REVIEW ARTICLE

Current Practice of Ultrasound-Assisted Regional Anesthesia

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INTRODUCTION

Ultrasound guidance in regional anesthesia was first described by La Grange et al. in 1978.[1] However, it is only with recent advancements in ultrasound technology during the last decade that ultrasound-guided regional anesthesia has become a more significant area of interest to anesthesiologists. In 2005, a detailed review article on ultrasound guidance in peripheral nerve blocks was published by Marhofer et al.[2]

Ultrasound guidance affords visualization of relevant anatomy as the regional block is being performed. Marhofer et al.,[2] as well as others who are major proponents of ultrasound assistance for performance of regional techniques, believe that ultrasound-facilitated visualization of precise needle guidance and ability to monitor local anesthetic spread during injection may improve success rate of the local anesthetic blockade while at the same time decreasing the incidence of complications. At the New York University (NYU) Department of Anesthesiology and the NYU Hospital for Joint Diseases, we routinely utilize ultrasound assistance in regional anesthesia. We believe that ultrasound guidance will have a progressively expanding role in regional anesthesia in the future as portable ultrasound equipment becomes more refined and affordable. In this article, we will focus on the current scope of practice of ultrasound-guided regional anesthesia at our institution.

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PRINCIPLES OF ULTRASOUND TECHNOLOGY

High-frequency ultrasound machines are necessary in order to produce images of nerves, vessels, and other relevant anatomical structures that are readily identifiable.[2] Sound waves typically in the frequency range of 1 to 15 MHz are used. These sound waves are generated by an ultrasound transducer. In most diagnostic applications of ultrasound, use is made of ultrasound waves reflected from interfaces between different tissues in the patient. Varying acoustic impedance characteristics of different tissues cause sound waves to be reflected, and this reflection, or echo, is collected by the probe. The amplitude of the reflected signal is then displayed on a digital monitor in a two-dimensional plane as varying degrees of brightness corresponding to the tissue location and degree of "echoity."

Different human anatomical structures have varying reflective properties, and, therefore, can be visualized by using ultrasound technology. "Hyperechoic" structures have a high reflective index and appear bright on screen. Bone and tendons, for example, are hyperechoic. "Hypoechoic" tissues have a low reflective index and appear dark on screen. At the opposite end of the spectrum, "anechoic" structures have no echogenicity because the ultrasound waves are not reflected. Fluid-filled structures are anechoic if there is little echogenic material within the fluid. Most body fluids (i.e., bile,

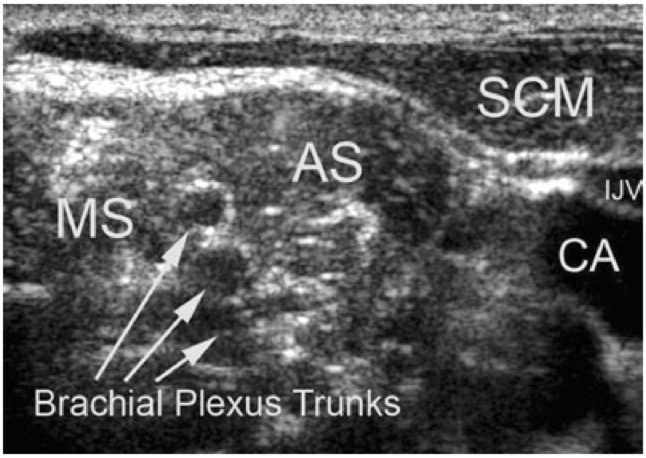

Figure 1. Ultrasound view of the brachial plexus trunks at the C6 level. Note the round appearing nerves between the anterior scalene (AS) and middle scalene (MS) muscles that have a hypoechoic quality surrounded by a hyperechoic perineurium. SCM, sternocleidomastoid muscle; CA, carotid artery; IJV, internal jugular vein.

urine) appear as anechoic *(gray)*. Other structures with high water content, like fat and blood vessels, fall between these two and demonstrate hypoechoic patterns. Peripheral nerves usually have a hyperechoic appearance. However, when visualized in areas close to the surface, as in brachial plexus blocks at the interscalene (C6–7) level, the trunks show a hypoechoic quality surrounded by a hyperechoic perineurium (Figure 1).

