Peripheral Nerve Blocks and Ultrasound Guidance for Regional Anesthesia

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Introduction

Peripheral nerve blocks can be performed using a variety of guidance techniques. Recently, ultrasound has gained popularity for regional anesthesia because it allows direct imaging of peripheral nerves, the block needle, and injection distribution. This chapter is a focused update of two chapters on peripheral nerve blockade from the previous edition. The sections to follow contain a selective description of the more common peripheral nerve blocks utilized in clinical practice.

Techniques for Localizing Neural Structures

PARESTHESIA TECHNIQUES

The paresthesia-seeking technique has a long, successful history as a simple method that requires little specialized equipment. A paresthesia is elicited when a needle makes direct contact with a nerve. Paresthesia-seeking techniques are reliant on patient cooperation and participation to guide the needle and local anesthetic injection accurately; therefore only small doses of sedation medication are recommended. Paresthesia techniques have been criticized for causing patient discomfort, although clinical studies have not shown a significant increase in neurologic complications with this technique. Caution should be used when initiating the injection of local anesthetic to ensure that the needle is not intraneural. There is controversy in the literature regarding the use of B-bevel (blunt bevel or short bevel) needles versus sharp needles regarding the incidence and severity of nerve injury if the needle inadvertently punctures or pierces the nerve. Because B-bevel needles have a blunt tip, which is likely to push the nerve aside, they are much less likely to penetrate the nerve; however, when an injury does occur, it appears to be more severe. In contrast, sharp needles are more likely to penetrate the nerve, but the injury appears to be less destructive. Success with the paresthesia technique is highly dependent on the skill of the practitioner and requires a thorough understanding of anatomy. This technique was slowly replaced in the 1980s when peripheral nerve stimulation was introduced. Currently, no single technique has been shown to be superior with respect to incidence of neurologic complications.

PERIPHERAL NERVE STIMULATION

Peripheral nerve stimulators deliver small pulses of electric current to the end of a block needle to cause depolarization...
and muscle contraction when the tip of the needle is in close proximity to a neural structure. This technique allows for localization of a specific peripheral nerve without requiring the elicitation of a paresthesia, thus allowing patients to be more sedated during block placement. It is necessary to attach the cathode (negative terminal) to the stimulating needle and the anode (positive terminal) to the surface of the patient because cathodal stimulation is more efficient than anodal stimulation. Most current-stimulating needles are coated with a thin layer of electrical insulation along the needle shaft with the exception of the tip. This allows for higher current density at the tip of the needle. Higher current output (>1.5 mA) is more likely to stimulate neural structures through tissue or fascial planes and can be associated with painful, vigorous muscle contractions. After localization of the correct motor response, the current is gradually decreased to a current of 0.5 mA or less. A motor response at a current of approximately 0.5 mA is appropriate when used to facilitate the location for injection of local anesthetic or catheter placement. Immediately following injection of local anesthetic or saline (ionic solutions), the current density at the needle tip will rapidly dissipate and the evoked motor response is eliminated (the Raj test)\(^5\).

The stimulating current pulse can be modified to produce a sensory response. The short-duration impulse commonly used (0.1 ms) is effective in stimulating motor fibers, but a longer-duration pulse (0.3 ms) will also stimulate sensory fibers, a useful feature if a pure sensory nerve is being sought.

### Ultrasound Guidance

Ultrasound imaging allows direct visualization of peripheral nerves, the block needle tip, and local anesthetic distribution.\(^6\) This imaging modality has proven highly useful for guiding targeted drug injections and catheter placement. This section describes the general principles of ultrasound imaging for regional blocks.

### FUNDAMENTAL ASSUMPTIONS AND ARTIFACTS

Ultrasound is sound with a frequency above the audible range (>20,000 cycles per second). The frequencies used in clinical imaging are within the range of 1 to 20 MHz. High-frequency ultrasound beams are well collimated and therefore can provide high resolution. For most regional blocks, the highest frequency is selected that adequately penetrates the depth of field. Sound waves reflect at the interface of tissues with different acoustic impedances to generate echoes. Ambient lighting has a large effect on visual discrimination: therefore dim lighting without glare is especially useful for imaging low-contrast targets such as peripheral nerves.

Ultrasound imaging is predicated on several common assumptions.\(^7\) First, the speed of sound through soft tissue is 1540 m/s, meaning 13 µs elapse for each centimeter of soft tissue traversed back and forth for the total fly-back time of received echoes. This assumption allows interconversion of time and distance for echo ranging. Local heterogeneities in soft tissue can cause artifactual bending of the block needle on ultrasound scans, known as the bayonet artifact (Fig. 46.1).\(^8,9\) Bayonet artifacts are commonly observed during the lateral in-plane approach to popliteal block (see Sciatic Nerve Blocks in the Popliteal Fossa) because more adipose tissue is present over the nerves near the posterior midline of the leg (adipose tissue has a slower speed of sound than the adjacent muscle). The speed of sound artifacts relate both to time-of-flight considerations and to refraction that occurs at the interface of tissues with different speeds of sound.

Second, ultrasound waves are assumed to take a straight path to and from tissue. When this does not occur, reverberation artifacts are displayed deep to the reflector. Reverberation artifacts are commonly observed from the block needle shaft at shallow angles of insertion because sound waves bounce back and forth between the walls of the needle before returning to the transducer (Fig. 46.2). Comet tail artifact is another type of reverberation artifact and helps identify strong reflectors such as the pleura during supraclavicular and intercostal blocks. At low receiver gain, the comet tail is seen as a tapering series of discrete echo bands just deep...
to a strongly reflecting structure. The spacing between the bands represents the distance between the anterior and posterior walls of the object. Internal reverberations (arising from within the object) cause the comet tail artifact, most intensely observed when the anatomic object is perpendicular to the beam. Comet tail artifact from the pleura relates to lung water content, because small collections of lung water lined by the strongly reflecting pleura can allow the sound beam to enter and then return at varying times to the transducer.

Third, all reflectors are assumed to be on the central ray of the transducer beam. When this assumption is not true, out-of-plane artifacts are observed (slice thickness artifacts). Definitive proof of out-of-plane artifacts requires multiple views, which are recommended when such ambiguities arise.

Unlike adjacent soft tissue, most biologic fluids do not significantly attenuate the sound beam and therefore cause acoustic enhancement (sometimes referred to as posterior acoustic enhancement or increased through-transmission). Acoustic enhancement artifacts deep to blood vessels can be erroneously interpreted as peripheral nerves (Fig. 46.4). For example, acoustic enhancement deep to the second part of the axillary artery in the axilla can be mistaken for the radial nerve. In the infraclavicular region, acoustic enhancement deep to the axillary artery can be mistaken for the posterior cord of the brachial plexus (and similarly, for the femoral artery and the femoral nerve in the inguinal region).

Acoustic shadowing occurs deep to strong reflecting structures, such as the cortical surface of mature bone (Fig. 46.5). Acoustic shadows from refraction (also termed refractile shadowing or lateral edge shadowing) are often observed deep to the edges of blood vessels when the vessels are imaged in the short-axis view. Refractive edge shadows can be seen from the carotid artery during stellate ganglion block or from the second part of the axillary artery during infraclavicular block. Refraction artifacts (e.g., refractile shadowing) are less apparent when spatial compound imaging (for further information, see later in this chapter) is used to reduce angle-dependent artifacts.

Transducer Selection, Manipulation, and Modes of Imaging

Ultrasound transducers consist of piezoelectric crystals that emit and receive high-frequency sound waves by interconverting electrical and mechanical energy. Transducer selection is important to the success of ultrasound-guided regional anesthesia procedures. High-frequency sound waves provide the best resolution but will not penetrate far into tissue. The frequency range is therefore chosen to be the highest that will allow adequate insonation of the entire depth of field. A low-frequency transducer can be used to image large nerves that lie deep, such as the cords of the...
brachial plexus that surround the second part of the axillary artery or the proximal sciatic nerve in the gluteal region.

The footprint size (i.e., the length of the active face transducer that contacts the skin) is chosen to provide a broad enough view of the structures of interest. As a general rule, the footprint should be at least as large as the anticipated depth of field. A square or landscape view is better than a keyhole view (i.e., depth greater than footprint) for guidance. As a rule of thumb, for in-plane technique (see Approaches to Regional Block With Ultrasound), every millimeter of the footprint is approximately a millimeter of guidance.

Linear-array transducers generally have a higher scanline density than curved arrays and therefore produce the best image quality. Images from linear arrays are usually displayed in a rectangular format. When a linear transducer is needed but space at the site of block is limited by anatomic structures such as adjacent bone, a compact linear (hockey stick) transducer that has a smaller footprint can be very useful. Curved arrays provide a broad field of view for a given footprint size and are generally used when space is limited (e.g., infraclavicular region). Curved probes are easier to rock (see Infraclavicular Blocks) and produce images in sector format.

Universal precautions should be used when handling dirty equipment. External surface probes require disinfection between every use and after extended periods of non-use, per instructions of the manufacturer. Do NOT drop any ultrasound transducer, because the active face of the transducer is especially sensitive to contact with hard surfaces.

One of the essential skills to acquire for regional block with ultrasound is transducer manipulation. For this reason, standardized nomenclature has been established:\[11\]

- Sliding (moving contact) the transducer along the known course of the nerve using a short-axis view often helps.
- Tilting (cross-plane, side-to-side) will vary the echo brightness of peripheral nerves. Optimizing this angle is critical to promote nerve visibility.
- Compression is often used to confirm venous structures. To improve imaging, compression not only provides better contact, but it also brings the structures closer to the surface of the transducer. Soft tissue is subject to compression; therefore estimates of tissue distances will vary.
- Rocking (in-plane, toward, or away from the indicator) is often necessary to improve visibility of the needle and anatomic structures when the working room is limited.
- Rotation of the probe will produce true short-axis views rather than oblique or long-axis views.

Anisotropy is the change in echogenicity with inclination of the transducer. In general, when objects are obliquely imaged, they appear less echogenic (Fig. 46.7). This relationship is most pronounced for tendons but also occurs for muscle and nerves.\[12\] Although the term anisotropy was first used to describe changes in received echoes when rocking the transducer with structures viewed in long axis, it has also been used for short-axis views when tilting the transducer. With experience, operators learn to rock and tilt the transducer naturally to fill in the received echoes from peripheral nerves. Sliding and rotating the transducer achieves needle tip localization after optimizing peripheral nerve echoes by tilting.

