. To confirm its identity, trace the vein proximally. The vein courses on the posterior (dorsal) aspect of the lower leg, superficial to the calf muscles (Figure 3-71).

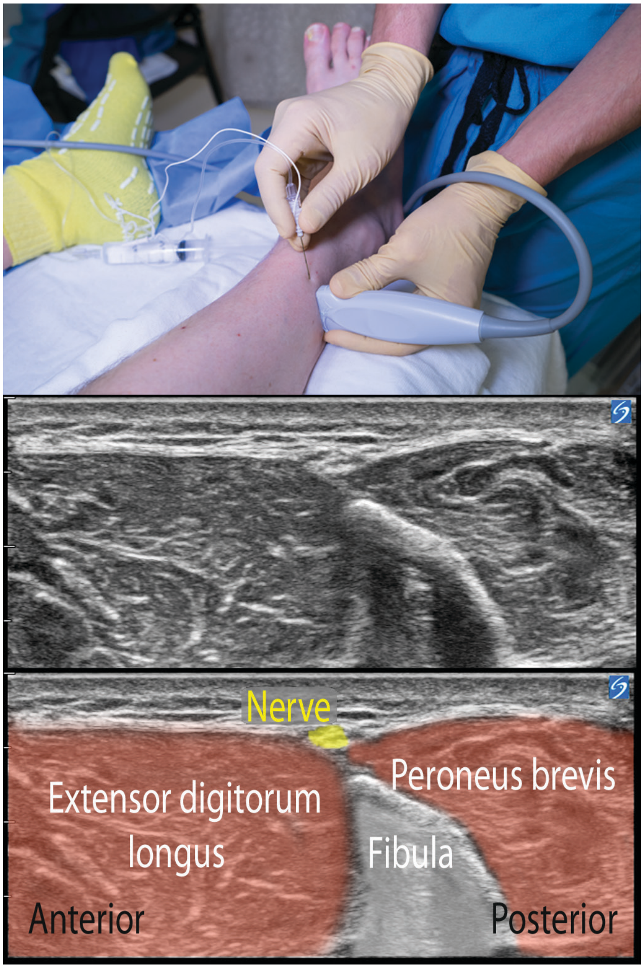


Figure 3-70 Position of the needle and probe and sonoanatomy of the superficial peroneal nerve at the ankle.

4. **The nerve can often be located anterior or posterior to the vein.** The vein itself can also vary in location from patient to patient.
5. **The nerve is most often in the same plane as the vein and is seen as hyperechoic honeycomb structure.**
6. **Place 3 to 5 mL of local anesthetic in the plane next to the nerve.**
7. **If the nerve cannot be specifically identified, place local anesthetic in the same plane as the vein, on both sides of the vein.** An in-plane or out-of-plane technique can be used.
8. **If the vein and nerve cannot be located, inject local anesthetic between the Achilles tendon and the peroneus brevis.**

Catheters

Because of the superficial location of these nerves and the fact that they are widely spread out, catheters are not placed for the ankle block.

Figure 3-71 Position of the needle and probe and sonoanatomy of the sural nerve at the ankle.

Complications

As with other blocks, complications include infection, vascular puncture, hematoma, local anesthetic toxicity, and nerve injury. Because of decreased perfusion, poor tissue healing, and preexisting neuropathy, special care for diabetic patients should be used with any nerve block of the distal lower extremity.

Pearls

- These nerves are located in areas of the ankle and leg that are bony or round, which leads to difficult transducer placement or compression of venous structures with the transducer. To improve imaging of the veins and nerves, use a gel-mound or stand-off technique (Figure 3-72). This may allow identification of the veins without collapsing them and thus improve the ability to find the nerve. Once the nerve location is confirmed and the excess gel has been removed, the actual block procedure can start in standard fashion (Figure 3-72).

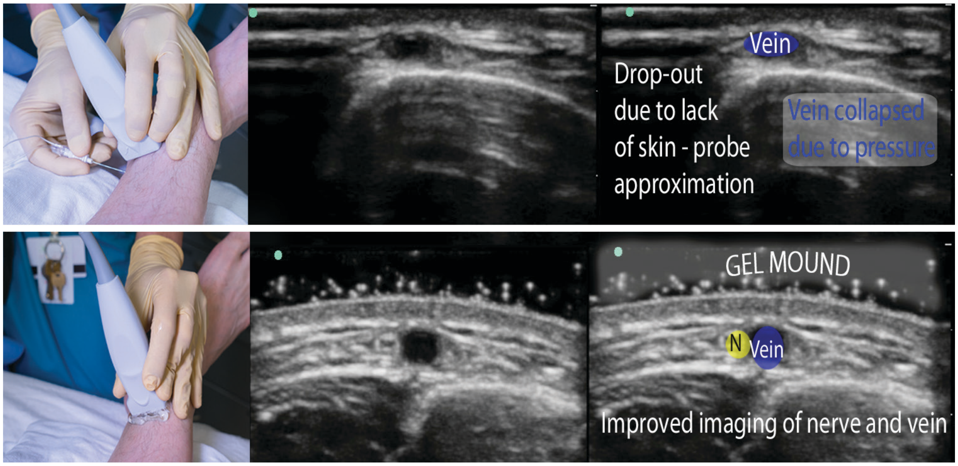
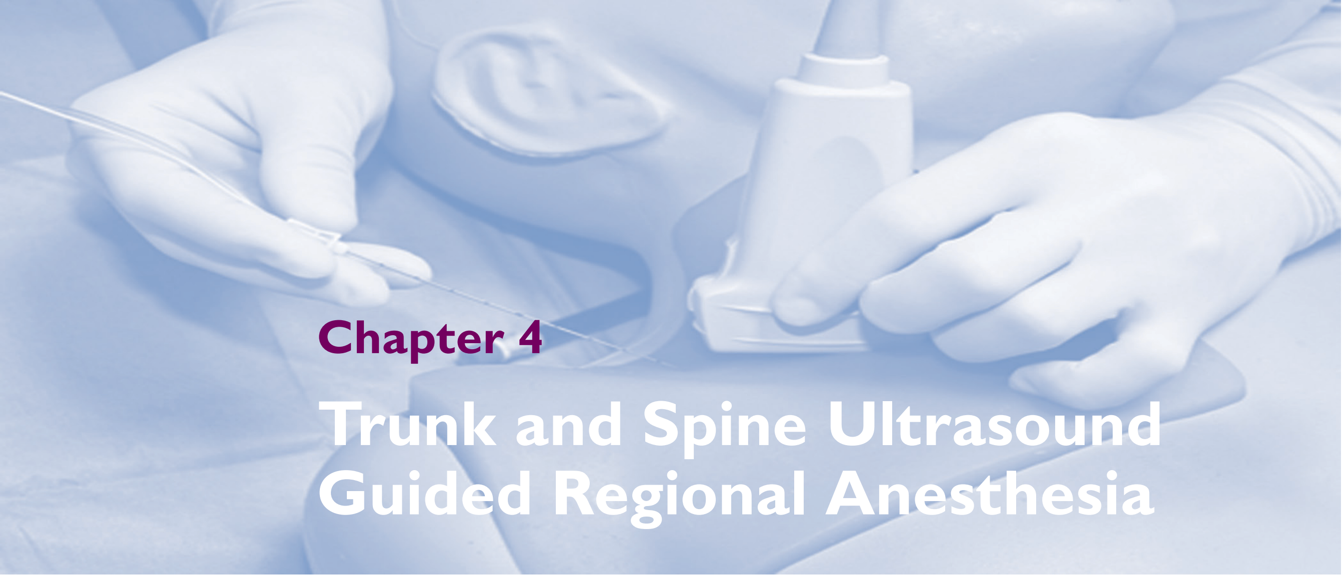


Figure 3-72 Gel-mound (stand-off) technique to improve imaging around small blood vessels, bony prominences, and small curved structures. Notice that the image of the probe on the medial ankle is partially lifted off, resulting in dropout of the left side of the ultrasound image *(top images)*. A gel mound improves the probe–skin interface while also improving the ability to image a small vein or nerve *(bottom images)*. N, nerve.

- Although the nerves targeted by the ultrasound-guided ankle block are similar in location to those targeted in the traditional ankle block, do not be afraid to scan proximally with the transducer and trace the nerves to confirm their identities.
- Because nerves branch as they course distally, blocks placed more proximally in the leg may result in even better anesthesia or analgesia.
- Several of these nerves are located in close proximity to arteries and veins. If the nerves are not visible, consider injection around these vascular landmarks.
- There are many tendons in the area that can be mistaken for nerves. If these tendons are traced proximally, they will be seen to disappear into muscles. Nerves usually increase in size as they are traced proximally.



Chapter 4

Trunk and Spine Ultrasound Guided Regional Anesthesia

Transversus Abdominis Plane Block

Introduction

The transversus abdominis plane (TAP) block is a block that is made possible with the use of ultrasound. The imaging is often easy but, as with all nerve blocks, if the needle is not placed accurately, success will be limited.

TAP blocks can be performed at various locations along the abdominal wall. It was traditionally performed on the lateral abdominal wall between the rib margin and the iliac crest. This TAP technique provided analgesia to the abdominal wall beneath the umbilicus. Later, subcostal TAP block techniques were developed to provide analgesia to the abdominal wall up to the T6 dermatome.

Anatomy

The anterior divisions of the T6-L1 nerve roots innervate the anterior abdominal wall. The spinal nerves of the abdominal region travel between the muscle layers of the abdominal wall, coursing anteriorly on the superficial part of the transversus abdominis muscle. The nerves ultimately perforate the posterior fascia and muscle belly of the rectus abdominis muscle to terminate as the cutaneous innervation of the anterior abdominal wall. There is marked variation in the points at which the nerves exit the transversus abdominis fascial plane, and this can lead to unpredictable and incomplete TAP blocks if they are performed too far anteriorly. Performing the TAP block as laterally as possible, between the rib margin and iliac crest, can provide reliable analgesia from T10 to L1 for lower abdominal procedures. Subcostal TAP blocks can provide analgesia for upper abdominal procedures, providing analgesia from T6 to T10.

The nerves that travel in the TAP also have lateral perforator branches. These branches are important for innervation of the anterolateral portion of the abdominal wall. Each lateral perforator branch splits from the main nerve at a variable point around the side of the abdominal wall. The branches pierce the internal oblique muscle superficially, terminating as the lateral cutaneous branch supplying sensation to the lateral portion of the abdominal wall. This is clinically significant because a non-midline surgical incision can contain innervation from this lateral cutaneous branch. Therefore, blocks should be performed as lateral as possible to include this nerve branch before it exits from the fascial plane between the internal oblique and transversus abdominis.

Clinical Applications

The TAP block is a useful alternative for abdominal procedures when an epidural block is contraindicated or as a postoperative analgesic block. Injections between the iliac crest and the costal margin result in analgesia for procedures at or below T10. Urology, obstetrics, gynecology, and general surgery procedures are all possible candidates for this nerve block. The specific injection sites for correct dermatome coverage can be matched to the surgical incision. The TAP block does not cover visceral pain, so vaginal vault pain after hysterectomy or peritoneal pain after intraabdominal procedures will not be eliminated. Despite the lack of analgesia for visceral pain, the TAP block can provide significant postoperative reduction in somatic pain.

Although most TAP blocks are performed bilaterally for midline or Pfannenstiel incisions, they can be performed unilaterally for one-sided procedures such as colostomy take-downs or inguinal hernia repairs.

Technique

Ultrasound Details

Monitors: ECG, noninvasive blood pressure monitor (NIBP), pulse oximeter.

Skin Preparation: Chlorhexidine with alcohol over the lower anterior abdominal wall. Ensure that the prep extends sufficiently posterior to clean the needle insertion site.

Probe: High-frequency linear probe (10-15 MHz). In obese patients, a curvilinear low-frequency probe may be necessary. The expected target depth in an 80-kg patient is 3 to 5 cm.

Patient Position: Supine.

Local Anesthetic Choice: Usually, 20 to 30 mL of local anesthetic is required on each side if multiple dermatomes are to be blocked. Be conscious of the total local anesthetic dose and the potential for toxicity. Concentrations of 0.25% for bupivacaine are adequate for analgesia lasting up to 24 hours.

Scanning Technique

Having a technique that is reliable in both slim and obese patients is important. The following techniques should permit success in patients of varying body habitus.

1. **Place the probe in a transverse plane with the medial end of the probe over the umbilicus** (Figure 4-1, *top row of images*).
2. **Obtain an image of the rectus abdominis muscle.** If the probe is slid or tilted medially, the medial edge of the rectus muscle and the linea alba at midline can be visualized. The rectus sheath is deep to the rectus abdominis muscle and is seen as hyperechoic layer underneath the muscle. Deep to the rectus sheath fascia lie the transversalis fascia and abdominal contents (see Figure 4-1).
3. **Slide the probe laterally across the abdominal wall with the goal of placing the probe in the anterior axillary line between the costal margin and the iliac crest.** As the probe is moved laterally, ensure that it curves around and remains in good contact with the surface of the abdominal wall.
4. **As the probe is moved laterally, the rectus abdominis muscle thins to its lateral aponeurosis (fascial layer).** This is seen as a narrow white band of tissue.
5. **Moving further laterally, the first muscle visible is the internal oblique, which is found at similar depth to the rectus abdominis.**
6. **Continuing to move laterally, the external oblique appears, superficial to the internal oblique. Finally, the transversus abdominis muscle appears, deep to the internal oblique.** It is helpful to start by scanning the rectus abdominis because the three important muscle layers of the TAP block (i.e., external oblique, internal oblique, and transversus abdominis) will be at observed a depth similar to that of the rectus abdominis (see Figure 4-1).
7. **The optimal site for injection is where all three muscles layers (external oblique, internal oblique, and transversus abdominis) are present on the lateral abdominal wall.** Success will be improved if the block is performed as far lateral or posterior as possible in order to block the nerves before they branch. The point at which the transversus abdominis muscle terminates posteriorly can be visualized during block performance (Figure 4-2).
8. **The nerves lie deep to the transversus abdominis fascia in the superficial part of the transversus abdominis muscle.**

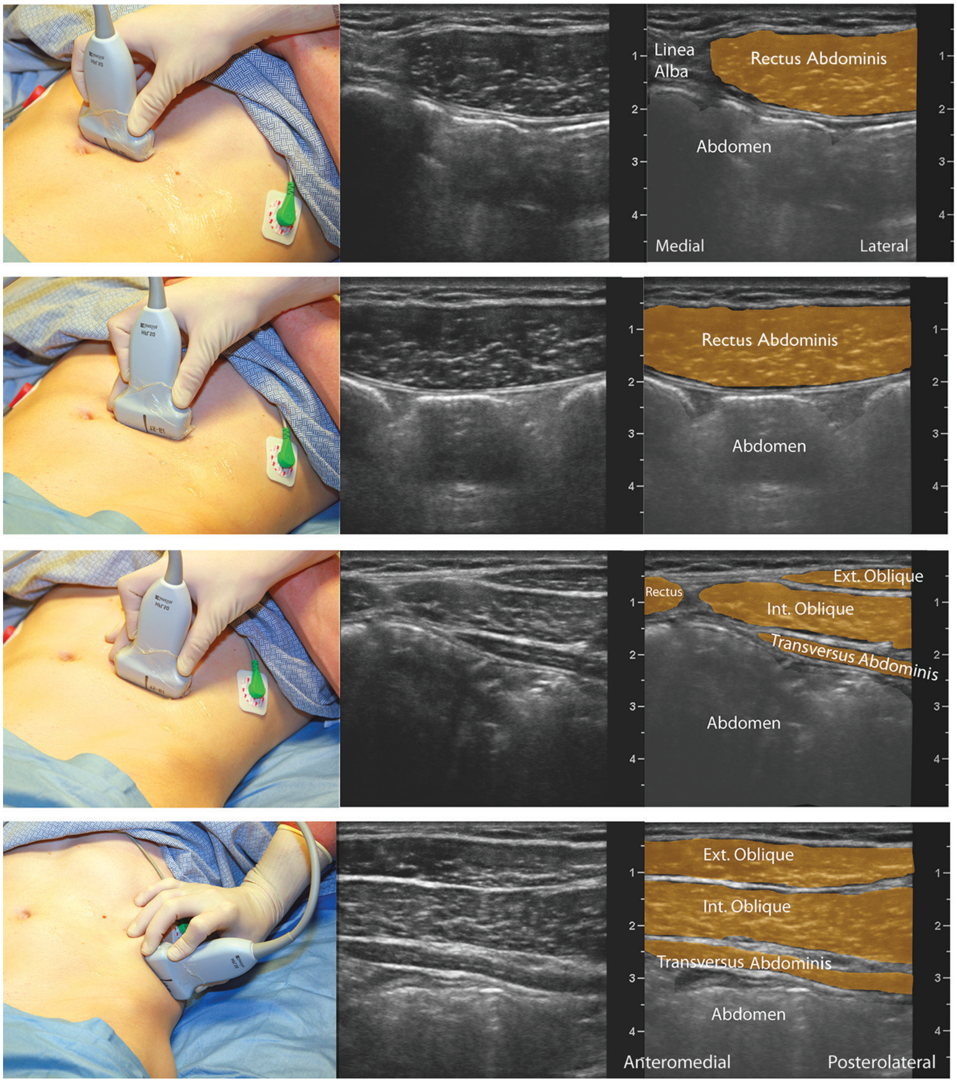


Figure 4-1 Transversus abdominis plane (TAP) block. From top to bottom, the sequential probe positions and abdominal wall muscle layers are identified. Notice the final probe position on the lateral abdominal wall *(bottom)*.

9. **The optimal site for injection is just underneath the hyperechoic fascial plane between the internal oblique and the transversus abdominis.** It is less effective to inject directly between the fascial layers separating these two muscles. Rather, target the injection just deep to this fascial layer but above the transversus abdominal muscle belly.
10. **The probe should be rotated obliquely so that needle advancement will traverse as many dermatomes as possible.** Studies have shown that spread of local

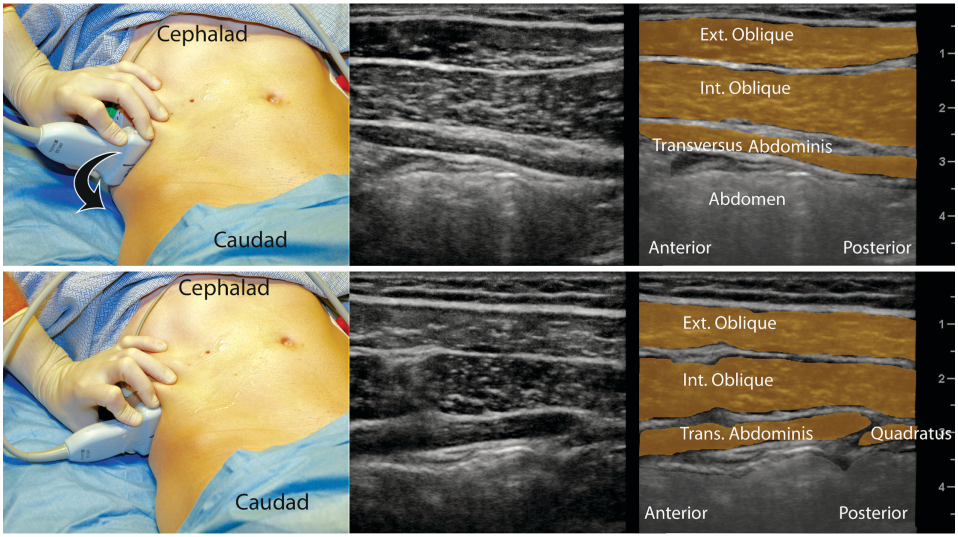


Figure 4-2 Identification of the posterior border of the transversus abdominis muscle. In the top image, the three muscle layers of the abdominal wall are identified. In the bottom image, the probe has been slid further posterior to identify the posterior border of the transversus abdominis. This positioning can be important for block success and patient comfort. Ext., external; Int., internal; Trans., transversus.

anesthetic can take hours to reach multiple levels by diffusion. Instead of relying on diffusion, continue to move the needle within the TAP during injection to create a larger area of local anesthetic deposition. If the probe is placed perpendicular to the dermatomes, the maximum amount of dermatomal coverage will be obtained from the injection (Figure 4-3).

11. **The needle is inserted in-plane from the anteromedial side of the probe, through the adipose tissue and the external and internal oblique muscles. The tip of the needle is placed in the superficial part of the transversus abdominis muscle.** Injection of a small volume of local anesthetic or saline can help guide needle placement. Take care not to inject too superficially (Figure 4-4).

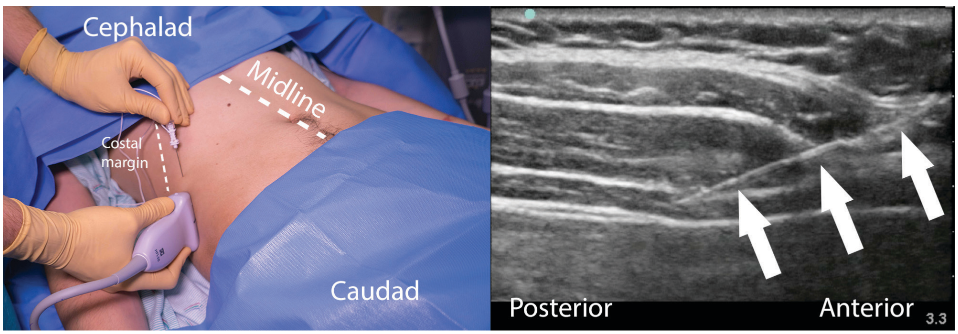


Figure 4-3 The probe is angled obliquely rather than vertically. The angle is similar to that of the costal margin which is found more cephalad. This oblique needle direction allows more dermatomes to be covered during needle advancement and injection.

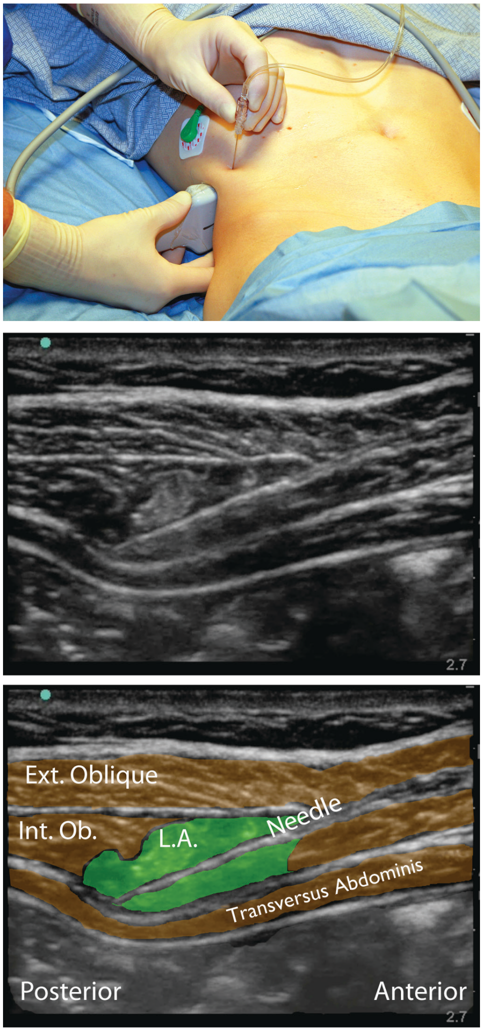


Figure 4-4 Needle advancement for the TAP block. In this demonstration, local anesthetic (L.A.) has been injected superficially within the internal oblique muscle. Injection in that location will likely result in block failure, so needle advancement should be continued. Ext., external; Int., internal; Ob., oblique.

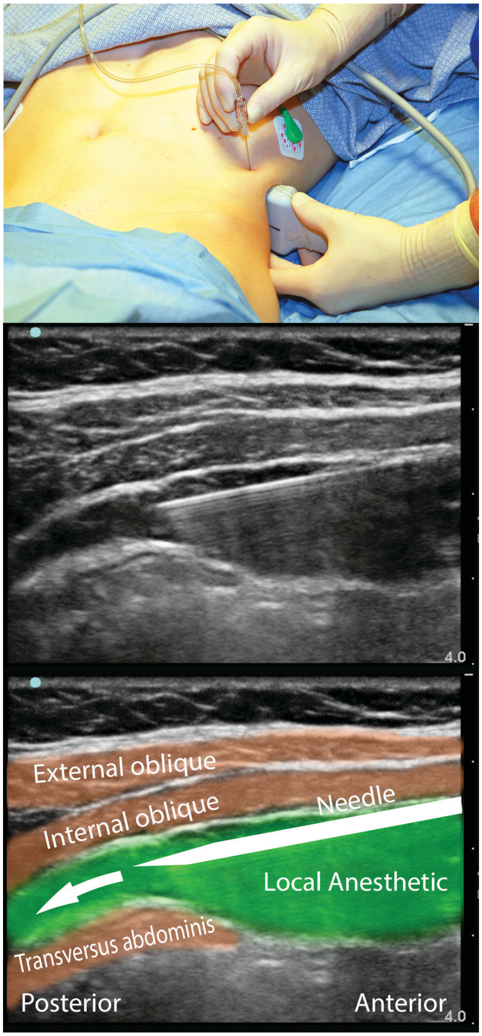


Figure 4-5 The needle has been placed between the internal oblique and the transversus abdominis. Injection of local anesthetic spreads the two muscles apart. Continue to advance the needle within the area of spread for wider dermatomal coverage.

