The techniques of peripheral neural blockade were developed early in the history of anesthesia. The American surgeons Halsted and Hall\(^1,2\) described the injection of cocaine into peripheral sites, including the ulnar, musculocutaneous, supratrochlear, and infraorbital nerves, for minor surgical procedures in the 1880s. James Leonard Corning\(^3\) recommended the use of an Esmarch bandage in 1885 to arrest local circulation, prolonging the cocaine-induced block and decreasing the uptake of that local anesthetic from the tissues. This concept was furthered by Heinrich F.W. Braun,\(^4\) who substituted epinephrine, a “chemical tourniquet,” in 1903. Braun\(^5\) also introduced the term *conduction anesthesia* in his 1905 textbook on local anesthesia, which described techniques for every region of the body. In 1920, the French surgeon Gaston Labat was invited by Charles Mayo to teach innovative methods of regional anesthesia at the Mayo Clinic. During his appointment there, Labat authored *Regional Anesthesia: Its Technic and Application*.\(^6\) The book was considered the definitive text on regional anesthesia for at least 30 years after its publication. Labat’s textbook focused on the intraoperative management of patients undergoing intraabdominal, head, neck, and extremity procedures using infiltration, peripheral, plexus, and splanchnic blockade. Neuraxial techniques were not widely applied at the time.

The use of peripheral nerve blockade has grown in popularity because it decreases pain as assessed by visual analog scale scores postoperatively, decreases the need for postoperative analgesics, decreases the incidence of nausea, shortens postanesthesia care unit time, and increases patient satisfaction.\(^7\) Peripheral nerve blocks can be customized and used for anesthesia, postoperative analgesia, and diagnosis and treatment of chronic pain disorders (see Chapters 64 and 98). The regional technique chosen depends on the surgical site, the anticipated length of the procedure, ambulation requirements, and the desired duration of postoperative pain control. Detailed anatomic knowledge enables the anesthesia provider to choose the appropriate technique for the intended surgical procedure and to salvage inadequate nerve blocks with local anesthetic supplementation. In addition, important side effects and complications of peripheral regional techniques must be understood. With appropriate selection

### Key Points

- Regional anesthesia is only successful when local anesthetic is inserted in close proximity to the targeted nerves. From the inception of regional anesthesia over a century ago, there have been several techniques designed and available to facilitate the correct placement of local anesthetic, including paresthesia-seeking, peripheral nerve stimulator, and most recently ultrasound guidance.
- Continuously administered peripheral nerve block improves outcome and rehabilitation after major surgery to the extremities, including surgery to the knee, hip, and shoulder.
- Total local anesthetic dosage should be determined and kept within acceptable limits. Accumulation may occur with continuous techniques.
- The frequency of neurologic complications after peripheral blockade is less than that associated with neuraxial techniques. Neurotoxicity and direct needle trauma are the major causes of neurologic complications.
- There are no data to support the superiority of one nerve localization technique—paresthesia, nerve stimulation, ultrasound—over another with regard to reducing the risk of nerve injury.
- A lipid infusion improves success of resuscitation from cardiac arrest because of local anesthetic toxicity if given immediately after a local anesthetic overdose (see Chapter 36)
and sedation, these techniques can be used in all age groups. Skillful application of peripheral neural blockade broadens the anesthesia provider’s range of options in providing optimal anesthetic care.

TECHNIQUES FOR LOCALIZING NEURAL STRUCTURES

PARESTHESIA TECHNIQUES

The paresthesia-seeking technique has a long, successful history as a simple technique 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 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 contacts 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 by many in the 1980s when peripheral nerve stimulation was introduced. Currently, no single technique has been shown to be superior with respect to success rate or incidence of complications.

PERIPHERAL NERVE STIMULATION

Peripheral nerve stimulators transmit a small electric current to the end of a stimulating needle that will 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 heavily sedated during block placement. A thorough understanding of anatomy is a prerequisite to this technique and all techniques of peripheral nerve blockade. 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 depolarization occurs as the cathode allows current to flow from the needle to the adjacent nerve. Current flows away from the needle causing hyperpolarization if the terminals are reversed. Most current-stimulating needles are coated with a thin layer of insulation along the needle with the exception of the tip. This allows for a more discrete field of stimulation only 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 of the injection of local anesthetic or catheter placement.

ULTRASOUND-GUIDED REGIONAL ANESTHESIA

Ultrasound-guided regional anesthesia is an exciting and rapidly developing technique used to visualize and localize nerve structures (see Chapter 58). Ultrasound allows visualization of the nerve target, the approaching needle, and the deposition of local anesthetic around the nerve. Superficial nerve structures (e.g., brachial plexus) are easily imaged in most patients and therefore are most suited for ultrasound guidance. Practitioners must become familiar with the fundamentals of ultrasound equipment, as well as sonoanatomy, to become proficient in ultrasound-guided regional anesthesia.

CERVICAL PLEXUS BLOCK

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 segmentally and the cutaneous sensation of the skin between the trigeminal innervated face and the T2 dermatome of the trunk. Blockade of the superficial cervical plexus results in anesthesia of only the cutaneous nerves.

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 repairs, and carotid endarterectomy. The ability to monitor the awake patient’s neurologic status continuously 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.

Technique

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. 57-1). It is possible to block the accessory nerve with this injection, resulting in temporary ipsilateral trapezius muscle paralysis.

DEEP CERVICAL PLEXUS. The deep cervical plexus block is a paravertebral block of the C2 to C4 spinal nerves as they emerge from their foramina in the cervical vertebrae (Fig. 57-2). The traditional approach uses three
Chapter 57: Peripheral Nerve Blocks

separate injections at C2, C3, and C4. The patient lies supine with the neck slightly extended and the head turned away from the side to be blocked. A line is drawn connecting the tip of the mastoid process and the Chassaignac tubercle (the transverse process of C6); a second line is drawn 1 cm posterior to this first line. The C2 transverse process lies 1 to 2 cm caudad to the mastoid process, where it can usually be palpated. The C3 and C4 transverse processes lie at 1.5-cm intervals along the second line. After skin wheals are raised over the transverse processes of C2, C3, and C4, three 22-gauge, 5-cm needles are advanced perpendicular to the skin entry site with a slight caudal angulation. The transverse process is contacted at a depth of 1.5 to 3 cm. If a paresthesia is obtained, 3 to 4 mL of solution is injected after careful aspiration for blood and cerebrospinal fluid. If no paresthesia is elicited initially, the needle is walked along the transverse process in the anteroposterior plane until a paresthesia is obtained.

This block can also be performed with a single injection of 10 to 12 mL at the C4 transverse process. Cephalad spread of the local anesthetic usually anesthetizes the C2 and C3 nerves. Cervical plexus anesthesia can also be observed after injection at the interscalene level for brachial plexus blockade. Maintenance of distal pressure and a horizontal or slightly head-down position can facilitate the onset of cervical plexus blockade using the interscalene technique.

Side Effects and Complications

Although these blocks are technically straightforward, needle placement for the deep cervical block allows local anesthetic injection in close proximity to a variety of neural and vascular structures. Complications and side effects include intravascular injection, blockade of the phrenic and superior laryngeal nerve, and spread of local anesthetic solution into the epidural and subarachnoid spaces.

Figure 57-1. Anatomic landmarks and method of needle placement for a superficial cervical plexus block.