Spatial compound imaging steers ultrasound beams in different, predetermined angles, typically within approximately 20 degrees from the perpendicular (Fig. 46.8). These multiple lines of insonation are then combined to produce a single composite image. Spatial compound imaging appears to reduce angle-dependent artifacts, anisotropic effects, and acoustic shadows. Another advantage for regional block is that the definition of tissue planes and the detection of nerve borders can be improved. In the systems that have been tested, spatial compound imaging improves needle tip visibility over a limited range of needle insertion angles (<30 degrees). The stray lines of sight (i.e., those that travel off the field underneath the transducer) can be used to form a wider field of view in a trapezoidal format.
A Doppler shift occurs when a wave source and receiver are moving relative to each other, which produces a change in frequency such that the frequencies of the transmitted and reflected sound waves are not the same. When a wave source and receiver are moving toward each other, the observed frequency is greater than the source frequency; and when moving away from each other, the observed frequency is lower. The change in frequency is related to the velocity of moving reflectors and the angle of insonation. In clinical medicine, red blood cells are the primary reflectors that produce Doppler shifts.

Fig. 46.7 (A) Sciatic nerve imaging in the subgluteal region. (B) The amplitude of the received echoes diminishes when the angle of insonation is changed away from perpendicular to the nerve path, thereby demonstrating anisotropy.

Fig. 46.8 Spatial compound imaging. Some forms of ultrasound imaging use multiple lines of sight by electronically steering the beam to different angles. These sonograms were obtained by placing a linear array test tool (the solid metal stylet of a 17-gauge epidural needle) over the active face of the transducer to isolate a single element. (A) External photograph demonstrates the linear array test tool applied to the active face of the ultrasound transducer. (B) Single-beam imaging is demonstrated. (C) Three lines of sight are used to form a compound image. The test tool images do not display the beam itself, but rather the transmit and receive apertures.
Needle Tip Visibility

A large number of factors influence needle tip visibility in clinical practice. Metal needles are hyperechoic and can cause reverberation artifact. Needle tip visibility is best when the needle path is parallel to the active face of the transducer. Under this condition, the needle is perpendicular to the sound beam; therefore strong specular reflections will be produced; that is, mirror-like reflections will be produced from a smooth surface. As the angle of incidence is increased, the mean brightness will decrease. In this same study, the bevel angles were found from 10 to 70 degrees but were found to have no effect on the needle tip echo. However, bevel orientation does influence the needle tip echo; visibility is best with the bevel either directly facing or averting the transducer. Because needle diameters are smaller than the scan plane thickness, larger needles are more echogenic than finer ones.

Visualization of needles in echogenic tissue is difficult, particularly in bright adipose tissue. A number of strategies have been proposed to improve needle tip visibility. A low-receiver gain can improve the detection of the needle tip echo. Spatial compound imaging can help identify the needle tip when the needle path is at an angle with respect to the transducer. However, one limitation of this strategy is that only a small triangular section of the field of imaging receives all the lines of sight and is therefore fully compounded. In addition, the range of angles for spatial compound imaging is limited and is usually exceeded by the desired needle insertion path. Rocking back the transducer can improve the angle between the ultrasound beam and needle during in-plane technique (see Approaches to Regional Block with Ultrasound). Most practitioners orient the needle so that the needle bevel faces the transducer.

Among needles originally developed for use in regional anesthesia, Hustead bevels tended to be more visible than side port needles that lack cutting bevels. Needles with echogenic modifications are now commercially marketed for peripheral nerve blocks. One engineering strategy has been to texture the needle surface so that echoes return to the transducer source, regardless of the angle of insonation (Fig. 46.10). One potential limitation of these needle designs is the finite size of the needle texturing. Low-frequency transducers produce longer wavelengths that may be too large to reflect strongly back from the textured surface of the needle.

Approaches to Regional Block With Ultrasound

Peripheral nerves can be directly detected with high-resolution ultrasound imaging. The fascicular echotexture is the most distinguishing feature of nerves (honeycomb architecture) (Fig. 46.11). More central nerves, such as the cervical ventral rami, have fewer fascicles and can appear monofascicular on ultrasound scans. Ultrasound frequencies of 10 MHz or higher are required to distinguish tendons from nerves based on echotexture alone. One of the most powerful techniques to identify nerve fascicles is to slide a broad linear transducer over the known course of a peripheral nerve with the nerve viewed in short axis (transverse cross section).

Nerves can be round, oval, or triangular in shape. Although nerve shape can change along the nerve path, the cross-sectional nerve area is relatively constant in the absence of major branching (Fig. 46.12).
nerves are pathologically enlarged either by entrapment or in certain neuromuscular disorders, such as Charcot-Marie-Tooth, type 1A, disease (Fig. 46.13). Some evidence suggests that patients with diabetic neuropathy also have enlarged peripheral nerves.

Although direct nerve imaging has led to a phenomenal increase in ultrasound-guided regional anesthesia, the identification of other nearby anatomic structures, such as the fascia and other connective tissue, is also critical in this endeavor. These layers permit favorable distribution of local anesthetic, making nerve contact with the block needle unnecessary.

Many approaches to regional blocks with ultrasound are available (Table 46.1). Peripheral nerves are usually viewed in short axis rather than long axis. The needle can approach within the plane of imaging (in-plane technique) or cross the plane of imaging as an echogenic dot (out-of-plane technique). For some regional blocks, offline markings (skin markings before needle insertion) are used instead of online imaging (i.e., imaging during needle insertion and injection). Most studies have suggested that adequate visualization and correct identification of the relevant structures (e.g., peripheral nerve, needle tip, local anesthetic, adjacent anatomic structures) is more important than the

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Fig. 46.10 **Photomicrographs of needles are used for regional block.** A plain conventional needle (A) and echogenic designs (B, C, D) are shown. A smooth needle may not generate a recordable echo because its rounded shaft reflects most incident sound away from the source. A variety of textured surfaces are manufactured and marketed to improve needle tip detection on acquired sonograms. (Modified from Gray AT. Atlas of Ultrasound-Guided Regional Anesthesia. 3rd ed. Philadelphia: Saunders; 2018)

Fig. 46.11 **Nerve echotexture.** (A) Fascicles of the common peroneal (short yellow arrow) and tibial (long yellow arrow) nerves are visualized in the popliteal fossa. In this sonogram the honeycomb appearance of a polyfascicular peripheral nerve is observed. (B) Close-up view shows detailed echotexture of the two nerves.
nevertheless, consistent practice patterns are developing among institutions and illustrate the underlying principles.

Successful injection for peripheral nerve block has typical characteristics (Fig. 46.14). Injections should distribute around the nerve (clarifying the nerve border), travel along the nerve path and branches, and separate the nerve from common anatomic structures such as adjacent arteries that are wrapped together in common fascia and connective tissue. Because anechoic fluid is typically injected, echoes received from the peripheral nerve will also be enhanced by increased through transmission (but not necessarily a sign of block success).

### REGIONAL BLOCK TECHNIQUES

#### Cervical Plexus Blocks

The cervical plexus is derived from the C1, C2, C3, and C4 spinal nerves and supplies branches to the prevertebral muscles, strap muscles of the neck, and phrenic nerve. The deep cervical plexus supplies the musculature of the neck.

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**Table 46.1 Examples of Approaches to Regional Blocks With Ultrasound Guidance**

<table>
<thead>
<tr>
<th>Approach</th>
<th>Examples of Regional Block</th>
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</thead>
<tbody>
<tr>
<td>Short-axis view, in-plane</td>
<td>Almost any peripheral nerve block, almost any peripheral catheter placement</td>
</tr>
<tr>
<td>Short-axis view, out-of-plane</td>
<td>Shallow blocks, interscalene catheter, lateral femoral cutaneous nerve block, femoral nerve catheter placement</td>
</tr>
<tr>
<td>Long-axis view, in-plane</td>
<td>Proximal fascia iliaca block, proximal obturator block, anterior sciatic block</td>
</tr>
<tr>
<td>Long-axis view, out-of-plane</td>
<td>Epidural placement (longitudinal parasagittal view during midline approach), transtracheal anesthesia</td>
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**Fig. 46.12 Cross-sectional area of a peripheral nerve as a function of nerve path length.** In this figure the cross-sectional area of the ulnar nerve is shown at various points in the upper extremity. Axilla (A); midhumerus (B); 2 cm proximal to medial epicondyle (C); medial epicondyle (D); 2 cm distal to medial epicondyle (E); arterial split (F); and wrist crease (G). Data are shown as mean values with standard deviations. Despite changes in shape that can occur, the cross-sectional area of nerves is relatively constant along the nerve path in the absence of major branching. *(Modified from Cartwright MS, Shin HW, Passmore LV, Walker FO. Ultrasonographic findings of the normal ulnar nerve in adults. Arch Phys Med Rehabil. 288[3]:394–396, 2007.)*

**Fig. 46.13 Sonogram demonstrates the popliteal fossa of a patient with Charcot-Marie-Tooth, type 1A, disorder.** The peripheral nerves are significantly enlarged because of the large fascicles (yellow arrows). Nerves of the symptomatic and asymptomatic sides can appear similar in these patients. Large tick marks are 10 mm apart.

**Fig. 46.14 Local anesthetic injection for successful peripheral nerve block.** The ulnar nerve and ulnar artery are viewed in short axis in the forearm in this sonogram. The nerve is surrounded with anechoic local anesthetic.
The superficial cervical plexus provides cutaneous sensation of the skin between the trigeminal innervation of the face and the T2 dermatome of the trunk.