In general, as ultrasound wave frequency is increased, a higher resolution is seen, but with lower penetration. Conversely, lower-frequency ultrasound waves result in deeper penetration, but with lower image resolution. Therefore, higher-frequency ultrasound may be suitable for smaller and superficial structures, while lower frequency is preferred for larger and deeper structures.

EQUIPMENT SELECTION

The ultrasound image quality is primarily determined by transducer probe characteristics such as frequency. The frequencies that we typically use for peripheral nerve identification vary between 5 and 13 MHz. For application in superficial anatomical structures as in interscalene, supraclavicular, and axillary brachial plexus blocks, probes producing frequencies in the range between 10 and 13 MHz are preferable. Visualization of deeper nerve structures, as required when performing nerve blocks in the infraclavicular or popliteal region, improves with frequencies between 5 and 7 MHz.

The shape of the ultrasound probe affects the image as well. A linear array probe emits ultrasound waves in a straight frontal direction, while a curved array probe emits in a fan-like fashion. Therefore, the resulting images appear different, depending on which probe is utilized. The ultrasound operator must choose the correct probe type for each task.

Optimal needle visibility or “echogenicity” is important for precise ultrasound guidance. Schafthalter-Zoppoth et al. identified and quantified a number of needle- and ultrasound-specific factors that alter needle visibility.[3] Based on their study, the largest needle size reasonably possible, inserted with a medium-size guide wire located in its shaft, provided the best ultrasound visibility. In addition to optimal echogenicity, the needle tip should be sharp enough for easy skin insertion while still blunt enough for the perception of subtle differences in resistance of anatomical structures as they are encountered. Simultaneous nerve stimulation capability can, in cases of difficult visibility, prove beneficial as well.

ULTRASOUND-GUIDED NERVE BLOCK TECHNIQUE

An understanding of anatomy and physiology, block techniques, anesthetic medications, and potential complications is a prerequisite to successfully perform peripheral nerve blocks. The same standards that apply to conventional nerve block procedures also should be applied to ultrasound-guided nerve blocks.

Strict sterile technique should be followed throughout the procedure. The probe should be covered in a sterile manner. A sterile sheath, probe cover, or even sterile glove can be utilized. Ultrasound gel should be applied between the probe and the inside of the sheath cover to avoid air trapping. Sterile gel should also be applied between the outside of the probe cover and the patient’s skin surface.[4]

In order to optimally identify nerve structures, the ultrasound beam should be oriented perpendicularly to the nerve axis. Image quality should be optimized by adjusting all available variables, i.e., frequency and penetration depth.[2] The next step is to insert and visualize the needle. Probe and needle alignment are important for needle and nerve visualization. Our preference is to utilize the approach of Perlas et al.—the “long axis” approach,[5] in which the needle is inserted and advanced in the longitudinal direction or along the long axis of the ultrasound probe (Figure 2). This is opposed to the transverse or “short axis” approach recommended by Marhofer et al.,[2] where the needle is inserted at right

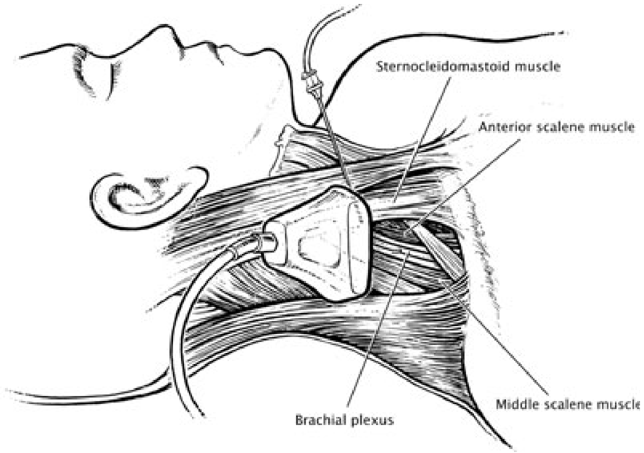

Figure 2. Ultrasound probe and needle in proper position for performing an ultrasound-guided interscalene nerve block. From front of probe moving laterally to the sternocleidomastoid muscle, the anterior scalene muscle, the brachial plexus in the interscalene groove, and the middle scalene muscle.