Figure 57-2. Anatomic landmarks and method of needle placement for deep cervical plexus blocks at C2, C3, and C4.
ACCESSORY NERVE BLOCK

The accessory nerve (cranial nerve XI) is occasionally blocked to supplement the interscalene brachial plexus approach for shoulder procedures. A blockade of the accessory nerve results in motor paralysis of the trapezius muscle, ensuring a lack of patient movement during the surgical procedure. The nerve traverses the posterior triangle of the neck (bordered by the posterior border of the sternocleidomastoid muscle, middle third of the clavicle, and anterior border of the trapezius muscle) in a superficial position after emerging from the substance of the sternocleidomastoid muscle at the junction of the superior and middle thirds of that muscle’s posterior border. It can be blocked easily at that site by an injection of 6 to 10 mL of local anesthetic. This nerve is often unintentionally anesthetized when a superficial cervical plexus block is performed.

UPPER EXTREMITY BLOCKS

Blockade of the brachial plexus (C5-T1) at several locations from the roots to the terminal branches will allow for surgical anesthesia of the upper extremity and shoulder. Successful regional anesthesia of the upper extremity requires knowledge of brachial plexus anatomy from its origin, where the nerves emerge from the intervertebral foramina, to its termination in the peripheral nerves.

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 vertebra, respectively. The anterior scalene muscle passes caudad 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. 57-3).

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.

Branches arising from the cervical roots are usually blocked only with the interscalene approach to the brachial plexus. Sensory distributions of the cervical roots and the peripheral nerves are shown in Figure 57-4.

**INTERSCALENE BLOCK**

**Clinical Applications**

The principal indication for interscalene block is surgery on the shoulder. Blockade occurs at the level of the superior and middle trunks. Although this approach can be used for forearm and hand surgery, blockade of the inferior trunk (C8 through T1) is often incomplete and requires supplementation of the ulnar nerve for adequate surgical anesthesia in that distribution.14

**Technique**

**Peripheral Nerve Stimulation or Paresthesia.** The brachial plexus shares a close physical relationship with several structures that serve as important landmarks for the performance of interscalene block. In its course between the anterior and middle scalene muscles, the plexus is superior and posterior to the second and third parts of the subclavian artery. The dome of the pleura lies anteromedial to the inferior trunk.

This technique can be performed with the patient’s arm in any position and is technically simple because of easy identification of necessary landmarks.13 The patient should be in the supine position, with the head turned away from the side to be blocked. 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 from this border over the belly of the anterior scalene muscle into the groove. A line is extended posterolaterally 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 constant or reliable landmark.

After injection of a skin wheal, a 22- to 25-gauge, 4-cm needle is inserted perpendicular to the skin with a 45-degree caudad and slightly posterior angle (Fig. 57-5). The needle is then advanced until a paresthesia or nerve stimulator response is elicited. This usually occurs at a superficial level. Paresthesia or motor response of the arm or shoulder is equally efficacious as a distal response.15 If a blunt needle is used, a “click” may be detected as the needle passes through the prevertebral fascia. If bone is encountered within 2 cm of the skin, it is likely to be a transverse process, and the needle can be “walked” across

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**Figure 57-4.** A, Cutaneous distribution of the cervical roots. B, Cutaneous distribution of the peripheral nerves.
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this structure to locate the nerve. Contraction of the dia-
phragm indicates phrenic nerve stimulation and anterior
needle placement; the needle should be redirected poste-
riorly to locate the brachial plexus.

After the appropriate paresthesia or motor response
is obtained, and after negative aspiration, 10 to 30 mL
of solution is injected incrementally, depending on the
desired extent of blockade. Radiographic studies sug-

Clinical studies, however, indicate vari-

various blockade of the lower trunk (i.e., ulnar nerve), even

with large volumes of solution.14

Ultrasound Guided. This block is well suited to the
use of ultrasound guidance. It is often easiest to obtain

Ultrasonic guided. 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 bra-

chial plexus and then trace the plexus up the neck with

the ultrasound probe until the plexus trunks are visual-

ized as hypoechoic structures between the anterior and

medial scalene muscles (Fig. 57-6). The needle can then

be advanced in an out-of-plane, or an in-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.16

Side Effects and Complications

At the conventional level (C6) of blockade, ipsilateral
phrenic nerve block resulting in diaphragmatic paresis
occurs in 100% of patients undergoing interscalene block-
ade,17 even with dilute solutions of local anesthetics, and
is associated with a 25% reduction in pulmonary func-
tion.18,19 This effect probably results from anterior spread
of the solution over the anterior scalene muscle and may
cause subjective symptoms of dyspnea. Although rare,
respiratory compromise can occur in patients with severe
respiratory disease. Techniques to decrease blockade of

the phrenic nerve include using very small volumes of

local anesthetic and localizing the brachial plexus at a

lower level in the neck.20

Involvement of the vagus, recurrent laryngeal, and
cervical sympathetic nerves is rarely significant, 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 mechanore-
ceptors by decreased venous return, producing an abrupt
withdrawal of sympathetic tone and enhanced parasymp-
pathetic output. This effect results in bradycardia, hypo-
tension, and syncope. The frequency is decreased when

prophylactic β-adrenergic blockers are administered.21

Figure 57-5. Interscalene block. The fin-
gers palpate the interscalene groove, and the
needle is inserted with a caudad and slightly
posterior angle.

Figure 57-6. Ultrasound image of the brachial plexus at the level of
interscalene block.
Some surgical approaches to the shoulder, such as total shoulder arthroplasty, are associated with neurologic risk to the brachial plexus. In such cases, an interscalene block can be placed postoperatively after the surgical service has ascertained and documented that no neurologic damage has occurred. Epidural and intrathecal injections can occur with this block, a finding emphasizing the importance of inserting the needle in a caudad direction. The proximity of significant neurovascular structures can increase the risk of serious neurologic complications when interscalene block is performed in heavily sedated or anesthetized patients. Accordingly, an interscalene block should be placed with the patient awake or under light sedation.

SUPRACLAVICULAR BLOCK

Clinical Applications

Indications for supraclavicular block are operations on the elbow, forearm, and hand. Blockade occurs at the distal trunk-proximal division level. At this point, the brachial plexus is compact, and a small volume of local anesthetic produces rapid onset of reliable blockade of the brachial plexus. An additional advantage is that the block can also be performed with the patient's arm in any position.

Technique

Peripheral Nerve Stimulation or Paresthesia. Several anatomic points are important in the performance of the supraclavicular approach. The three trunks are clustered vertically over the first rib cephaloposterior to the subclavian artery, which can often be palpated in a slender, relaxed patient. The neurovascular bundle lies inferior to the clavicle at about its midpoint. The first rib acts as a medial barrier to the needle’s reaching the pleural dome and is short, broad, and flat, with an anteroposterior orientation at the site of the plexus.

The patient is placed in a supine position, with the head turned away from the side to be blocked. The arm to be anesthetized should be adducted, and the hand should be extended along the side. In the classic technique, the midpoint of the clavicle should be identified and marked. The posterior border of the sternocleidomastoid can be easily palpated when the patient raises the head slightly. The palpating fingers can then roll over the belly of the anterior scalene muscle into the interscalene groove, where a mark should be made approximately 1.5 to 2.0 cm posterior to the midpoint of the clavicle. Palpation of the subclavian artery at this point confirms the landmark.

After injection of a skin wheal, the anesthesiologist stands at the side of the patient facing the patient’s head. A 22-gauge, 4-cm needle is directed in a caudad, slightly medial, and posterior direction until a paresthesia or motor response is elicited or the first rib is encountered. If a syringe is attached, this orientation causes the needle shaft and syringe to lie almost parallel to a line joining the skin entry and the patient’s ear. If the first rib is encountered without elicitation of a paresthesia, the needle can be systematically walked anteriorly and posteriorly along the rib until the plexus or the subclavian artery is located (Fig. 57-7). Location of the artery provides a useful landmark. The needle can be withdrawn and reinserted in a more posterolateral direction that usually results in a paresthesia or motor response. After localization of the brachial plexus, aspiration for blood should be performed before incremental injections of a total volume of 20 to 30 mL of local anesthetic.
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The rib usually is contacted at a needle depth of 3 to 4 cm; however, in an obese patient or in the presence of tissue distortion resulting from hematoma or injection of solution, the depth may exceed the needle length. Nonetheless, before the needle is advanced further, gentle probing in the anterior and posterior directions should be done at the 2- to 3-cm depth if paresthesias are not obtained. Multiple injections can improve the quality or shorten the onset of blockade.