12. **To reach as many dermatomes as possible, advance the needle during the injection of local anesthetic.** This ensures optimal spread of local anesthetic over several dermatomes. Do not inject all of the local anesthetic in one location. Continue to move the needle within the TAP throughout the injection (Figure 4-5).
13. **The needle used can make this block easy or difficult to perform.** A traditional nerve block needle can be used, but often it is too blunt, making it difficult to pierce the fascial planes smoothly. The needle may then jump through the muscle layers as it pops through the fascia and end up too deep, potentially even in the abdominal cavity.

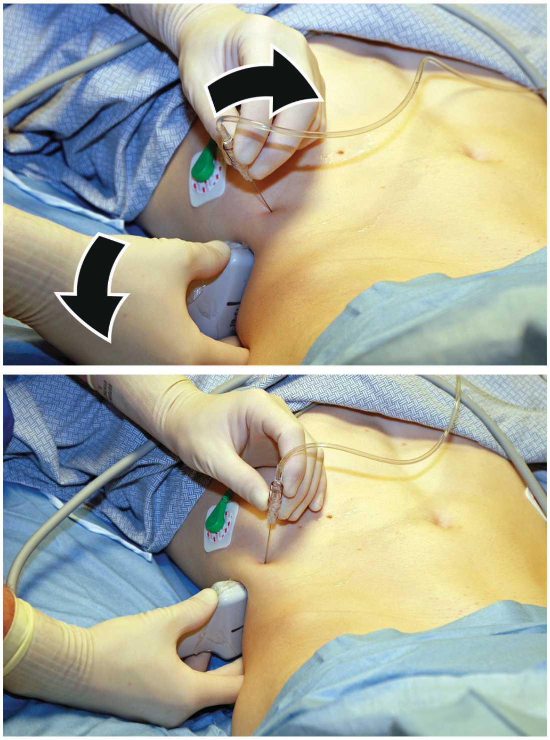


Figure 4-6 Probe position and needle angle are critical to successful needle identification. A probe and needle orientation that does not improve needle imaging (*top image*). Instead, aim the ultrasound beam toward the needle while advancing the needle with a flat angle *(bottom image)*. This improves needle identification for deep blocks such as the TAP block.

A 22-gauge Quinke spinal needle attached to extension tubing is sharp enough to pierce the fascial planes but still blunt enough to provide a tactile pop as it penetrates the tissues. In obese patients, an echogenic needle can assist with visualization at steep insertion angles. Always use long needles for the TAP block to allow for a flat needle angle and good needle visibility under ultrasound.

14. **To improve needle visibility throughout this block, aim the ultrasound beam into the needle to help reduce the angle of needle insertion.** Also, insert the needle 3 to 5 cm away from the probe to provide for a shallow and more visible needle approach (Figure 4-6).

Alternative Techniques

A TAP block can be performed with the needle advanced out-of- plane as well. With abdominal contents deep, it is imperative for the operator to understand where the tip of the needle is at all times, using one of the techniques described in “How to Visualize Nerves and Needles” in chapter 1. The needle may be inserted in an anterior-to-posterior direction with care taken to follow the needle tip as it is inserted.

To obtain analgesia above the umbilicus, a subcostal TAP block is necessary. For a subcostal TAP block, use the following steps.

1. **Place the probe over the lateral edge of the rectus abdominis muscle at the level of the umbilicus**.

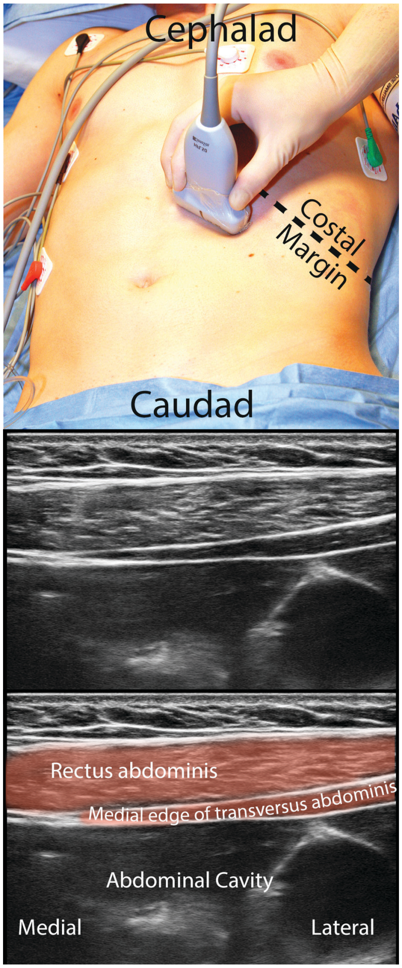


Figure 4-7 Positioning of the probe parallel to the costal margin and ultrasound image for the subcostal TAP block.

2. **Scan cranially, up the lateral edge of the rectus abdominis toward the costal margin.**
3. **As the probe moves cranially, the transversus abdominis muscle can be seen extending underneath the rectus abdominis muscle (**Figure 4-7).
4. **Once the probe reaches the costal margin, slowly rotate the probe obliquely until it is parallel to the costal margin.**
5. **The needle is inserted in a medial-to-lateral direction, parallel and caudad to the costal margin. Hydrodissect in the plane below the rectus abdominis but above the transversus abdominis.** During injection, continue to move the probe and needle laterally to cover several dermatomes (Figure 4-8).
6. **Identify the superior epigastric arteries to perform this block safely.** The superior epigastric arteries lie directly in the TAP plane between the rectus abdominis muscle and the transversus abdominis muscle. Use color Doppler imaging to confirm the artery's position if there is any question.

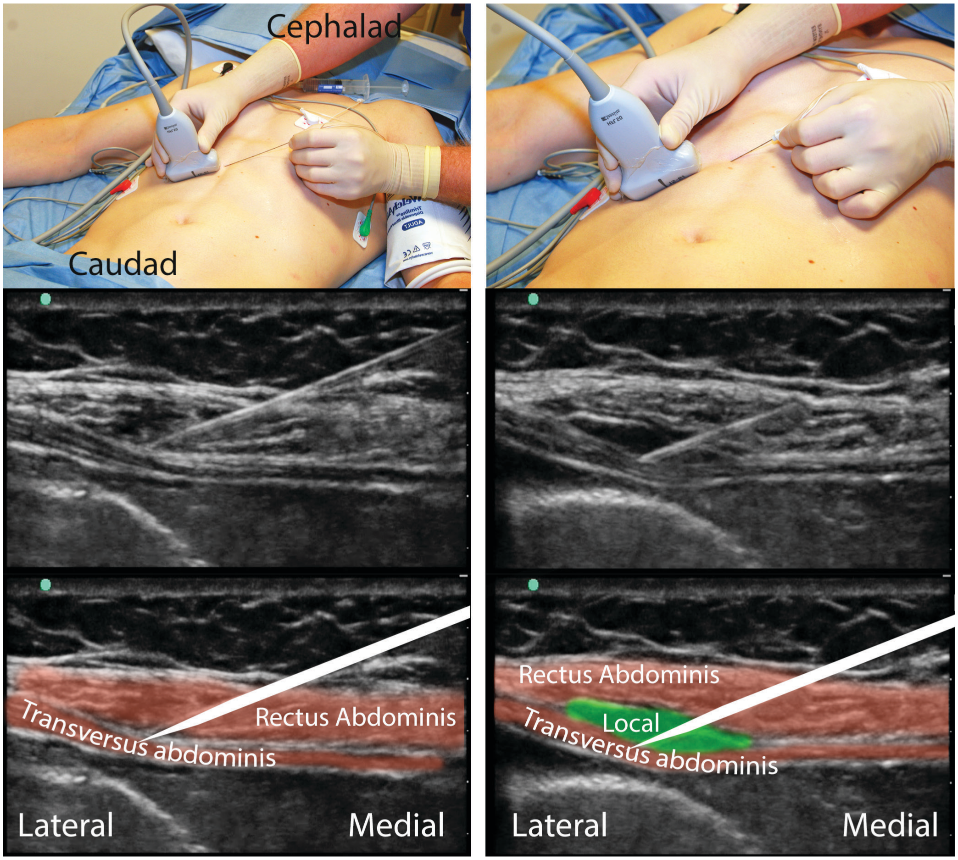


Figure 4-8 Needle entry close to the lateral edge of the rectus abdominis muscle for a subcostal TAP block *(left)*. Needle advancement and injection of local anesthetic is visible between the rectus and underlying transversus abdominis *(right)*.

7. **It may be challenging to keep the needle in the correct tissue plane as the body curves laterally during this block. Occasionally, multiple injections are required to ensure optimal spread of local anesthetic.**

Catheters

Catheters can be inserted using the TAP block technique. A detailed knowledge of the sonoanatomy of the abdominal wall and suitable skill in observing needle advancement are required before a catheter technique is attempted. The approach is identical to the in-plane single-shot technique described earlier. The Tuohy needle can be challenging to use for placement of a TAP catheter because it can be difficult to pierce the deeper fascial layers with a blunt needle inserted at a shallow angle. Stiff catheters can be difficult to keep in position in the potential TAP space. Sometimes, more success can be achieved with a soft catheter inserted in this space. To insert soft catheters, advance the Tuohy needle several centimeters within the plane, using local anesthetic to assist spreading of the tissues. Once the needle is inserted, place the catheter where the needle has already tracked. This allows the catheter to be effectively tunneled several centimeters in the correct plane (Figure 4-9).

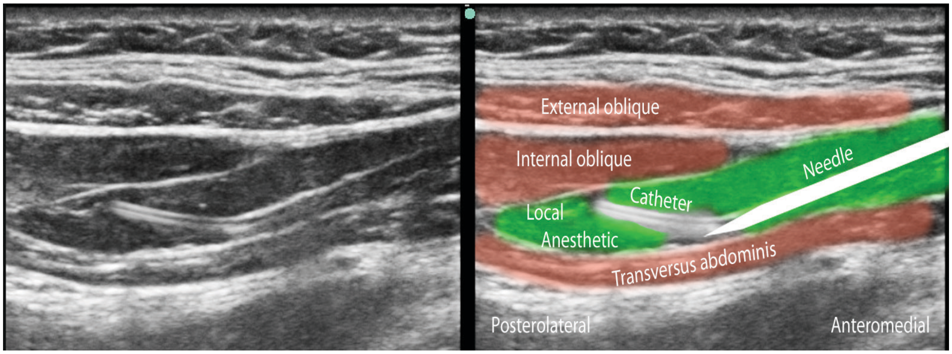


Figure 4-9 Ultrasound image of a catheter feeding out of a Tuohy needle within the TAP. Create space for the catheter by using a bolus of local anesthetic.

The needle insertion site can be located very close to the surgical incision, making preoperative catheter placement impractical. Often, TAP catheters are inserted postoperatively to avoid issues of sterility in the surgical field. Postoperative TAP catheters can be placed while the patient still under general anesthesia, making the procedure more comfortable for the patient. If placing catheters preoperatively or to make the insertion site more posterior, consider a needle approach from the posterior (dorsal) side, aiming anteriorly. This can be accomplished by placing the patient in a lateral or semilateral position to make room for a posterior needle insertion.

Complications

Complications of the TAP block include abdominal perforation, liver hematoma, block failure, pneumothorax, hematoma, and local anesthetic toxicity.

Pearls

- The TAP block can be placed after surgery with the patient still anesthetized or in the post-anesthesia care unit.
- In obstetrics, the block can be placed after skin closure for cesarean section under a spinal or epidural anesthetic.
- If the block is performed preoperatively, sedation is important because this blocks can be uncomfortable for the patient. However, oversedation will result in airway obstruction, which causes the abdomen to rock, making it almost impossible to perform the block. Ensure adequate airway control while sedating for this block.
- If performing bilateral TAP blocks, be cognizant of the total volume of local anesthetic used, particularly in patients with a low body weight. Be sure to keep track of any local anesthetic used by the surgeon as well.
- If a TAP block is performed for inguinal hernia repair, the block should be placed in the more caudad portion of the abdominal wall, just superior to the iliac crest, to ensure that the L1 dermatome is captured (see “Ilioinguinal-Iliohypogastric Nerve Block”).
- Initially, use saline to check injection depth, rather than local anesthetic. In a small patient, particularly when performing bilateral blocks, it is very easy to reach a potentially toxic local anesthetic dose. Do not waste local anesthetic finding the correct depth or locating the needle.

Quadratus Lumborum Block

Introduction

The quadratus lumborum block is an emerging block with limited evidence for efficacy compared with other blocks such as the TAP block. The interest in this block arises from the limitations and variations in spread of local anesthetic encountered with the TAP block. To find a more consistent block and to mirror the position of the original landmark TAP block in the triangle of Petit (inferior lumbar triangle), the concept of a quadratus lumborum block was developed. The hope with this block is to increase the spread of local anesthetic by permitting spread through tissue layers. Some reports claim significant cephalad and paravertebral spread resulting in better and more extensive analgesia. Despite at least three separate descriptions of this block, the published evidence on improvement of postsurgical outcomes is limited.

This block is performed more posterior than the TAP block and closer to the origin of the segmental nerves in an effort to produce more extensive analgesia from a single injection of local anesthetic. The thoracolumbar fascial layers and the arcuate ligament of the diaphragm permit the possibility of an extensive spread of local anesthetic injected at this level. As with all fascial plane blocks, the spread of local anesthetic through the tissues can be variable. The main advantages of the quadratus lumborum block are simplicity, safety of performance, and improved local anesthetic spread. The disadvantage is the greater depth and vague tissue planes in obese patients.

Anatomy

The quadratus lumborum is a muscle in the lower back that forms part of posterior wall of the abdominal cavity. The muscle originates from the inferior border of the 12th rib and extends to the transverse processes of the lumbar vertebrae down to the posterior iliac crest. The quadratus muscle has four small tendinous connections to the transverse processes of the upper four lumbar vertebrae. The quadratus lumborum muscle is surrounded by the transversalis fascia anteriorly and the thoracolumbar fascia posteriorly and laterally. The muscular relations to the quadratus lumborum muscle include the psoas major muscle anteromedially, the sacrospinalis muscle posteriorly, and the latissimus dorsi laterally. Lateral and anterior to the quadratus lumborum within the abdominal wall are the external oblique, internal oblique, and the transversus abdominis muscles of the TAP block. These three muscles continue posteriorly as the thoracolumbar and transversalis fascia which envelopes the quadratus lumborum muscle. Superiorly, there is an intimate connection with the lateral arcuate ligament of the diaphragm on the 12th rib. The lumbar spinal segmental nerves exit the foramina and traverse in close relation to the quadratus lumborum before running within the TAP. Three different quadratus lumborum block approaches have been described (QL1, QL2, and QL3); the QL3 approach is described first, and others are described in the "Alternative Approaches" section.

Clinical Applications

Like the TAP block, the quadratus lumborum is useful for abdominal procedures when an epidural block is not indicated. Urology, gynecology, and general surgery procedures are all possible candidates for this nerve block.

Technique

Ultrasound Details

Monitors: ECG, NIBP, pulse oximeter.

Skin Preparation: Chlorhexidine with alcohol over the lower lateral abdominal wall. Ensure that the prep extends sufficiently posterior to clean the needle insertion site.

Probe: A curvilinear low-frequency probe (2-5 MHz) allows full evaluation of the quadratus lumborum muscle and surrounding anatomy. In patients weighing less than 90 kg, a linear probe may also effectively be utilized. The expected target depth in an 80-kg patient is 3 to 5 cm.

Patient Position: Lateral with the upper hip flexed, or semilateral with a pillow or blanket placed under the ipsilateral hip.

Local Anesthetic Choice: Usually, 30 mL of local anesthetic is required on each side if multiple dermatomes are to be blocked. Be conscious of the total local anesthetic dose and the potential for toxicity. Bupivacaine 0.25% is adequate for analgesia.

Scanning Technique

1. **It is essential to ensure proper positioning so that the probe can be easily placed on the posterior abdominal wall. The patient can be positioned in full lateral or semilateral position with a folded towel or pillow underneath the hip** (Figure 4-10).

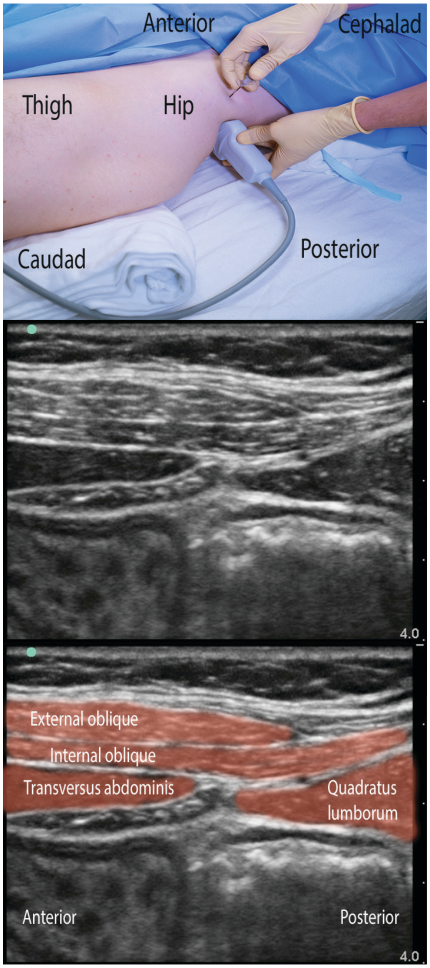


Figure 4-10 For the quadratus lumborum block, the patient is placed in a semilateral position with a folded blanket underneath the ipsilateral hip. The ultrasound probe is located just above the iliac crest.

2. **Start by finding the three muscles of the TAP (i.e., external oblique, internal oblique, and transversus abdominis) in the midaxillary line between the rib cage and the iliac crest. Then slide the probe posteriorly**.
3. **The TAP muscles will all taper and end as a hyperechoic fascial layer. Medial and posterior to this, the quadratus lumborum will appear as a dark, oval-shaped muscle.** (see Figure 4-10).
4. **Superficial and lateral to the quadratus lumborum, the latissimus dorsi can be identified.** The latissimus appears at similar depth but posterior to the external oblique muscle. The quadratus lumborum sits deep and further posterior to the latissimus dorsi. The psoas muscle should be identified deep and anterior to the quadratus lumborum (Figure 4-11).
5. **Confirm the identity of the quadratus lumborum by finding the body and transverse processes of the lumbar vertebrae.** The transverse process of lumbar vertebrae can often be identified as a dark shadow (Figure 4-12). The quadratus lumborum is attached to the lateral tip of the transverse process. The ultrasound probe can be tilted slowly in a cephalad-to-caudad direction to make the shadow of the transverse process appear and disappear. The transverse processes can be small and the imaging subtle, so use slow movements of the probe.

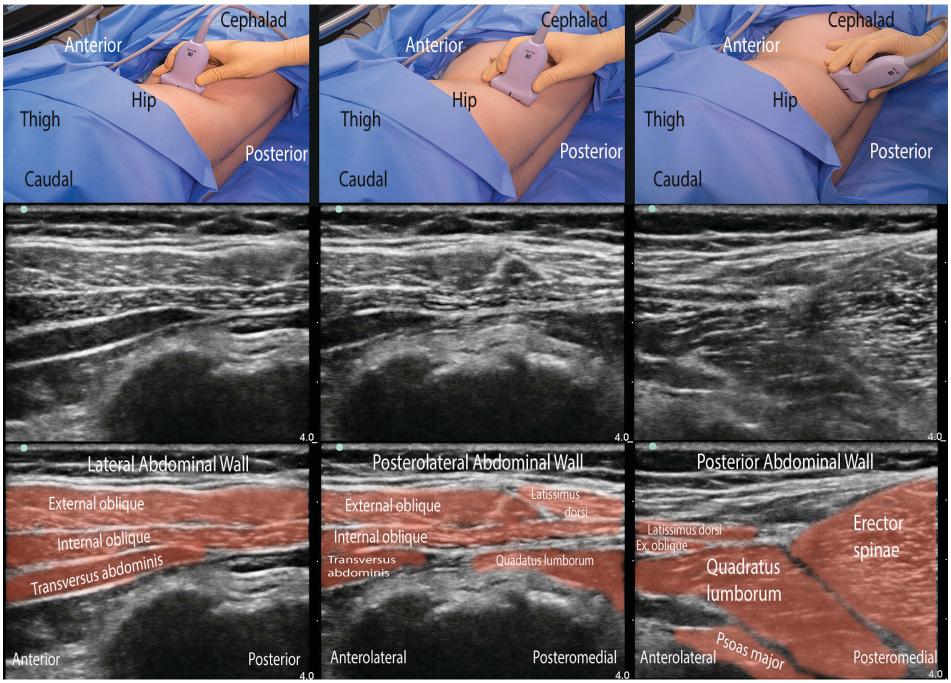


Figure 4-11 The scan is performed systematically from the lateral abdominal wall posteriorly for a patient in the lateral decubitus position. Probe position starts lateral to identify the three muscles of the abdominal wall *(left images)*. As the probe is moved posteriorly, the three muscles taper, and the quadratus lumborum is identified *(middle images)*. Further posteriorly, the erector spinae (superficial) and the psoas major (deep) help to identify the quadratus lumborum *(right images)*.

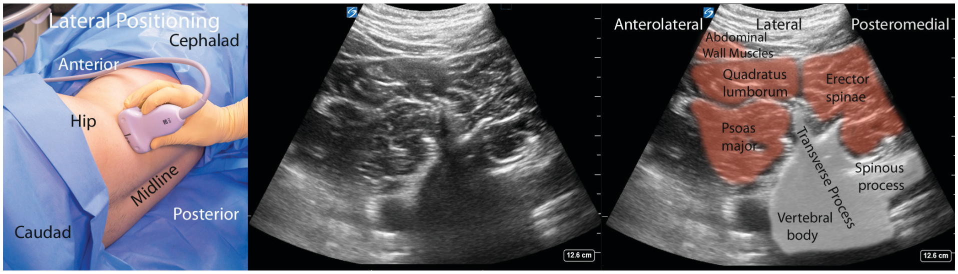


Figure 4-12 To confirm the quadratus lumborum, slide or angle the probe to visualize the bony landmarks of the spine. The quadratus lumborum is closely associated with the transverse process of the vertebra and is located between the erector spinae and psoas major. A curvilinear probe is usually required to image these deep structures.

6. **Position the quadratus lumborum muscle in the middle of the screen**.
7. **Insert the needle from the anterior side of the probe, in-plane, aiming posteriorly. The needle is advanced in-plane in a lateral/anterior to medial/posterior direction.** Determine the site of injection (Figure 4-13). Injection of local anesthetic does not have to be limited to one injection site.
8. **The end point for needle advancement is the fascia between the quadratus lumborum and the deeper psoas muscle** (Figure 4-14). Incrementally inject 20 to 30 mL of local anesthetic.

Alternative Techniques

The alternative techniques for this block have similar positioning and needle direction. What differs is the needle tip placement and injection. The technique described earlier is for the QL3 or transmuscular approach. This approach results in the deepest injection, but it does have the psoas muscle as a safety backstop. The QL1 and QL2 approaches are more superficial injections. They are similar but more posterior than an ultrasound TAP block. No outcome differences have been reported among the three different approaches to blockade of the quadratus lumborum (see Figure 4-13). However, as more evidence is published, one of these injection sites may prove superior to the others.

QL1 and QL2 Approaches

All three quadratus lumborum approaches use the same patient and probe position described earlier.

QL1 approach: Find the posterior taper of the abdominal wall muscles as they coalesce posteriorly and meet the quadratus lumborum (see Step 3 under "Scanning Technique"). The needle is advanced in an anterior-to-posterior direction toward the anterolateral border of the quadratus lumborum (Figure 4-15). The final needle position lies deep to the thoracolumbar fascia and superficial to the transversalis fascia of the abdominal wall. Inject the local anesthetic at that location. This is similar to a very posterior TAP block approach and will possibly be the approach most familiar to anesthesiologists.