angles to the long part of the probe, so that identification of the needle is possible only when the needle crosses the ultrasound beam of the probe. We prefer the longitudinal (long axis) technique because of the ability to continuously monitor needle advancement from skin insertion to positioning of the needle tip next to the targeted nerve structure.

Besides the gauge, the insertion angle of the needle is the main factor that determines needle visibility.[3,6] In the longitudinal approach, the needle is inserted along its long axis parallel to the ultrasonic beam to visualize the entire shaft and tip. However, needle tip visibility is considerably reduced at steep insertion angles (see below: "infraclavicular brachial plexus block").[6]

Moreover, the needle tip is favorably visualized within an anechoic background such as in expanding local anesthetic during injections or in blood vessels. The use of unagitated local anesthetic solutions will promote visibility further as air bubbles within the solution tend to cause a phenomenon called acoustic shadowing distally and, therefore, make proper visualization more difficult.[6] Artifactual reverberation echoes within acoustic shadows distal to gas or air collections result from virtually total sound reflection at tissue–air interfaces. The targeted nerve structures often can be more easily identified following the injection of undisturbed bubble-free local anesthetic, as well.[6]

UPPER EXTREMITY NERVE BLOCKS

The brachial plexus originates from the nerve roots of C5 to T1. The nerves course between the anterior and middle scalene muscles, in the interscalene groove as the superior middle and inferior trunks. They then form the posterior, medial, and lateral cords as they travel with the subclavian and axillary arteries.[2] The cords are named for their location relative to the axillary artery. Distally the individual nerves, the median, ulnar, radial and musculocutaneous nerves, are formed.

We will describe single-shot ultrasound-guided block techniques at the interscalene, supraclavicular, infraclavicular, and axillary levels of the brachial plexus.

INTERSCALENE BRACHIAL PLEXUS BLOCK

Ultrasound-guided interscalene brachial plexus imaging and blocks have been well-documented.[2,4,5,7] Interscalene blocks are typically performed at the level of the cricoid cartilage, which corresponds to C6, in the interscalene groove. The patient is positioned supine, with the head tilted slightly to the contralateral side. After sterile skin and probe preparation, a linear array 10 to 13 MHz ultrasound probe is placed at the C6 level, perpendicular to the long axis of the neck/interscalene groove so that the carotid artery, internal jugular vein, sternocleidomastoid, anterior, and middle scalene muscles come into view (Figure 2). Between the anterior and middle scalene muscles, usually two to three hypoechoic, round to oval structures with a hyperechoic rim surrounding them, should be visualized. These represent the trunks of the brachial plexus.

If the nerves are difficult to visualize at this level, the probe should slowly be moved caudally toward the supraclavicular region (C7), where the nerves often appear as a "bunch of grapes" close to the skin surface.[4,7] Once identified, the nerves can then be traced back to the C6 level by moving the probe cranially.

When performing the interscalene block, a 20- to 22-gauge 5-cm needle is introduced along the long axis of the probe, parallel to the ultrasonic beam. The approach to the brachial plexus can be accomplished from either the anterior or posterior[7] direction relative to the ultrasound probe. With the probe in place, it is easy to identify the pulsatile carotid artery. The sternocleidomastoid muscle is located superficial to this. If the patient is asked to Valsalva, the internal jugular artery is easily visualized as it enlarges. Lateral to these vessels are the anterior scalene muscle, the brachial plexus, and the middle scalene muscle (Figure 3). When the anterior approach is chosen, which is our approach of choice, the needle initially traverses the sternocleidomastoid muscle. Prior to entering the anterior scalene muscle, an inward displacement of the platysma is observed on the