Clinical Applications

Blocks of the cervical plexus are easy to perform and provide anesthesia for surgical procedures in the distribution of C2 to C4, including lymph node dissections, plastic surgery repairs, and carotid endarterectomy.20,21 The ability to continuously monitor the awake patient’s neurologic status is an advantage of this anesthetic technique for the latter procedure and has resulted in an upsurge in the popularity of this technique. Bilateral blocks can be used for tracheostomy and thyroidectomy. A variety of approaches to cervical plexus block have been described, including some guided by ultrasound imaging.22,23

Superficial Cervical Plexus

The superficial cervical plexus is blocked at the midpoint of the posterior border of the sternocleidomastoid muscle. A skin wheal is made at this point, and a 22-gauge, 4-cm needle is advanced, injecting 5 mL of solution along the posterior border and medial surface of the sternocleidomastoid muscle (Fig. 46.15). It is possible to block the accessory nerve with this injection, resulting in temporary ipsilateral trapezius muscle paralysis. Deep cervical plexus blocks also are possible but have been associated with a higher incidence of respiratory complications.24

Brachial Plexus Blocks

BRACHIAL PLEXUS ANATOMY

The brachial plexus is derived from the anterior primary rami of the fifth, sixth, seventh, and eighth cervical nerves and the first thoracic nerve, with variable contributions from the fourth cervical and second thoracic nerves. After leaving their intervertebral foramina, these nerves course anterolaterally and inferiorly to lie between the anterior and middle scalene muscles, which arise from the anterior and posterior tubercles of the cervical vertebrae, respectively. The anterior scalene muscle passes caudally and laterally to insert into the scalene tubercle of the first rib; the middle scalene muscle inserts on the first rib posterior to the subclavian artery, which passes between these two scalene muscles along the subclavian groove. The prevertebral fascia invests the anterior and middle scalene muscles, fusing laterally to enclose the brachial plexus in a fascial sheath.

Between the scalene muscles, these nerve roots unite to form three trunks, which emerge from the interscalene space to lie cephaloposterior to the subclavian artery as it courses along the upper surface of the first rib. The superior (C5 and C6), middle (C7), and inferior (C8 and T1) trunks are arranged accordingly and are not in a strict horizontal formation, as often depicted. At the lateral edge of the first rib, each trunk forms anterior and posterior divisions that pass posterior to the midportion of the clavicle to enter the axilla. Within the axilla, these divisions form the lateral, posterior, and medial cords, named for their relationship with the second part of the axillary artery. The superior divisions from the superior and middle trunks form the lateral cord, the inferior divisions from all three trunks form the posterior cord, and the anterior division of the inferior trunk continues as the medial cord.

At the lateral border of the pectoralis minor, the three cords divide into the peripheral nerves of the upper extremity. The lateral cord gives rise to the lateral head of the median nerve and the musculocutaneous nerve; the medial cord gives rise to the medial head of the median nerve, as well as the ulnar, the medial antebrachial, and the medial brachial cutaneous nerves; and the posterior cord divides into the axillary and radial nerves (Fig. 46.16).

Aside from the branches from the cords that form the peripheral nerves as described, several branches arise from the roots of the brachial plexus providing motor innervation to the rhomboid muscles (C5), the subclavian muscles (C5 and C6), and the serratus anterior muscle (C5, C6, and C7). The suprascapular nerve arises from C5 and C6, supplies the muscles of the dorsal aspect of the scapula, and makes a significant contribution to the sensory supply of the shoulder joint.

Sensory distributions of the cervical roots and the peripheral nerves are shown in Fig. 46.17.

Branches arising from the cervical roots were traditionally blocked with the interscalene approach to the brachial plexus. However, interscalene block has a well-documented risk of concomitant phrenic nerve block. This can result in symptomatic hemidiaphragmatic paralysis and respiratory compromise, especially among those patients with obesity or moderate to severe obstructive pulmonary disease.25,26 Recent evidence suggests diaphragm paresis may be avoidable with more distal “lung-sparing” block techniques that target the terminal nerves supplying the shoulder joint.

By design, brachial plexus blocks above the clavicle (e.g., interscalene and supraclavicular blocks) primarily target local anesthetic placement near the ventral rami, trunks, and divisions. Blocks below the clavicle (e.g., infraclavicular and axillary blocks) primarily target the cords and terminal nerves.
Interscalene Blocks

The interscalene block is often chosen for regional anesthesia technique of the shoulder in those patients without significant pulmonary disease. Blockade occurs at the level of the superior and middle trunks of the brachial plexus. Although this approach can be used for forearm and hand surgery, blockade of the inferior trunk (C8 and T1) can be incomplete and may require supplementation of the ulnar nerve for adequate surgical anesthesia in that distribution. Ultrasound guidance for interscalene block reduces the chance of inferior trunk sparing.
Several adjacent anatomic structures can serve as important landmarks for performance of interscalene block. The patient should be in the supine position, with the head turned away from the side to be blocked and the patient’s arm in any comfortable position. The posterior border of the sternocleidomastoid muscle is readily palpated by having the patient briefly lift the head. The interscalene groove can be palpated by rolling the fingers posterolaterally away from this border over the belly of the anterior scalene muscle into the groove (Fig. 46.18). A line is extended laterally from the cricoid cartilage to intersect the interscalene groove, indicating the level of the transverse process of C6. Although the external jugular vein often overlies this point of intersection, it is not a consistent landmark.

Ultrasound-Guided Technique

Traditional approaches to the interscalene block include paresthesia or peripheral nerve stimulation technique. However, this block is well suited to the use of ultrasound guidance. It is often easiest to obtain a supraclavicular view of the subclavian artery and brachial plexus (Fig. 46.19) and then trace the plexus up the neck with the ultrasound probe until the plexus trunks are visualized as hypoechoic structures between the anterior and medial scalene muscles (the “stoplight” sign). The needle can then be advanced with either an in-plane or out-of-plane approach. After negative aspiration, a small test dose is administered, and local anesthetic spread around the brachial plexus confirms appropriate placement of the needle. Volumes as little as 5 mL may be successful and associated with a decreased frequency of diaphragmatic paresis.

Side Effects and Complications

At the traditional (C6) level of interscalene block, ipsilateral phrenic nerve block and resultant diaphragmatic paresis are inevitable. This effect probably results from the proximity of the phrenic nerve at this level and may cause subjective symptoms of dyspnea. Respiratory compromise can occur in patients with severe preexisting respiratory disease or contralateral phrenic nerve dysfunction.

Involvement of the vagus, recurrent laryngeal, and cervical sympathetic nerves is rarely significant if unilateral, but the patient experiencing symptoms related to these side effects may require reassurance. The risk of pneumothorax is small when the needle is correctly placed at the C5 or C6 level because of the distance from the dome of the pleura.

Severe hypotension and bradycardia (i.e., Bezold-Jarisch reflex) can occur in awake, sitting patients undergoing shoulder surgery under an interscalene block. The cause is presumed to be stimulation of intracardiac mechanoreceptors by decreased venous return, producing an abrupt withdrawal of sympathetic tone and enhanced parasympathetic output. This effect results in bradycardia, hypotension, and syncope. The frequency is decreased when prophylactic β-adrenergic blockers are administered.
Epidural and intrathecal injections can occur with this block. The proximity of significant neurovascular structures may increase the risk of serious neurologic complications when interscalene block is performed in heavily sedated or anesthetized patients. Accordingly, interscalene blocks are usually placed under light sedation in adult patients.

**Supraventricular Blocks.** Indications for supraventricular blocks include operations on the elbow, forearm, and hand. Blockade occurs at the distal trunk–proximal division level of the brachial plexus. At this point, the brachial plexus is relatively compact, and a small volume of local anesthetic produces rapid onset of reliable blockade.

**Ultrasound-Guided Technique**

The patient is placed in supine position, with the head turned away from the side to be blocked. The arm to be anesthetized is adducted against the side of the body. Similar to interscalene block, traditional approaches to the supraventricular block include paresthesia or peripheral nerve stimulation. Given the widespread use and availability of ultrasound, this block is now more commonly performed with sonographic guidance. This allows the practitioner to visualize the brachial plexus, subclavian artery, pleura, and first rib. The inherent safety of this technique requires continuous visualization of the needle tip and adjacent anatomic structures during needle advancement.

A high-frequency (15-6 MHz) linear transducer is positioned just proximal to the supraventricular fossa to obtain a supraventricular view (see Fig. 46.19). The brachial plexus trunks and divisions are clustered vertically over the first rib on the lateral side of the subclavian artery. The first rib acts as a medial barrier to the needle reaching the pleural dome and is short, wide, and flat.

The needle can then be advanced under direct ultrasound guidance using an in-plane approach from lateral to medial.\(^\text{34,35}\) The transducer rests near the clavicle so manipulation can be challenging. Thus advanced skills with needle control are required. After negative aspiration, a small test dose is administered, and local anesthetic spread around the brachial plexus confirms appropriate placement of the needle tip. Volumes as low as 15 to 30 mL may be successful.

**Side Effects and Complications**

The prevalence of pneumothorax after supraventricular block is 0.5% to 6% and diminishes with increased experience. Importantly, although the use of ultrasound may decrease the incidence of pneumothorax, the risk has not been eliminated.\(^\text{36}\) When this occurs, the onset of symptoms is usually delayed, and it can take up to 24 hours to develop. Thus routine chest radiography after the block is not justified. The supraventricular approach is best avoided when the patient is uncooperative or cannot tolerate any degree of respiratory compromise. Other complications include phrenic nerve block (as high as 40%-60%), Horner’s syndrome, and neuropathy. The presence of phrenic or cervical sympathetic nerve block usually requires only reassurance. Although nerve damage can occur, it is uncommon and usually self-limited.

**Suprascapular Nerve Blocks.** Suprascapular nerve (SSN) block above the clavicle (anterior approach) is a viable alternative to interscalene block for analgesia of the shoulder region.\(^\text{37,38}\) The advantage of this more peripheral approach is that the chance of concomitant phrenic nerve block is significantly reduced. In addition, if the block is semi-selective then other nerves that contribute articular branches to the shoulder joint (e.g., axillary nerve, lateral pectoral nerve) also can be blocked. The anterior approach to SSN block is more shallow (5-10 mm depth) than the more traditional block of the SSN block at the suprascapular notch (20-40 mm depth). Furthermore, the suprascapular notch has variable morphology and in some subjects this landmark is absent. The SSN is the primary sensory innervation of the shoulder joint\(^\text{39}\) and is not blocked with approaches to the brachial plexus below the clavicle. Selective low-volume approaches to SSN block above the clavicle also may be useful for pain medicine and rehabilitation.\(^\text{40}\)

**Indications**

The SSN, a mixed-motor and sensory nerve originating from the superior trunk (C5 and C6 nerve roots and often C4 as well) makes a significant contribution to the sensory supply of the shoulder joint. The SSN root may be accessed from within the posterior cervical triangle of the neck where it passes underneath the omohyoid muscle toward the suprascapular notch. The SSN, unlike the suprascapular vessels that remain superficial, then passes deep to the superior transverse scapular ligament exiting through the scapular foramen into the supraspinous fossa finally providing nerve branches to muscles of the shoulder girdle.