QL2 approach: The final needle position should be between the erector spinae, latissimus dorsi, and the quadratus lumborum muscles posterior to the middle layer of the

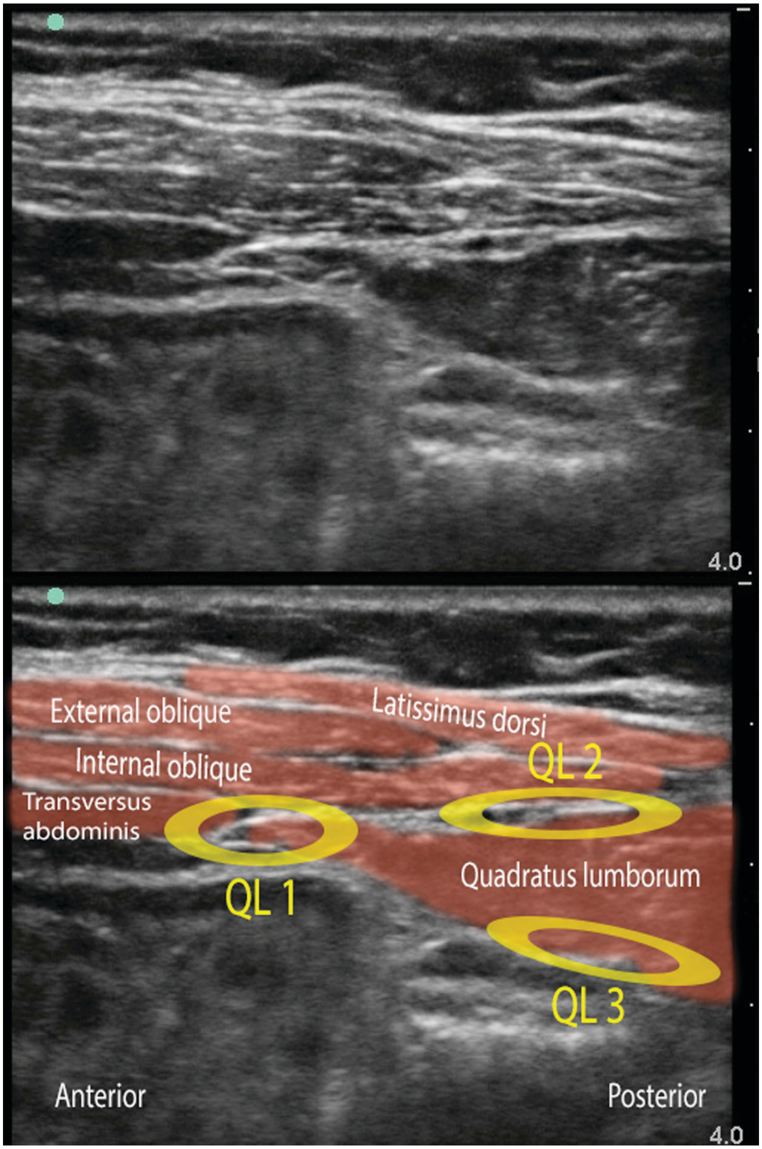


Figure 4-13 There are several descriptions of the quadratus lumborum block. The QL1 variation is performed by injecting at the lateral anterior border of the quadratus muscle. The QL2 variation is performed by injecting on the superficial border of the quadratus lumborum. The QL3 variation is performed by injecting deep to the quadratus lumborum.

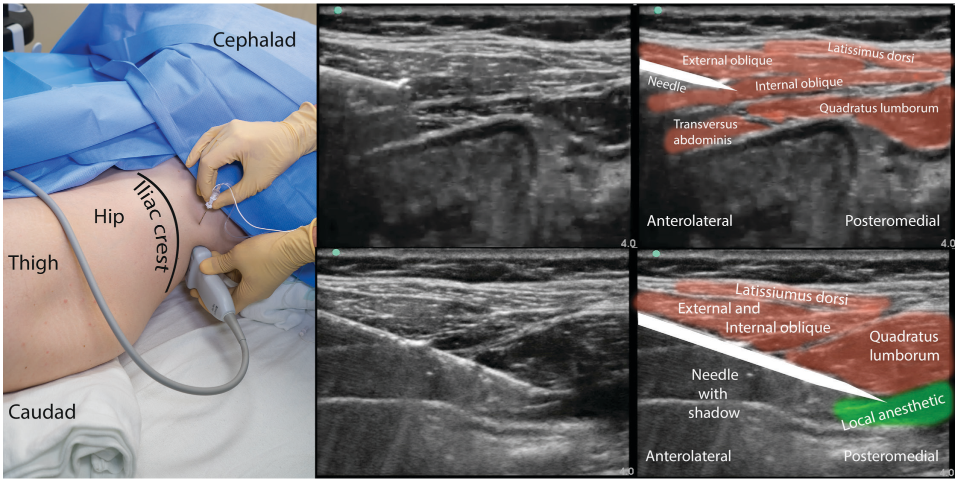


Figure 4-14 Quadratus lumborum block with injection at the QL3 location. The needle is advanced from anterolateral to posteromedial with a target injection site deep to the quadratus lumborum.

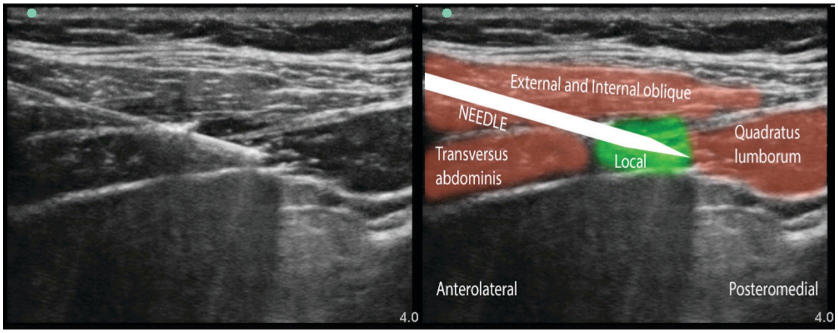


Figure 4-15 Quadratus lumborum block with injection at the QL1 location. The injection is targeted at the anterolateral border of the muscle.

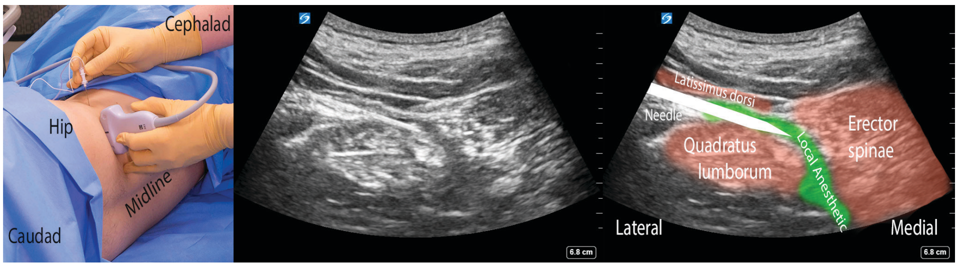


Figure 4-16 Quadratus lumborum block with injection at the QL2 location. The injection is targeted at the superficial border of the quadratus lumborum, and local anesthetic can be visualized tracking medially.

thoracolumbar fascia (Figure 4-16). The needle is advanced dorsal (shallow) to the quadratus lumborum muscle to this position, usually traversing the external oblique to reach its end point.

Complications

Complications include block failure, inadvertent intraperitoneal injection, intravascular injection, and bruising.

Pearls

- Flexion of the patient's hip can help identify the quadratus lumborum.
- If landmark identification is difficult, increase the depth on the ultrasound screen and identify the dark shadow of the vertebral body with the spinous process behind it. Find the transverse process rising up as a dark shadow 90 degrees to the spinous process. Use the bony shadow to orient the muscle positions. Remember that the quadratus lumborum is attached to the tip of the spinous processes (see Figure 4-12).
- Because of the depth of the block, it may be helpful to perform a prescan to carefully identify the known landmarks of the external oblique, internal oblique, and transversus abdominis muscles. Once these are identified, increase the depth to allow for identification of the quadratus lumborum.
- If the needle is in the correct trajectory passing the QL1 injection point lateral to the quadratus lumborum, inject local anesthetic at that level first. Then, continue needle advancement to the injection point between the quadratus lumborum and psoas major (QL3) or superficial to the quadratus lumborum (QL2).

Ilioinguinal-Iliohypogastric Nerve Block

Introduction

The ilioinguinal-iliohypogastric nerve block can be used for anesthesia and analgesia during and after inguinal surgery, including inguinal hernia repairs. The nerve block was classically performed as a landmark technique that utilized tactile puncture of fascial planes. These landmark and fascial pop techniques had relatively poor outcomes leading to block failure and complications.

Anatomy

The ilioinguinal (L1) and iliohypogastric (T12 and L1) nerves are branches of the lumbar plexus. These nerves exit the neuraxis between the iliacus and psoas muscles posteriorly. They then pierce the transversus abdominis to run in the TAP between the internal oblique and the transversus abdominis.

Clinical Applications

The ilioinguinal-iliohypogastric block can be used for analgesia during inguinal surgery (e.g., hernia repair) or surgery on the scrotum (e.g., orchiectomy). Additionally, this block can be used as a diagnostic tool to detect chronic somatic pain after inguinal hernia repair. The ilioinguinal-iliohypogastric block can be performed bilaterally if necessary. However, use of this block alone for surgical anesthesia is often difficult because of the lack of visceral coverage.

Technique

Ultrasound Details

Monitors: ECG, NIBP, pulse oximeter.

Skin Preparation: Chlorhexidine with alcohol.

Probe: Middle- to high-frequency linear probe (6-15 MHz). In obese patients, a curvilinear low-frequency probe may be necessary. The expected target depth in an 80-kg patient is 3 to 5 cm.

Patient Position: Supine.

Local Anesthetic Choice: Usually, 10 to 20 mL of local anesthetic can effectively achieve a unilateral analgesic block. Be conscious of the total local anesthetic dose and the potential for toxicity because surgeons also routinely use local anesthetic for these surgeries without asking whether an ilioinguinal-iliohypogastric block has already been performed. Bupivacaine 0.25% to 0.5% and ropivacaine 0.25% to 0.5% are adequate for analgesia lasting between 12 to 24 hours. For shorter-duration blocks, mepivacaine 1.5% to 2% can be used.

Scanning Technique

1. **Place the patient in a supine position.**
2. **Place the probe over the bony prominence of the anterior superior iliac spine (ASIS).** The probe should be rotated so that one side rests on the ASIS and the other side points toward the umbilicus (Figure 4-17).
3. **Slide the probe cranial and caudal, keeping the bony iliac crest in the lateral part of the ultrasound image.** Sometimes, it helps to slide the probe more posteriorly along the iliac crest.
4. **Identify the layers of the anterior abdominal wall.** The layers of the abdominal wall in this location, from superficial to deep, are (1) adipose and connective tissue,

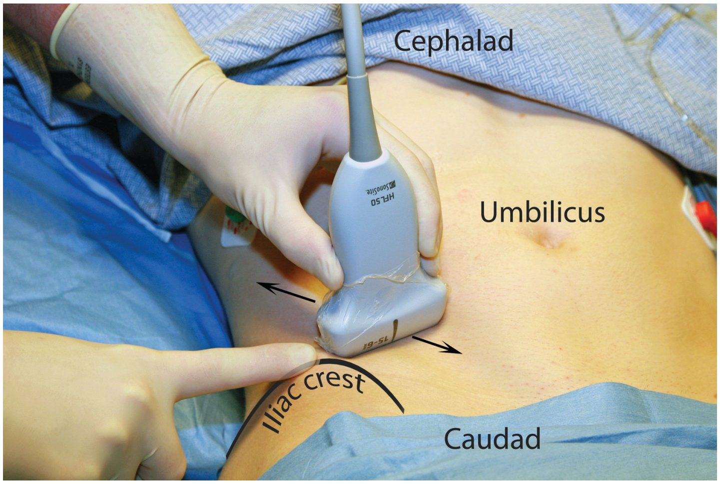


Figure 4-17 Probe position for the ilioinguinal-iliohypogastric nerve block. The lateral end the probe is positioned on the anterior superior iliac spine, and the medial end is pointed toward the umbilicus. Sliding the probe *(arrows)* helps to improve identification of the sonoanatomy.

(2) external oblique, (3) internal oblique, and (4) transversus abdominis. In some patients, a fourth muscle, the iliacus or iliopsoas, may be visualized as a thick, deep muscle underneath the transversus abdominis (Figure 4-18).

5. **As the probe is moved in the caudad-to-cephalad direction, the most superficial muscle, the external oblique, can be seen thickening more cranially. When the probe is moved in caudally in the opposite direction, the external oblique thins to the point of disappearance.** The lower anterior portion of external oblique is an aponeurosis (fascial connective tissue).
6. **The ilioinguinal and iliohypogastric nerves are located between the internal oblique and the transversus abdominis, similar to their locations in a TAP block.** Sometimes they appear as a bright (hyperechoic) band between these two muscle

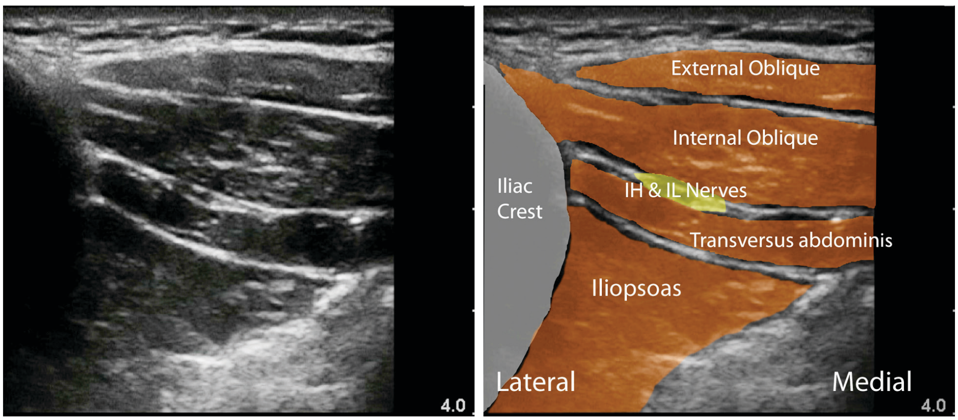


Figure 4-18 Ultrasound image of the muscle layers and iliac crest obtained during performance of ilioinguinal-iliohypograstric nerve block.

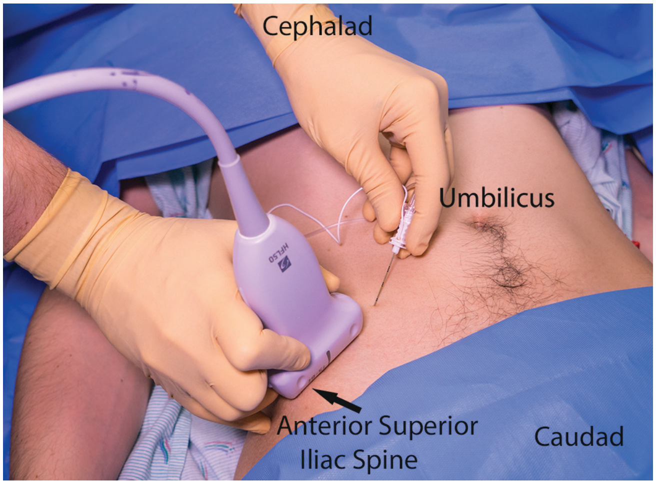


Figure 4-19 Needle entry for an in-plane ilioinguinal-iliohypograstric nerve block is performed by advancing from the medial end of the probe, aiming laterally.

layers and at other times as a hypoechoic (dark) oval with a bright, hyperechoic covering. The nerves are very closely related to the iliac crest, so one should attempt to visualize them just superior and medial to the dark acoustic shadow from the iliac crest or ASIS.

7. **Attempt to perform the block as laterally as possible because the nerve branches as it courses anteriorly and may be harder to visualize there.**
8. **Advance the needle from medial to lateral** (Figure 4-19).
9. **Advance the needle until it enters the fascial plane between the internal oblique and transversus abdominis muscles** (Figure 4-20). The local anesthetic will spread in the plane between these muscles, so there is no need to aim directly for the nerves with the needle. The local anesthetic will also continue to track in this plane after injection.
10. **If the specific nerves cannot be identified, just place the local anesthetic in the fascial plane.**

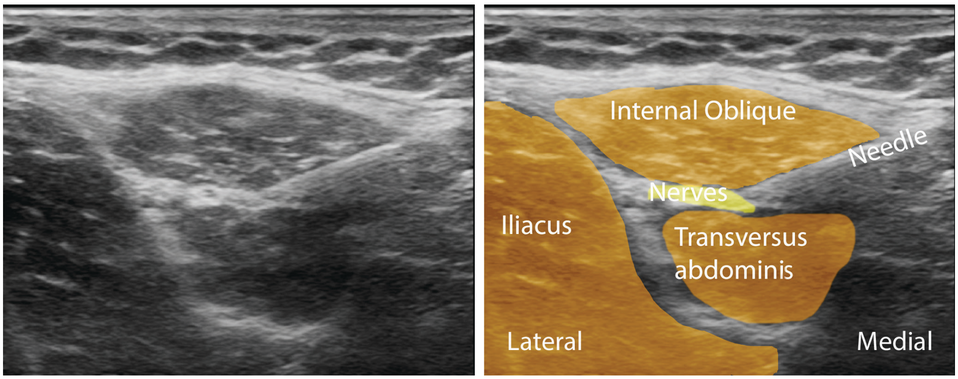


Figure 4-20 In-plane image of a needle advanced from a medial approach toward the ilioinguinal and iliohypogastric nerves.

Alternative Techniques

Because of the depth of this nerve, an out-of-plane technique can be used when needle visualization is compromised with an in-plane technique.

1. Identify the muscle planes and/or the nerves as described in the description of the in-plane technique. Put the target structures in the middle of the ultrasound image, and then place the image of the needle in the middle of the ultrasound probe. Start several centimeters away from the probe in an attempt to make the "dot" of the needle brighter (Figure 4-21).
2. Use one or more of the out-of-plane techniques described in "How to Visualize Nerves and Needles" in Chapter 1. These techniques include (1) sliding the probe, (2) tilting the probe, and (3) adjusting the needle.
3. As with the in-plane technique, the needle does not need to be advanced directly to the nerve but rather just into the fascial plane between the internal oblique and the transversus abdominis. The local anesthetic will spread to the nerve within the fascial plane (Figure 4-22).

Complications

Complications of the ilioinguinal-iliohypogastric block include, but are not limited to, block failure, hematoma, nerve damage from the needle or local anesthetic, abdominal wall puncture, and femoral nerve block if the local is placed too deep in the wrong plane. Assess the patient for leg weakness before ambulation after surgery.

Pearls

- The ilioinguinal-iliohypogastric nerves are located very close to the iliac crest. Try to keep some portion of the iliac crest in the image during the block to ensure accurate placement of the local anesthetic.
- The nerves are covered by a fascial layer. Attempt to inject the local anesthetic slightly deep to the fascia between the internal oblique and transversus abdominis to ensure the best results.

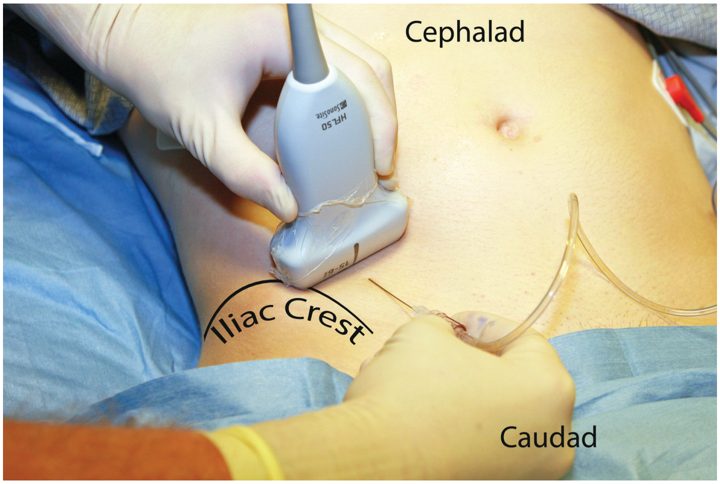


Figure 4-21 Out-of-plane approach for the ilioinguinal-iliohypogastric nerve block.

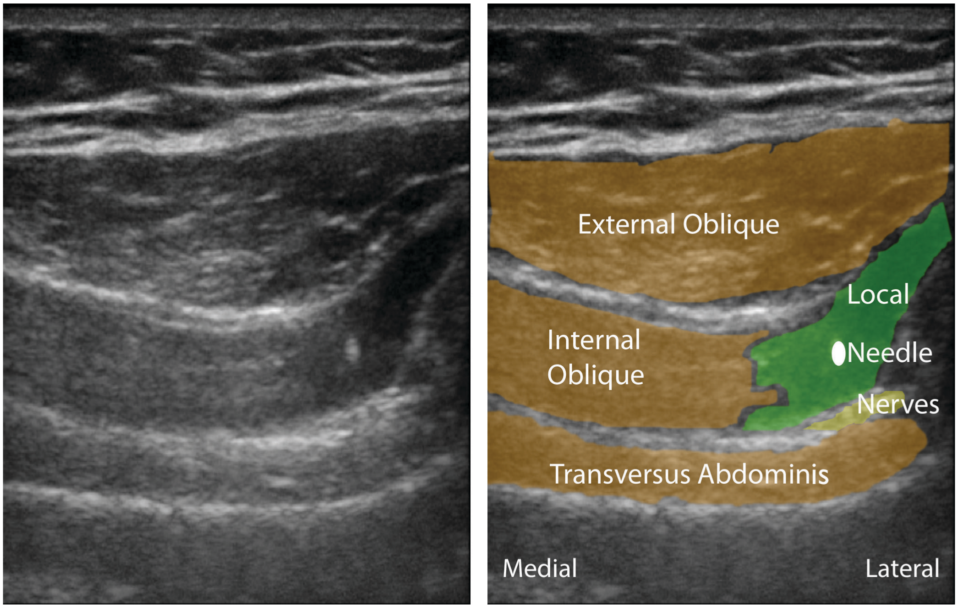


Figure 4-22 Ultrasound image of local anesthetic spread and the needle tip during an out-of-plane injection for an ilioinguinal-iliohypogastric nerve block.

- For obese patients, in whom imaging of the anatomy and needle may be difficult, inject in several fascial planes to ensure that the local anesthetic makes it to the correct plane.
- The initial placement of the probe for identification of the layers of the abdominal wall musculature is crucial. If there is a lot of overlying adipose tissue, the muscles can be deep and difficult to identify. To improve the image, adjust the frequency of the probe and change the focus position of the beam to help identify deeper nerves.
- If the muscles are still difficult to identify, slide the probe to the umbilicus and scan to identify the rectus abdominis muscle (see "Transversus Abdominis Nerve Block"). Slide the probe to the lateral edge of the rectus abdominis and identify the three muscle layers (external oblique, internal oblique, and transversus abdominis). At the level of the umbilicus, the internal oblique will be a continuation of the lateral aponeurosis of the rectus abdominis. Once the internal oblique is recognized, scan laterally to identify the external oblique muscle superficial and the transversus abdominis muscle deep to it. Finally, slide the probe to the ASIS as before, all the while imaging the three muscle planes.
- Once you are confident with this block or when the nerves are well identified, a smaller needle (e.g., 25 gauge) can be used as an attempt to reduce puncture pain and bruising.
- This block can result in quadriceps weakness from injection deep to the transversus abdominis and underneath the fascia of the iliacus (e.g., fascia iliaca block). If the block is performed preoperatively, ensure quadriceps motor strength before surgery. Surgeons often aggressively infiltrate local anesthetic in this area, leading to femoral blocks of their own. At discharge, be vigilant for quadriceps weakness as a potential complication. Femur fractures have been reported as a result of inadvertent femoral blocks.
- This area can be highly vascularized. Before injection, use color Doppler imaging to identify any accompanying vessels. Then, ensure that the needle does not unintentionally puncture the vessels.

Rectus Sheath Nerve Block

Introduction

The rectus sheath block is useful for midline abdominal incisions. Prior techniques using fascial "clicks" or "scratches" for placing local anesthetic in this area were effective but inconsistent. Ultrasound has greatly increased the success of this block by allowing direct visualization of the rectus sheath. One of the theoretical benefits of the rectus sheath block is access to the continuous plane on the posterior portion of the rectus abdominis. This may allow local anesthetic to spread and cover multiple dermatomal levels. This is another plane block that can be performed under general anesthesia for greater patient comfort.

Anatomy

The lower five intercostal nerves and the subcostal nerve pierce the sheath of the rectus abdominis muscle and terminate as the anterior cutaneous branch. These branches supply the rectus abdominis muscle and the skin overlying it. Behind the body of the muscle lies a fascial layer. Above the arcuate line (found between the umbilicus and the pubis), the fascia deep to the rectus abdominis is a continuation of the internal oblique and transversus abdominis muscles. Below the arcuate line, the hyperechoic fascia layer deep to the rectus muscles is the transversalis fascia and parietal peritoneum. Irrespective of level, the abdominal contents lie beneath this bright fascia.

Clinical Applications

The rectus sheath block is useful for midline incisions from the pubis to the xiphoid. This block can substitute for an epidural when an epidural contraindicated. One should recognize that somatic pain (abdominal wall) will be reduced but visceral pain (abdominal organs) will not be covered with this block.

Technique

Ultrasound Details

Probe: High-frequency linear probe (10-15 MHz); expected target depth in 80-kg patient,: 2 to 3 cm, depending greatly on the amount of adipose tissue.

Patient Position: Supine.

Local Anesthetic Choice: This block is performed primarily for postoperative analgesia, so longer-acting local anesthetic agents are preferred. Use bupivacaine 0.25% to 0.5% or ropivacaine 0.25% to 0.5%.

Needle: A 22-gauge, 100-mm (4-inch) insulated block needle can be used. Others prefer a 25-gauge hypodermic or spinal needle for slim patients and pediatric cases. Smaller needles tend to cause less patient discomfort.