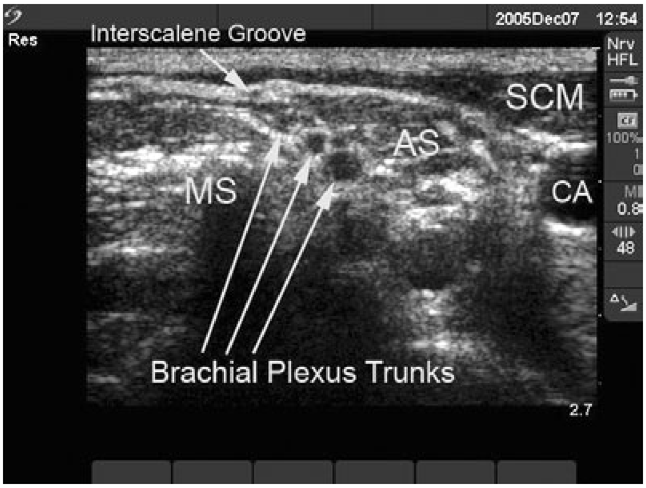

Figure 3. Ultrasound view for performing an interscalene nerve block. Note the round appearing nerves in the interscalene groove that have a hypoechoic interior surrounded by a hyperechoic exterior appearance. They are located between the anterior scalene (AS) and middle scalene (MS) muscles. The carotid artery (CA) that pulsates during real-time visualization is a helpful anatomic landmark. The sternocleidomastoid muscle (SCM) is noted. If the patient is asked to Valsalva, the internal jugular vein usually can be visualized.

screen. This is followed by the perception of a "pop" as the needle enters the anterior scalene muscle. Once the trunks of the brachial plexus are reached between the anterior and middle scalene muscle, a second "pop" is felt through the block needle as the neurovascular sheath is perforated. The position of the needle tip is confirmed by observing the pattern of local anesthetic spread around the brachial plexus trunks on the ultrasound image as the injection is performed.[2,4]

SUPRACLAVICULAR BRACHIAL PLEXUS BLOCK

The supraclavicular block is performed caudad in the neck from where the interscalene block is performed. Marhofer et al. suggest that the brachial plexus at the supraclavicular level can be visualized by moving the ultrasound probe caudally, away from the position at the interscalene block (C6) level.[2] The patient is positioned supine, with the head turned 35 to 45 degrees to the contralateral side. Following sterile skin and probe preparation, a linear 10 to 13 MHz probe is positioned in the transverse (short axis) position relative to the brachial plexus in the supraclavicular fossa. Visualization of the subclavian vessels, first rib, cervical pleura, and possibly lung tissue should be achieved from this position. Brachial plexus divisions are seen again as distinct round to oval hypoechoic structures with a hyperechoic rim surrounding them. The nerves are typically arranged in a sheet-like fashion around the artery, extending from the area superficial to the artery to the area lateral to it.

The approach to the brachial plexus is technically easier from the lateral (posterior, relative to the ultrasound probe) position for this block. A 20- to 22-gauge 5-cm needle is inserted posteriorly and advanced along the long axis of the probe, parallel to the ultrasonic beam. Once the needle tip is positioned next to the nerves, local anesthetic injection is initiated. Observe local anesthetic spread, and if it is not uniform, engulfing most of the nerve divisions, the needle may be repositioned carefully before the remainder of the local anesthetic is administered.