**Ultrasound Guided.** The use of ultrasound for the supraclavicular block allows the practitioner to see the brachial plexus structures, as well as the subclavian artery and pleura, just below the first rib. The inherent safety of this technique requires continuous visualization of the needle tip during needle advancement (see Chapter 58).

**Side Effects and Complications**

Although the block is more difficult in obese patients (see Chapter 71), an increased risk of complications has not been documented. The prevalence of pneumothorax after supraclavicular block is 0.5% to 6% and diminishes with increased experience. Importantly, although the use of ultrasound has perhaps decreased the incidence of pneumothorax, the risk has not been eliminated. The onset of symptoms is usually delayed, and it can take up to 24 hours. Thus, routine chest radiography after onset of symptoms is usually delayed, and it can take up to 24 hours. Thus, routine chest radiography after the block is not justified. The supraclavicular approach is best avoided when the patient is uncooperative or cannot tolerate any degree of respiratory compromise. Other complications include frequent phrenic nerve block (40% to 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 is self-limited.

**Infracavicular Block**

**Clinical Applications**

Infracavicular block provides anesthesia to the arm and hand. Blockade occurs at the level of the cords and offers the theoretical advantages of avoiding pneumothorax while affording block of the musculocutaneous and axillary nerves. No special arm positioning is required. A nerve stimulator ultrasound visualization is required because there are no palpable vascular landmarks to aid in directing the needle.

**Technique**

**Peripheral Nerve Stimulation or Paresthesia.** The needle is inserted 2 cm below the midpoint of the infracavicular border and is advanced laterally, using a nerve stimulator to identify the plexus. Marking a line between the C6 tubercle and the axillary artery with the arm abducted is helpful in visualizing the course of the plexus. An incremental injection of 20 to 30 mL of solution is sufficient after the needle is correctly placed. Success rate is improved with a distal motor response. A coracoid technique, with needle insertion site 2 cm medial and 2 cm caudal to the coracoid process, has also been described. However, the more lateral insertion site can result in the absence of blockade of the musculocutaneous nerve, removing the major advantage of this approach over the simpler axillary block.

**Ultrasound Guided.** Ultrasound guidance is frequently used to visualize the neurovascular bundle and ideally, local anesthetic spread should be visualized around the axillary artery (see Chapter 58).

**Side Effects and Complications**

Because of the blind approach to the plexus, the risk of intravascular injection may be increased. Exaggerated medial needle direction may result in pneumothorax.

**Axillary Block**

**Clinical Applications**

The axillary approach to the brachial plexus is popular because of its ease, reliability, and safety. Blockade occurs at the level of the terminal nerves. Although blockade of the musculocutaneous nerve is not always produced with this approach, it can be supplemented at the level of the axilla or at the elbow. Indications for axillary block include surgery to the forearm and hand. Elbow procedures are also performed successfully using the axillary approach. This block is ideally suited for outpatients and is easily adapted to the pediatric population (see Chapter 92). However, axillary block is unsuitable for surgical procedures on the upper arm or shoulder, and the patient must be able to abduct the arm to perform the block.

Anatomic concepts that should be considered before an axillary block include the following:

1. The neurovascular bundle is multicompartmental.
2. The axillary artery is the most important landmark.
3. Although anatomic variations exist, typically, the median nerve is found superior to the artery, the ulnar nerve is inferior, and the radial nerve is posterior and somewhat lateral (Fig. 57-8).
4. At this level, the musculocutaneous nerve has already left the sheath and lies with the coracobrachialis muscle.
5. The intercostobrachial nerve, a branch of the T2 intercostal nerve, is usually blocked by the skin wheal overlying the artery; however, adequate anesthesia for the tourniquet can be ensured by extending the wheal 1 to 2 cm caudal and cephalad.

**Technique**

**Peripheral Nerve Stimulation, Paresthesia, or Sheath.** The patient should be in the supine position with the arm to be blocked placed at a right angle to the body and the elbow flexed to 90 degrees. The dorsum of the hand rests on the bed or pillow; hyperabduction of the arm with placement of the hand beneath the patient’s head is not recommended, because this position frequently obliterates the pulse.

The axillary artery is palpated, and a line is drawn tracing its course from the lower axilla as far proximally as possible. The artery is then fixed against the patient’s
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1. Paresthesias can be sought with a 25-gauge, 2-cm needle, beginning deeply (i.e., radial nerve) or with the nerves supplying the surgical site. Needles longer than 2 cm are rarely needed to reach the neurovascular bundle. Smaller needles and a short needle bevel may be associated with a less frequent risk of nerve damage. Each paresthesia is injected with 10 mL of local anesthetic.

2. A nerve stimulator can also be used with an insulated needle to locate the nerves. Stimulation with a low current threshold (0.5 mA) decreases onset time, but increases block performance time compared with higher-threshold stimulation (1.0 mA).

3. A short-bevel needle can be advanced until the axillary sheath is entered, as evidenced by a fascial click, whereupon 40 to 50 mL of solution is injected after negative aspiration.

4. A transarterial technique can be used, whereby the needle pierces the artery and 40 to 50 mL of solution is injected posterior to the artery. Alternatively, half of the solution is injected posterior and half is injected anterior to the artery. Great care must be taken to avoid intravascular injection with this technique, particularly because the pressure of injection within the compartments of the axillary sheath may move anatomic structures in relation to the immobile needle.

5. Ultrasound guidance with visualization of local anesthetic spread around the four nerves (with and without motor stimulation) decreases block onset time and can reduce the number of needle relocations; however, the rates of success and complications are similar to other approaches. Ultrasound can also help with the success with smaller volumes of local anesthetic, although the overall duration of sensory and motor block will be markedly decreased.

Classically, upon completion of the injection, the arm should be adducted and returned to the patient’s side to prevent the humeral head from obstructing proximal flow of the local anesthetic solution. However, maintaining the arm in abduction decreases onset time and prolongs both sensory and motor block. If the musculocutaneous nerve is not blocked by the axillary approach, it can be blocked by injection within the body of the coracobrachialis muscle or at the elbow superficially at the lateral...
aspect of the antecubital fossa just above the interepicondylar line.

Success Rate With Axillary Block Techniques
The success rate for an axillary block depends on the definition of a successful block (i.e., surgical anesthesia versus blockade of all four terminal nerves of the upper extremity), the technique used to localize the brachial plexus, and the number of injections. Success rates with single-injection techniques can vary. Thompson and Rorie confirmed the presence of multiple compartments limits diffusion of the local anesthetic (and the success conclusion that the presence of multiple compartments limits diffusion of the local anesthetic (and the success of single injection compared to multiple injection techniques). Although Partridge and coworkers confirmed the presence of these compartments, they concluded that the “septa” dividing them were incomplete based on injections of methylene blue and latex solutions into cadavers. The controversy surrounding single- versus multiple-injection techniques remains unresolved.