Scanning Technique

1. **Place the ultrasound transducer in a transverse plane across the abdomen in the midline** (Figure 4-23). As the probe is moved laterally a few centimeters, the body of the rectus abdominis muscle is visualized (Figure 4-24). As the probe is moved further lateral, the lateral border of the rectus muscle can be identified.
2. **Deep to the rectus abdominis muscle, identify the bright white (hyperechoic) layer of fascia, the transversalis fascia.** Beneath this bright fascia lie the abdominal contents (see Figure 4-24).
3. **One injection will not provide analgesia to the whole of the abdomen from sternum to pubis.** Although there is good multidermatomal spread with this block,

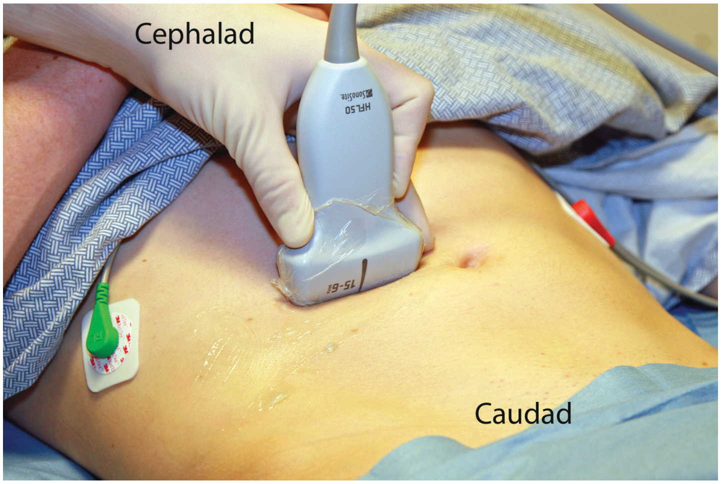


Figure 4-23 Initial probe position for a rectus sheath nerve block.

multiple injections are necessary for large incisions, and all blocks need to be performed bilaterally. The level of local anesthetic injection will vary depending on the site of the surgery. Inject the rectus abdominis at the same level as the incision, just lateral to the incision.

4. **The needle is advanced in-plane from lateral to medial.** The needle is advanced through the adipose tissue, through the muscle, and toward the transversalis fascia (Figure 4-25).
5. **The optimal injection point is just superficial to the posterior fascia. Focus the majority of the local anesthetic on the lateral aspect of the rectus abdominis** (Figure 4-26).
6. **If the needle is difficult to image, confirm needle location with several small test injections of local anesthetic.**
7. **Once the needle is placed successfully, a total 10 to 20 mL of local anesthetic is injected.**

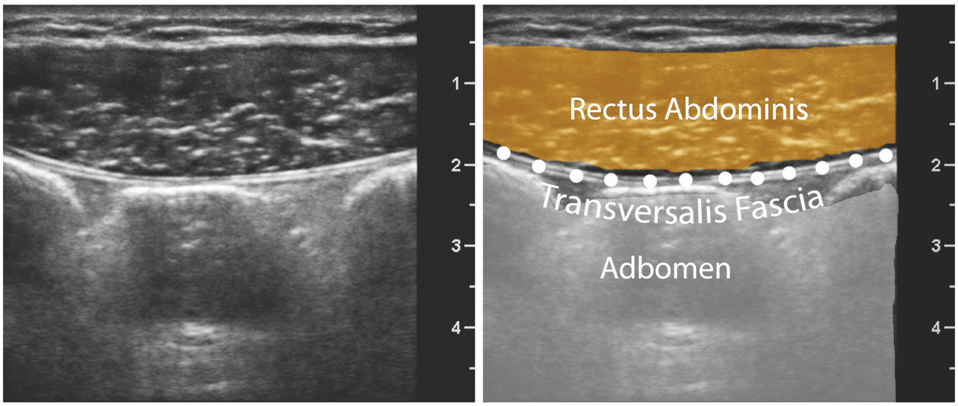


Figure 4-24 Ultrasound image of rectus abdominis muscle. The fascia dividing the muscle from the intraabdominal contents is the transversalis fascia.

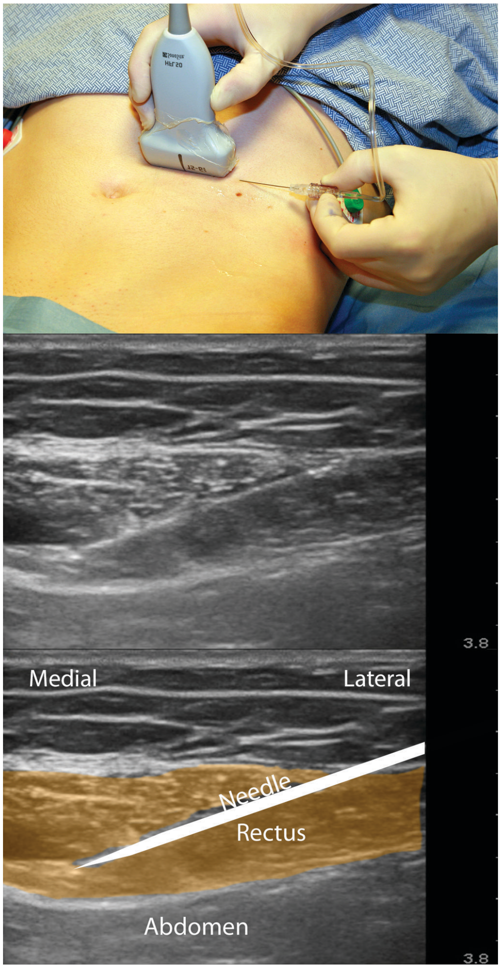


Figure 4-25 In-plane injection for a rectus sheath nerve block. Ensure spread of local anesthetic to the lateral border of the rectus muscle for best efficacy.

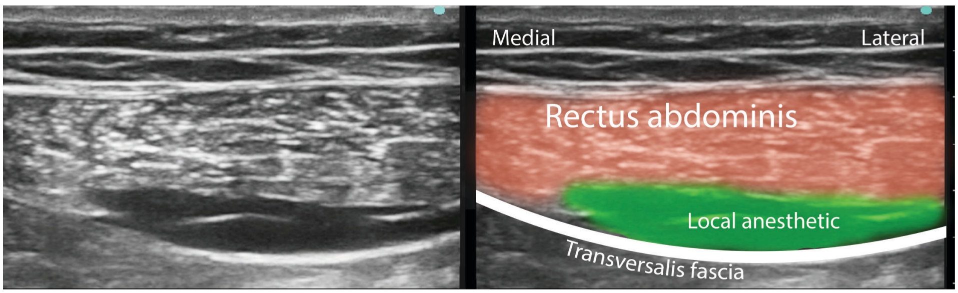


Figure 4-26 Correct placement of local anesthetic deep to the muscle for a rectus sheath nerve block.

Alternative Techniques

The technique for catheter placement is identical to that for a single-shot block and should be considered for a midline abdominal incision that is not too long. The disadvantage with this approach is that the catheter insertion site is very close to the surgical wound, so catheters are best placed in the postoperative period. Often, these blocks are placed while the patient is still under anesthesia at the end of the case, which eliminates patient discomfort during the block.

Complications

Complications of the rectus sheath block include block failure, inadvertent intraperitoneal injection, intravascular injection, and bruising.

Pearls

- In obese patients, the adipose tissue can be confused with the rectus abdominis. Slide the probe medially and laterally to visualize the tapering of the rectus abdominis on either side. Laterally, the rectus abdominis tapers to end in the linea semilunaris; the three muscle layers of the lateral abdominal wall (external oblique, internal oblique, and transversus abdominis) can also be visualized in the same plane.
- Success depends on the length of the surgical incision and how many individual bilateral blocks the anesthesiologist places. Consider four different injection sites for larger incisions: two upper injections bilaterally and two lower injections bilaterally.
- If time permits only one injection site bilaterally, block the upper dermatomes above the umbilicus. This should improve pain with respiration, potentially improving lung function and recovery.
- Sometimes, these blocks are performed above the umbilicus in conjunction with TAP blocks (for analgesia below the umbilicus).
- If performing pre-operative rectus sheath blocks, be sure to communicate well with the surgeon before the start of the case to identify exactly where the incision will be placed.

Intercostal Nerve Blocks

Introduction

The intercostal nerve block is one of the basic nerve blocks for anesthesia of the chest wall and abdomen. For years, this block has been used for numerous indications such as rib fracture and thoracotomy. With increasing obesity rates, traditional palpation of the ribs (the primary landmark for a landmark technique) has become more difficult. The main risk of intercostal nerve blocks is pleural puncture, but with ultrasound guidance and good technique, this risk should be attenuated.

Anatomy

The somatic sensory innervation of the thorax and upper abdomen is derived from the ventral rami of the spinal nerves, which travel anterior in the subcostal groove of the corresponding rib. Each nerve runs between the innermost and internal intercostal muscles. Each has a lateral cutaneous branch that splits off in the anterior axillary line and terminates in the ventral abdomen as the anterior cutaneous branch.

Clinical Applications

Single- or multiple-level intercostal blocks are useful for almost any thoracic or upper abdominal wall surgery. These blocks can often be used when an epidural is difficult or contraindicated or when unilateral analgesia is desired (e.g., thoracotomy, rib fractures). If paravertebral nerve blocks (PVBs) are difficult or contraindicated, consider an intercostal nerve block.

Technique

Ultrasound Details

Monitors: ECG, NIBP, pulse oximeter.

Skin Preparation: Chlorhexidine with alcohol.

Probe: A high-frequency linear probe (10-15 MHz); expected target depth in an 80-kg patient, 1 to 2 cm.

Patient Position: The patient can be positioned in a sitting, lateral, or prone position. Sitting or prone positioning is best for bilateral blocks. Lateral positioning is effective for unilateral blocks.

Local Anesthetic Choice: Usually, 20 to 40 mL of local anesthetic is required on each side if multiple intercostal levels are to be blocked. Typically. 5 mL is deposited at each intercostal space. Bupivacaine 0.25% or ropivacaine 0.25% is adequate for analgesia lasting up to 24 hours. Be conscious of the total local anesthetic dose and the potential for toxicity because these blocks are associated with the highest systemic absorption of any nerve block.

Scanning Technique

1. **Position the patient as desired and ensure correct sidedness if performing a unilateral block.**
2. **The probe should initially be placed on the back in a coronal (vertical) plane over the angle of the rib, at least 8 to 10 cm from the midline** (Figure 4-27). These blocks can also be performed more laterally in the midaxillary line and still be effective. Probe placement too far medially will require the block to be performed deeper, near the paravertebral space, increasing the level of difficulty.
3. **Identify the bright (hyperechoic) concave bumps of the ribs with acoustic dropout (dark anechoic shadow) beneath the bony reflection** (Figure 4-28).

Figure 4-27 Patient positioning and probe placement for the intercostal nerve block.

4. **Identify the space between the ribs and a deeper bright line of the pleura approximately 1 cm deeper than the level of the ribs. This is the intercostal space.**
5. **Sometimes, it is possible to identify the multiple layers of the intercostal muscles superficial to the pleura.** The muscle layers from superficial to deep are the external intercostals, the internal intercostals, and the innermost intercostals (Figure 4-29). The nerves will be located between the internal and innermost intercostals. Often, it is difficult to identify specific muscles, and they will appear en masse above the pleura. The intercostal nerves usually are not visible because they are covered by the subcostal groove of the overhanging rib.
6. **Slide the probe medially and laterally along the rib. As the probe is moved medially, the rib will descend deeper as it articulates with the transverse process.** Medial to this site is a paravertebral space (see "Paravertebral Nerve Block").
7. **Laterally, the upper ribs are covered by the scapula, which often makes performance of the intercostal block at that site impossible. In that case, a PVB is a suitable alternative.** Otherwise, continue laterally to the midaxillary line, where the scapula no longer shadows the ribs, and an image of the ribs and pleura will be available. For more caudal blocks, slide the probe inferiorly. Although the ribs will still be visible, the parietal peritoneum, not the pleura, will be seen between the ribs. The parietal peritoneum appears hyperechoic, but less so than the pleura.
8. **Insert the needle approximately 1 to 2 cm away from the probe, aiming cranially** (Figure 4-30).

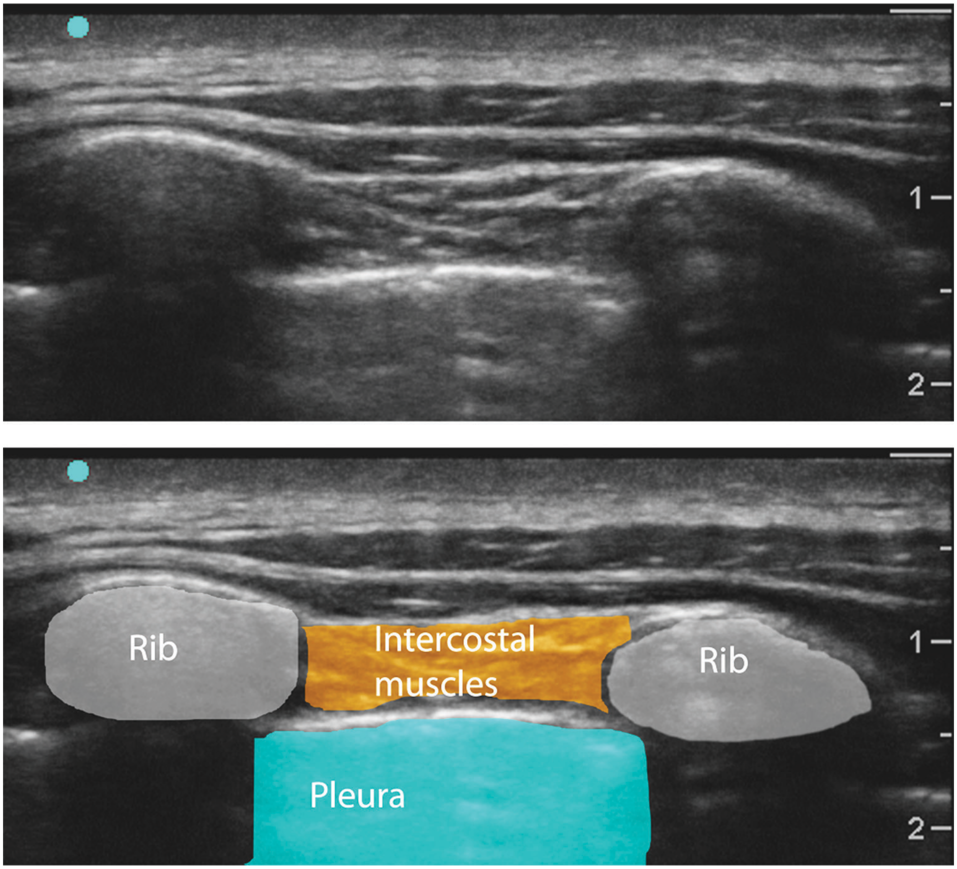


Figure 4-28 Ultrasound image of ribs, intercostal muscles, and pleura for an intercostal nerve block.

9. **Advance the needle to the inferior side of the rib.** Ensure that the needle is advanced to the deeper part of the rib, not just to the superficial border.
10. **Inject the local anesthetic between the innermost intercostal and the internal intercostal muscles** (Figure 4-31).
11. **Keep the needle tip above the pleura at all times, and inject the local anesthetic after careful aspiration.** If the needle tip is not visible, use small injections of saline or local anesthetic to locate the needle. Look for the local anesthetic to push the pleura deeper as it is injected. This is a good sign that the needle tip is in the correct position.

Alternative Techniques

Transverse Image, In-Plane Technique

The probe can be placed in the transverse plane and the needle advanced from medial to lateral or from lateral to medial. The image will be similar to the paravertebral image, but the injection point will be more lateral and shallower. We have used this technique for obese

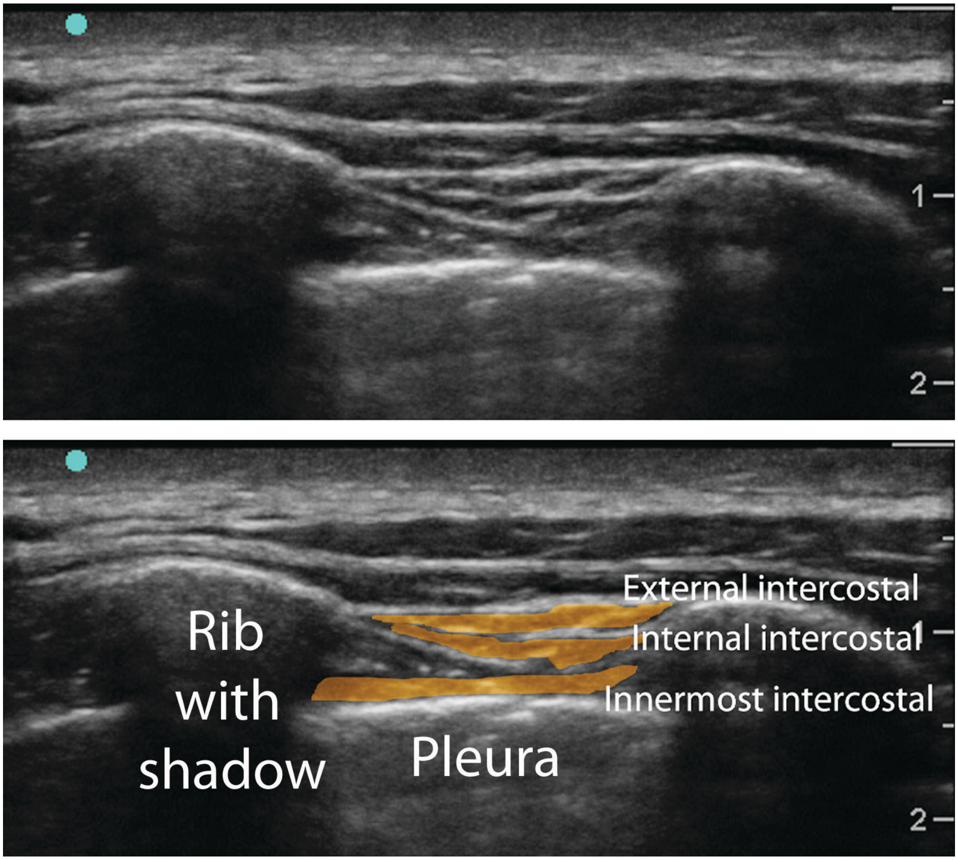


Figure 4-29 Ultrasound image demonstrating individual intercostal muscles.

patients in whom the paravertebral space is too deep to visualize and in the postoperative setting, where it can more difficult to get exposure to the patient's back. Continuous catheters can also be placed with this technique. These blocks can be performed on the lateral and anterior chest walls. Use a similar technique as for the transverse paravertebral approach (see "Paravertebral Nerve Block"), but the injection point will be more lateral.

1. Identify the intercostal space through Step 7 as described earlier.
2. Keeping a rib in the center of the image, slowly rotate the probe 90 degrees so that a longitudinal image of the rib is identified on the screen (Figure 4-32). It will appear as a hyperechoic stripe with full dropout beneath it.
3. Slide the probe caudally off the inferior border of the rib, keeping the probe parallel to the ribs.
4. The intercostal muscles and the pleura deep to them should now be visible (see Figure 4-32).
5. Find the area where the pleura is most shallow. Then, advance the needle in-plane from lateral to medial or from medial to lateral. Inject when the needle is above the pleura but deep to most of the musculature (Figure 4-33).

Figure 4-30 Probe and needle position for an in-plane intercostal nerve block.

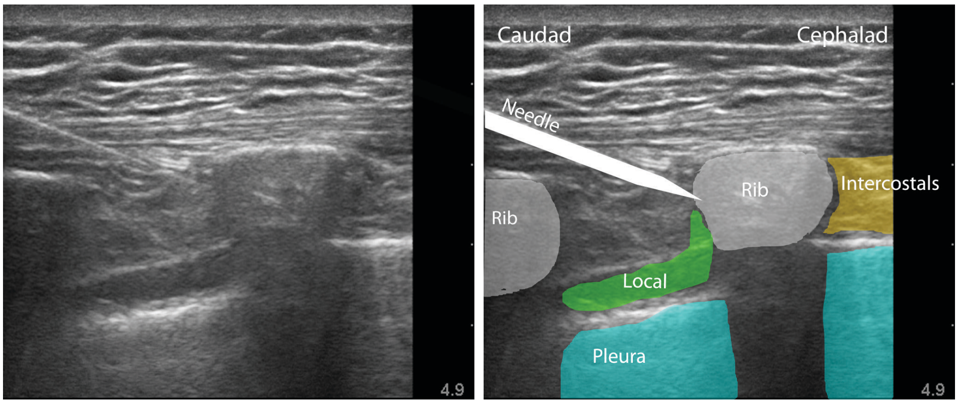


Figure 4-31 Ultrasound image of a needle advanced in-plane for the intercostal nerve block.

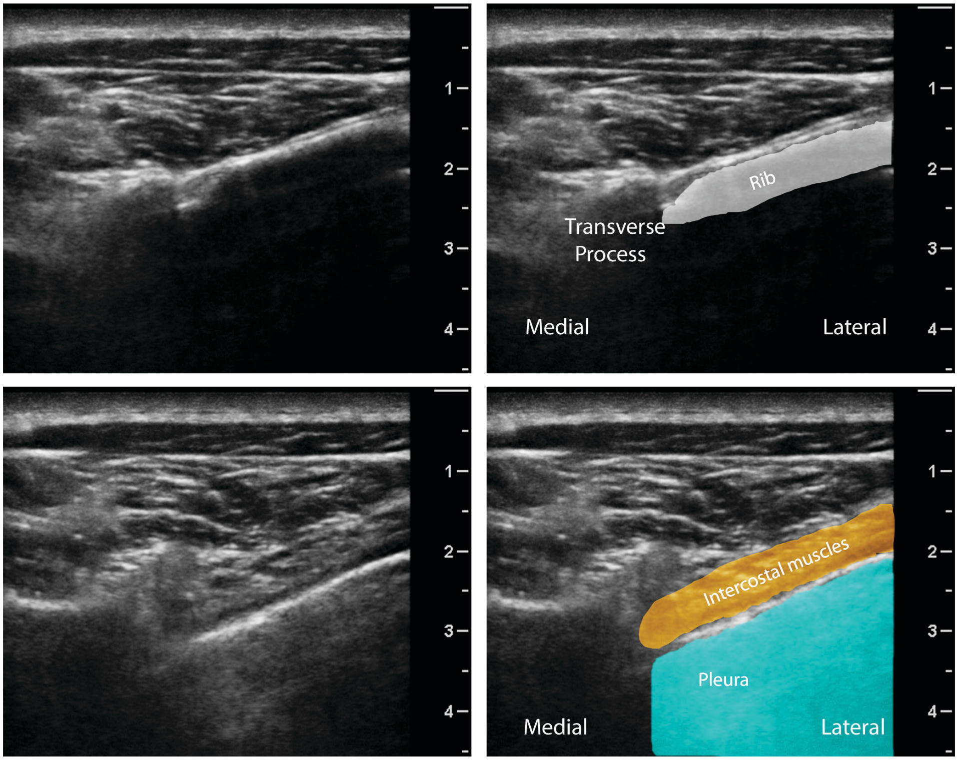


Figure 4-32 Ultrasound images obtained with the probe placed transversely along the length of the rib demonstrate the dropout shadow as the rib is scanned along its length *(upper images)*. In the lower images, the probe is moved caudad, still parallel to the length of the rib, but now lies over the length of the intercostal muscles. Deep to the intercostal muscles is the pleura.

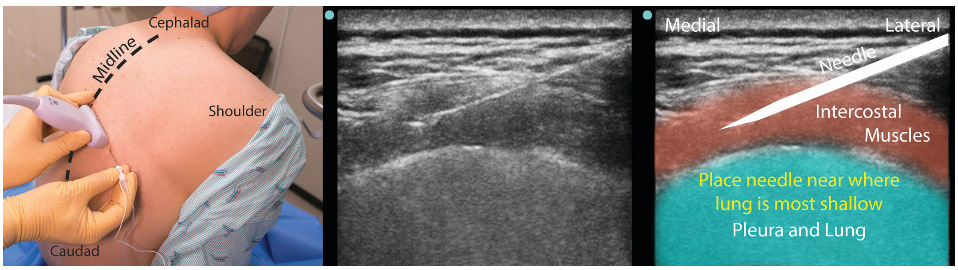


Figure 4-33 Transverse image of an in-plane intercostal nerve block. Find the shallowest location of pleura to improve ease of needle advancement. Place the needle just above pleura before injection.

6. If placing a catheter, use the lateral-to-medial technique. This allows the tip of the catheter to be placed as close as possible to the paravertebral space where multilevel spread can occur.
7. Look for the local anesthetic to push the pleura deeper as it is infiltrated. This is a good sign that the needle tip is in the correct position.
8. For catheter insertion, inject the local anesthetic to create space, then advance the catheter beyond the needle tip into that space.

Complications

Complications include block failure, pneumothorax, hematoma, epidural spread, and local anesthetic toxicity from high rates of absorption in the intercostal space.