Although it is a highly effective block,[8] because of the concern about causing pneumothorax with this procedure, we do not routinely perform this technique.[2]

INFRACLAVICULAR BRACHIAL PLEXUS BLOCK

Many people who use ultrasound for regional anesthesia find it especially helpful when performing infraclavicular nerve blocks. The anatomy that is seen with the ultrasound machine, including the axillary artery and the cords of the brachial plexus, supplies helpful information for location of the correct site of injection of local anesthetic. In addition, the block is easy to perform even with lower-quality ultrasound units, even with probe frequencies as low as 2.5 MHz as described by Sandhu et al.[9] Variations of this technique have been well-documented.[9–13]

At the infraclavicular level, the lateral, posterior, and medial cords of the brachial plexus are arranged circumferentially around the second part of the axillary artery. The patient is positioned supine, with the head tilted slightly to the contralateral side[4] (Figure 4). After sterile skin and probe preparation, a 5 to 7 MHz ultrasound probe is then positioned in the sagittal plane to obtain a cross-sectional view of the subclavian/axillary vessels and nerves (Figure 5). Optimal view of the structures is typically achieved when the probe is applied 1 to 2 cm medial to the coracoid process and inferior to the clavicle. The main structures for orientation that initially come into view are the hypoechoic subclavian blood vessels, with the artery being pulsatile and the vein compressible. The cords have a hyperechoic quality at this level. The cords of the brachial plexus are oriented with the lateral cord most cephalad, the medial cord most caudad, and the posterior cord posterior to the artery (Figure 6). A 20- to 22-gauge, 8- to 10-cm block

Figure 4. Demonstration of proper probe position and direction of needle entry for performing an ultrasound-guided infraclavicular nerve block.

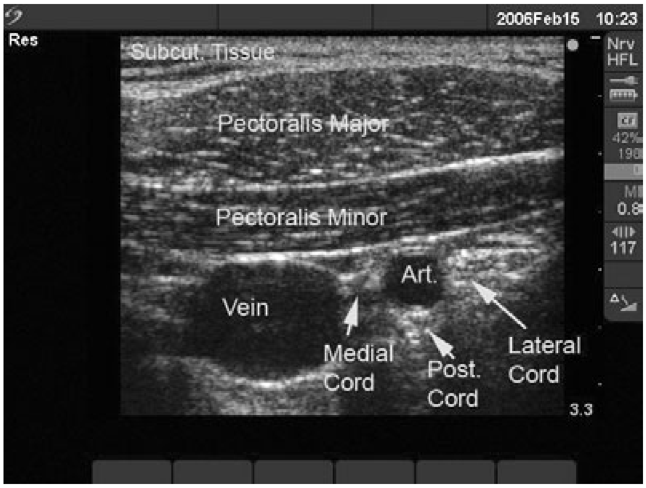

Figure 6. Ultrasound image of the brachial plexus in the infraclavicular area. Note how the cords surround the artery with the medial cord located between the vein and the artery. Art., artery; Post., posterior; Subcut., subcutaneous.

Figure 5. Anatomic plane cut by the ultrasound probe when performing the infraclavicular block. Note the brachial plexus surrounding the axillary artery.

needle is introduced from the cephalad side of the probe, and advanced along its long axis. The needle is then observed navigating the major and minor pectoral muscle, and eventually, when approaching the neurovascular bundle, an inward movement of the perivascular/perineural sheath is seen, followed by the perception of a “pop” through the needle. We aim to guide the needle tip to the “5 o’clock” position (or “7 o’clock” position, depending on the probe/screen orientation) of the artery, next to the posterior cord. This position is confirmed by observing a “crescent” type pattern of local anesthetic spread around the subclavian/axillary artery, engulfing all the cords, when the injection is made. In cases with suboptimal and limited local anesthetic spread (posterior/lateral), a supplemental injection between the subclavian/axillary artery and vein, next to the medial cord, may become necessary.

In obese patients, the insertion angle of the needle may have to be very steep to reach the described position next to the posterior cord. This results in a marked reduction in tip visibility of a 20- to 22-gauge needle. While some of the colleagues at our institution feel comfortable navigating the needle based on observed tissue movement, others prefer using larger-bore needles (17 to 18 gauge) that result in improved needle tip visibility in infraclavicular brachial plexus blocks. Large-bore needles also are more rigid and, therefore, do not bend out of the sonographic plane.[6]

AXILLARY BRACHIAL PLEXUS BLOCK

Conventional approaches (transarterial, nerve stimulator facilitated) to the axillary block remain highly popular, despite relatively high failure rates.[2,14] The brachial plexus block at the axillary level blocks the median, ulnar, and radial nerves, but tends to spare the musculocutaneous nerve since it leaves the brachial plexus prior to entering the axilla, usually just distal to the coracoid process. This is one of the main reasons why we prefer the infraclavicular method that commonly results in a quick and reliable blockade suitable for surgical procedures below the shoulder.