Eliciting a paresthesia is as efficacious as peripheral nerve stimulation (with a motor response of 0.5 to 1.0 mA). Most studies suggest that two-injection transarterial techniques are equivalent to single-paresthesia or single-nerve stimulation approaches. In general, the efficacy of paresthesia and peripheral nerve stimulator techniques increases when multiple injections are used. Conversely, success rates with perivascular or fascial click approaches are variously reliable.

Side Effects and Complications
Nerve injury and systemic toxicity are the most significant complications associated with the axillary approach. The assertion that neuropathies are more common with the paresthesia technique is not supported by the available data. Even when paresthesias are not sought, they often occur unintentionally. Injection of large volumes of local anesthetic, particularly with the transarterial approach, increases the risk of intravascular injection and systemic toxicity of local anesthetics. Hematoma and infection are rare complications.

PERIPHERAL BLOCKS AT THE MIDHUMERAL LEVEL, ELBOW, AND WRIST
Clinical Applications
As techniques for brachial plexus blockade have gained popularity, indications for peripheral nerve blockade at the wrist and elbow have diminished. However, these techniques can be useful when limited anesthesia is required, when contraindications to brachial plexus block exist. Injection of large volumes of local anesthetic, particularly with the transarterial approach, increases the risk of intravascular injection and systemic toxicity of local anesthetics. Hematoma and infection are rare complications.

Midhumeral Block
Midhumeral block involves blocking each of the four nerves of the brachial plexus separately in the humeral canal at the level of the proximal one third and distal two thirds of the humerus. At this level, the median and ulnar nerves are located on the lateral and medial aspects of the brachial artery, respectively. The musculocutaneous nerve is identified within the body of the biceps muscle, and the radial nerve lies adjacent to the humerus. A volume of 8 to 10 mL of local anesthetic is injected after localization of each nerve with a nerve stimulator (or ultrasound). Midhumeral block has been reported to have a higher success rate than traditional (defined as stimulation of two nerves) axillary brachial plexus block. In this study, time to complete the block was not different between the two techniques; however, the onset of complete sensory block was shorter in the axillary approach, whereas the success rate of blockade of all four major nerves was higher in the midhumeral group.

Median Nerve Block
Block of the median nerve provides anesthesia of the palmar aspects of the thumb and index finger, the middle finger and radial half of the ring finger, and the nail beds of the same digits. Motor block includes the muscles of the thenar eminence, lumbrical muscles of the first and second digits, and in the case of the block at the elbow, median-innervated wrist flexor muscles of the forearm.

Technique at the Elbow. With the patient’s arm placed in the anatomic position (palm up), a line is drawn connecting the medial and lateral epicondyles of the humerus. The major landmark for this technique is the brachial artery, which is found medial to the biceps tendon at the intercondylar line. The median nerve lies medial to the artery (Fig. 57-9) and can be blocked with 3 to 5 mL of solution after eliciting a paresthesia. If no paresthesia is

Figure 57-9. Anatomic landmarks for median and radial nerve blocks at the elbow.
obtained, the local anesthetic can be injected in a fanlike pattern medial to the palpated artery.

**Technique at the Wrist.** The median nerve is located between the flexor carpi radialis and palmaris longus tendons and can be blocked at a point 2 to 3 cm proximal to the wrist crease (Fig. 57-10). The palmaris longus tendon is congenitally or postsurgically absent from some patients. A loss of resistance is felt as the needle passes through the flexor retinaculum, at which point 2 to 4 mL of solution should be injected. A superficial palmar branch supplying the skin of the thenar eminence can be blocked by injecting 0.5 to 1 mL of local anesthetic subcutaneously above the retinaculum. Paresthesias should not be sought because of the confinement of this nerve within the carpal tunnel.

**Radial Nerve Block**

Block of the radial nerve provides anesthesia to the lateral aspect of the dorsum of the hand (i.e., thumb side) and the proximal portion of the thumb, index, middle, and lateral half of the ring fingers.

**Technique at the Elbow.** The radial nerve can be blocked at the elbow as it passes over the anterior aspect of the lateral epicondyle. The intercondylar line and lateral edge of the biceps tendon are marked. A 22-gauge, 3- to 4-cm needle is inserted at a point 2 cm lateral to the biceps tendon and is advanced until bone is encountered (see Fig. 57-9). A fanlike injection is made using 3 to 5 mL of local anesthetic.

**Technique at the Wrist.** The radial nerve block at the wrist is a field block of the multiple peripheral branches descending along the dorsum and radial side of the wrist. The extensor pollicis longus tendon can be identified when the patient extends the thumb. The needle insertion is over this tendon at the base of the first metacarpal; the injection is superficial to the tendon. A volume of 2 mL of local anesthetic is injected proximally along the tendon, and an additional 1 mL is injected as the needle passes at a right angle across the anatomic snuffbox (Fig. 57-11).

**Ulnar Nerve Block**

Blockade of the ulnar nerve provides anesthesia of the ulnar side of the hand, the little finger, and the ring finger and all the small muscles of the hand, except those of the thenar eminence and the first and second lumbrical muscles.

**Technique at the Elbow.** Although the ulnar nerve is easily accessible at its subcutaneous position posterior to the medial epicondyle, blockade at this site is associated with a high incidence of nerve injury. The nerve is surrounded by fibrous tissue at this point, requiring an intraneural injection for successful blockade. Use of a very fine needle with a small volume of local anesthetic (1 mL) diminishes the risk; however, the nerve can be blocked satisfactorily with 5 to 10 mL of local anesthetic at a site 3 to 5 cm proximal to the elbow. The local anesthetic should be injected in a fanlike fashion without elicitation of a paresthesia.

**Technique at the Wrist.** At the wrist, the ulnar nerve lies beneath the flexor carpi ulnaris tendon between the ulnar artery and the pisiform bone. At this point, it has already given off its palmar cutaneous and dorsal branches. The nerve can be approached by directing the needle medially from the radial side of the tendon or, alternatively, by directing the needle radially from the ulnar side of the tendon (see Fig. 57-10). After eliciting a paresthesia, 3 to 5 mL of anesthetic solution is injected or spread in a fanlike fashion.

**Musculocutaneous Nerve Block**

The musculocutaneous nerve terminates as the lateral cutaneous nerve of the forearm. This nerve provides

![Figure 57-10. Anatomic landmarks for median and ulnar nerve blocks at the wrist. An alternative method for ulnar nerve block, from the ulnar side of the wrist, is shown.](#)

![Figure 57-11. Anatomic landmarks and method of needle insertion for a radial nerve block at the wrist.](#)
sensory innervation to the skin on the radial side of the forearm up to the radiocarpal joint. This block is usually performed to supplement the axillary approach to brachial plexus anesthesia.

**Technique at the Elbow.** The lateral cutaneous nerve of the forearm can be blocked 1 cm proximal to the intercondylar line immediately lateral to the biceps tendon. Fanlike infiltration of 3 to 5 mL of local anesthetic subcutaneously at this site provides excellent anesthesia of this nerve.

**Peripheral Blockade at the Elbow Versus the Wrist**
The forearm cutaneous nerves arise in the upper arm, and they are not anesthetized by block of the peripheral nerves at the elbow. There is no advantage of a block of the peripheral nerves of the upper extremity when comparing elbow with wrist techniques; both provide sensory anesthesia of the hand.

**Side Effects and Complications**
In general, distal peripheral blocks have a less frequent risk of complications. However, intravascular injection can occur, and the usual precautions of incremental injection after aspiration are recommended. The risk of nerve injury is more frequent when more distal peripheral blocks are performed, possibly because of superficial nerve placement between bony and ligamentous structures, thereby offering ready access to the probing needle point.

**INTRAVENOUS REGIONAL BLOCKS**
Intravenous regional blocks were first described by a German surgeon, August Bier, in 1908. Early methods involved two tourniquets and the first synthetic local anesthetic, procaine. The technique lost popularity as reliable methods of blocking the brachial plexus evolved.