Pearls

- **For rib fractures and after thoracotomies:** Start by positioning the probe in a coronal (vertical) plane at the point of maximum bony tenderness or at the lateral part of the thoracotomy scar. Scan the rib medially to ensure that the block is performed at the correct spinal level.
- **For anesthesia of the lateral thorax and lateral abdominal wall:** The injection point should be posterior and medial (not more than 15 cm from midline) to ensure that the lateral branch of the intercostal nerve is included in the block.
- **Look for the pleura to be pushed deeper during injection.** This is a specific sign of good needle position for an intercostal block, similar to a paravertebral block. However, even if the pleura is not pushed deeper on injection, the block may still be effective, so do not risk a pneumothorax just to ensure that the pleura is moving deeper during injection (Figures 4-33, Figure 4-50 and Figure 4-52).
- **These blocks can be performed postoperatively, when one is better able to evaluate the extent of excision and the dermatomal levels affected.**

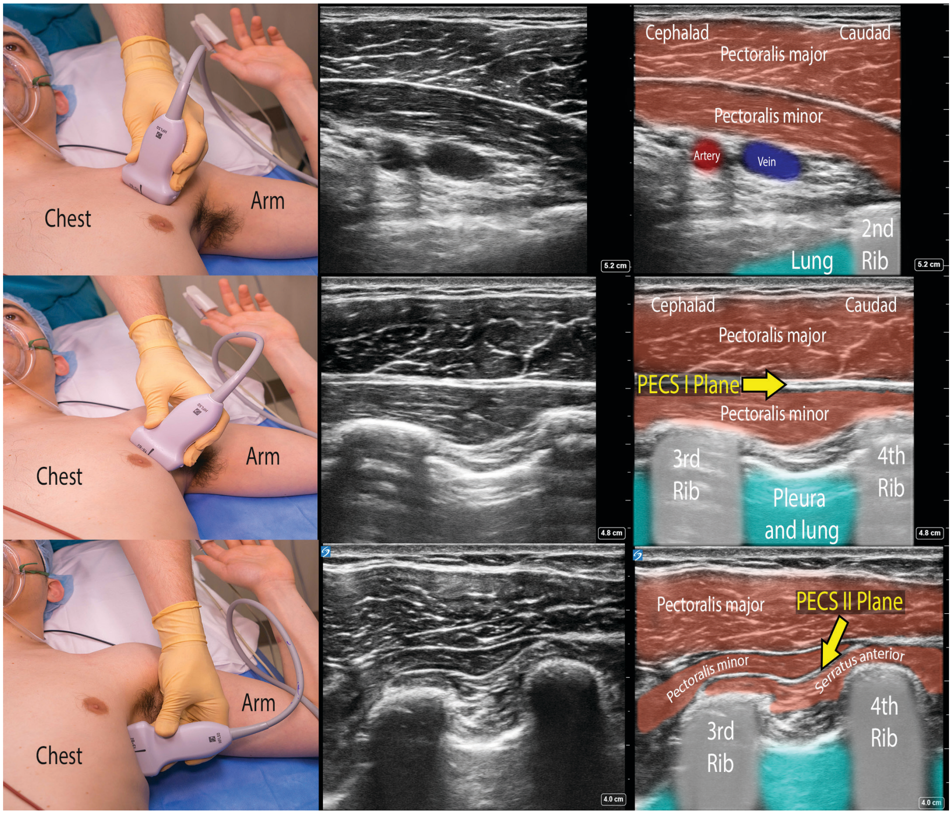


Figure 4-34 Probe positions and sonoanatomy for the PECS I and PECS II blocks. In the upper images, the probe is placed in the deltopectoral groove. The axillary artery and vein can be imaged, as with an infraclavicular nerve block. Next, slide the probe caudally to locate the pectoralis major and minor overlying the third and fourth ribs *(middle images)*. The PECS I injection plane is here between the pectoralis major and minor muscles. Slide the probe further caudally and laterally to identify the posterior edge of the pectoralis minor muscle *(bottom images)*. The muscle overlying the ribs is the serratus anterior. The PECS II injection plane is between the serratus and the pectoralis minor, near the lateral edge of the pectoralis minor.

PECS Block

Introduction

The pectoral blocks (PECS I and II) and the serratus plane block were developed to provide analgesia for chest surgeries including breast surgery. They provide alternative or supplemental analgesia to surgical infiltration or PVBs. Data on the clinical efficacy of these techniques is currently lacking. Success rates compared with the paravertebral blocks have yet to be demonstrated, but their simplicity and safety have made the PECS blocks popular. The original description of the ultrasound-guided PECS I block targeted only the lateral and medial pectoral nerves. These blocks can be useful in painful breast surgeries such as mastectomy with immediate reconstruction or placement of tissue expander deep to the pectoralis muscles. The PECS I block is rarely used on its own now; it is typically combined with the deeper PECS II block, a serratus plane block, or PVBs. The PECS II block is used to augment axillary pain. The serratus plane block is the latest iteration of these anterior chest wall blocks; it is placed further lateral and inferior than the PECS II, potentially providing more extensive analgesia of the chest wall.

Anatomy

The nerve supply of the breast and chest wall is complex, with multiple nerves contributing to postoperative pain. The thoracic intercostal nerves provide the innervation of the chest wall and breast tissue via their lateral and terminal branches in dermatomes 2 through 6. The axilla has cutaneous innervation provided by thoracic dermatomes 1 and 2. The anterior terminal branch of the thoracic nerves runs between the intercostal muscles and the rib, where it terminates by piercing the fascia and supplying the medial portion of the breast. The anterior terminal branches of the thoracic nerves are not blocked by the PECS block. The lateral perforator branch leaves the intercostal nerve and travels between the serratus anterior and the pectoralis minor before piercing the tissues and supplying the skin over the middle and lateral portions of the breast. The course of the lateral perforator branch of the thoracic nerve through these fascial layers permits it to be blocked by the PECS II.

Deeper in the chest wall, the fascia overlying the pectoral muscles and the pectoralis major and minor muscles themselves are innervated by the lateral and medical pectoral nerves. The pectoral nerves are branches of the lateral and medial cords of the brachial plexus and run between the pectoralis major and minor muscles. Branches of the thoracoacromial artery are also found in the intermuscular layer.

An advantage of the PECS block compared with the paravertebral block is that the serratus anterior and its nerve supply (the long thoracic nerve) can be blocked. In some complex axillary dissection cases, the surgeon might be concerned about injuring the long thoracic nerve, making a PECS block unsuitable. The superior aspect of the breast has innervation from the cervical plexus, and neither paravertebral blocks nor PECS block provide analgesia there.

Clinical Applications

Breast surgery for oncology or plastic surgery, axillary dissection, chest wall dissection, and placement of tissue expanders or implants are procedures in which pectoralis muscle relaxation is useful. This block is less useful for medial dissection of the breast. The serratus plane block (discussed later) can be used for fractured ribs, thoracic surgery, and chest tube placement.

Technique

Ultrasound Details

Monitors: ECG, NIBP, pulse oximeter.

Skin Preparation: Chlorhexidine with alcohol.

Probe: A high-frequency linear probe (10-15 MHz); expected target depth in an 80-kg patient, 2 to 3 cm.

Patient Position: The patient is positioned supine with the arm abducted 45 degrees.

Local Anesthetic Choice: A 20-mL injection is used for PECS II and a 10-mL injection for PECS I. Bupivacaine 0.25% or ropivacaine 0.25% is adequate for analgesia lasting up to 24 hours. Be conscious of the total local anesthetic dose in bilateral cases or when surgeons inject local anesthetic as well. There have been no studies published at this stage looking at the peak systemic absorption, but this block is very close to the intercostal space, and the potential for toxicity with an intercostal nerve block is well known.

Scanning Technique

1. **Position the patient supine with the arm slightly abducted.** Place the ultrasound screen beside the patient's waist on the side to be blocked. Pull the patient's stretcher forward to position the operator at the head of the bed.
2. **From a position standing at the patient's head, place the probe in the delto-pectoral groove immediately below the clavicle.** It is exactly the same placement as for an infraclavicular nerve block (Figure 4-34).
3. **Identify the pulsatile axillary artery in the subclavian area.** The vein is compressible and lies caudad to the artery. Inferior or slightly caudad to the artery, and usually easily identifiable, is the second rib. The bright, hyperechoic line of the second rib will be identified because of the black drop out shadow deep to it. The pleura can be identified on either side of the rib and will be located next to and deep to the rib.
4. **Identify the pectoral muscles shallow to the artery: pectoralis major (superficial) and pectoralis minor (deeper).**
5. **Once the second rib and pleura are identified, the probe should be moved caudad and laterally down the chest.** Count each rib as the probe moves down the chest wall. Stop at the fourth rib (see Figure 4-34).
6. **With third and fourth ribs in the picture, tilt the probe lateral to medial to identify the muscle layers and the fascial layers between them.** At this point, the pectoralis minor muscle is thin and tapers to a point caudally and laterally. The larger pectoralis major muscle is located above. The serratus anterior muscle can be identified lying over the ribs and appears as a very thin band of muscle.
7. **During scanning, try to identify the thoracoacromial artery running between the pectoral muscles before needle insertion.** If this artery cannot be identified, it may be located more medially. It is a good landmark for the PECS I and also should be avoided with a needle (Figure 4-35).
8. **Start with a PECS II block. The needle is inserted in-plane in a cephalad-to-caudad direction.** The needle is aimed with the goal of using the fourth rib as a bony backstop. The end point for needle insertion is the fascial plane between the pectoralis minor and the serratus anterior. If the plane between these two muscles cannot be injected, simply inject on the fourth rib (Figures 4-36 and 4-37).
9. **As with all fascial plane injections, the spread can be variable, and some needle manipulation may be required to obtain optimal spread of local anesthetic.** A good sign is when the local anesthetic spreads between the plane of the muscles and not within the muscles. 15 to 20 mL of ropivacaine 0.25% or bupivacaine 0.25% is injected slowly with an incremental injection technique after negative aspiration.
10. **After completion of the first injection, the needle is withdrawn to the fascial plane between the pectoralis major and pectoralis minor.** This is the site of

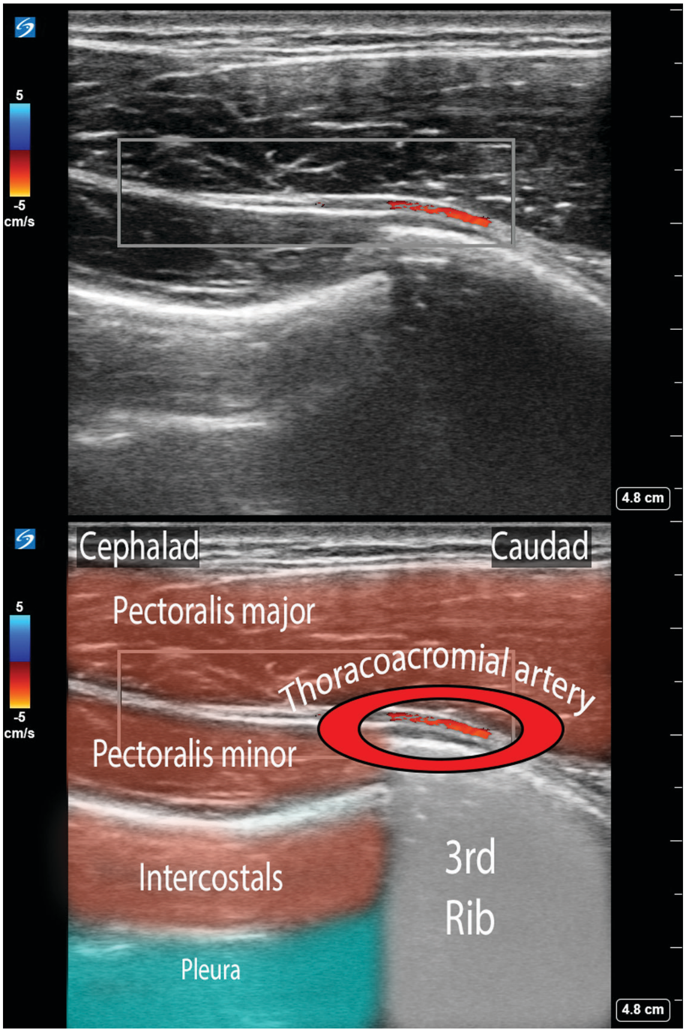


Figure 4-35 The thoracoacromial artery can be located between the pectoralis major and minor. During a PECS I injection, be wary of blood vessels within this plane. Doppler imaging can be useful to identify small arteries and veins.

PECS I block (see Figure 4-37). After negative aspiration, 10 mL of ropivacaine or bupivacaine is injected incrementally (Figure 4-38).

Alternative Techniques

Out-of-plane needle advancements can be performed with the PECS blocks as well. Because the needle is advanced very close to the lung, good technique is a must. Catheters can also be placed here, but placement should be performed postoperatively because the catheters will likely lie within the surgical field.

If standing at the head of the bed (as described earlier) is not possible, the operator can stand at the patient's side to perform the block. The benefit of standing at the head of the bed is that the operator may find aligning the needle and probe to be easier.

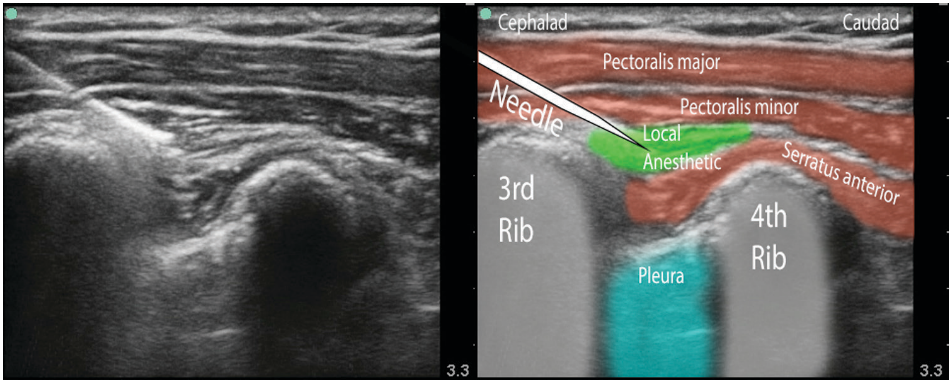


Figure 4-36 If performing both a PECS I and a PECS II block, perform the PECS II block first. This will help imaging in the event that air bubbles are inadvertently injected. For a PECS II block, inject between the pectoralis minor and the serratus anterior. Often, the serratus anterior is very small and difficult to identify. If so, injection on the fourth rib is an appropriate adjustment.

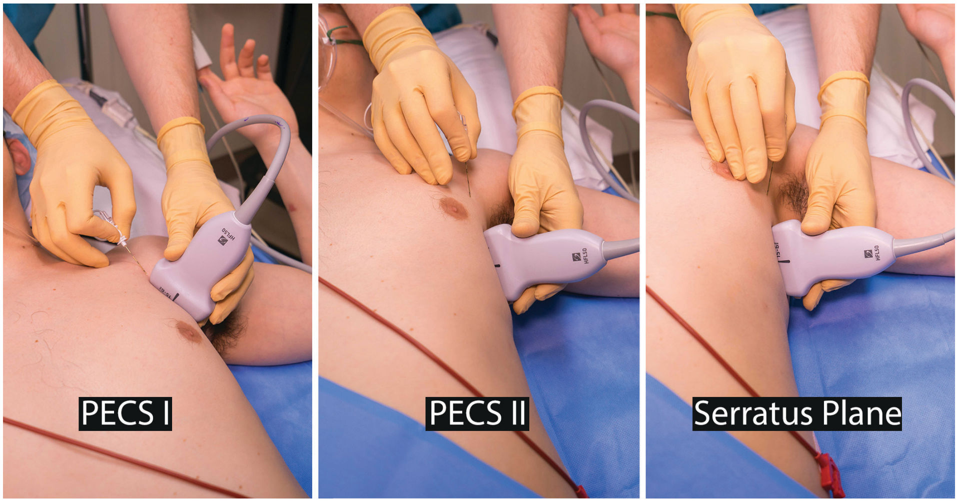


Figure 4-37 Probe and needle positions for the PECS I, PECS II, and serratus plane blocks.

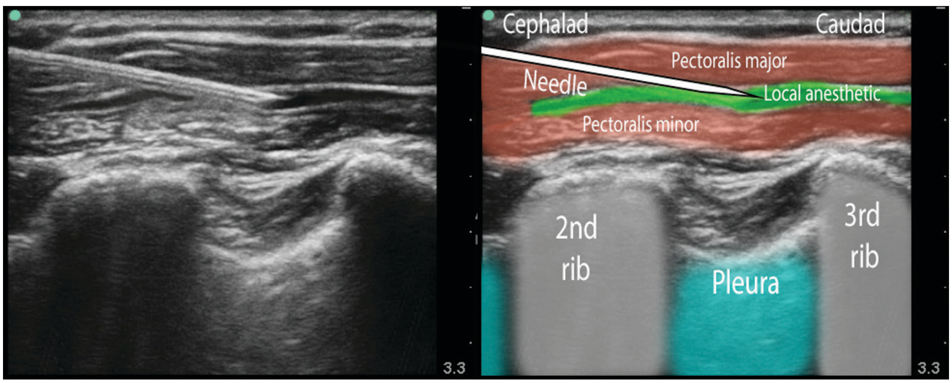


Figure 4-38 PECS I injection should be performed after other injections because it is the shallowest. Inject the local anesthetic between the pectoralis major and pectoralis minor muscles.

Serratus Plane Block

The serratus plane block provides more extensive chest wall coverage than the PECS blocks. It has been used for rib fractures, thoracic surgery, and breast surgery. Currently, comparative literature on the efficacy of this block is limited, as are toxicity data.

The anatomy and clinical applications have already been discussed (see "PECS Block"). The ultrasound details are the same as for the PECS block.

Technique

1. **Place the patient in a supine position with the arm abducted 45 degrees.**
2. **At the level of the nipple, place a high-frequency linear probe on the anterior axillary line. This is the level of the fourth rib** (Figure 4-39).
3. **Identify the fourth rib and slide down to the fifth rib.**
4. **Move the probe posterior to the posterior axillary line.** The latissimus dorsi should come into view. Tilting the probe posteriorly may help identify this muscle (see Figure 4-39).
5. **The serratus muscle is located inferiorly to the latissimus dorsi.**
6. **Using color Doppler ultrasound, search for vessels including the thoracodorsal artery in the plane above the serratus and ensure that they are not in the intended path for needle advancement** (Figure 4-40).
7. **Advance the needle in-plane from superior and anterior to inferior and posterior** (see Figure 4-37).
8. **The ideal end point for needle injection is superficial** (Figure 4-41) **or deep** (Figure 4-42) **to the serratus muscle.** After negative aspiration, inject 20 mL of bupivacaine 0.25% or ropivacaine 0.25%. If injection cannot be made over the serratus, place the local anesthetic under the serratus, on top of the rib.

Complications

Complications of the serratus plane block include block failure or incomplete coverage, pneumothorax, hematoma, and local anesthetic toxicity from high rates of absorption.

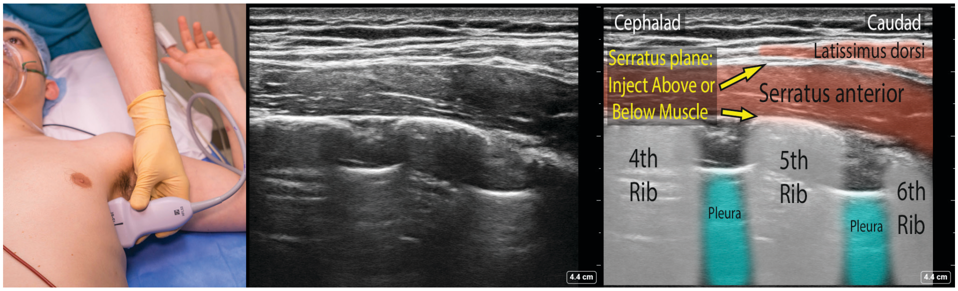


Figure 4-39 The serratus plane block can be performed by identifying the muscle overlying the ribs on the lateral side of the chest. This image shows the serratus anterior muscle and the anterior edge of the latissimus dorsi. The serratus anterior is rarely this this well developed. Instead, look for a thin muscle just shallow to the rib. Local anesthetic can be injected above or below the serratus anterior.

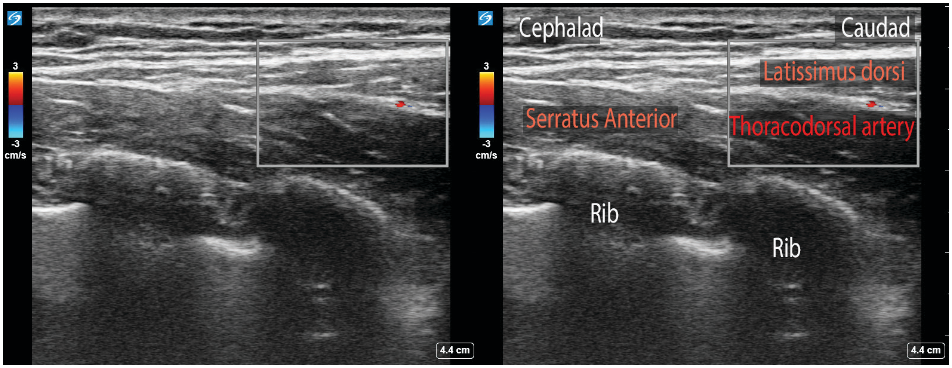


Figure 4-40 The thoracodorsal artery can overlie the serratus anterior muscle. Use caution when advancing needles within this plane. Doppler imaging can use useful for identifying small blood vessels.

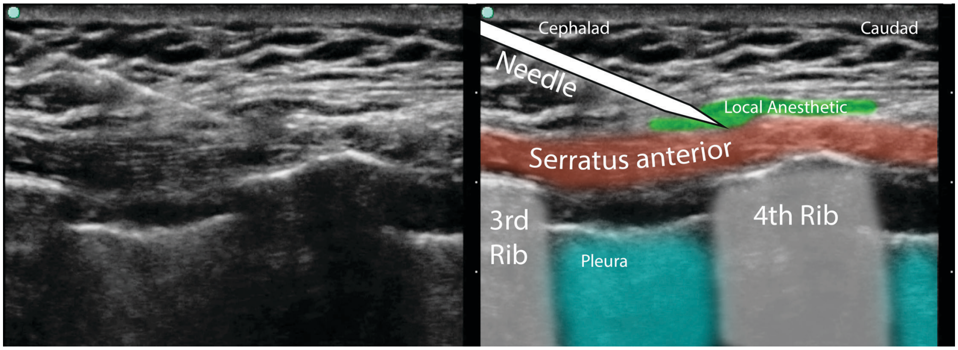


Figure 4-41 Serratus plane block with injection above the serratus anterior muscle.

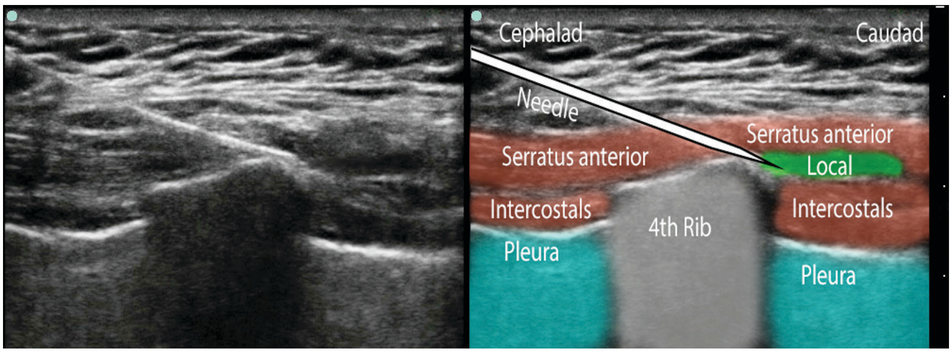


Figure 4-42 Serratus plane injection underneath the serratus anterior muscle. Aim the needle at the rib; the rib will provide a backstop against needle overadvancement toward the pleura. Visualize spread above the intercostals but below the serratus anterior.

Pearls

1. During the initial scanning, increasing the depth, increasing the gain, lowering the frequency, or adjusting the focal position on the ultrasound screen can make identification of the rib and pleura easier.

2. Use a tilting motion of the probe, as described in Chapter 1, to improve the image of the landmark structures. Sliding the probe more anteriorly or laterally also will make the pleura and ribs brighter and easier to follow down the chest wall.
3. To improve safety, use the fourth rib as a bony backstop for needle advancement.
4. Use color Doppler imaging to ensure that there are no arterial branches in the intended path of the needle.
5. If the serratus anterior is not easily identifiable during performance of the PECS block, move the probe laterally or posterior into the axilla. The serratus anterior will become thicker and more easily identifiable. Once the layer is identified, move the probe slowly anterior.
6. In frail or elderly patients, the serratus anterior is not always easily visible, so inject the local anesthetic onto the fourth rib.
7. If tissue or muscle planes are unclear due to obesity or lack of muscle mass, inject in several planes to ensure proper local anesthetic spread. As always, keep the total local anesthetic dose in mind when using large volumes to avoid local anesthetic systemic toxicity.
8. For surgical axillary dissections, the T1 dermatome is not easily covered by the PECS or serratus blocks. Consider adding a paravertebral block of T1 and T2 to PECS block for adequate coverage.
9. If the breast surgery is medial and inferior, consider PVBs instead of PECS blocks for better analgesia.
10. Always plan to perform the deeper injection first, to avoid any accidental air injection that would degrade the image deep to the offending air.

Paravertebral Nerve Block

Introduction

The PVB can be used for analgesia in the thoracic or lumbar dermatomes. One of the benefits of PVBs is that a single injection will spread over several vertebral levels, both cranially and caudally. PVBs can be performed as single-shot injections or with catheter placement and as unilateral or bilateral blocks for anesthesia and analgesia. Recently, there has been increased interest in the use of thoracic PVBs in breast surgery because of reports indicating reduced chronic pain and potentially reduced rates of cancer recurrence.

Landmark techniques have worked well for those with experience in placing a needle into the paravertebral space. PVBs were not routinely used because it was difficult to ascertain certain important anatomic landmarks using only the landmark techniques (e.g., exact vertebral levels, depth to the transverse process, location of the lung).

PVBs can now be performed using ultrasound in one of two ways: (1) ultrasound assistance—to determine the location and depth to the transverse process and to visualize the location and depth of the pleura, and (2) real-time needle guidance—to advance the needle into the paravertebral space using ultrasound visualization. Several approaches using real-time ultrasound guidance are described here.