The patient is positioned supine. The arm is rotated externally and abducted 90 degrees at the shoulder, and the forearm is flexed 90 degrees at the elbow. Following sterile skin and probe preparation, a 10 to 13 MHz ultrasound probe is positioned in the transverse plane high in the axilla to obtain a cross-sectional view of the axillary vessels and nerves. The nerves appear as round or oval hypoechoic structures, including hyperechoic rims, around the axillary artery. The exact locations of the individual nerves relative to the axillary artery appear to be highly variable, and the nerves tend to be displaced further by minimal palpation or application of the ultrasound probe.[2,14] Regardless of the exact position of the nerves, the aim of this block is to inject around the axillary artery within the neurovascular sheath, which provides a predictable result.

When performing an axillary brachial plexus block, a 22-gauge 5-cm block needle is introduced along the long axis of the probe and advanced within the plane of the ultrasonic beam. Once the needle is in position, local anesthetic is injected, and its spread around the artery is visualized. It is sometimes necessary to inject several times around the artery to ensure an adequate block. Using ultrasound allows for predictability without eliciting paresthesia or traversing the axillary artery. In addition, the musculocutaneous nerve can be blocked by identifying the nerve within the substance of the coracobrachialis muscle and injecting around it.

LOWER EXTREMITY NERVE BLOCKS

The lumbar plexus is formed from the nerve roots of the first four lumbar vertebrae. The lumbar plexus courses anteriorly to the transverse processes and forms the nerves supplying the anterior portion of the lower extremity, including the femoral, lateral femoral cutaneous, and obturator nerves. The sciatic nerve supplies the remainder of the nerve supply to the lower extremity. It courses down the posterior thigh where, just proximal to the popliteal fossa, it divides into the common peroneal and the tibial nerves.[2,15]

We will describe single-shot ultrasound-guided block techniques for the psoas compartment, femoral nerve, and two levels of the sciatic nerve.

LUMBAR PLEXUS (PSOAS COMPARTMENT) BLOCK

The lumbar plexus (psoas compartment) block is a useful anesthetic technique for operations of the hip and anterolateral areas of the thigh.

The patient is positioned either sitting or in lateral decubitus position. After sterile skin and probe preparation, a 5 to 7 MHz ultrasound probe is positioned 4 to 5 cm lateral to the L3 spinous process. With ultrasound assistance, the L3 spinous process, transverse process, and paraspinous muscle should be identified. A 20- to 22-gauge 10-cm needle is inserted from the lateral side and advanced along the long axis of the probe until contact is made with the transverse process. The needle is then walked off superiorly, while either loss of resistance or nerve stimulation is verified continuously. The final position of the needle tip is confirmed by observing the pattern of local anesthetic spread just deep to the transverse process.

FEMORAL NERVE BLOCK

The femoral nerve arises from the lumbar plexus and courses beneath the inguinal ligament, into the thigh. It is located lateral to the femoral artery and vein[15] (Figure 7). The femoral nerve block is useful for pain relief following procedures at the knee level.