**Clinical Applications**
The Bier block has multiple advantages, including ease of administration, rapidity of recovery, rapid onset, muscular relaxation, and controllable extent of anesthesia. It is an excellent technique for short (<90 minutes) open surgical procedures and for closed reductions of bony fractures.

**Technique**
An intravenous cannula is placed in the upper extremity to be blocked as distally as possible; the patient should also have an intravenous cannula in the nonoperative upper extremity for administration of fluids and other drugs. Traditionally, a double tourniquet is placed on the operative side; both cuffs should have secure closures and reliable pressure gauges. After exsanguination of the arm, the proximal cuff is inflated to approximately 150 mm Hg greater than the systolic pressure, and absence of a radial pulse confirms adequate tourniquet pressure. The total dose of local anesthetic is based on the patient’s weight, and it is injected slowly (3 mg/kg of 0.5% prilocaine or lidocaine, without epinephrine). The use of bupivacaine for intravenous regional anesthesia has been associated with local anesthetic toxicity and death and is not recommended (see Chapter 36). However, dilute solutions (0.125% levobupivacaine) of long-acting amides and the addition of adjuvants (tramadol, ketorolac, clonidine) have been used to prolong sensory block and analgesia after tourniquet deflation.

The onset of anesthesia is usually within 5 minutes. When the patient complains of tourniquet pain, the distal tourniquet, which overlies anesthetized skin, is inflated, and the proximal tourniquet is released. 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. The tourniquet can be released safely after 25 minutes, but the patient should be closely observed for local anesthetic toxicity for several minutes after the tourniquet release. Slow injection of local anesthetic solutions at a distal site decreases the risk of toxicity.

**Side Effects and Complications**
Technical problems with this block include tourniquet discomfort, rapidity of recovery 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 toxic reactions. Injection of the drug as distally as possible at a slow rate decreases blood levels and theoretically may increase safety. Cyclic deflation of the tourniquet at 10-second intervals increases the time to peak arterial lidocaine levels that can decrease potential toxicity. Other rare complications associated with this technique include phlebitis (with 2-chloroprocaine), development of compartment syndrome, and loss of a limb.

**BLOCKS OF THE THORAX AND ABDOMEN**

**PARAVERTEBRAL BLOCK**
Anatomic landmarks of the wedge-shaped paravertebral space include the parietal pleura anteriorly; the vertebral body, intervertebral disk, and foramen medially; and the posterior intercostal membrane laterally and the superior costotransverse ligament posteriorly. The neural structures within the paravertebral space include the intercostal nerve, the dorsal rami and communications, and the sympathetic chain. The intercostal nerve itself is fragmented within the paravertebral space and is blocked easily with local anesthetics. Awareness of the spinous processes, transverse processes, ribs, and costotransverse ligaments are essential while performing the block.

**Clinical Applications**
The paravertebral block can be used to provide anesthesia or analgesia to patients undergoing intrathoracic, abdominal, or pelvic procedures or surgery to the breast.
Thoracic paravertebral block provides analgesia comparable to epidural techniques, but with fewer side effects and complications.\textsuperscript{53,54} Paravertebral block can be useful in the diagnosis and treatment of certain chronic pain disorders, including postthoracotomy and postmastectomy pain.

**Technique**

**Thoracic Paravertebral Block.** Thoracic paravertebral blockade occurs as the spinal nerves emerge from the vertebral foramina. This results in somatic and sympathetic block of multiple contiguous thoracic dermatomes above and below the injection site.

**Neural Localization.** Peripheral nerve stimulation has been used to signify entry into the paravertebral space and guard against pleural puncture. The peripheral nerve stimulator will elicit a motor response on the intercostal muscles before the needle enters the pleura. Caution needs to be taken during a multilevel block, because local anesthetic injected at one level can spread to the contiguous levels and either modify or abolish the intercostal motor response. Ultrasound measurements of the depth from skin to the transverse process and from skin to the parietal pleura have been found to correlate closely to the actual needle depth. Theoretically, knowing the maximal insertion depth could minimize the risk of pneumothorax.

Thoracic paravertebral block can be performed with the patient in the sitting, lateral, or prone position; the sitting position allows easy identification of landmarks. Typically, the thoracic spinal processes are identified, and the needle is inserted 2.5 to 3 cm lateral to the most cephalad aspect of the spinal process and advanced perpendicular to the skin in all planes to contact the transverse process of the vertebra below, typically at a depth of 2 to 4 cm. After the transverse process is identified, traditionally, the needle is redirected cephalad and gradually advanced until a loss of resistance is felt 1 to 1.5 cm past the superior edge. However, walking the needle caudad can decrease the risk of pneumothorax.\textsuperscript{51} The safety of this procedure relies on the proceduralist not advancing the needle farther than 1 to 1.5 cm past the skin-transverse process distance.

Although spread of local anesthetic is variable, a single injection of 15 mL produces unilateral somatic blockade over four or five dermatomes; there is a tendency for caudal (compared with cephalad) spread.\textsuperscript{51} To achieve greater spread, 3 to 4 mL of a local anesthetic may be injected at each segment.\textsuperscript{55}

**Lumbar Paravertebral Block.** Lumbar nerves exit the vertebral foramina inferior to the caudal edge of the transverse process. Each nerve divides into anterior and posterior branches; the anterior branches of L1 through L4 (with a contribution from T12) form the lumbar plexus.

The patient is placed in the prone position as described for intercostal blockade. Lines are drawn across the cephalad edges of the lumbar vertebral spinous processes. These lines lie opposite the caudal edges of the homologous transverse processes (Fig. 57-12, A). A skin wheal is raised 3 cm lateral to the midline, and a 20-gauge, 10-cm needle is advanced perpendicularly until it contacts the transverse process at a depth of 3 to 5 cm. The needle is then redirected to walk off the caudal edge of the transverse process. At 1 to 2 cm (the thickness of the transverse process) beyond this point, 6 to 10 mL of local anesthetic is injected (see Fig. 57-12, B). Elicitation of a paresthesia or use of a nerve stimulator is helpful in confirming correct needle placement.

**Side Effects and Complications**

Because of the proximity of the neuraxis, epidural or subarachnoid injection of local anesthetic is a risk.\textsuperscript{49} Intravascular injection through the lumbar vessels, vena cava, or aorta is possible. Pleural puncture and pneumothorax have occurred with frequencies of 1.1% and 0.5%, respectively.\textsuperscript{51}

**Intercostal Nerve Block and Interpleural Catheter Placement**

The intercostal nerves are the primary rami of T1 through T11. T12 is technically a subcostal nerve, and it supplies branches to the ilioinguinal and iliohypogastric 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 costal 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 celiac plexus blocks and light general anesthesia to provide excellent surgical conditions for intraabdominal procedures. In a similar fashion, intrathoracic surgery can be accomplished using intercostal and stellate ganglion blocks with endotracheal sedation. Although surgical applications are possible, the majority of indications are for postoperative analgesia.

Interpleural catheter placement for management of postoperative pain was first described by Reiestad and Stromskag in 1986.\textsuperscript{56} Because the mechanism of action is poorly understood, and reports of efficacy have varied, the use of this technique has varied in frequency over time. Overall, the results with cholecystectomy have been most favorable. The advantages of interpleural analgesia are more difficult to prove in patients undergoing thoracotomy, perhaps because of technical problems relating to blood in the pleural space and chest tube drainage. Recent applications include analgesia after minimally invasive cardiopulmonary bypass surgery.\textsuperscript{57}
**Technique**

**INTERCOSTAL BLOCK.** The intercostal nerve can be readily 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. 57-13, A). 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 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 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. 57-13, B, C). This process is repeated at each rib. Appropriate intravenous sedation providing analgesia and some degree of amnesia is desirable for the patient’s comfort. Ultrasound imaging of the intercostal nerves has been reported, but the visibility is highly variable.