Studies examining the extent of local anesthetic spread with a single-injection PVB have been variable. Some patients have an extensive dermatomal spread after a single injection, reaching up to six vertebral levels. In others, the spread may reach only one or two dermatome levels. If analgesia must be supplied to more than a couple of dermatome levels, multiple injections should be used to ensure adequate spread.

Anatomy

The paravertebral space is a triangular space in the thorax bounded medially by the vertebral body. Anteriorly, the parietal and visceral pleura of the lung delineate the border of the paravertebral space. Laterally, the paravertebral space ends at the apex of the triangle between the ribs and intercostal muscles and the pleura. The transverse processes and the superior costotransverse ligament form the posterior border of the paravertebral space. The paravertebral space is divided by a fascia called the endothoracic fascia, which usually is not visible under ultrasound. This fascia divides the paravertebral space into an anterior and posterior compartments. The anterior compartment, also known as the extrapleural compartment, carries the sympathetic chain. The posterior compartment, known as the sub-endothoracic compartment, carries the spinal nerve roots as they exit the spinal cord. It is unclear which compartment of the paravertebral space is best for deposition of local anesthetic because spread patterns and clinical results vary from study to study. Clinically, consider injecting in several different planes within the paravertebral space for best results.

Clinical Applications

PVBs are used in thoracic surgeries such as chest wall surgery (e.g., thoracotomy, video-assisted thoracoscopic surgery [VATS], rib fractures) and breast surgery. They are also used in unilateral or bilateral abdominal surgeries (e.g., inguinal hernia, umbilical hernia, colostomy takedown, nephrectomy). PVBs may be considered when an epidural is contraindicated.

Technique

There are two techniques for imaging a thoracic PVB. The first technique uses a transverse probe position with the ultrasound probe parallel to the ribs. The second technique describes a parasagittal ultrasound probe position with the ultrasound probe placed parallel to the

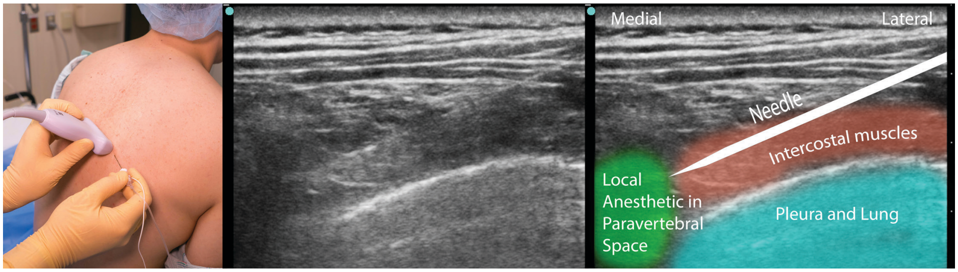


Figure 4-43 Transverse scan with in- plane needle advancement from lateral to medial for a paravertebral nerve block. The needle is advanced, and local anesthetic is injected in the paravertebral space. Do not advance the needle much farther than the visible medial edge of the pleura.

spine. In-plane or out-of-plane imaging techniques can be used for needle advancement with each of these techniques. Here, we describe two scanning techniques and four total needle approaches to the paravertebral space. No single technique has proved useful in all patient populations, and there is no published evidence that one needle technique is more efficacious than another.

Risks and Benefits of Each Approach

Transverse Scan, In-Plane Approach

1. See Figure 4-43.
2. Benefits
   a. This approach is useful in patients weighing less than 80 kg.
   b. It can provide good needle visualization.
   c. Shallow injections performed during hydrodissection may still result in an intercostal block even if the paravertebral injection is suboptimal.
   d. It is the easiest technique to learn if the user has prior experience with in-plane blocks.
3. Risks
   a. The needle aims at the neuraxis.
   b. The initial needle trajectory aims at the lung.
   c. This approach is difficult in obese patients due to a steep needle angle.
   d. Tight intercostal spaces can make needle advancement to the target difficult.
4. **Summary:** This is the preferred approach for single-injection PVBs in patients weighing less than 80 kg.

Transverse Scan, Out-of-Plane Approach

1. See Figure 4-44.
2. Benefits
   a. The needle is directed at the paravertebral space at all times (never at the lung or spinal column).
   b. Catheters are easily placed with a medial insertion site.
   c. It provides a good approach for obese patients.
3. Risks
   a. The out-of-plane needle angle must be acute, so it is not possible to follow a hyperechoic dot on the screen down to the paravertebral space
   b. Tight intertransverse spaces can inhibit needle advancement.

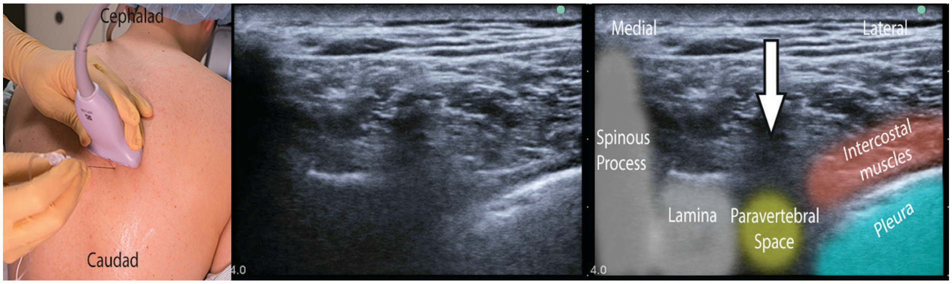


Figure 4-44 Transverse scan with the needle out-of-plane. The needle is advanced from the caudal side, aiming cranially. It is advanced at such a steep angle that the white dot signifying the needle is often not visible. Use small, intermittent injections of saline or local anesthetic to help confirm needle tip location *(arrow)*. Once the tip is located within the paravertebral space, inject the majority of local anesthetic there.

3. **Summary:** This is the preferred approach for deep blocks in patients weighing more than 80 kg or for continuous catheter placement.

Parasagittal Scan, In-Plane Approach

1. See Figure 4-45.
2. Benefits
   a. If the needle is kept in-plane, it never is directed at pleura or at the spinal column.
   b. This needle approach is similar to that used for the standard landmark technique (if the user has prior experience).
3. Risks
   a. The needle is almost impossible to visualize because of the steep needle approach
   b. Because of inability to image the needle, it is difficult to ensure that it is not directed at the pleura.
4. **Summary:** This is the preferred approach when using echogenic needles or with inexperienced operators.

Parasagittal Scan, Out-of-Plane Approach

1. See Figure 4-46.

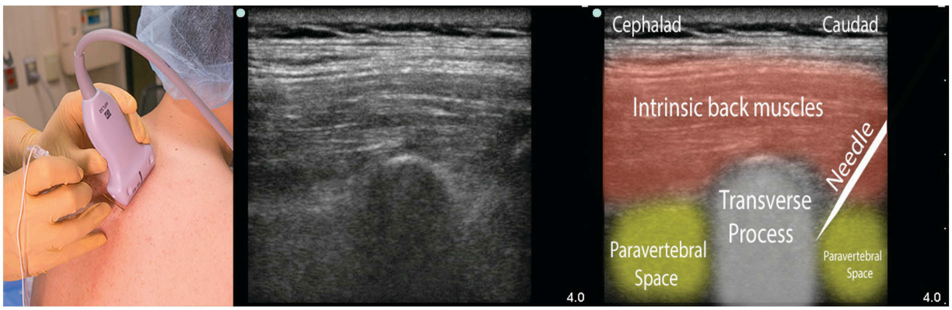


Figure 4-45 Parasagittal scan with in-plane needle for a paravertebral block. The needle insertion is started very close to the probe and advanced at a steep angle. It is often difficult to visualize the needle, so use intermittent boluses of saline or local anesthetic to help assess tip location. Advance the needle at a steep angle to place it within the paravertebral space without hitting the other bony landmarks.

2. Benefits
   a. The needle usually can be advanced between the transverse processes without difficulty.
3. Risks
   a. This approach conveys a false sense of safety, but the needle can be advanced into the pleura or neuraxis without ever being visualized (even with hydrodissection techniques).
   b. Needle location is very difficult to confirm because the needle angle is so steep.
   c. This technique gives novices a false sense of safety, which is concerning in a high-risk, difficult nerve block.
4. **Summary:** This approach is rarely used because of the risks outlined here.

Ultrasound Details

Monitors: ECG, NIBP, pulse oximeter.

Skin Preparation: Chlorhexidine with alcohol.

Probe: High-frequency linear probe (10-15 MHz). In obese patients, a curvilinear low-frequency probe may be necessary. Expected target depth in an 80-kg patient, 2 to 3 cm.

Patient Position: Patients may be placed in a sitting, prone, or lateral position. Usually for unilateral blocks, the lateral position is used. For bilateral blocks, position the patient in a sitting or prone position.

Local Anesthetic Choice: For anesthetic blocks, ropivacaine 0.5% or even 0.75% can be used. Total volumes should be calculated and should be less than 3 mg/kg for ropivacaine or bupivacaine because local anesthetic is highly absorbed in this area. Use epinephrine 1:400,000 (2.5 μg/mL) to decrease peak absorption of the local anesthetic. After the total dose has been calculated, individual levels can be injected separately, dividing the total dose equally among the levels. Usually, at least 5 mL is placed at each level. Some practitioners prefer a single injection. If a single-injection block is being used to cover multiple

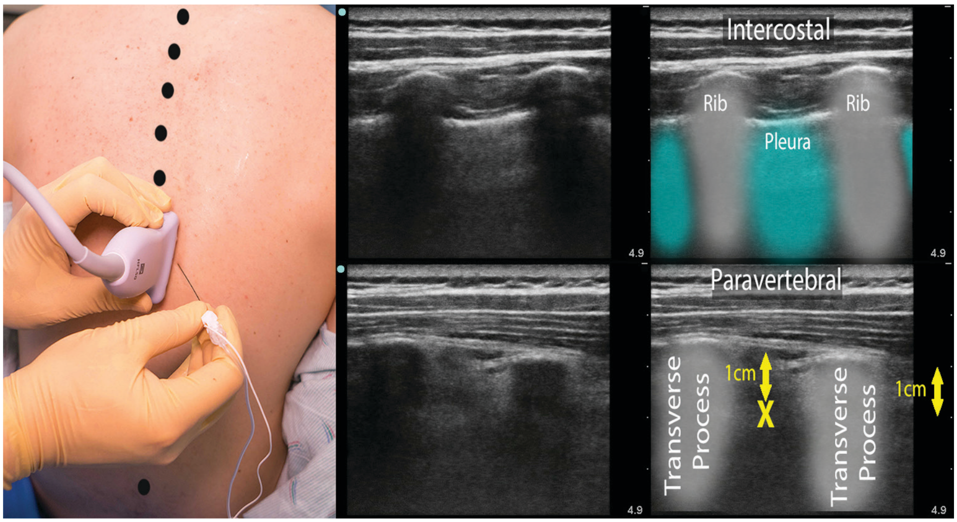


Figure 4-46 Parasagittal scan with out-of-plane needle advancement for the paravertebral block. Ensure imaging of a paravertebral space *(bottom)*, not an intercostal space *(top)*. The pleura should not be well visualized between the transverse processes. Advance the needle from the center of the probe, using small intermittent boluses to help assess needle tip location. Aim the needle lateral to medial with a very steep angle.

dermatomes, up to 30 mL of local anesthetic may be injected. Spread can be variable, so we recommend using several injections to cover a large area. For example, to cover an entire mastectomy (T1-6), inject at levels T2, T4 and T6. Injection at each level is not required because PVBs should spread over several levels.

Scanning Technique

Regardless of the approach used, assessment and confirmation of the correct dermatomal level is very important. The ribs are a reliable marker to assess block position. Identifying the first rib on ultrasound, then counting down to the desired level, is an effective and accurate technique. Alternatively, finding the 12th rib, then counting ribs cephalad as the probe is moved cranially is also effective. This should be done just posterior to the angle of the rib (4-5 cm lateral to the midline) to ensure that the scapula is not in the way. For blocks placed postoperatively, use ultrasound to identify the rib closest to the incision, and then move the probe posteriorly and medially, keeping the appropriate rib in plane.

Identify the rib as a hyperechoic (bright), curved stripe with an acoustic shadow deep (dark dropout). Between the ribs, the intercostal muscles will appear gray, and the pleura will appear bright (hyperechoic) beneath them. Sometimes, the pleura can be seen sliding back and forth during respiration (see Figure 4-47).

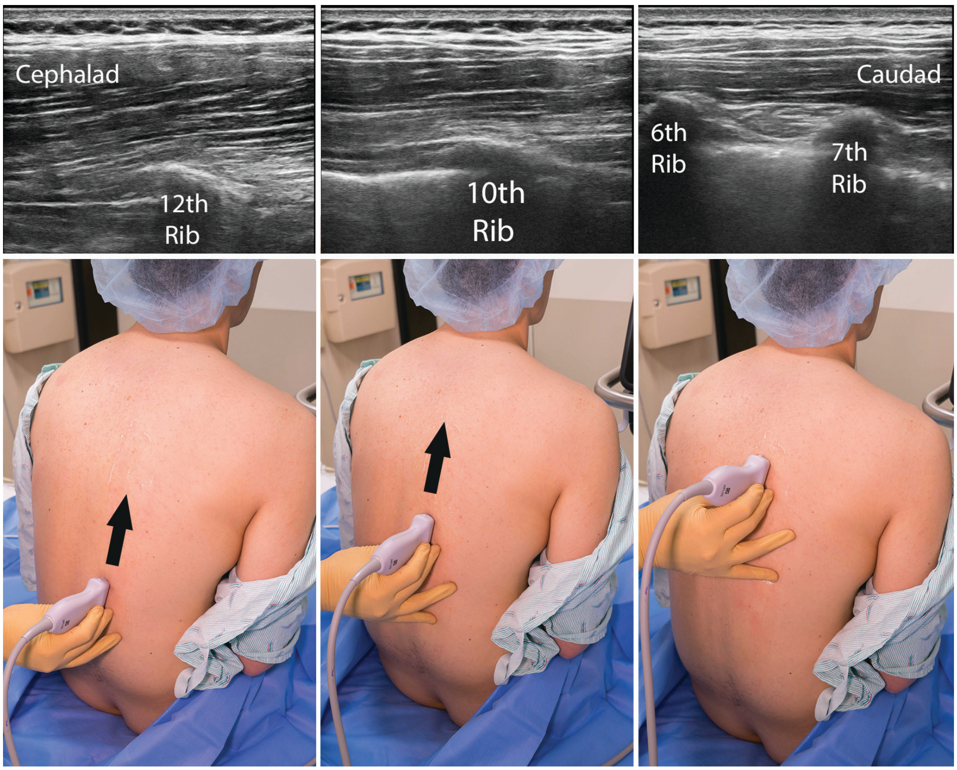


Figure 4-47 Identification of the correct level for a paravertebral nerve block or thoracic epidural placement can be accomplished by finding the most caudal rib (T12) and then sliding the probe cephalad while counting ribs. Ribs can also be counted down from T1.

Paravertebral Scanning Technique 1: Transverse Scanning with In-Plane and Out-of-Plane Needle Advancement

1. **Identify the appropriate spinal level, as described previously.**
2. **Turn the probe 90 degrees so it lies in the transverse plane parallel to the ribs** (Figure 4-48).
3. **Slide the probe cranial or caudal until the rib is identified.** Use slight rotations of the probe until the rib is visualized across the entire ultrasound screen (Figure 4-49).
4. **The rib will appear as a hyperechoic (bright) structure with complete ultrasound dropout below it (shadow). The medial border of the rib will join up with a transverse process.** The articulation (costotransverse joint) can be identified as a slight depression between the rib and the transverse process (Figures 4-50 and 4-51).
5. **Once the rib is identified, slide the probe caudally a few millimeters until it lies just beneath but still parallel to the rib.** The transverse process may still be visible, but now the intercostal muscles (gray) and the pleura (bright, deep) should be visible. The pleura appear as a bright stripe, similar to the rib, but with two different characteristics: (1) it is about 1 cm deeper than the rib, and (2) it has a shimmering quality with some ultrasound penetration deep to it (i.e., not as much dark shadow as the rib) (see Figure 4-51).
6. **The transverse process is an important landmark for the PVB.** The transverse process helps to mark the injection point. The target injection site is about 1 cm deep to the superficial border of the transverse process. Injecting medial to the transverse process results in a higher chance of a spinal or epidural injection.
7. **The transverse process should not be visible, especially when the probe is in the exact center of the paravertebral space** (see Figure 4-51). However, the transverse process may be used as the medial limit of needle insertion. If no transverse process is visible, slide the probe cephalad and caudad to reveal the transverse processes above and below (see Figures 4-50 and 4-51). We have found improved multilevel spread and better clinical success with these blocks when the transverse process is not visible and the needle is placed in the paravertebral space, not more laterally in the intercostal space.
8. **Transverse Scan Needle Advancement**
   a. **In- plane: Once the image is obtained, the needle is inserted in a lateral-to-medial direction.** Advance the needle as far medially as the transverse process and/or the medial visible edge of the pleura. The needle should be positioned deep to the convex hyperechoic transverse process. The needle should be advanced until it is just above the pleura (about 0.5 cm above pleura) or 1 cm deeper than the depth of the transverse process (see Figure 4-43).
   b. **Out-of-plane: Center the paravertebral space on the ultrasound image.** Identify the lamina medial to the paravertebral space and the pleura lateral to the paravertebral space. The correct depth for injection is approximately 1 cm deeper than the transverse process. Notice that the transverse process is not visible with this imaging technique (compare Figures 4-43, 4-44, 4-50, and 4-51). Place the needle immediately adjacent to the center of the probe. Advance the needle from the middle of the probe until it is located at the appropriate depth—1 cm deeper than the transverse process. The position of the needle tip can be confirmed by making small injections while the needle is advanced into the PVB space. It is easier to advance from caudal to cranial because the space between the bony structures (transverse processes and ribs) is larger in this direction (see Figure 4-44).

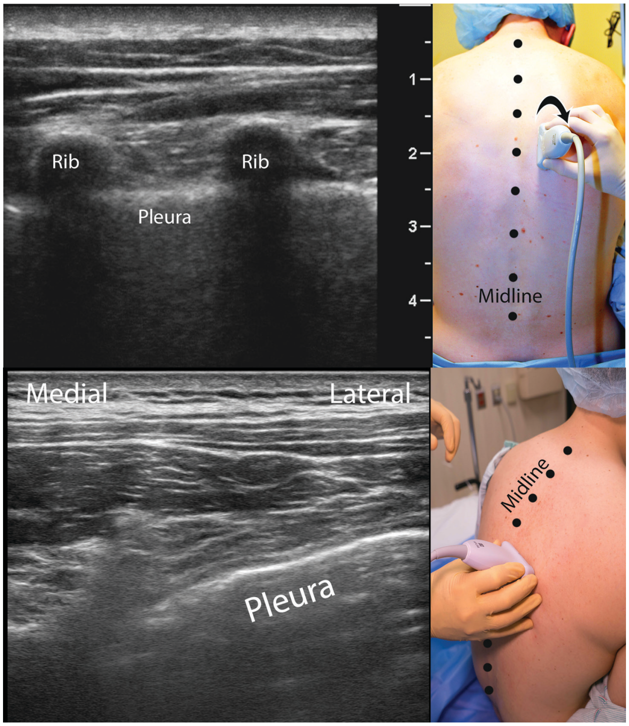


Figure 4-48 Probe placement and ultrasound images for the paravertebral nerve block. The upper images show a parasagittal scan with the probe parallel to the spine. The lower images show a transverse scan with the probe perpendicular to the spine.

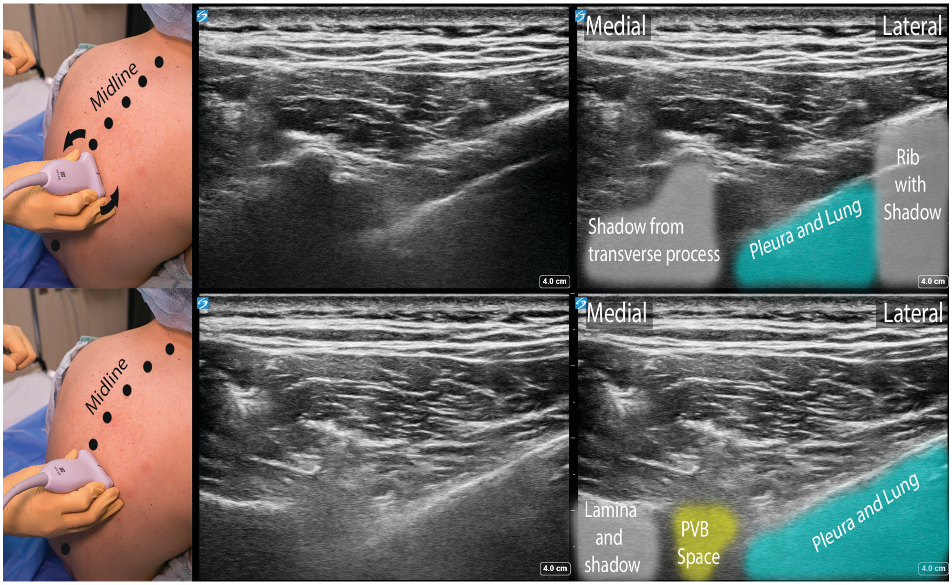


Figure 4-49 Probe placement and ultrasound images of the transverse process, ribs, and pleura. In the upper images, all three structures are visualized, suggesting that the scanning plane is not within a rib interspace. Use rotation *(curved arrows)* to better align the probe to a rib interspace. In the lower images, the probe is completely within an intercostal space, so no rib or transverse process is visible.

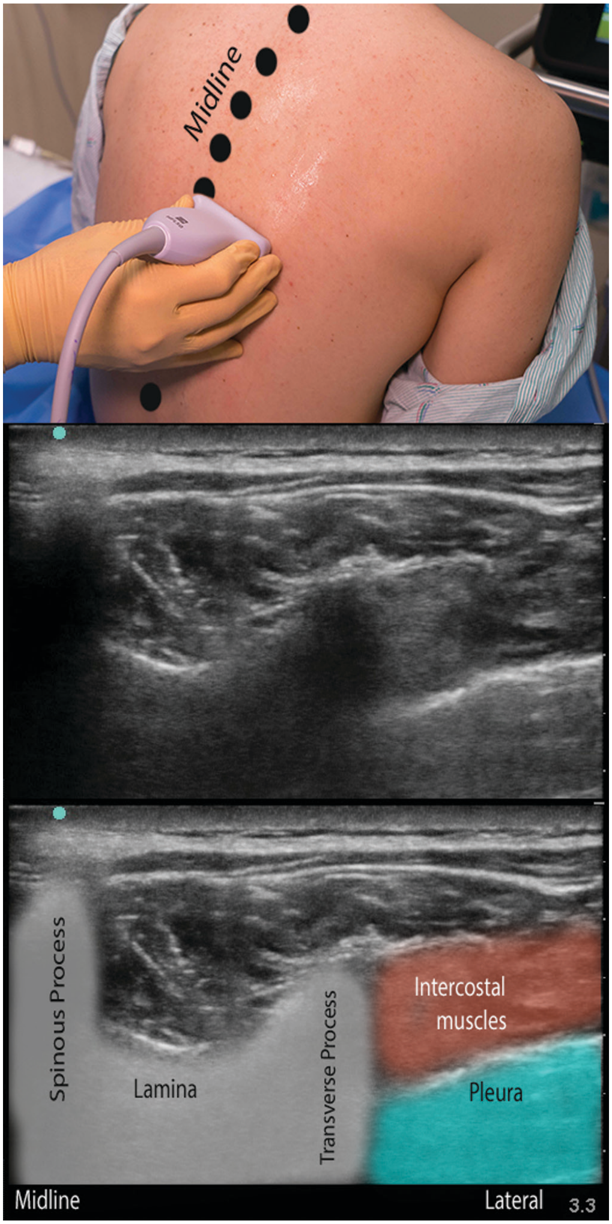


Figure 4-50 Ultrasound image obtained with the probe positioned in a transverse plane overlying a thoracic vertebra. The transverse process is visible, along with the other vertebral structures (spinous process and lamina).

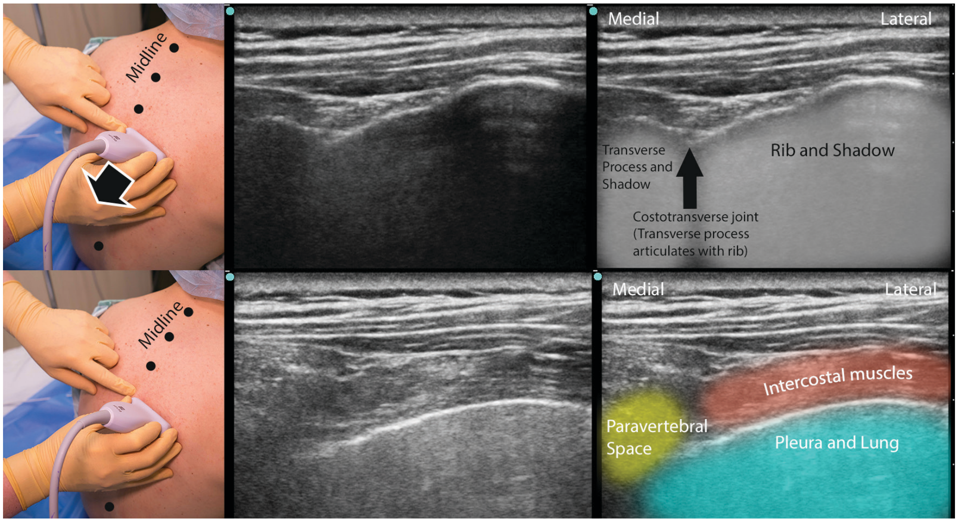


Figure 4-51 Ultrasound image of the paravertebral space with no part of transverse process visible *(bottom)*. If the transverse process or ribs are visible, slide the probe caudally to better image the paravertebral space.