The patient is positioned supine. The groin is exposed, and following sterile skin and probe preparation, a 10 to 13 MHz ultrasound probe (5 to 7 MHz probe if deep structures are suspected) is applied along the inguinal crease in the transverse plane to obtain a

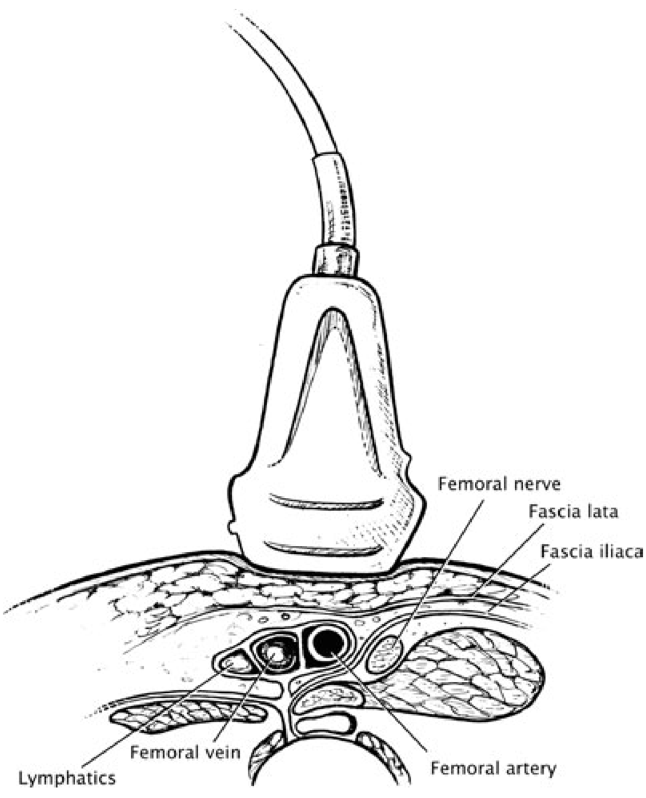

Figure 7. Drawing demonstrating the anatomic plane cut by the ultrasound probe overlying the femoral nerve. Note the femoral nerve, artery, and vein.

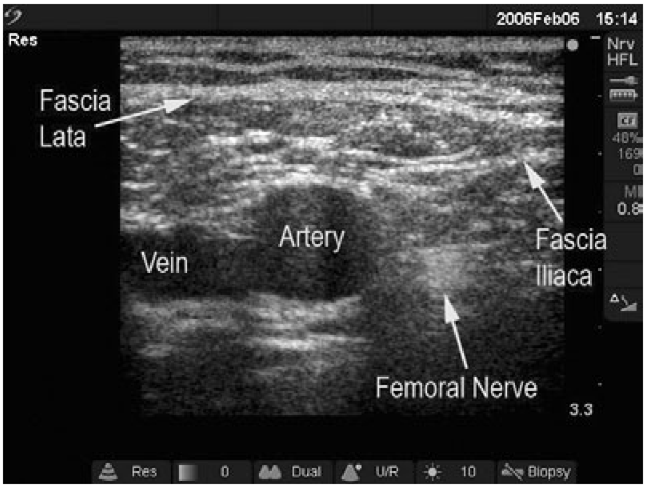

Figure 8. Ultrasound view of the femoral nerve, artery, and vein just caudad to the inguinal ligament. Note the nerve is deep to the fascia that laterally becomes two distinct fascial planes, the fascia iliaca and fascia lata.

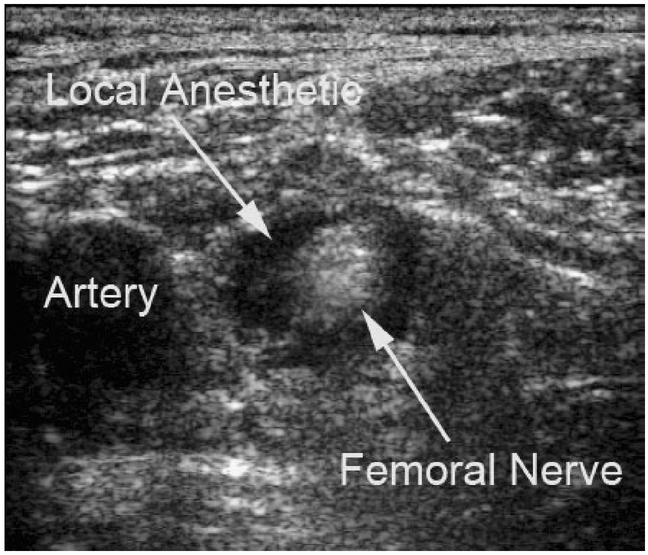

Figure 9. Local anesthetic, which is a liquid and not having echogenicity, appears clear, surrounding the femoral nerve.