**Ultrasound-Guided Technique**

The anterior SSN block is performed in the supine position with head turned to the contralateral side when accessing the nerve within the posterior cervical triangle (similar positioning as the interscalene nerve block). Alternatively, the patient would be in a seated position to access the scapula for a more distal and posterior SSN block. In the seated position, ask the patient to place his/her hand over to the contralateral shoulder (full shoulder adduction) to move the target (nerve) and scapula lateral from the thorax. Ultrasound guidance is the preferred technique, although a landmark-based method with nerve stimulation for neuro-localization is an option.

**Proximal Suprascapular Nerve Block (Anterior Suprascapular Nerve Block).** The anterior SSN block technique has emerged as the preferred lung-sparing block alternative to interscalene nerve block.\(^\text{37,41}\) A high-frequency linear transducer (15-6 MHz) probe is positioned just proximal to the supraventricular fossa. Under dynamic scanning, the SSN can be visualized as a round hypoechoic structure deep to the inferior belly of the omohyoid muscle and lateral to the superior trunk in the posterior cervical triangle of the neck (Fig. 46.20) Consider tracing the SSN from its origin (nerve root C5) to facilitate identification. The nerve is then traced more posterior-lateral to a distance away from the superior trunk. A 22-gauge, 5-cm needle is most often selected with shallow 2- to 3-cm depths to the target. Through an out-of-plane or in-plane approach approximately 5 to 15
mL of local anesthetic is deposited deep into omohyoid muscle, but shallow to the prevertebral fascia (higher volumes could result in phrenic nerve blockade). Color Doppler use is advised as the superficial cervical artery and the suprascapular artery, also hypoechoic structures, are strong mimickers of the SSN within the posterior cervical triangle. Auyong and colleagues have shown the anterior SSN block technique provides noninferior, yet lung-sparing, analgesia compared to interscalene nerve block without need for additional terminal nerve block supplementation (e.g., axillary or SSN block).\textsuperscript{41}

**Shoulder Block (Suprascapular Nerve Plus Axillary [Circumflex] Nerve Block)\textsuperscript{42}**

In contrast to the anterior suprascapular block, a more distal block of the SSN at the scapula requires the axillary (circumflex) nerve to be also blocked to be remotely comparable to more proximal brachial plexus blockade.\textsuperscript{43,44} Unfortunately, the posterior SSN block even with the axillary (circumflex) nerve block will not provide complete anesthesia to the shoulder joint; therefore routinely general anesthesia with supplemental opioid medications would be expected for adequate analgesia.

**Side Effects and Complications**

Serious side effects and complications are primarily due to insertion complications and side effects from local anesthetics use.

Avoid directly targeting the SSN in the suprascapular notch because accidental anterior needle advancement can puncture the pleura. Also, avoid intramuscular placement whether it be avoiding deposit of local anesthesia within the omohyoid (anterior) or within the supraspinatus muscle (posterior), which may result in myotoxicity/myonecrosis. Additionally, the axillary (circumflex) nerve and posterior circumflex artery lie only 2 to 3 mm below the inferior capsule within the neurovascular quadrangular space. Thus a more proximal injection on the posterior upper arm carries a risk of entering the glenohumeral joint space with the block needle and higher local anesthesia volumes have been associated with spread to the posterior cord resulting in radial nerve blockade.

**INFRACLAVICULAR BLOCKS**

The advantages of the infraclavicular block are that it usually results in complete brachial plexus anesthesia, it is a stable place for a catheter, and no manipulation of the arm is necessary.\textsuperscript{45-47} The disadvantages are that the infraclavicular block is a deeper block; therefore needle or probe manipulations are necessary, along with steep angles of needle insertion that result in needle tip visibility issues. Although the arm can remain at the side of the patient, the block is easier when the arm is abducted to straighten the neurovascular bundle. The three arterial wall-hugging cords are named with respect to the second part of the axillary artery; therefore the expected positions are medial, lateral, and posterior. The artery is visualized in short-axis view deep to the pectoralis major and minor muscles (Fig. 46.21). Most practitioners use an in-plane approach from the head of the...
AXILLARY BLOCKS

The axillary block is a versatile block for upper extremity anesthesia. Although relatively safe and effective with classical approaches, the cardinal weakness has been the failure to block the musculocutaneous nerve. With the advent of ultrasound imaging, this limitation can be overcome by directly visualizing the musculocutaneous nerve.

The axillary block provides surgical anesthesia of the elbow and more distal upper extremity. The shallow depth of the neurovascular bundle (a 20-mm field is typical) and the large amount of working room make this block relatively easy with ultrasound guidance (Table 46.3). Usually, three arterial wall-hugging branches (median, ulnar, and radial) and one branch with a characteristic medial-to-lateral course in the axilla (musculocutaneous) are visualized. In addition, the musculocutaneous nerve has a characteristic change in shape as it moves from adjacent to the artery (round) to within the coracobrachialis muscle (flat) and then exiting the muscle (triangular).

Both in-plane (with needle approaching from the lateral side of the arm) and out-of-plane (with needle approaching from distal to proximal) techniques can be used (Figs. 46.22 and 46.23). The block is performed in the proximal axilla, with the transducer gently pressed against the chest wall to visualize the conjoint tendon of the latissimus dorsi and teres major. A high-frequency linear probe with a small footprint (25–50 mm) with sterile cover can be used for axillary block. The ideal location for local anesthetic injection is between the nerves and the artery so that separation between the two structures occurs to ensure distribution within the neurovascular bundle. These injections result in excellent clinical sensory and motor blocks. The musculocutaneous nerve is usually blocked within the coracobrachialis, where its flat shape gives a large amount of surface area for rapid block. Duplication of the axillary artery and musculocutaneous-median nerve fusion (low-lying lateral cord) are common anatomic variations in the axilla.

Trunk Blocks

INTERCOSTAL NERVE BLOCKS

The intercostal nerves are the primary rami of T1 through T11. T12 is technically the subcostal nerve, and it can communicate with the iliohypogastric and ilioinguinal nerves. Fibers from T1 contribute to the brachial plexus; T2 and T3 provide a few fibers to the formation of the intercostobrachial nerve, which supplies the skin of the medial aspect of the upper arm. Each intercostal nerve has four branches: the gray ramus communicans, which passes anteriorly to the sympathetic ganglion; the posterior cutaneous branch, supplying skin and muscle in the paravertebral area; the lateral cutaneous branch, arising just anterior to the midaxillary line and sending subcutaneous branches anteriorly and posteriorly; and the anterior cutaneous branch, which is the termination of the nerve.

Medial to the posterior angles of the ribs, the intercostal nerves lie between the pleura and the internal intercostal fascia. At the posterior angle of the rib, the nerve lies in the costal groove accompanied by the intercostal vein and artery.

Clinical Applications

Few surgical procedures can be performed with an intercostal block alone, and the application of these blocks in combination with other techniques has largely been supplanted by epidural blockade. However, in patients with contraindications to neuraxial blockade, these techniques can be used alone or combined with other blocks and light

| Table 46.2 Examples of Sonographic Landmarks for Infraclavicular Block |
|------------------------|-----------------|-----------------|
| Proximal | Optimal Location | Distal |
| Cephalic vein | Pectoralis minor muscle (midportion) | Subscapular artery |
| Thoracoacromial artery | Brachial plexus cords surround axillary artery | Coracobrachialis muscle |
| Chest wall and pleura | Posterior (or medial) cord underneath axillary artery | Anterior circumflex artery |

Intraclavicular block is usually performed at the level of the second part of the axillary artery (deep to the pectoralis minor muscle). Proximal and distal landmarks along the course of the axillary artery are listed.

<table>
<thead>
<tr>
<th>Box 46.2 Sonographic Signs Indicating Infraclavicular Block Success</th>
</tr>
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<tbody>
<tr>
<td>• Reduction in axillary artery diameter during injection</td>
</tr>
<tr>
<td>• &quot;U-shaped&quot; distribution underneath the axillary artery</td>
</tr>
<tr>
<td>• Separation of cords from axillary artery</td>
</tr>
<tr>
<td>• White wall appearance to the axillary artery (free walls)</td>
</tr>
<tr>
<td>• Dark layer underneath the axillary artery (long-axis view)</td>
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Several studies of clinical block characteristics have validated the high predictive value of local anesthetic distribution underneath the axillary artery for three-cord anesthesia ("U-shaped" distribution).

| Table 46.3 Comparison of the Infraclavicular and Axillary Approaches to Brachial Plexus Block |
|--------------------|---------------------|-----|-----|
|                     | Infraclavicular Block | Axillary Block |
| Depth | Deep (two overlying muscles) | Shallow |
| Onset  | Slower | Faster |
| Tourniquet tolerance | Good | Fair |
| Catheter success | High | Low |
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general anesthesia to provide excellent surgical conditions for intraabdominal procedures. Although surgical applications are possible, the majority of indications are for postoperative analgesia. Intercostal blocks provide a viable alternative to epidural and paravertebral blocks, with a similar safety and efficacy profile.

Intercostal Block Technique

The intercostal nerve can be blocked at the angle of the rib just lateral to the sacrospinalis muscle group. The patient is placed in the prone position with a pillow placed under the abdomen to reduce the lumbar curve (Fig. 46.24). A line is drawn along the posterior vertebral spines. Nearly parallel lines are drawn along the posterior angles of the rib, which can be palpated 6 to 8 cm from the midline. These lines angle medially at the upper levels to prevent overlying of the scapula. The inferior edge of each targeted rib is palpated and is marked on the line intersecting the posterior angle of the rib. After appropriate skin preparation, skin wheals are injected at each of these points. A 22-gauge, short-bevel, 4-cm needle is attached to a 10-mL syringe. Beginning at the lowest marked rib, the index finger of the left hand displaces the skin up over the patient’s rib. The needle is inserted at the tip of the finger until it rests on the rib. The fingers of the left hand are shifted to grasp the needle hub firmly. The left hand then walks the needle 3 to 5 mm off the lower rib edge, where 3 to 5 mL of local anesthetic are injected (see Fig. 46.24B and C). This process is repeated at each marked rib. Appropriate intravenous sedation providing analgesia and some degree of amnesia is desirable for the patient’s comfort.