9. **Aspirate, then inject the local anesthetic in incremental doses (3–5 mL at a time).**
10. **In deep and difficult blocks, use small injections of saline or local anesthetic to confirm the needle tip position.** Losing the needle tip in this block can result in major morbidity and mortality (e.g., pneumothorax, inadvertent spinal or epidural injection, intravascular injection).
11. **Depression of the pleura is a specific sign of a properly located paravertebral injection.** Although no study has confirmed that pleural depression leads to improved outcomes, this sign suggests that the needle does not need to be advanced farther (see Figure 4-52).

Paravertebral Scanning Technique 2: Parasagittal Approach with In-Plane and Out-of-Plane Needle Advancement

1. **After identifying the appropriate level, place the probe in a parasagittal plane (parallel to the spine, 4-5 cm lateral to midline).** Identify the ribs, as described earlier, to find the appropriate level.
2. **Once the appropriate rib has been identified, slide the probe medially to image the paravertebral space and transverse processes** (Figure 4-53). There are distinct differences between the ribs and transverse processes. Compared with the transverse processes, the ribs are slightly more cranial and/or more shallow, have pleura in between, and are more convex (see Figure 4-53).
3. **The transverse processes, in this orientation, appear hyperechoic and flatter and produce dropout (dark shadow) deep.** Pleura often is not visible with imaging of the transverse processes in this orientation. If pleura is visible, it should be deeper and much more faint.
4. **If the probe is moved too far medially, the paravertebral space will not be visible because of interference from the lateral portion of the facets and lamina of the vertebrae.** Move the probe laterally so that the paravertebral space will become visible.

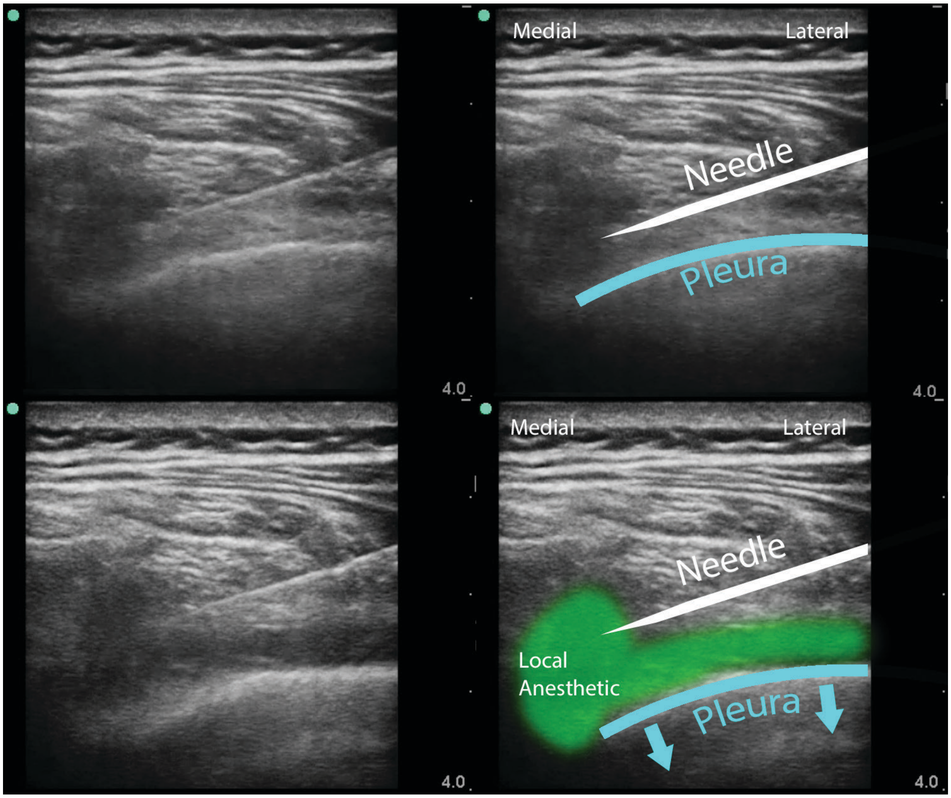


Figure 4-52 Injection of local anesthetic within the paravertebral space often pushes the pleura deeper. Irrespective of the needle approach is used, visualization of the pleura being pushed deeper is a good ultrasound sign of a proper paravertebral injection.

5. **The ideal image is of two transverse processes with the targeted paravertebral space visible between.**
6. **Parasagittal Plane Needle Advancement**
   a. **In-plane:** Once the image is obtained, slide the probe cephalad to move the target space closer to the caudal edge of the probe, where the needle will enter. This movement permits the needle to pass into the paravertebral space rather than hitting the transverse process. The needle is inserted in-plane from caudal to cranial. The end point for needle advancement is 1 cm deep to the superficial (dorsal) surface of the transverse process if no pleura is visible, or just superior to the pleura if it is visible. The needle angle is often so steep that needle visibility is difficult. Use intermittent injections through the needle to confirm needle depth (see Figure 4-45).
   b. **Out-of-plane:** Once the image is obtained, center the paravertebral space on the ultrasound image. Identify the correct depth on the screen. Advance the needle from the middle of the probe (Figure 4-46). The needle is placed on the lateral side of the probe aiming in a lateral-to-medial direction and therefore away from the pleura. Needle position can be confirmed by small injections. The end point for needle advancement is 1 cm

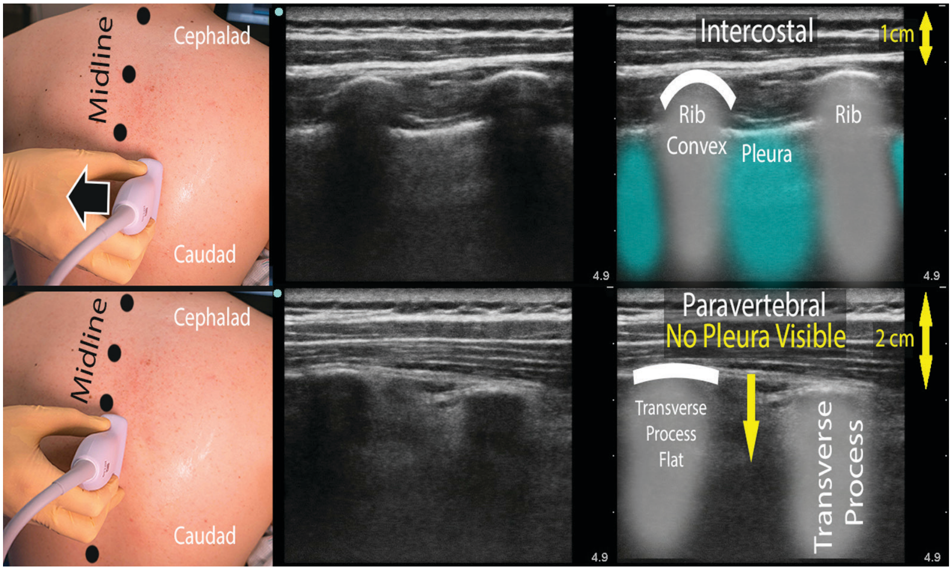


Figure 4-53 Ultrasound identification of the ribs and transverse processes. The ribs are slightly more cranial, have pleura in between, are more convex, and are shallower than the transverse processes.

deep to the superficial surface of the transverse process if no pleura is visible, or just superior to the pleura if it is visible.

7. Aspirate, then inject the local anesthetic in incremental doses (3-5 mL at a time).

Alternative Techniques

Catheters can be placed using techniques similar to those used with single-shot injections. Catheters can be difficult to advance in the paravertebral space. The addition of nerve stimulation to PVBs for single-shot injection or catheter placement is possible. Intercostal muscle twitching with nerve stimulation signifies correct placement of the needle in the paravertebral space.

Complications

Complications include pneumothorax, epidural injection, intrathecal injection, hematoma, and local anesthetic toxicity (high absorption area).

Pearls

1. PVBs can be difficult in obese patients. We recommend that practitioners use ultrasound on slim patients initially to get familiar with this technique.
2. In obese patients or patients with deep musculature, a microconvex or curvilinear ultrasound probe has two advantages. First, the probe has a lower frequency, which permits better penetration of the tissues. Second, the footprint of the probe allows it to be steered aggressively into the advancing needle, permitting a shallower angle of needle insertion and better needle visibility (Figure 4-54).

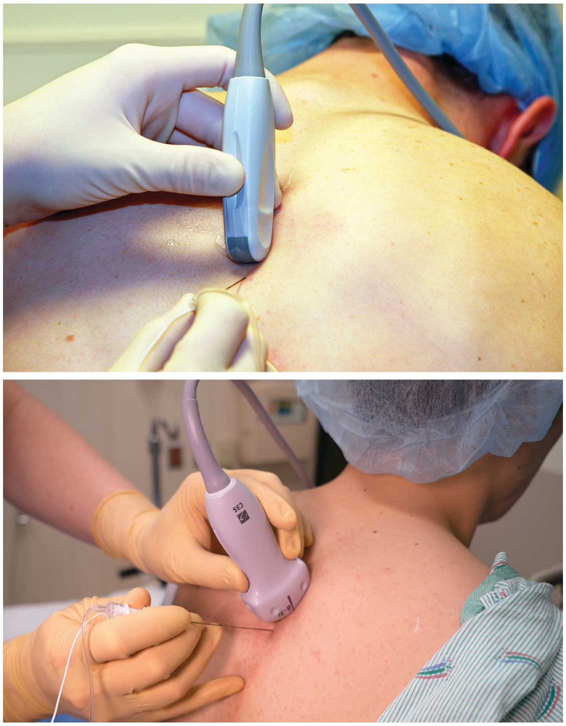


Figure 4-54 A curvilinear *(top)* or microconvex *(bottom)* probe may assist with needle identification during performance of paravertebral nerve blocks using a caudad-to-cephalad approach.

3. The paravertebral space is shallowest in the midthoracic region, making imaging easier. This is a good place to begin learning this block.
4. Remember to adjust the frequency and focus position of the ultrasound unit to optimize the image with this deeper nerve block.
5. Identification of the costotransverse ligament can be difficult for even for expert sonographers. The probe can be held in a parasagittal plane, but the ligament does not run in a truly sagittal direction. The superior costotransverse ligament moves obliquely and laterally as it ascends, making scanning along its length difficult. The ligament can often be seen in part as a hyperechoic line traversing the image, but is difficult to image in its entirety from one rib to the next transverse process above.
6. Because these blocks can result in high levels of intravascular absorption, use saline, rather than local anesthetic, to hydrodissect and help assess needle tip location. Once the needle tip is properly placed, inject the desired local anesthetic dose. This way, local anesthetic is not wasted on needle localization in the shallow tissues.

Neuraxial Anesthesia and Analgesia

Introduction

Placement of epidural blocks is a must-know technique for all anesthesiologists. These blocks are typically performed without resorting to ultrasound guidance. With the increase in obesity in the general population, however, reliance on simple bony landmarks is becoming increasingly difficult. Real-time ultrasound guidance for neuraxial needle placement is difficult and is generally inhibited by the bony structures through which ultrasound cannot penetrate. Although real-time neuraxial techniques have been described, the best use for neuraxial ultrasound is in the identification of landmarks and the assessment of depth to target structures before the neuraxial block is performed.

Anatomy

Classic landmarks for the performance of lumbar epidural or spinal anesthesia include the intercristal line and the midline. The intercristal line is not always at the level of L4; rather, it can lie anywhere from L5 to L2 when identified by a pure landmark technique. This can lead to a noncongruent epidural block, but it can be of greater consequence when a spinal block is planned. A spinal block placed above the termination of the spinal cord as a result of incorrect identification of the intercristal line has potentially dire consequences.

For most practitioners, use of ultrasound for neuraxial identification requires a methodical approach to attain an understanding of the sonoanatomy. A review of normal anatomy without ultrasound is therefore relevant.

First, review the bony anatomy of the lumbar and thoracic spine, as well as the sacrum. This is best done with the use of a skeleton model or an anatomy textbook. As ultrasound images are obtained and reviewed, return to this image to correlate the skeleton model with the sonoanatomy (Figure 4-55).

The anatomy of the posterior surface of the spine and sacrum is most relevant to ultrasound because this is the surface that will reflect ultrasound waves to create an image. For the thoracic vertebrae, evaluate the spinous process, lamina, and facet joints (formed from the articular processes). For the lumbar spine, evaluate the spinous process, lamina, interspaces, superior/inferior articular processes forming facet joints, and transverse processes. For the sacrum, pay particular attention to the L5-S1 interspace. Evaluate (1) the relevant depths of various structures (e.g., lamina, facets, transverse process, ribs), (2) what structures lie medial or lateral to each other, (3) what different parts of the vertebrae are visible as the probe is moved up, down, left, and right in transverse, midline, and paramedian planes.

It is important to realize that not all parts of a vertebra will be visible in a single scan plane. The probe has to be moved up and down and from side to side to build a three-dimensional mental image all the anatomy. Unlike peripheral nerve scanning, epidural scanning does not allow visualization of nerves. Instead, the bony and ligamentous sonoanatomy is used to help create a three-dimensional understanding of where the vertebral interspaces or neuraxis might be. Ultrasound allows for direct visualization of the vertebral bodies, the sacrum, paraspinous muscles, and bright echogenic shadows of the ligaments supporting the vertebrae.

Clinical Applications

Ultrasound can be used to for a number of purposes:

1. To identify the midline.
2. To identify the depth of needle placement for either epidural or spinal blocks.
3. To identify the correct vertebral level for injection.

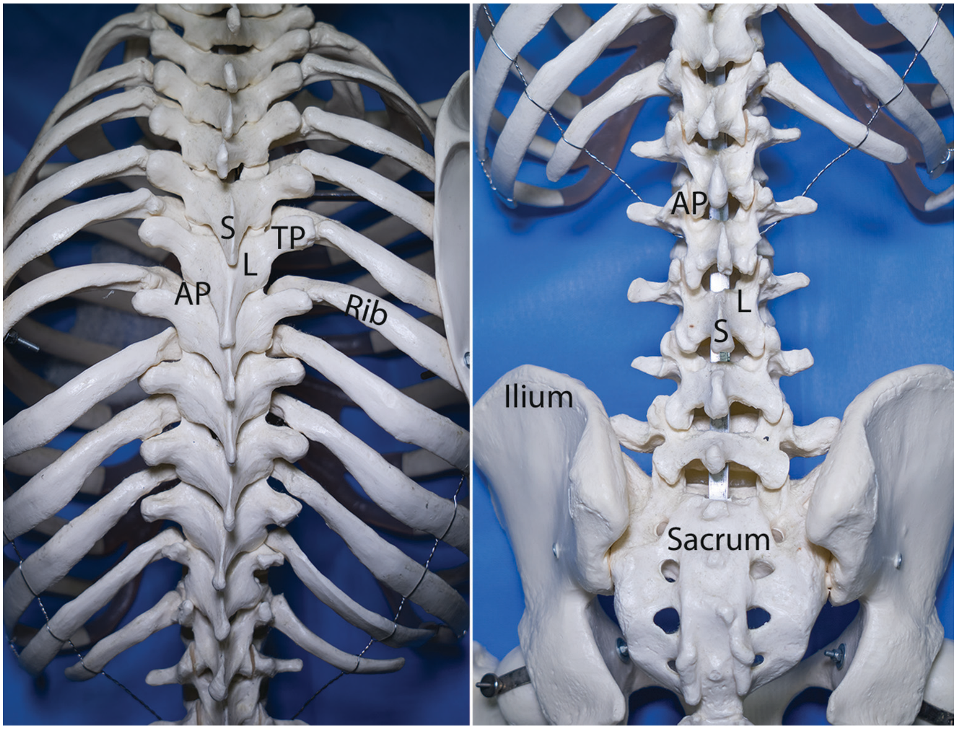


Figure 4-55 Skeleton model of the bony landmarks of the thoracic *(left)* and lumbar *(right)* regions. Use this image to compare the bony structures found on the ultrasound images. AP, articular process; L, lamina; S, spinous process; TP, transverse process.

4. To identify the degree of rotation in a scoliotic spine and compensate for it during injection.
5. To identify interspaces through which a needle can be advanced.
6. To assist in real-time needle placement of neuraxial injections.

The method for scanning as described previously (see "Technique") can be used for identification of lumbar and thoracic epidural as well as spinal landmarks. We recommend using these techniques in an ultrasound-assisted procedure initially, rather than for real-time guidance. An ultrasound-assisted procedure can mark the important landmarks and measure depth, but the ultrasound is not used in real time during needle insertion. Advancing to real-time spinal and then epidural placement is the next step (see later discussion).

Technique

Ultrasound Details

Monitors: ECG, NIBP, pulse oximeter.

Skin Preparation: Chlorhexidine with alcohol is preferred for its antiseptic properties.

Probe: A low-frequency curvilinear probe (2-5 MHz) will allow for penetration of the ultrasound beams when scanning deep structures in most adult patients. In the pediatric population, it is possible to use a high-frequency linear probe (8-15 MHz). The probe is held with the nondominant hand, and a skin marker pen or the needle is manipulated with the dominant hand.

Figure 4-56 Identification of the lumbar midline. Place a low-frequency probe in the lumbar region. Scan in a medial-to-lateral direction across the back to identify the spinous process that marks the midline.

Patient Position: The patient should be positioned in the same manner as the acutal neuraxial anesthetic technique to be used. A fetal position with a curved spine makes it easier for the ultrasound waves and the needle to penetrate between the vertebrae and provide the user with enhanced images of deeper structures. Scanning can also be done with the patient in the sitting or the lateral position.

Local Anesthetic Choice: Use standard spinal or epidural dosing. The choice of local anesthetic does not change when ultrasound guidance is used.

Scanning Technique—Lumbar

1. **Identify the midline:** Place the probe on the patient's back in a transverse plane, and slide it from left to right across the back (Figure 4-56). The shadow cast by the spinous process is the key identifier. If the shadow is not clearly identified with the initial scan, move the probe 1 cm cephalad and repeat the process (Figure 4-57).
2. **Marking the midline:** Once the midline is identified, slide the probe up and down the back over the spinous processes. A superior spinous process and inferior spinous process can be marked on the back (Figure 4-58). Connect these two marks at different levels to clearly identify midline.
3. **Identify the lumbar vertebral level:** For lumbar approaches to the spine, count up from the sacrum. Place the probe in the paramedian position, about 1 inch (2 cm) from midline over the vertebral lamina. Next, move the probe caudad and look for the solid hyperechoic line of the sacrum. Sometimes, a slight tilt toward the midline will help improve the

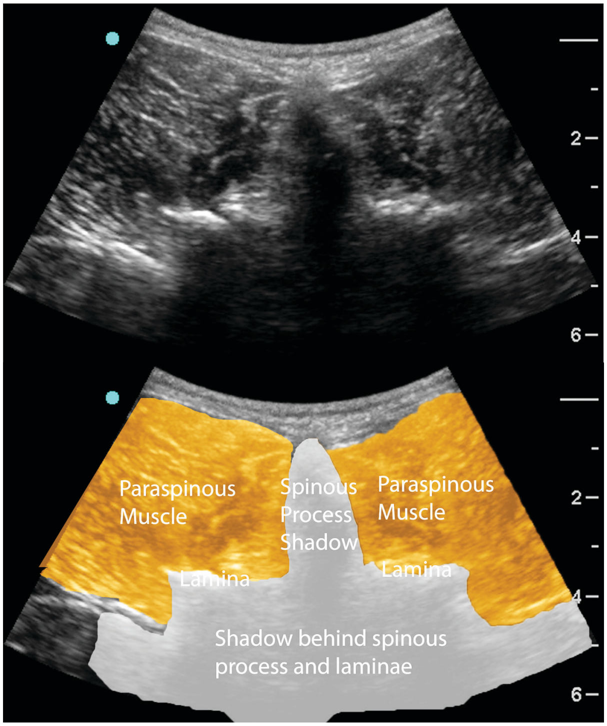


Figure 4-57 Ultrasound image of the midline of the back. The shadow cast by the spinous process is the key identifier. Also notice the symmetry of the image (lamina and paraspinous muscles on each side), which helps to confirm midline.

Figure 4-58 Marking the midline with a pen after locating the spinous processes using ultrasound at two separate levels.

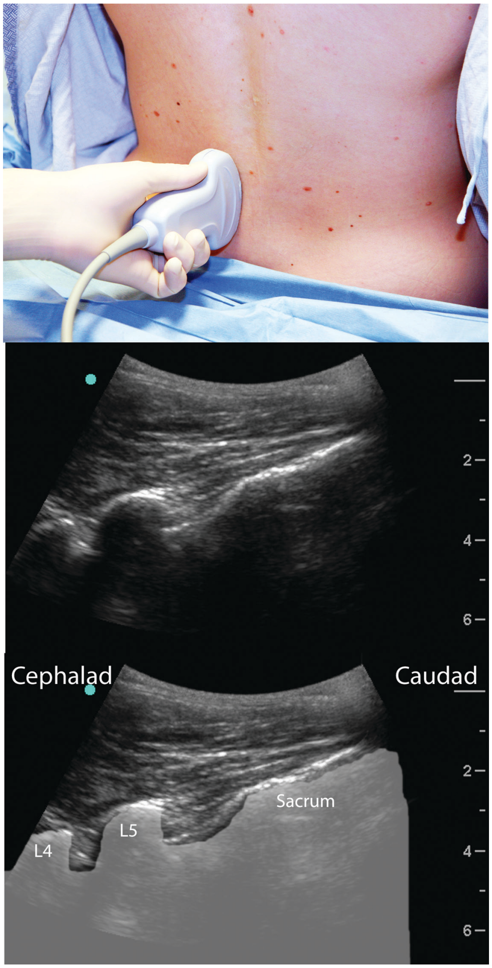


Figure 4-59 With the ultrasound probe turned parallel to the spine, slide 1 to 2 cm off midline. This paramedian view reveals the lamina of L4 and L5 and also the continuous bony structure *(white line)* of the sacrum.

image (Figure 4-59). Once the sacrum has been identified, slide the probe cranially. Count the lamina as the probe ascends (Figure 4-60). Often, these lamina or articular processes are not clear enough to count distinct levels. Move the probe laterally to identify the transverse processes, and count transverse processes to help confirm the exact vertebral level (see Figure 3-43). The sacrum does not have transverse processes.

4. **Find the interspace:** The lumbar vertebral interspaces will be located just medial to the lamina and facet joints if these structures can be adequately visualized. Slide the probe medially or tilt the probe so that the beam aims medially—this is called the *paramedian sagittal oblique view*. Now the ligamentum flavum and the posterior vertebral body (posterior longitudinal ligament) should be visible between the lamina (Figure 4-61). The ligamentum flavum can be difficult to visualize, but the deeper bright, hyperechoic vertebral body should be easy to identify if the space is open. The ligamentum flavum attaches from the lamina above to the lamina below. This approximates the depth for loss of resistance in an epidural block.

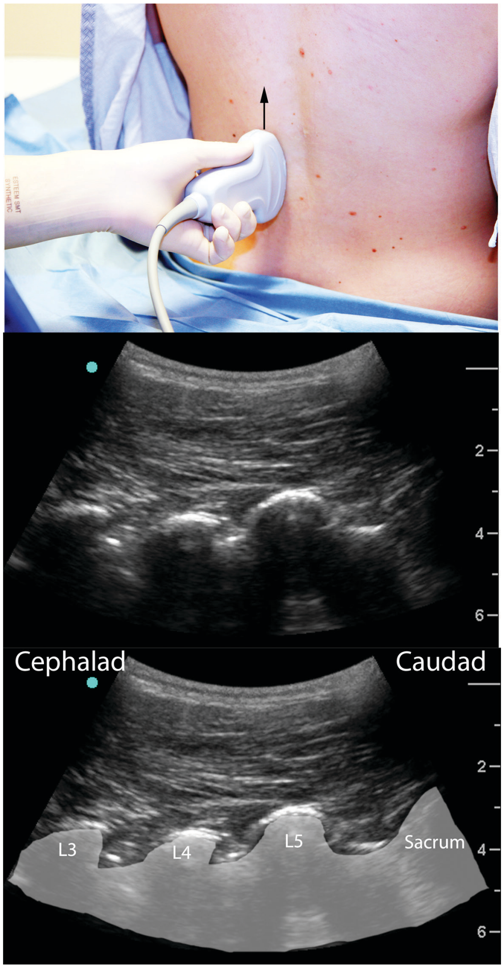


Figure 4-60 Use the peaks of the lamina or facet joints to count levels up from the sacrum. Each hyperechoic bump can be used to locate the appropriate lumbar level as the probe is slid cephalad.

5. **Find the ligamentum flavum in short axis:** The ligamentum flavum can also be found in short axis. With the probe turned in the transverse view, identify the shadow of the spinous process, then look for the bright reflection of the lamina, which can be seen as a pair of horizontal hyperechoic lines just lateral to the spinous process. Next, move the probe cephalad and caudad to identify the articular processes. These appear as small bumps at a similar level as the lamina. The ligamentum flavum will be a hyperechoic line running between the articular processes horizontally across the screen., The deepest midline reflection that is identifiable deeper than the reflection of the lamina and articular processes is that of the posterior longitudinal ligament and the posterior portion of the vertebral body. Deep on the screen to the hyperechoic reflection of the posterior longitudinal ligament is the dropout shadow of the vertebral body. The reflection of the ligamentum flavum is key. This is the location of the interspinous space, where the needle should enter for spinal or epidural. To find this image, tilt the probe in a slightly cephalad direction (Figure 4-62).