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.

**INTERPLEURAL CATHETER.** The technique for interpleural catheter placement is simple and can be performed with the patient in a lateral (and slightly oblique) or sitting position. The sixth or seventh intercostal space is identified. Needle insertion is performed approximately 10 cm lateral from the posterior midline, and an epidural needle tip is advanced until it rests on the cephalad edge of the rib below the intercostal space to be entered. A glass syringe filled with saline or air is then attached to the needle, and the unit is advanced slowly over the superior edge of the rib. When the tip of the needle enters the parietal pleura, the solution in the syringe is drawn into the chest cavity because of the negative intrathoracic pressure. This effect can be observed in mechanically and spontaneously ventilating patients, but it is accentuated in the latter group.

The catheter is then inserted approximately 5 to 8 cm into the interpleural space and is secured on the chest.
wall. During needle positioning and catheter placement, care must be taken to minimize entrainment of air through the needle. Lung parenchymal damage can occur with loss-of-resistance techniques or insertion of excessive lengths of catheter.

**Side Effects and Complications**

The major complication feared 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 0.42%. If this unusual complication occurs, treatment is usually limited to observation, administration of oxygen, or needle aspiration. Rarely, chest tube drainage is required when these treatments are unsuccessful.

The risk of systemic local anesthetic toxicity is present with multiple intercostal blocks because of the large volumes and rapid 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. Interpleural block should not be performed in patients with pleural fibrosis or inflammation, pleural effusion, lung parenchymal disease associated with pleural disease, or bleeding diathesis. Pleural disease can result in poor spread of local anesthetic solutions or rapid uptake in the case of inflammation. Patients with severe pulmonary disease who rely on their intercostal muscles can exhibit respiratory decompensation after bilateral intercostal blockade.

**TRANSVERSUS ABDOMINUS PLANE BLOCK**

The lateral abdominal wall consists of subcutaneous tissue, the external oblique muscle, the internal oblique muscle, and the transversus abdominis muscle progressing from superficial to deep. The fascial sheath that lies deep to the internal oblique muscle and superficial to the transversus abdominis muscle is the target for the transversus abdominis plane (TAP) block. The nerves that exit the thoracolumbar spinal column pass laterally through the fascial layer to innervate the abdominal wall.

The landmarks for the TAP block are referred to as the triangle of Petit, and they consist of the iliac crest, the latissimus dorsi muscle, and the external oblique muscle. The triangle of Petit is located along the midaxillary line inferior to the lower costal margin and superior to the iliac crest.

**Indications**

TAP blocks are indicated for any lower abdominal surgery, including hernia repair, appendectomy, caesarean delivery, abdominal hysterectomy, laparoscopic surgery, renal transplantation, and prostatectomy. Bilateral blocks can be used for midline incisions or laparoscopic procedures. It is reasonable to expect analgesia between T10 and L1 with a single injection.

**Technique**

**LOSS OF RESISTANCE (BLIND INJECTION).** The point of entry for the blind TAP block is the lumbar triangle of petit. This is situated between the lower costal margin and iliac crest. It is bound anteriorly by the external oblique muscle and posteriorly by the latissimus dorsi. This technique relies on feeling double “pops” as the needle traverses the external oblique and internal oblique muscles. A blunt needle will make the loss of resistance more significant.

**ULTRASOUND-GUIDED.** The patient is positioned supine. Using sterile technique the ultrasound probe is placed...
firmed several centimeters superior and parallel to the iliac crest. A 21-gauge, 10-cm insulated needle is inserted several centimeters medially to the probe using an in-plane approach. Bowel peristalsis can often be seen just deep to the transversus abdominis muscle layer. After negative aspiration, 15 to 20 mL of local anesthetic is incrementally injected under ultrasound visualization (see Chapter 58).

**Side Effects and Complications**
Peritoneal puncture is possible (even with ultrasound guidance), and there has been one reported case of a liver hematoma following a blind TAP block technique.

**ILIOINGUINAL AND ILOHYPOGASTRIC BLOCKS**
The ilioinguinal and iliohypogastric nerves arise from the first lumbar spinal root. They pierce the transversus abdominis cephalad and medial to the anterior superior iliac spine and lie between the transversus abdominus and internal oblique muscles. After traveling a short distance caudal 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 anterior 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 in the inguinal region.

**Indications**
Ilioinguinal and iliohypogastric 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.

The ilioinguinal and iliohypogastric nerves arise from the first lumbar spinal root. They pierce the transversus abdominis cephalad and medial to the anterior superior iliac spine and lie between the transversus abdominis and internal oblique muscles. After traveling a short distance caudal 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 anterior 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 in the inguinal region.

**Technique**
**Landmark Technique.** These blocks are performed using a loss-of-resistance technique. The local anesthetic should be inserted between the transversus abdominus 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 farther until another loss of resistance is noted as the needle passes out of the internal oblique to lie between it and the transversus abdominus where another 2 mL of local anesthetic is injected. The needle is withdrawn, and the same procedure is repeated two more times in a fanlike distribution between the internal and external oblique and then the internal oblique and the transversus abdominus muscle. A total 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 blocks (see Chapter 58).

**LOWER EXTREMITY BLOCKS**
Knowledge of the anatomy of the lumbosacral plexus and peripheral nerves of the lower extremity enables anesthesiologists to provide comprehensive anesthetic care. These blocks are safe and have certain advantages, such as postoperative pain relief and lack of complete sympathetectomy, which make them ideal for selected patients.

Historically, lower extremity blocks were less popular than blocks used routinely for surgical procedures of the upper extremity, in part because of the widespread acceptance and safety of spinal and epidural anesthesia. Unlike the brachial plexus, the nerves supplying the lower extremity are not anatomically clustered where they can be blocked easily with a relatively superficial injection of local anesthetic. Because of the anatomic considerations, lower extremity blocks are technically more difficult and require more training and practice before expertise is acquired. Many of these blocks were classically performed using paresthesia, loss of resistance, or field block technique, and success rates varied. Advances in needles, catheters, nerve stimulator technology, and ultrasound imaging have facilitated localization of neural structures and improved success rate. Recent applications have focused on postoperative analgesia (rather than intraoperative anesthesia) to improve patient comfort and to assist in rehabilitation and hospital dismissal.

**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 occasion-
ally from L5 (Fig. 57-14). The plexus lies between the
psosas major and quadratus lumborum muscles in the so-
called 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 impor-
tant for lower extremity surgery: the posterior cuta-
naneous 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 the greater sciatic foramen and are blocked
by the same technique. The sciatic nerve is a combina-
tion 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 popli-
teal fossa, with the tibial nerve passing medially and the
common peroneal laterally. The cutaneous distributions
of the lumbosacral and peripheral nerves are shown in
Figure 57-15.