Alternatively, intercostal block can be performed in the supine patient at the midaxillary line. Theoretically, the lateral cutaneous branch of the nerve can be missed, but computed tomography studies show that injected solutions spread several centimeters along the costal groove. Further injection of 1 to 2 mL of local anesthetic as the needle is withdrawn blocks the subcutaneous branches.
Alternative Techniques

Intercostal blocks are possible with ultrasound imaging for guidance. However, the intercostal nerves and vessels are small (about 1-2 mm in diameter) and run in the costal groove and can therefore be difficult to directly image. Similarly, the innermost intercostal muscle, which separates the intercostal nerves and vessels from the internal and external intercostal muscles, is incomplete in the posterior thorax and can be difficult to image. When detected, the innermost intercostal muscle is thin and hypoechoic on ultrasound scans. Intercostal arteries are most visible medially before they enter the costal groove. Intercostal arteries are more tortuous in elderly patients, and therefore more exposed and vulnerable to injury. Intercostal injections dent the pleura, similar to the displacement seen with paravertebral injections. Injections of local anesthetic at the angle of the rib can track medially along the intercostal vessels within the costal groove toward the paravertebral space. While variations on ultrasound-guided intercostal nerve blocks have been developed, including anterior approaches to intercostal branches in the serratus plane and parasternal region, new technologies are now being developed to improve ultrasound imaging of intercostal nerves and vessels.

Side Effects and Complications

The major complication with intercostal blockade is pneumothorax. The actual incidence, however, was as low as 0.07% in a large series performed by anesthesiologists at all levels of training. Routine postoperative chest radiographs showed an incidence of nonsymptomatic pneumothorax of 0.4% to 1.0%. If this unusual complication occurs, treatment is usually limited to observation, administration of oxygen, or needle aspiration. Rarely, chest tube drainage is required.

The risk of systemic local anesthetic toxicity is present with multiple intercostal blocks because of the large volumes and rapid systemic absorption of the solutions. Use of epinephrine has been shown to decrease blood levels. Patients should be monitored and observed carefully during the block and for at least 20 to 30 minutes afterward. Patients with severe pulmonary disease who rely on their intercostal muscles can exhibit respiratory decompensation after bilateral intercostal blockade.

TRANSVERSUS ABDOMINIS PLANE BLOCKS

Four peripheral nerves, the subcostal, ilioinguinal, iliohypogastric, and genitofemoral, primarily innervate the lower abdominal wall. The extended course of the first three nerves through the abdominal wall within the layer between the transversus abdominis and the internal oblique muscles makes this the desired anatomic location for regional block. For ultrasound-guided transversus abdominis plane (TAP) block, the patient is usually in the supine position (Fig. 46.25). The transducer is placed between the iliac crest and costal margin in the midaxillary line. In this location, the muscle layers of the lateral abdominal wall (external oblique, internal oblique, and transversus abdominis) are well defined. Injection is in-plane from the anterior side and directed toward the posterolateral corner of the transversus abdominis muscle. The respiratory motion of the peritoneal cavity and influence of muscle contraction makes general anesthesia an appealing option for performing this block. The transversus abdominis muscle is relatively thin; therefore careful placement of the needle tip is necessary.
ILIOINGUINAL AND ILIOHYPOGASTRIC NERVE BLOCKS

The ilioinguinal and iliohypogastric nerves arise from the first lumbar spinal root. They pierce the transversus abdominis muscle cephalad and medial to the anterior superior iliac spine to lie between the transversus abdominis and internal oblique muscles. After traveling a short distance caudally and medially, their ventral rami pierce the internal oblique muscle before giving off branches, which then pierce the external oblique and provide sensory fibers to the skin. The ilioinguinal nerve courses anteriorly and inferiorly to the inguinal ring, where it exits to supply the skin on the proximal, medial portion of the thigh. The iliohypogastric nerve supplies the skin of the inguinal region.

Indications

Ilioinguinal and iliohypogastric nerve blocks are used for analgesia following inguinal hernia repair and for lower abdominal procedures utilizing a Pfannenstiel incision. These blocks have been shown to reduce pain associated with herniorrhaphy significantly, although they do not provide visceral analgesia, and they cannot be used as the sole anesthetic during surgery. Despite the relatively simple technique, a failure rate as frequent as 10% to 25% has been reported.

Landmark-Based Technique. These blocks can be performed using a loss-of-resistance technique. The local anesthetic should be injected between the transversus abdominis and the internal oblique and between the internal and external oblique muscles.

The anterior superior iliac spine is located and a mark is made 2 cm cephalad and 2 cm medial. A blunt needle is inserted perpendicular to the skin through a small puncture site. Increased resistance is noted as the needle passes into the external oblique muscle. A loss of resistance is then observed as the needle passes through the external oblique muscle to lie between it and the internal oblique muscle. After negative aspiration, 2 mL of local anesthetic is injected. The needle is then inserted further until another loss of resistance is noted as the needle passes out of the internal oblique to lie between it and the transversus abdominis muscle. Typically, a total volume of approximately 12 mL of local anesthetic is used.

It is often difficult to appreciate the loss of resistance. Given the potential complications of advancing the needle too far, ultrasound guidance is often used for these

Fig. 46.25 Transversus abdominis plane (TAP) block with ultrasound guidance. (A) Abdominal wall image demonstrates the approach for TAP block. (B) In this sonogram the external oblique (EO), internal oblique (IO), and transversus abdominis (TA) muscles are identified (the three-layer-cake appearance). Nerves (yellow arrow) are seen entering the plane between the IO and TA muscles. (C) The needle approaches in-plane and is directed toward the posterolateral edge of the TA muscles. (D) The kayak sign demonstrates successful TAP injection. The fascia between the IO and TA muscles is split apart in the shape resembling a kayak.
blocks. The ilioinguinal and iliohypogastric nerves cannot be selectively blocked, even if injection volumes of less than 1 mL are used.

**Side Effects and Complications**

Blind injection can result in inadvertent injury to the intestine or blood vessels with perforation of the large and small bowel and pelvic hematoma. Lower extremity weakness owing to local anesthetic spread and subsequent femoral nerve blockade can also occur.

**Lower Extremity Blocks**

**LOWER EXTREMITY ANATOMY**

The nerve supply to the lower extremity is derived from the lumbar and sacral plexuses. The lumbar plexus is formed by the anterior rami of the first four lumbar nerves, frequently including a branch from T12 and occasionally from L5 (Fig. 46.26). The plexus lies between the psoas major and quadratus lumborum muscles in the psoas compartment. The lower components of the plexus, L2, L3, and L4, primarily innervate the anterior and medial thigh. The anterior divisions of L2, L3, and L4 form the obturator nerve; the posterior divisions of the same components form the femoral nerve; and the lateral femoral cutaneous nerve is formed from posterior divisions of L2 and L3.

The sacral plexus gives off two nerves that are important for lower extremity surgery: the posterior cutaneous nerve of the thigh and the sciatic nerve. The posterior cutaneous nerve of the thigh and the sciatic nerve are derived from the first, second, and third sacral nerves plus branches from the anterior rami of L4 and L5, respectively. These nerves pass through the pelvis together and are blocked by the same technique. The sciatic nerve is a combination of two major nerve trunks, the tibial (i.e., ventral branches of the anterior rami of L4, L5, S1, S2, and S3) and the common peroneal (i.e., dorsal branches of the anterior rami of L4, L5, S1, S2, and S3), which form the sciatic nerve. The trunks separate at or above the popliteal fossa, with the tibial nerve passing medially and the common peroneal laterally. The cutaneous distributions of the lumbosacral and peripheral nerves are shown in Fig. 46.27.

**FEMORAL NERVE BLOCKS**

The advantages of using ultrasound to guide femoral nerve block include a more complete block, local anesthetic volume sparing, and fewer side effects such as vascular punctures. The femoral nerve usually lies lateral to the femoral artery in the groove formed by the iliacus and psoas muscles. The nerve can be oval or triangular in cross-sectional shape with an anteroposterior diameter of approximately 3 mm and a mediolateral diameter of 10 mm. The best depiction of the femoral nerve is from 10 cm proximal to 5 cm distal to the inguinal ligament. According to the pelvic...
inclination, some tilting of the ultrasound probe is necessary for the sound beam to meet the nerve perpendicularly for optimal scanning. In addition, the femoral nerve has a slight medial-to-lateral course; therefore some rotation of the probe is also necessary for the best view of the nerve. Because the femoral nerve is covered by echobright adipose tissue and fascia, the echogenic outer sheath of the nerve is difficult to establish. In some patients, the psoas tendon can appear similar to the femoral nerve. However, the psoas tendon lies deep within the muscle. If the profunda femoris artery (i.e., the deep branch of the femoral artery) is visualized, then the transducer is usually too distal for complete femoral nerve block. The femoral nerve is often identified as a slight indentation in the surface of the iliacus and psoas muscles.

For femoral nerve block, a broad (35-50 mm footprint) linear transducer is used (Fig. 46.28). Both in-plane (from lateral to medial) and out-of-plane (from distal to proximal) approaches can be used. The advantage of the in-plane approach is visualization of the approaching needle. The disadvantages are the longer needle path and a tendency of the needle to skim over the fascia iliaca by deforming it rather than puncturing it. The out-of-plane approach is often used for catheter placement.

For either approach, the needle tip is positioned between the fascia iliaca and the iliopsoas muscle near the lateral corner of the femoral nerve to avoid the femoral vessels, similar to the method for fascia iliaca block.

The fascia iliaca has a characteristic mediolateral slant. The desired distribution is local anesthetic layering under or completely around the femoral nerve. When layering of local anesthetic is restricted over the nerve, the concern is that the fascia iliaca is intact and that block failure will result. In the obese patient, femoral nerve imaging is challenging and ultrasound can therefore be combined with nerve stimulation for successful block in these patients. After successful injection of a local anesthetic, distal branches of the femoral nerve can be appreciated by sliding the transducer along the known course of the nerve.

**Fascia Iliaca (Modified Femoral Nerve) Blocks**

**Technique.** The fascia iliaca block was originally described in children and involved detection of a double pop sensation as the needle traverses the fascia lata and fascia iliaca of the thigh (see also Chapter 77). Penetration of both layers of fascia is important for block success. To facilitate the appreciation of the “clicks” or “pops,” the use of a short-bevel or bullet-tipped needle has been advocated to provide more tactile feedback than with cutting needles.