cross-sectional view of the femoral vessels and nerve[4] (Figure 7). The hypoechoic pulsatile artery usually is easily identified. The artery can be further visualized if the ultrasound machine has a color flow probe. The compressible femoral vein is found medial to the artery, while the hyperechoic branches of the femoral nerve can be located lateral to the femoral artery (Figure 8). A 20- to 22-gauge 5-cm needle is inserted from either the medial or lateral side and advanced along the long axis of the probe, parallel to the ultrasonic beam and directed toward the femoral nerve. Soon after skin insertion, a brief inward movement of the fascia lata is observed, followed by the perception of the first "pop" through the needle. Another brief inward displacement of the fascia iliaca/perineural sheath is often seen, and the second "pop" is felt once perforated. The position of the needle tip is confirmed by observing the pattern of local anesthetic spread around the femoral nerve immediately lateral to the artery on the ultrasound image as the injection is performed (Figure 9).

SCIATIC NERVE BLOCK

The sciatic nerve block is performed for operations involving the foot and ankle. The nerve originates from the lumbosacral plexus, and courses into the posterior thigh between the greater trochanter and the ischial tuberosity.

The patient is positioned in lateral decubitus position. After sterile skin and probe preparation, a 5 to 7 MHz ultrasound probe is positioned in the subgluteal region. The sciatic nerve should appear as a hyperechoic circular structure bordered by two or three muscular structures. A 20- to 22-gauge 5- to 8-cm block needle is inserted from the lateral side and advanced along the long axis of the probe until the needle tip is positioned just lateral to the nerve. Occasionally, a "pop" is felt as the needle enters the sheath. The final position of the needle tip is then confirmed by observing the pattern of local anesthetic spread around the sciatic nerve.

POPLITEAL FOSSA BLOCK

The sciatic nerve block in the popliteal fossa is a well-suited anesthetic technique for operations below the knee. In the popliteal fossa, the sciatic nerve is bordered superolaterally by the long head of the biceps femoris muscle and superomedially by the semimembranosus and semitendinosus muscles.

The patient is positioned prone. After sterile skin and probe preparation, a 5 to 7 MHz ultrasound probe is then positioned 6 to 8 cm proximal and parallel to the popliteal crease in the transverse plane relative to the sciatic nerve. The sciatic nerve presents as an oval to irregular hyperechoic structure posterio-lateral to the popliteal artery. Dabo and Chan[4] suggest that the probe should be moved proximally and distally to locate the bifurcation of the sciatic nerve, with the goal being to direct the needle proximal to the site of division of the sciatic nerve. A 20- to 22-gauge 5-cm needle is inserted from the lateral side and advanced along the long axis of the probe, parallel to the ultrasonic beam and directed toward the nerve. A subtle "pop" may or may not be felt before the immediate vicinity of the nerve is reached. The position of the needle tip is confirmed by observing the pattern of local anesthetic spread around the sciatic nerve. Occasionally, an incomplete or unilateral spread is observed, requiring a second injection from the medial side of the ultrasound probe.

CONCLUSION

Ultrasound-enabled visualization is earning a place in the armamentarium of the regional anesthesiologist. It provides the practitioner with the ability to observe vital structures such as nerves and vessels and their relation to the needle being used for local anesthetic injection while the injection is actually occurring. The ability to note local anesthetic spread as it occurs will hopefully improve the quality of the block, as well as decrease the incidence of side effects and complications.[2] Applications beyond the scope of this article as in epidural anesthesia[16–18] and in pediatric procedures[19] have been described and are expected to evolve further as well. With the continuous development of portable, more sophisticated and affordable ultrasound equipment, we should expect to see a progressively mounting interest in this technique among anesthesiologists around the world.

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