PSOAS COMPARTMENT BLOCK
(POSTERIOR APPROACH TO THE
LUMBAR PLEXUS)

The psoas compartment block uses a technique in which
a needle is placed into the space between the psoas major
and quadratus lumborum muscles. The block was initially
performed using a loss-of-resistance technique and a large
volume of injected solution to provide anesthesia to the
hip and anterolateral thigh.65

Clinical Applications
The psoas compartment block provides blockade of the
three main components of the lumbar plexus with a sin-
gle injection.66 The technique must be combined with a
sciatic block for anesthesia of the entire lower extremity.
Psoas compartment block is often used to provide postop-
erative analgesia for patients undergoing major knee and
hip surgery.67,68

Technique
Although loss-of-resistance or paresthesia techniques
are feasible,69 most practitioners use nerve stimulation
to confirm the location of the lumbar plexus.64 With
the classic technique, the patient is placed in the lateral
position, with hips flexed and operative extremity upper-
most. A line is drawn to connect the iliac crests (i.e.,
terrocristal line), identifying the fourth lumbar spine.
A skin wheal is raised 3 cm caudad and 5 cm lateral to

Figure 57-14. The lumbar plexus
lies in the psoas compartment
between the psoas major and qua-
dratus lumborum muscles.
the midline on the side to be blocked. A 21-gauge, 10-cm stimulating needle is then advanced perpendicular to the skin entry site until it contacts the fifth lumbar transverse process. The needle is redirected cephalad until it slides off the transverse process. The lumbar plexus is identified by elicitation of a quadriceps motor response, and after negative aspiration, 30 mL of local anesthetic is incrementally injected.

Based on anatomic imaging studies, Capdevila and colleagues\textsuperscript{70} modified the classic psoas technique (Fig. 57-16). Needle insertion site is the junction of the lateral third and medial two thirds of a line between the spinous
process of L4 and a line parallel to the spinal column passing through the posterior superior iliac spine. (The spinous process of L4 was estimated to be approximately 1 cm cephalad to the upper edge of the iliac crests.) The needle is advanced perpendicularly to the skin until contact with the transverse process of L4 is obtained and is then advanced under the transverse process until quadriceps femoris muscle twitches are elicited. Despite a difference between men and women in the depth of the lumbar plexus, the distance from the L4 transverse process to the lumbar plexus was comparable (median value, 2 cm) in both sexes (see Fig. 57-12). It is crucial to achieve contact with the L4 transverse process to establish appropriate needle depth and position. A more recent study using ultrasound imaging demonstrated that the intersection of the middle and lateral thirds of the intercrestal line between the midline, and a parallel line through the pos terosuperior iliac spine was too lateral to permit needle–transverse process contact in 50% of patients.\textsuperscript{71}

**Ultrasound-Guided Psoas Compartment Block**

Despite the recent popularity of ultrasound guidance in regional anesthesia, there has been limited interest in using ultrasound for lumbar plexus blockade (see Chapter 58). This is likely due to the deep nature of the block; the increasing number of obese patients (also see Chapter 71); and the need for specialized curved-array, low-frequency transducers. Although images of the lumbar plexus have been obtained in volunteers and cadavers, the actual clinical experience for using ultrasound guidance to facilitate the placement of lumbar plexus blocks has not been well described.

**Side Effects and Complications**

Unlike the relatively minor complications associated with other lower extremity nerve blocks, the risks associated with a posterior lumbar plexus block can be quite severe.\textsuperscript{72} Because of the proximity of the neuraxis, intrathecal or epidural local anesthetic or catheter placement is a potential complication. Epidural spread of local anesthetic is the most common complication with an incidence ranging from 1.8% to 16%.\textsuperscript{64,66,67,70} Factors that contribute to epidural spread are a medially directed needle, large volumes of local anesthetic, and the presence of a spinal deformity (scoliosis). Less commonly, intrathecal or subarachnoid injection or catheter placement can lead to risk of widespread spinal anesthesia.

Because the psoas compartment block results in injection of local anesthetic into large, richly vascularized muscles (e.g., psoas, quadratus lumborum), the early plasma concentrations are significantly higher than levels obtained during a femoral block. Patients must be monitored for signs of local anesthetic toxicity when given large boluses of local anesthetics. Because of the same rich vascular supply, severe retroperitoneal or renal capsular hematomas have occurred in patients who have undergone a psoas compartment block while anticoagulated, or who received anticoagulation medication shortly after block placement or in the presence of a continuous psoas catheter. Although larger studies are needed, the American Society of Regional Anesthesia conservatively recommends that patients having a lumbar plexus block be managed in much the same way as those undergoing neuraxial blockade when thromboprophylaxis is ordered.\textsuperscript{73}

**PERIVASCULAR THREE-IN-ONE (FEMORAL) NERVE BLOCK**

The femoral nerve is formed within the psoas major muscle by posterior divisions of the second, third, and fourth lumbar nerves. It emerges from the lateral border of the psoas muscle to descend in the groove between the psoas and iliacus muscles and enters the thigh by passing beneath the inguinal ligament lateral to the femoral artery. At this point, the nerve divides into multiple terminal branches, which have been classified as anterior and posterior. The anterior branches are primarily cutaneous, and the deep branches are chiefly motor. The femoral nerve supplies the anterior compartment muscles of the thigh (i.e., quadriceps, sartorius) and the skin of the anterior thigh from the inguinal ligament to the knee. Its terminal branch is the saphenous nerve, which supplies an area of skin along the medial side of the leg from the knee to the big toe.

**Clinical Applications**

The perivascular approach (i.e., three-in-one block) to the lumbar plexus is based on the premise that injection of a large volume of local anesthetic within the femoral canal while maintaining distal pressure will result in proximal spread of the solution into the psoas compartment and subsequent lumbar plexus block.\textsuperscript{74} However, imaging studies suggest that blockade occurs through lateral (lateral femoral cutaneous nerve) and medial (obturator nerve) spread of injected local anesthetic.\textsuperscript{75}

Indications for femoral nerve block include anesthesia for knee arthroscopy in combination with intraarticular local anesthesia and analgesia for femoral shaft fractures, anterior cruciate ligament reconstruction, and total knee arthroplasty as a part of multimodal regimens. Their use in complex knee operations is associated with smaller pain scores and fewer hospital admissions following same-day surgery.\textsuperscript{64,67}

**Technique**

**FEMORAL BLOCK**

**PERIPHERAL NERVE STIMULATION OR PARESTHESIA.** The patient is placed in the supine position. A line is drawn between the anterior superior iliac spine and the pubic tubercle, identifying the inguinal ligament. The femoral artery is marked. A 22-gauge, 4-cm needle is advanced lateral to this line (Fig. 57-17, A). Elicitation of a motor response (or paresthesia) verifies correct needle position. Commonly, the anterior branch of the femoral nerve is identified first. Stimulation of this branch leads to contraction of the sartorius muscle and should not be accepted. The needle should be redirected slightly laterally and with a deeper direction to encounter the posterior branch of the femoral nerve. Stimulation of this branch is identified by patellar ascension as the quadriceps contract. A total of 20 to 40 mL of local anesthetic is injected incrementally after negative aspiration. Reliable anesthesia of the femoral and lateral
femoral cutaneous nerves can be predicted with 20 mL; however, obturator nerve block might not occur even with volumes greater than 30 mL.

**Ultrasound Guided.** The use of ultrasound can be useful in patients in whom it is difficult to palpate a femoral pulse, because of weight, anatomic variability, or changes to the needle insertion site (before radiation or surgery). The femoral nerve can be identified lateral to the artery as a triangular shaped structure.

**Technique**

**Fascia Iliaca Nerve (Modified Femoral) Block.** The fascia iliaca block was originally described in children (see Chapter 92). The clinical applications for its use are the same as those for femoral nerve block. The simplicity of the double pop technique has been emphasized. The double pop refers to the sensation felt as the needle traverses the fascia lata then the fascia iliaca. Penetration of both layers of fascia is important for successful fascia iliaca blockade (see Fig. 57-17). 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 cutting needles. The needle entry site for the fascia iliaca block is determined by drawing a line between the pubic tubercle and the anterior superior iliac crest and dividing this line into thirds. The needle entry point is one centimeter caudal to the intersection of the medial

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**Figure 57-17.** A, Anatomic landmarks for lateral femoral cutaneous, femoral, and obturator nerve blocks. B, For an obturator nerve block, the needle is walked off the inferior pubic ramus in a medial and cephalad direction until it passes into the obturator canal.
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 spread of local anesthetic behind the fascia iliaca.