Because the fascia iliaca invests the iliopsoas muscle and femoral nerve, high volumes of dilute long-acting local anesthetic can be injected to block nerves of the lumbar plexus via this anterior approach. The clinical applications for fascia iliaca block are similar as those for femoral nerve block.
The needle entry site for the fascia iliaca block is determined by drawing a line between the pubic tubercle and the anterior superior iliac spine and dividing this line into thirds. The needle entry point is 1 cm caudal to the intersection of the medial two thirds and lateral one third along this line. This site is well away from the femoral artery, which is useful for patients in whom femoral artery puncture is contraindicated. Ultrasound can also be used to visualize the two fascial layers and monitor the spread of local anesthetic beneath the fascia iliaca.

**Side Effects and Complications.** Intravascular injection and hematoma are possible because of the proximity of the femoral artery. Anatomically, the femoral nerve and artery are located in separate sheaths approximately 1 cm apart. In most patients with normal anatomy, the femoral artery can be easily palpated, allowing correct, safe needle positioning lateral to the pulsation. The presence of femoral vascular grafts is a relative contraindication to these techniques, but these grafts are easily identified with ultrasound imaging in most cases. Because the injection is made between the femoral and lateral femoral cutaneous nerves, nerve damage is rare.

**SAPHENOUS NERVE BLOCKS ABOVE THE KNEE (INCLUDING ADDUCTOR CANAL BLOCK)**

**Indications**
Several approaches to the saphenous nerve block have been described using an above-the-knee approach. When used in combination with multimodal analgesia, a saphenous nerve block at or near the mid-thigh can be as effective or in some studies preferable to a femoral nerve block following knee surgery because of reduced rates of quadriceps weakness.

The correct “adductor canal block” location is a source of active debate even though the putative anatomic targets may be separated by mere inches. The “true” adductor canal block may best be determined with ultrasound by identifying the medial border of the sartorius muscle converging with the medial border of the adductor longus muscle. A double contour is appreciated on the roof of the canal, which denotes the vastoadductor membrane. This anatomic distinction holds importance as the nerve to the vastus medialis often lies outside the adductor canal in a distinct fascial sheath. Hence a too distal adductor canal block within the “true” adductor canal may miss the nerve to the vastus medialis, a major contributor to knee joint pain following total knee arthroplasty. Jaeger and colleagues advocate for a periarterial injection of local anesthesia lateral to the femoral artery under the sartorius muscle deep to the vastoadductor membrane midway between the anterior superior iliac spine and the patella where local anesthetic is likely to bathe both the saphenous nerve and the nerve to the vastus medialis.

**Anatomy**
As the saphenous nerve is a terminal sensory branch of the femoral nerve above the knee, it supplies innervation to the infrapatellar branches to the knee joint. It pierces the fascia lata between the tendons of the sartorius and gracilis muscles before it runs in the adductor canal along the posterior border of the sartorius muscle. The nerve emerges and divides at the level of the knee before continuing distally along the medial border of the lower leg.

**Technique**
Adductor canal block is performed in the supine position with thigh positioned in slight external rotation with leg extended to expose the inner thigh. Ultrasound guidance is the preferred neurolocalization technique, although nerve stimulation would also be an option or both used in combination.

**Ultrasound-Guided Technique.** A high-frequency linear transducer (15-6 MHz) probe is positioned transverse on the anteromedial thigh, which is scanned in short-axis beginning at the junction between the middle and distal thirds of the thigh. The thick vastoadductor membrane...
defines the border between vastus medialis muscle (lateral), sartorius muscle (anterior), and femoral artery (most medial). Periarterial deposit of local anesthesia is desired lateral to the femoral artery midway between the anterior superior iliac spine and the patella.

Side Effects and Complications

The risks of complications with this block are low, although the same theoretical risks with all regional anesthetic techniques apply to this block. Vascular injury leading to arterial pseudoaneurysm is possible. Intramuscular spread of local anesthetic should be avoided as cases of myonecrosis have been reported and unexpected thigh weakness should prompt evaluation. Although adductor canal block is considered among the more selective “muscle-sparing” peripheral blocks of the lower extremity, caution is still advised and fall prevention strategies are important, including patient education on avoidance of unsupported ambulation.

SAPHENOUS NERVE BLOCKS BELOW THE KNEE

Indications

The saphenous nerve provides innervation to the medial aspect of the lower extremity from the knee to the medial malleolus. Saphenous nerve blocks are commonly combined with popliteal and ankle blockade. Several approaches to the saphenous nerve block have been described, including a paravenous (below the knee) approach. Ultrasound guidance can be used for this technique. The saphenous nerve can be blocked at the level of the ankle and can be combined with other injections for ankle block.

Anatomy

The saphenous nerve emerges from the adductor canal hiatus and divides at the level of the knee before continuing distally along the medial border of the tibia, posterior to the great saphenous vein. The saphenous nerve is located approximately 1 cm medial and 1 cm posterior to the great saphenous vein at the level of the tibial tuberosity.

Technique

The saphenous nerve at this point is purely sensory; therefore a field block technique is possible and likely equally effective to nerve stimulation. Ultrasound guidance has gained significant popularity as a tool to identify the neural and vascular structures that lie in close proximity to the saphenous nerve.

Paravenous Approach. At the level of the tibial tuberosity, approximately 5 to 10 mL of local anesthetic is infiltrated deep to the great saphenous vein.

Localized Field Block. Approximately 5 to 10 mL of local anesthetic may be infiltrated from the medial condyle of the tibia anteriorly to the tibial tuberosity and posteriorly to the medial head of the gastrocnemius muscle. Success rates for this technique range from 33% to 65%.

Side Effects and Complications

The risks of complications with this block are low, although the same risk pattern for all regional anesthetic techniques apply to this block; that is, nerve or tissue damage and vascular puncture with hematoma formation. Given that the great saphenous vein is used as a landmark for the field block technique, minor hematoma formation is not uncommon.

SCIATIC NERVE BLOCKS IN THE POPLITEAL FOSSA

The sciatic nerve can be blocked anywhere along its course from the gluteal region to the popliteal fossa. Many approaches have been described, including those from the anterior aspect of the thigh. One of the most common approaches is to block the sciatic nerve in the popliteal fossa using a lateral approach in supine position with the leg elevated. In this anatomic location, the block can be performed close to the skin surface. The division of the sciatic nerve provides a broad target with large surface area to promote clinical block characteristics. For this technique, the needle tip is positioned between the tibial and common peroneal components of the sciatic nerve near the division so that a single injection distributes to both nerves. By sliding the transducer along the known course of the sciatic nerve, its characteristic division in the popliteal fossa can be identified. This method of sliding assessment is also important to verify the local anesthetic distribution after injection. The tibial nerve has a straighter course than the common peroneal nerve and has approximately twice the cross-sectional area. The tibial nerve lies posterior to the popliteal artery and vein at the popliteal crease, and this location can be a useful starting point when imaging is difficult. When the foot is moved, the nerves of the popliteal fossa have characteristic motions that can be helpful for nerve identification in some patients. The advantages of this
Peripheral Nerve Blocks and Ultrasound Guidance for Regional Anesthesia

approach are the convenient position, the transducer position is remote from the site of needle entry, and the parallel in-plane approach of the block needle results in optimal needle tip visibility. After injection, following the local anesthetic distribution around and along the nerve path (Fig. 46.31) is relatively easy.

ALTERNATIVE APPROACHES TO SCIATIC NERVE BLOCK

The sciatic nerve can be blocked anywhere along its course. However, approaches proximal to the popliteal fossa are usually more difficult because the nerve lies deeper from the skin surface. The sciatic nerve is a mobile structure with position and orientation varying with extremity motion.83,84 Because of the depth and variation in position, ultrasound guidance is useful for proximal sciatic nerve blocks in both adults and children.85

For procedures above the knee, the parasacral sciatic nerve block can provide an advantage over more distal approaches because the block of both the sciatic and posterior femoral cutaneous nerves is possible.86-89 Alternatively, the posterior femoral cutaneous nerve can be blocked separately using ultrasound guidance.90 The subgluteal approach to sciatic nerve block is useful when block of the hamstring muscles is indicated.91 The anterior approach to sciatic nerve block is useful when the patient cannot be positioned for other approaches due to pain or leg traction.92-94 These proximal approaches to sciatic nerve block may require multiple injections for rapid onset.91 The
NERVE BLOCKS AT THE ANKLE

Ankle blocks are relatively simple to perform and offer adequate anesthesia for surgical procedures of the foot. These blocks are traditionally performed at the level of the malleoli and guided by surface landmarks.

Four of the five individual nerves that can be blocked at the ankle to provide anesthesia of the foot are terminal branches of the sciatic nerve: the tibial, sural, superficial peroneal, and deep peroneal nerves (Fig. 46.32). The sciatic nerve divides at or above the apex of the popliteal fossa to form the common peroneal and tibial nerves. The superficial peroneal nerve forms in the leg from both the anterior and posterior divisions of the peroneal nerves. The sural nerve forms in the leg from both divisions of the fibula, where it divides into the superficial and deep peroneal branches (Fig. 46.32A and B). A paresthesia is often elicited; however, it is not necessary for a successful block. If a paresthesia is obtained, 3 to 5 mL of local anesthetic should be injected. Otherwise, 7 to 10 mL of local anesthetic should be injected as the needle is slowly withdrawn from the posterior aspect of the ankle. Blockade of the tibial nerve provides anesthesia of the heel, plantar portion of the toes, and the sole of the foot, as well as some motor branches in the same area. Ultrasound imaging of the tibial nerve can shorten onset time (Fig. 46.34).

Sural Nerve Technique. The sural nerve is located superficially between the lateral malleolus and the Achilles tendon. A 25-gauge, 3-cm needle is inserted lateral to the tendon and is directed toward the malleolus as 5 to 10 mL of solution is injected subcutaneously (see Figs. 46.33 and 46.35). This block provides anesthesia of the lateral foot and the lateral aspects of the proximal sole of the foot.

Deep Peroneal, Superficial Peroneal, and Saphenous Nerve Techniques. The deep peroneal, superficial peroneal, and saphenous nerves can be blocked through a single needle entry site (see Fig. 46.35). A line is drawn across the dorsum of the foot connecting the malleoli. The extensor hallucis longus tendon is identified by having the patient dorsiflex the big toe. The anterior tibial artery lies between this structure and the tendon of the extensor digitorum longus muscle and is palpable at this level. A skin wheal is raised just lateral to the arterial pulsation between the two tendons on the intermalleolar line. A 25-gauge, 3-cm needle is advanced perpendicularly to the skin entry site, and 3 to 5 mL of local anesthetic is injected deep to the extensor retinaculum to block the deep peroneal nerve. This technique anesthetizes the skin between the first and second toes and the short extensors of the toes.