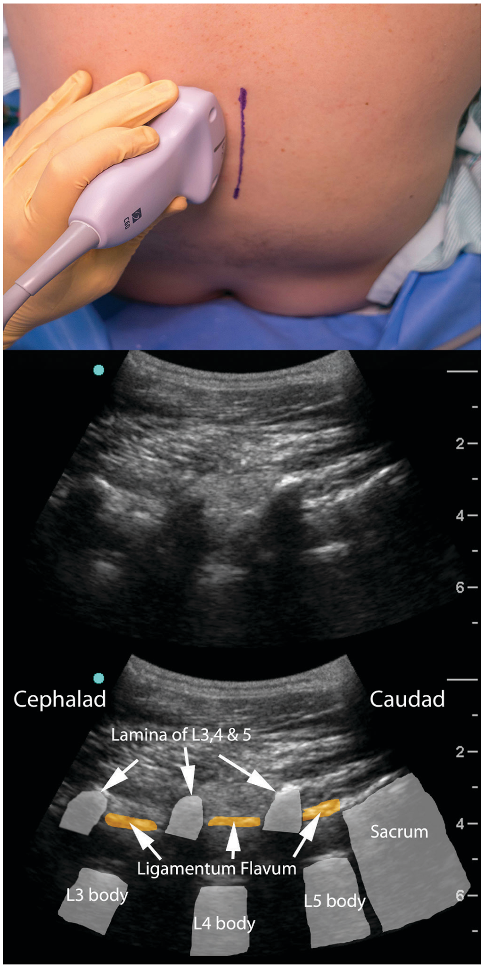


Figure 4-61 With the probe 1 to 2 cm lateral to midline, angle the beam toward midline (paramedian sagittal oblique probe position). The ultrasound image between the lamina reveals a paramedian window where the ligamentum flavum (shallow) and the body of the corresponding vertebra (deep) appear as white lines.

6. **Measuring the depth to the epidural space:** Depth to the epidural space can be found in short or long axis. Obtain the views described that show the ligamentum flavum superficial to the posterior longitudinal ligament. Now use the ultrasound calipers or depth markings on the side of the ultrasound image to measure the distance from the skin to the intended target. The identification of a lumbar interspace, the estimated depth to the epidural space (ligamentum flavum), and knowledge of the midline can facilitate placement of a spinal or epidural block (Figure 4-63).
7. **Identify the degree of spinal rotation:** Ultrasound is useful for patients who are obese or have scoliotic spines. Determining rotation of the spine is difficult by palpation alone. Find the spinous process by using the steps described earlier. Then, look for the lamina about 3 cm deeper and just lateral to the spinous process. In a normal spine, the lamina should lie horizontally. In a patient with scoliosis, the probe will have to be angled to the left or right in an effort to make the lamina appear horizontal on the screen. Once

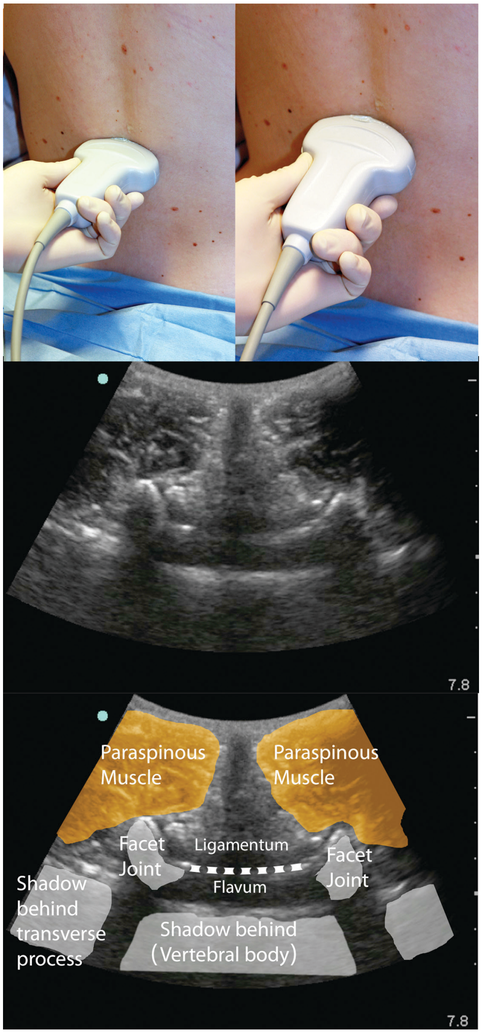


Figure 4-62 Probe placement and ultrasound image of the spine in short axis with the probe in a transverse plane. The ultrasound image reveals the ligamentum flavum *(dotted line)* and the posterior aspect of the vertebral body (deep). This intervertebral window can be centered on the probe and marked to identify an appropriate space for needle advancement (see Figure 4-65). Slight tilting of the probe in a cephalad-caudad direction can significantly improve imaging *(top images)*.

the spinous process is in the midline and the lamina appear horizontal on the ultrasound screen, take note of the probe position on the patient's back. Notice the degree of rotation of the probe and the midpoint of the probe. Attempt to reproduce that same probe angle with the needle to help guide your attempts at spinal or epidural placement (Figure 4-64).

8. **Start the needle at the intersection of the midline mark and the vertebral interspace mark where the ligamentum flavum was visible. Advance the needle perpendicular to all planes or with a slight cephalad angle** (Figure 4-65).

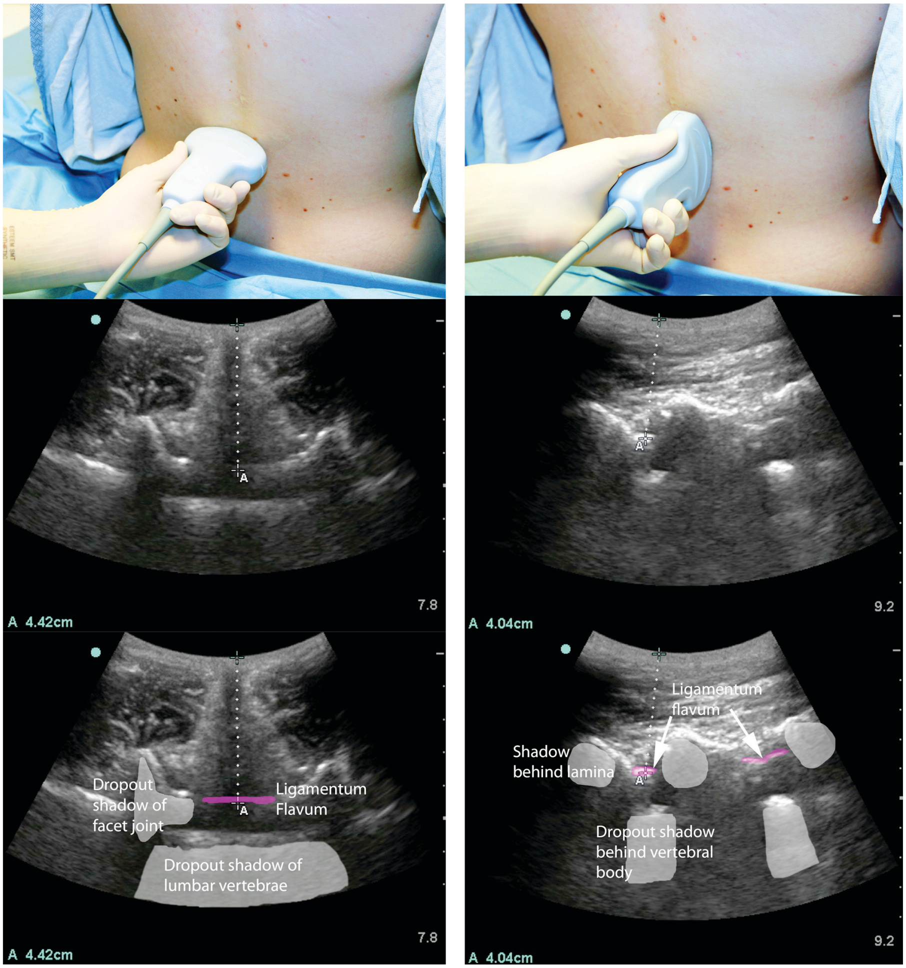


Figure 4-63 Ultrasound image of the spine in long-axis *(left)* and short-axis *(right)* views demonstrating the ligamentum flavum. Use the ultrasound caliper tool to estimate the depth of the epidural space.

Scanning Technique—Thoracic

1. **Identify the correct thoracic level:** As described earlier for the PVB, count the ribs up from the 12th rib in the paramedian plane until the appropriate vertebral level is identified.
2. **Identify the midline:** As with lumbar imaging, it is helpful to identify the midline. Place the probe on the patient's back in a transverse plane, then move the probe until the shadow is cast by the spinous process down the middle of the image. Mark this as the midline. Repeat this maneuver for two or three levels up or down the spine. Two accurate levels of midline will now be marked. Connect these dots for a good representation of true midline (Figure 4-66).
3. **Identify the lamina depth:** Lateral to midline is the hyperechoic lamina, which usually is found perpendicular to the spinous process at the thoracic level. From the lamina, the transverse processes of the vertebra should be more lateral and form a continuous bony

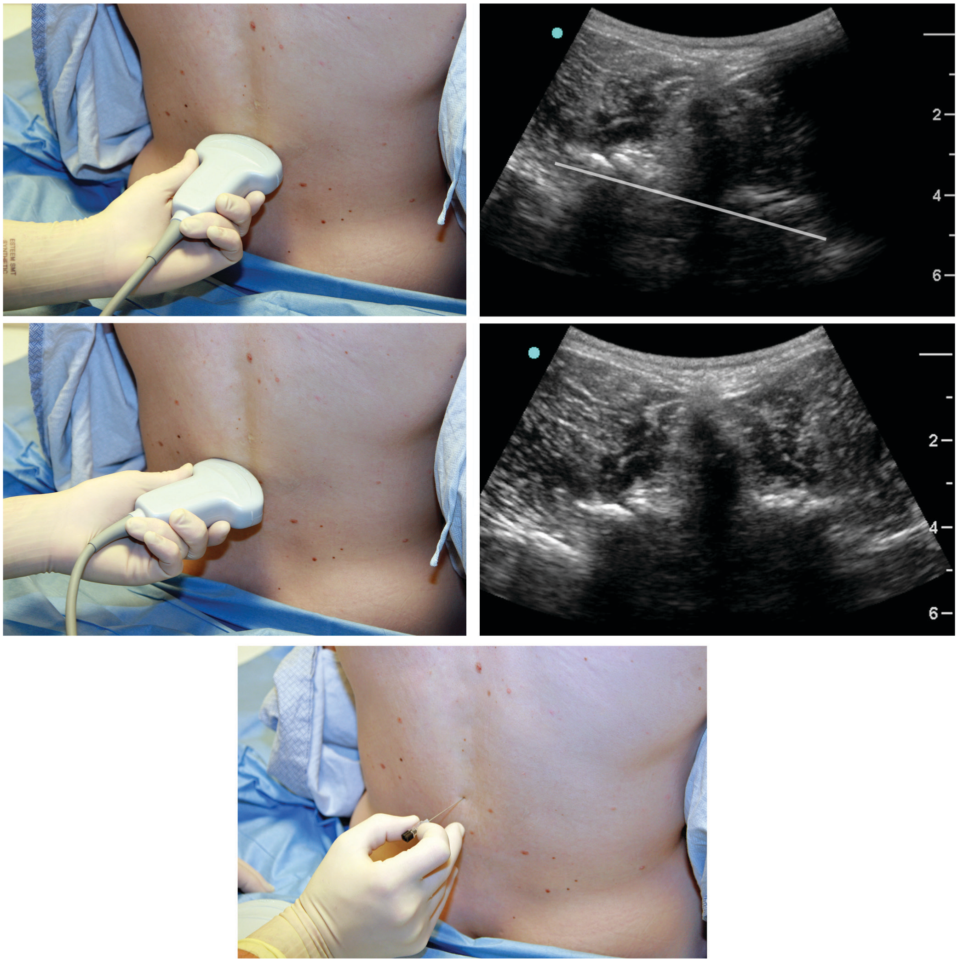


Figure 4-64 Ultrasound can be used to determine the degree of spinal curvature. The hyperechoic reflection from the lamina should be level on the ultrasound image *(middle images)*. If the lamina are at uneven levels *(top images)*, tilt the probe to make the lamina appear level on the screen. This helps the operator determine the degree of curvature for spinal placement. When advancing the needle, use an angle similar to that of the probe *(bottom image)*.

structure. The transverse process will be shallower than the lamina and will help in PVB placement (see Figure 4-51). Use the caliper tool to measure from the lamina to the top of the image. This skin-to-lamina depth can help guide epidural needle insertion. Lamina depth can be measured in the transverse or the parasagittal plane (Figure 4-67).

4. **Identify an interlaminar space for thoracic epidural placement:** Rotate the probe 90 degrees from transverse into a parasagittal plane. At this level, the lamina can be imaged. A medial tilt of the probe usually allows for improved imaging of the lamina. Between the lamina, there will be an interlaminar space with a hyperechoic line a bit deeper. This hyperechoic line is usually the articular process of the thoracic region but is sometimes referred to as the ligamentum flavum. Because of its bright appearance, it is likely bone, not ligament. In the upper thoracic vertebrae, the lamina overlap and there

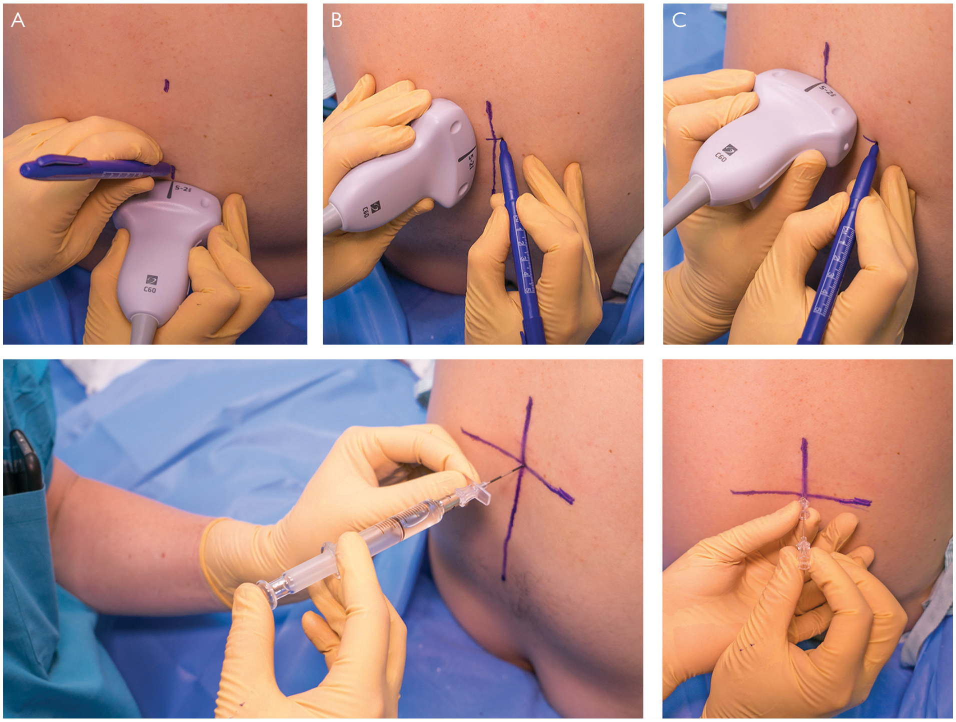


Figure 4-65 Once the midline ultrasound mark (A) and either a parasagittal interspace mark (B) or a transverse interspace mark (C) have been made, connect the midline and interspace marks. These marks should form crosshairs in the lumbar region. Advance the epidural Tuohy needle *(lower left)* or spinal needle *(lower right)* perpendicular to all planes.

is no large acoustic window between the lamina to view the ligamentum flavum. Needles should be targeted to this interlaminar space for thoracic epidural placement. The skin can be marked to help guide needle placement (Figure 4-68).

5. **Ultrasound-assisted epidural placement:** Most of the time, we use the marks on the skin to assist in needle placement. After performing the procedures described, there will be a midline mark and an interlaminar space mark. Often, we mark two different interlaminar spaces in case the first attempt is unsuccessful. The midline and interlaminar space

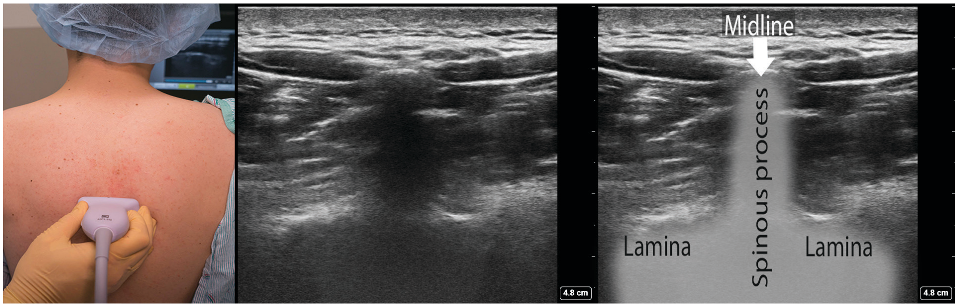


Figure 4-66 In the thoracic region, the midline can be marked by identifying the spinous processes.

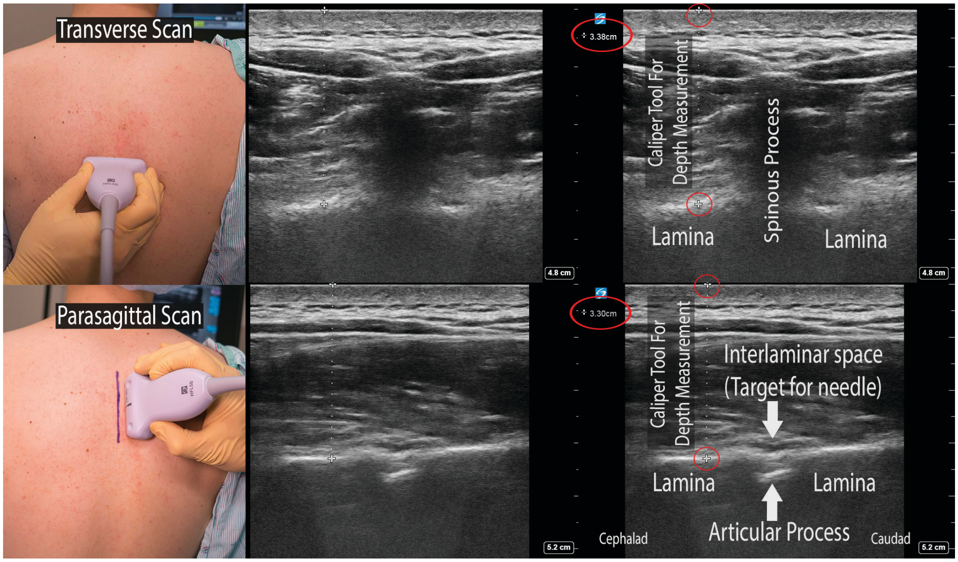


Figure 4-67 For thoracic epidural placement, it is helpful to know the depth to lamina. Utilize the ultrasound caliper tool to assess the depth. These depth measurements can be performed in the transverse plane *(top images)* or in the paramedian plane *(bottom images)*.

markings will create an "X" on the patient's back. Because of the bony anatomy of the thoracic vertebrae, it is still important to advance a Tuohy needle with a cephalad angle to best guide the needle between the lamina. It is usually not possible to advance the needle perpendicular to the skin in all planes. A midline or paramedian approach can be used. Loss of resistance confirms epidural placement of the needle tip (Figure 4-69).

Real-Time Placement of Neuraxial Injections

After the operator has developed proficiency using ultrasound assistance for marking the spine as described, the next step is to attempt real-time spinal and epidural injections. This is an advanced technique.

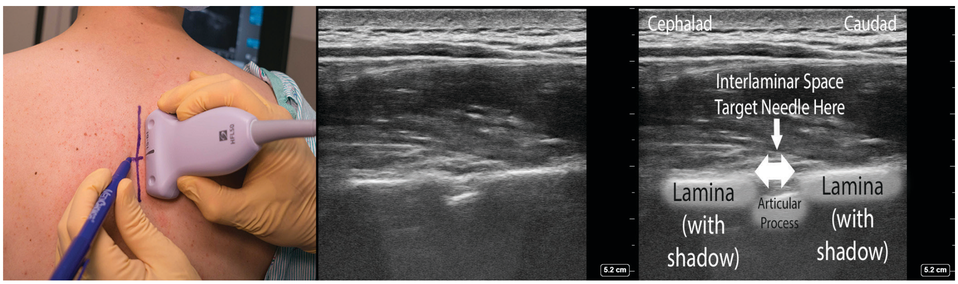


Figure 4-68 With the probe in a parasagittal plane (parallel to the spine), slide about 1 to 2 cm lateral from midline. Next, tilt the beam, aiming toward the midline (paramedian sagittal oblique view). Identify the flat lamina and the interlaminar spaces (small breaks between the lamina). These interlaminar spaces contain the facet joints of thoracic vertebrae and small windows to place an epidural catheter. These interlaminar spaces can be marked with a pen on the skin.

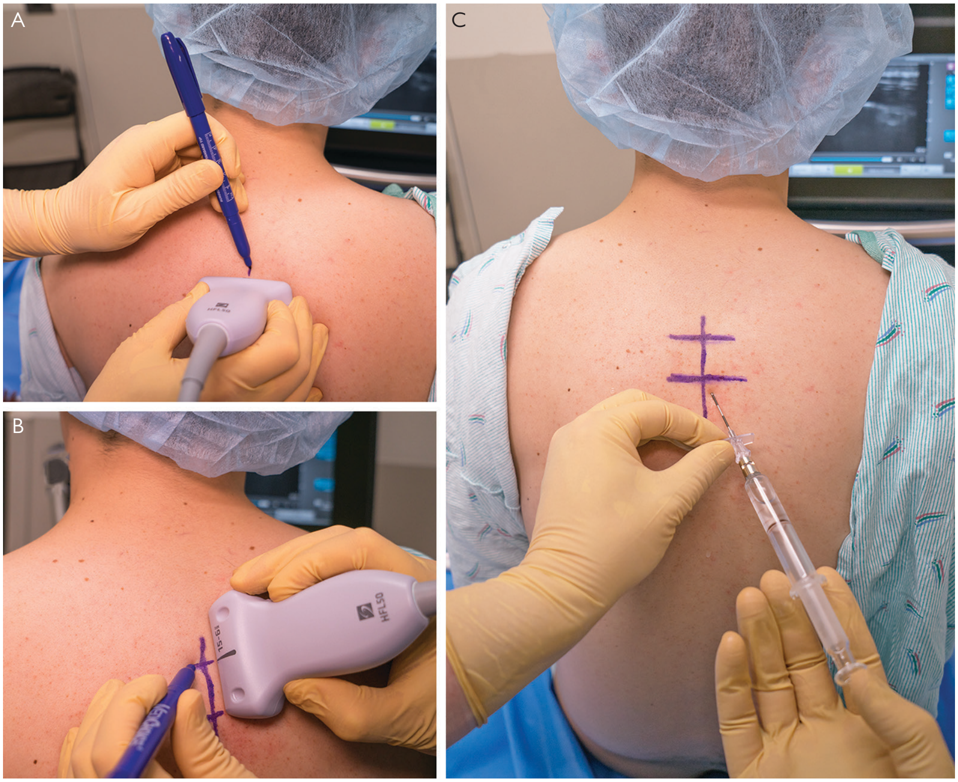


Figure 4-69 After the midline (A) and the interlaminar spaces (B) of the thoracic region have been marked, a needle can be advanced with a midline or paramedian approach (C). Start the needle approximately 1 cm below the interlaminar skin mark to angle the needle into the epidural space.

An important key point is that we are introducing a needle into the central nervous system, and ultrasound gel should not be tracked to the epidural space or CSF, even if sterile. To prevent this problem, use sterile saline as a coupling agent between the probe cover and the skin. This way, no ultrasound gel can be tracked into or near the central nervous system by the needle. It is still appropriate to use gel inside the sterile probe cover.

Patient positioning and equipment: Place the patient in a sitting or lateral position, using the traditional fetal position to open up the spinal space. Use a low-frequency curvilinear probe (2-5 MHz) and the usual spinal or epidural kit. Loss of resistance can be determined by moving one hand from the needle to the syringe after each small advance. Alternatively, have an assistant hold the transducer while the epidural or spinal needle is advanced.

Using an initial transverse (short-axis) scan to estimate the depth of the lamina, dura, and posterior longitudinal ligament can be helpful. When the probe is then turned 90 degrees and tilted to a paramedian position, the depth of familiar structures will help the practitioner confidently identify them in the paramedian oblique view.

The needle is introduced in-plane from the inferior end of the probe or out-of-plane from the middle of the probe. The needle is advanced into the ligamentum flavum at the depth of the lamina. Continue the epidural procedure after loss of resistance by attaching a syringe for an epidural block. Performing these procedures for spinal blocks may help the operator gain some experience before attempting an epidural.

Further Reading

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