The needle is directed laterally through the same skin wheal while injecting 3 to 5 mL of local anesthetic subcutaneously, blocking the superficial peroneal nerve and resulting in anesthesia of the dorsum of the foot, excluding the first interdigital cleft. The same maneuver can be performed in the medial direction, thereby anesthetizing the saphenous nerve, a terminal branch of the femoral nerve that supplies a strip along the medial aspect of the foot.

Side Effects and Complications

Multiple injections are required for this procedure, which can result in discomfort for the patient. Persistent paresthesias can occur, but they are generally self-limited. The presence of edema or induration in the area of the ankle block can make palpation of landmarks difficult. When this pathology is present, a more proximal block is usually performed (e.g., popliteal and saphenous nerves blocks in the distal thigh). Intravascular injection is possible but unlikely if aspiration for blood is negative.
**INTRAVENOUS REGIONAL ANESTHESIA (OR BIER BLOCK)**

**Introduction and Clinical Applications**

Intravenous regional blocks were first described in 1908 by the German surgeon, August Bier. The Bier block has multiple advantages, including ease of administration, rapid onset and recovery, muscular relaxation, and controllable duration of anesthesia. It is an excellent technique for short (<60 minutes) surgical procedures. Bier blocks are also used in the management of complex regional pain syndromes (for further details on intravenous regional analgesia in pain syndromes, see Chapter 51). Most commonly IVRA is used for upper extremity procedures such as excision of soft tissue masses or carpal tunnel release. Lower extremity blocks are also possible.
Technique (Upper Extremity)

With this technique blood is replaced with local anesthetic using a tourniquet to isolate the extremity from the central circulation. The duration of surgical anesthesia and analgesia for Bier block is essentially the time of tourniquet inflation. Contraindications to Bier block are the same as contraindications to tourniquet placement (limb ischemia, infection).

Prerequisites

Place a thin intravenous catheter (20 or 22 gauge) in the operative extremity (to reduce the amount of bleeding when the catheter is removed). Use only a minimal amount of dressing to secure the catheter. The intravenous catheter is usually placed distal or near the surgical site (although it is not clear if this influences block quality). If intravenous access is difficult, the procedure may need to be aborted.

Importantly, the patient should also have an intravenous cannula in the nonoperative upper extremity for administration of fluids and other drugs. If antibiotics are indicated they should be administered before the block (to allow these drugs to effectively reach the surgical site before tourniquet inflation). Lipid emulsion should be immediately available in the event that local anesthetic systemic toxicity occurs (see Chapter 29 for more details).

Extremity Exsanguination and Tourniquet Inflation

Raise the extremity above the level of the heart prior to exsanguination with an Esmarch bandage. This will passively drain venous blood from the extremity over one to two minutes (this can be done during the timeout). Stretch and wrap an Esmarch bandage around the extremity from distal to proximal in a spiral overlapping fashion, continuing until the cuff of the tourniquet is covered.

Following exsanguination with an Esmarch bandage, the tourniquet is typically inflated to 250 mm Hg or 100 mm Hg above systolic blood pressure. Therefore it is important that the patient be normotensive (systolic blood pressure 150 mm Hg or less) during the period of tourniquet inflation. If necessary, sedation or antihypertensive medications may be given. Another alternative is to increase the tourniquet inflation pressure to 275 mm Hg for brief tourniquet runs (usually <60 minutes for Bier blocks). For these reasons, it is important that blood pressure be carefully monitored and controlled during intravenous regional anesthesia. Both the surgical conditions and block quality are highly dependent on the exsanguination of the extremity.

Use of a single, wide cuff allows use of smaller inflation pressures during intravenous regional anesthesia. The postulated advantage is that the smaller pressures will decrease the incidence of neurologic complications related to high inflation pressures with the narrow double cuffs. 98

Preservative free 2-chloroprocaine 0.5%, lidocaine 0.5%, or prilocaine 0.5% can be used for intravenous regional anesthesia (plain solution, without epinephrine). 99-101 For upper extremity anesthesia, an arm (about 0.6 mL/kg, maximum 50 mL) or forearm (about 0.4 mL/kg, maximum 25 mL) tourniquet can be used, depending on the surgical site. 102 Bupivacaine is not recommended for intravenous regional anesthesia because cases of severe local anesthetic toxicity have been reported. 103 However, dilute solutions of long-acting amides (0.125% levobupivacaine or 0.2% ropivacaine) have successfully been used to prolong sensory block and analgesia after tourniquet deflation. 104-106

An additional temporary tourniquet (used for intravenous placement) can be placed immediately proximal to the surgical site while the first 10 or 20 mL of local anesthetic is injected via the catheter (the second tourniquet is then released). This will confine local anesthetic to the distal extremity and promote block onset. 107, 108 Inject slowly so that venous pressures remain low. If the injection is at a distal site the leakage under the tourniquet will be reduced. The onset of anesthesia is usually within 5 to 10 minutes. After injection, the intravenous catheter is typically removed (although repeat injections using an indwelling catheter have been described).

Because the Bier block does not result in prolonged analgesia, long-acting local anesthetic should be infiltrated into the surgical field prior to tourniquet deflation. In this manner the onset of infiltrative analgesia matches the offset of the Bier block.

Tourniquet Deflation

The tourniquet can be safely released after 25 minutes, but the patient should be closely observed for local anesthetic toxicity for several minutes after the tourniquet release. Shorter tourniquet times (<25 minutes) are possible with 2-chloroprocaine because this local anesthetic is rapidly degraded by plasma esterases when blood re-enters the extremity upon tourniquet deflation. Rare cases of systemic toxicity from 2-chloroprocaine have been reported in patients with atypical esterases. 109

Systemic plasma levels of local anesthetic will increase with venous return from the extremity following tourniquet deflation. This occurs when the tourniquet inflation pressure is less than venous levels (nearly 0 mm Hg). Cyclic deflation of the tourniquet at 10-second intervals for two or three cycles increases the time to peak arterial lidocaine levels, which may decrease potential toxicity. 110 It is recommended to not raise the extremity immediately after the tourniquet is removed, as this will promote venous return containing local anesthetic. Reinflate the tourniquet if any signs of systemic toxicity occur.

Comments

Double-Cuff Tourniquets. A double-cuff tourniquet can be used instead of a single-cuff tourniquet to extend the tourniquet tolerance time (Fig. 46.36). Both adjacent cuffs should have secure closures and reliable pressure gauges. After exsanguination of the arm, the proximal cuff is inflated to approximately 100 mm Hg greater than the systolic pressure, and absence of a radial pulse confirms adequate tourniquet pressure. When the patient complains of tourniquet pain, the distal tourniquet, which overlies anesthetized skin, is inflated, and the proximal tourniquet is released. However, if a long tourniquet time is anticipated it is usually best to choose other peripheral nerve block or provide a general anesthesia.

Additives and Adjuncts. Additives and adjuncts should be used with caution because prolonged exposure of these compounds to the venous endothelium during tourniquet
inflation may result in phlebitis (even if the compounds are considered safe for routine intravenous use).

**Complications**

Technical problems with this block include tourniquet discomfort, rapid resolution leading to postoperative pain, difficulty in providing a bloodless field, and the necessity of exsanguination in the case of a painful injury. Accidental or early deflation of the tourniquet or use of excessive doses of local anesthetics can result in systemic toxicity. Injection of the drug as distally as possible at a slow rate decreases blood levels and theoretically may increase safety. Nerve injury and compartment syndrome have been reported with long tourniquet times and high tourniquet inflation pressures. Hypertonic solutions can cause compartment syndrome and should never be used for intravenous regional anesthesia.\(^{111}\)

**Continuous Catheter Techniques**

The advantages cited for continuous nerve blockade include prolongation of surgical anesthesia, decreased risk of systemic toxicity because of lower incremental doses, postoperative pain relief, and sympathectomy. Catheter placement using over-needle and through-needle methods have been described. Advances in equipment technology, including the development of stimulating needles and catheters and portable pumps allowing local anesthetic infusion after hospital dismissal, have increased the success rate and popularity of continuous peripheral blockade (Fig. 46.37). Although concern regarding accurate catheter placement and maintenance still exists, the use of stimulating catheters and radiographic confirmation may further improve the functionality. Ultrasound guidance appears to produce more consistent times for catheter placement.\(^{112}\) Overall, continuous peripheral nerve block provides superior analgesia compared with conventional opioid therapy. Minor technical problems such as catheter kinking, displacement or leakage, and bacterial colonization are frequent, with no adverse clinical consequences in the large majority of cases. Major neurologic and infectious adverse events are rare.

Methods of providing continuous brachial plexus anesthesia have been described since the 1940s. These methods frequently offer ingenious solutions for the placing and securing of the needle or catheter. This technique is especially applicable to patients with upper extremity or digit replantation, total shoulder or elbow arthroplasty, or reflex sympathetic dystrophies, for which prolonged pain relief and sympathectomy are advantageous.

Continuous lower extremity techniques were also described decades ago, but until recently have remained underused compared with continuous upper extremity and neuraxial approaches. Reliable, improved success rates and the risk of spinal hematoma after neuraxial techniques led clinicians to reconsider continuous lower extremity blocks. Contemporary applications for continuous psoas compartment, sciatic, femoral, adductor canal, and popliteal fossa blockade have been reported. Compared with conventional systemic and neuraxial analgesic methods, continuous lower extremity blocks provide superior analgesia with fewer side effects, improve peripoperative outcomes, and accelerate hospital dismissal after major joint replacement.

**TESTING THE CATHETER**

Test injections of saline, local anesthetic, or air with real-time ultrasound imaging can be used to assess catheter placement and confirm catheter tip location.
tip function. The overall success rate of peripheral nerve catheter placement with ultrasound guidance is high, so the additional value of these subsequent tests is still being established.113,114

SECURING THE CATHETER

Catheter migration and dislodgement are clinically relevant issues. Catheter threading distances do not seem to correlate with the chance of dislodgement.115 Excessively large threading distances (>5 cm) may result in catheter knotting. If ultrasound guidance is used for catheter placement, sterile dry gauze can be used to remove excess gel prior to securing the catheter. Skin adhesive applied to the catheter at the skin exit site may reduce catheter dislodgement, fluid leakage at the site, and chance of catheter related infection.116,117 Application of skin adhesive at more than one site along the catheter may improve fixation.118 A partial loop or coiling the catheter at the exit site will help reduce catheter dislodgement, and a variety of strain relief devices are now commercially available. Some practitioners elect to use tunnel catheters that are intended to remain in place for a prolonged period of time.

Choice of Local Anesthetic

The choice of local anesthetic for a peripheral nerve block depends to some extent on the duration of the surgical procedure, although other factors are also important (see Chapter 29). Prolonged blockade for up to 24 hours often occurs with long-acting local anesthetics such as bupivacaine or ropivacaine. Although this feature often results in superb postoperative pain relief, it may be undesirable in some patients because of the possible risk of nerve or tissue injury in a partially blocked limb. A short- or medium-acting local anesthetic, such as lidocaine or mepivacaine, may be more appropriate for surgical anesthesia. Whatever drug is chosen, the total dosage should be calculated for each patient and should be kept within safe limits (see Chapter 29 for details).

The highest concentrations of local anesthetic drugs are not appropriate for peripheral neural blockade; therefore 0.75% bupivacaine or ropivacaine, 2% lidocaine, 2% mepivacaine, and 3% 2-chloroprocaine are not recommended. The lowest concentrations of the same local anesthetics (i.e., 0.25% bupivacaine or ropivacaine and 0.5% mepivacaine or lidocaine) might not provide complete motor blockade.

Vasoconstrictors, usually epinephrine, can be added to the chosen local anesthetic to improve onset of action, to decrease drug uptake, and to prolong action. A concentration of 1:200,000 epinephrine is usually recommended. Ideally, the epinephrine should be added to the local anesthetic at the time the block is to be performed. Commercially prepared solutions with epinephrine have a lower pH than those in which it is freshly added, resulting in a higher percentage of ionized drug molecules. These ionized molecules do not readily cross the neural membrane, delaying the onset of drug action after injection. Epinephrine should not be added to the local anesthetic for blocks of the digits or penis because tissue ischemia can result. Various other additives, including steroids, clonidine, dexmedetomidine, opioids, and ketamine have been reported to enhance or prolong local anesthetic peripheral nerve blockade. Liposomal bupivacaine, which slowly releases this local anesthetic, is now FDA approved for some peripheral nerve blocks.

Complications and Safety

Nerve injury is a recognized complication of peripheral regional techniques (Box 46.3). Risk factors contributing to neurologic deficit after regional anesthesia include neural ischemia, traumatic injury to the nerves during needle or catheter placement, and infection. However, postoperative neurologic injury because of pressure from improper patient positioning, tightly applied casts or surgical dressings, and surgical trauma is often attributed to the regional anesthetic. Patient factors such as body habitus or a preexisting neurologic dysfunction can also contribute.119-121

Although needle gauge, type (i.e., short vs. long bevel), and bevel configuration can influence the degree of nerve injury after peripheral nerve block, the findings are conflicting, and there are no confirmatory human studies. Theoretically, localization of neural structures with a nerve stimulator or ultrasound guidance would allow a high success rate without increasing the risk of neurologic complications, but this has not been established. Likewise, prolonged
exposure, high dose, or high concentrations of local anesthetic solutions can also result in permanent neurologic deficits. In laboratory models, the addition of epinephrine increases the neurotoxicity of local anesthetic solutions and decreases nerve blood flow; however, the clinical relevance of these findings in humans remains unclear. Nerve damage caused by traumatic needle placement, local anesthetic neurotoxicity, and neural ischemia during the performance of a regional anesthetic can worsen neurologic outcome in the presence of an additional patient factor or surgical injury.

Hemorrhagic complications have been described with nearly every peripheral technique and range from localized bruising and tenderness to severe hematomas or hemorrhagic complications. The placement of peripheral nerve blocks in patients with a coagulopathy should be performed with caution, especially in a deep, noncompressible site where an expanding hematoma could go unnoticed (e.g., lumbar plexus) or in a location where a hematoma could compress the airway (e.g., interscalene).²²

Prevention of neurologic complications begins during the preoperative visit with a careful evaluation of the patient’s medical history and appropriate preoperative discussion of the risks and benefits of the available anesthetic techniques. It is imperative that all preoperative neurologic deficits are documented to allow early diagnosis of new or worsening neurologic dysfunction postoperatively. Postoperative sensory or motor deficits must also be distinguished from residual (prolonged) local anesthetic effect. Imaging techniques, such as computed tomography and magnetic resonance imaging, are useful in identifying infectious processes and expanding hematomas. Although most neurologic complications resolve completely within several days or weeks, significant neural injuries necessitate neurologic consultation to document the degree of involvement and coordinate further workup. Neurophysiologic testing, such as nerve conduction studies, evoked potentials, and electromyography, are often useful in establishing a diagnosis and prognosis.

Infectious complications can be caused by exogenous (contaminated medication or equipment) or endogenous sources. Infection at the site of needle placement is an absolute contraindication to peripheral nerve blockade, although caution should be used in patients with nearby cellulitis or systemic blood infections (bacteremia or sepsis). Although bacterial colonization of peripheral nerve catheters is not uncommon, cellulitis, abscess, or bacteremia are extremely rare.¹²³⁻¹²⁵

Several large studies have established that severe systemic toxicity (seizures with or without cardiac arrest) occur on the order of 1:1000 for peripheral nerve blocks. Therefore practitioners of regional anesthesia must be familiar with the immediate detection and treatment of systemic local anesthetic toxicity. Systemic local anesthetic toxicity can occur immediately from an intravascular injection or it may be delayed because of rapid or excessive systemic absorption of local anesthetic. In addition to frequent aspiration during injection of local anesthetic, the addition of epinephrine can help alert the practitioner to potential intravascular injection. Attaching intravenous tubing to the needle allows immobility of the needle during injection. Typically, an assistant will aspirate with the syringe after each 5 mL injection of local anesthetic. Recent studies indicate that lipid emulsion rescue therapy improves success of resuscitation from cardiac arrest due to local anesthetic toxicity if given immediately after a local anesthetic overdose.¹²⁶⁻¹³⁰

For more details on treatment of local anesthetic toxicity, see Chapter 29.

Training

Interventional sonography is not without risks. Many studies have now demonstrated efficacy of ultrasound-guided regional blockade. Ultrasound has the potential to prevent and detect two important adverse events during peripheral nerve blocks: intravascular injection and intraneural injection of a local anesthetic.¹³¹⁻¹³² The characteristic contrast from dissolved gas that is distributed within the vessel lumen can identify intravascular injection. The hallmark sign of intraneural injection is nerve expansion during injection (Fig. 46.38). Although ultrasound may have a profound impact on the safety of regional blockade,
confirmatory studies of clinical practice are in progress. Many of these adverse events have only been recognized in retrospect by the review of recorded sonograms, which is a valuable training practice.

One of the original techniques developed for training novices in ultrasound-guided interventions was use of a tissue-equivalent phantom. The phantom consisted of simulated tissue for needle placement practice (Fig. 46.39). To be realistic, the speed of sound must be similar as in soft tissue. In the first prototype, the phantom and container were clear; as a result, visual confirmation was possible. Several phantoms are now marketed for regional anesthesia purposes, and biologic tissue models that simulate nerve tissue. In the first prototype, the phantom and container were clear; as a result, visual confirmation was possible. Several phantoms are now marketed for regional anesthesia purposes, and biologic tissue models that simulate nerve tissue. In the first prototype, the phantom and container were clear; as a result, visual confirmation was possible. Several phantoms are now marketed for regional anesthesia purposes, and biologic tissue models that simulate nerve tissue. In the first prototype, the phantom and container were clear; as a result, visual confirmation was possible. Several phantoms are now marketed for regional anesthesia purposes, and biologic tissue models that simulate nerve tissue. In the first prototype, the phantom and container were clear; as a result, visual confirmation was possible. Several phantoms are now marketed for regional anesthesia purposes, and biologic tissue models that simulate nerve tissue. In the first prototype, the phantom and container were clear; as a result, visual confirmation was possible. Several phantoms are now marketed for regional anesthesia purposes, and biologic tissue models that simulate nerve tissue. In the first prototype, the phantom and container were clear; as a result, visual confirmation was possible. Several phantoms are now marketed for regional anesthesia purposes, and biologic tissue models that simulate nerve tissue. In the first prototype, the phantom and container were clear; as a result, visual confirmation was possible. Several phantoms are now marketed for regional anesthesia purposes, and biologic tissue models that simulate nerve tissue. In the first prototype, the phantom and container were clear; as a result, visual confirmation was possible. Several phantoms are now marketed for regional anesthesia purposes, and biologic tissue models that simulate nerve tissue. In the first prototype, the phantom and container were clear; as a result, visual confirmation was possible. Several phantoms are now marketed for regional anesthesia purposes, and biologic tissue models that simulate nerve tissue. In the first prototype, the phantom and container were clear; as a result, visual confirmation was possible. Several phantoms are now marketed for regional anesthesia purposes, and biologic tissue models that simulate nerve tissue. In the first prototype, the phantom and container were clear; as a result, visual confirmation was possible.

A number of other effective teaching tools are being used. Cadavers have the advantage of realistic regional anatomic structures and can be used for simulated interventions. The cost and use of specialized embalming methods that preserve nerve imaging and cadaver flexibility have limited this approach to a few specialized institutions. Most training studies have concluded that skills for ultrasound-guided procedures can be rapidly acquired. One training study has identified common errors of novices while learning ultrasound-guided regional blocks. These errors included advancing the needle when it was not visualized and unintentional probe movement. Novices often advance the needle even when it is not visualized, presumably because the natural inclination is to assume the needle has not reached the field of view. The potentially quality-compromising behaviors were largely eliminated by the end of the study period, which ranged from 66 to 114 blocks per training participant.

**Summary and Conclusions**

Peripheral nerve block techniques benefit the patient intraoperatively and postoperatively. Successfully mastering these techniques and applying them to the appropriate clinical situations add valuable options to the anesthetic care. Knowledge of regional anesthesia is also essential for the diagnosis and treatment of acute and chronic pain syndromes (see Chapters 51 and 82).

Ultrasound is a guidance tool that many people are electing to choose for regional anesthesia blocks. Once proficiency is established for a particular procedure, starting to use ultrasound for other interventional applications is relatively easy. Ultrasound imaging can prevent and detect critical events such as intravascular or intraneural injection that may improve safety during regional anesthesia procedures. However, if safety outcomes are to improve, then education and training play key roles in reducing these relatively uncommon adverse events.

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