Side Effects and Complications
Intravascular injection and hematoma are possible because of the proximity of the femoral artery. Anatomically, the 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. Nerve damage is rare.

LATERAL FEMORAL CUTANEOUS NERVE BLOCK
The lateral femoral cutaneous nerve (L2 and L3) emerges at the lateral border of the psoas muscle immediately caudad to the ilioinguinal nerve. It descends under the iliac fascia to enter the thigh deep to the inguinal ligament 1 to 2 cm medial to the anterior superior iliac spine. The nerve emerges from the fascia lata 7 to 10 cm below the spine and divides into anterior and posterior branches. The skin of the lateral portion of the thigh from the hip to midthigh is supplied by the posterior branch; the anterior branch supplies the anterolateral thigh to the knee.

Clinical Applications
The lateral femoral cutaneous nerve block is useful for skin graft harvesting and can be used in concert with other peripheral nerve blocks for complete anesthesia of the lower extremity.

Technique
A point is marked 2 cm medial and 2 cm caudal to the anterior superior iliac spine. A 22-gauge, 4-cm needle is advanced perpendicular to the skin entry site until a sudden release indicates passage through the fascia lata. As the needle is moved in a fanlike pattern laterally and medially, 10 to 15 mL of solution is injected, depositing local anesthetic above and below the fascia (see Fig. 57-17, A). Although a sensory nerve, the lateral femoral cutaneous nerve can be localized using a nerve stimulator technique by seeking pulsatile tingling in the distribution of the nerve.77

Side Effects and Complications
There is an infrequent risk of associated complications because there are no large blood vessels near this nerve. In addition, the likelihood of rapid uptake or intravascular injection is low.

SAPHENOUS NERVE BLOCK
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 using both a transsartorial (above the knee) and paravenous (below the knee) approach.78 Ultrasound guidance can be used for both techniques. The saphenous nerve can also be blocked at the level of the ankle and will be described as part of the ankle block.

Anatomy
The saphenous nerve is a cutaneous sensory branch off the posterior division of the femoral nerve. 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 tibia, posterior to the great saphenous vein. The saphenous nerve is located approximately 1 cm medial and 1 cm posterior to the saphenous vein at the level of the tibial tuberosity.

Technique
The saphenous nerve is purely sensory; therefore, a field block technique is most common. Ultrasound guidance can also be used to identify the neural and vascular structures.

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%.

Transsartorial Approach. The sartorius muscle is palpated on the medial side of the leg, just cephalad to the patella. At the upper pole of the patella, a 22-gauge, 5-cm needle is advanced 45 degrees from the coronal plane, through the muscle belly of the sartorius until a fascial pop is noted. Approximately 5 to 10 mL of local anesthetic is injected. Success rates for this technique range from 70% to 80%.

Ultrasound Guided. Ultrasound-guided saphenous nerve block can be performed either above or below the knee. For the transsartorial technique, the nerve can be found lying medial to the vastus medialis muscle within the fascia.

Side Effects and Complications
The risks of complications with this block are low, although the same theoretical risks all regional anesthetic techniques apply to this block. Given that the great saphenous vein is used as a landmark for the field block technique, minor hematoma formation is not uncommon.

OBTURATOR NERVE BLOCK
The obturator nerve is derived primarily from the third and fourth lumbar nerves, with an occasional minor
PARASACRAL BLOCK

Parasacral block will consistently block both components of the sciatic nerve and the posterior cutaneous nerve of the thigh. Spread of local anesthetic may also anesthetize other branches of the sacral plexus including the superior and inferior gluteal and pudendal nerves. The pelvic splanchnic nerves (S2-S4), the terminal portion of the sympathetic trunk, the inferior hypogastric plexus, and the obturator nerve all lie in close proximity to the elements of the sacral plexus and can all be anesthetized with this approach.81

Clinical Applications

For procedures about the knee, the parasacral block can provide an advantage over more distal approaches to the sciatic nerve because of the block of both the sciatic and posterior cutaneous nerves, particularly if a tourniquet is used. For procedures below the knee, the adductor weakness from the obturator and superior gluteal nerve block may actually be disadvantageous for mobilization of the patient. This technique is also useful when immediate access to the individual nerves of the sacral plexus is not possible, such as owing to trauma or infection.

Technique

This approach is based on the bony relationship of the posterior superior iliac spine and the ischial tuberosity. The patient is positioned laterally with the side to be blocked uppermost. The most prominent aspects of the posterior superior iliac spine and the ischial tuberosity are identified, and a line is drawn joining these two points. Along the line, a mark is made at 6 cm inferior to the posterior superior iliac spine, defining the needle insertion site (Fig. 57-18). A 21-gauge, 10-cm, insulated needle is advanced in a sagittal plane until an evoked motor response is elicited, typically at a depth of 5 to 7 cm from the skin. Once the needle is placed properly, 20 to 30 mL of local anesthetic is injected slowly and incrementally. Plantar flexion of the foot (tibial nerve component) or dorsiflexion (common peroneal nerve) is an acceptable motor response. Because of the proximal nature of the block, a hamstring motor response also is acceptable.

Complications

Because the sacral nerves represent the parasympathetic portion of the autonomic nervous system, sympathetic blockade and its potential for hypotension are not seen with transsacral block unless excessive volumes of solution spread proximally to the lumbar sympathetic fibers. Loss of parasympathetic function to bowel, bladder, and sphincters can occur.82 Injection of local anesthetic through misdirected needles into the subarachnoid or vascular compartments is a remote risk. Classically, the dural sac terminates at the lower border of S2; however, there are clinical reports of subarachnoid puncture with a 6- to 7-cm caudal needle to suggest individual variations below this “classic” location. Finally, an appreciation of the pelvic contents, especially colon, rectum, and bladder, is important. Should a deeply inserted needle enter the colon or rectum and not be noticed, it can result in contamination of the sacral canal.

SCIATIC NERVE BLOCK

The sciatic nerve (L4 and L5, S1 through S3) is the largest of the four peripheral nerves of the lower extremity,
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with a width of 2 cm as it leaves the pelvis with the posterior cutaneous nerve of the thigh. The sciatic nerve is composed of two nerves bound by a common sheath of connective tissue; the tibial component is medial and anterior, and the common peroneal component is lateral and slightly posterior. After passing through the sacrosciatic foramen beneath the piriformis muscle, it lies between the greater trochanter of the femur and the ischial tuberosity. The nerve becomes superficial at the lower border of the gluteus maximus muscle, where it begins its descent down the posterior aspect of the thigh to the popliteal fossa. The nerve supplies cutaneous innervation to the posterior aspect of the thigh and the entire leg and foot below the knee, except a thin medial strip supplied by the saphenous nerve.

Clinical Applications

Because of its wide sensory distribution, the sciatic nerve block can be used, together with a saphenous or femoral nerve block, for any surgical procedure below the knee that does not require a thigh tourniquet. It can also be combined with other peripheral nerve blocks to provide anesthesia for surgical procedures involving the thigh and knee. This form of anesthesia avoids the sympathectomy associated with neuraxial blocks and therefore may be advantageous when any shift in hemodynamics could be deleterious, such as in patients with severe aortic stenosis.

Technique

Classic (Posterior) Approach of Labat. For the classic (posterior) approach of Labat, the patient is positioned laterally, with the leg to be blocked rolled forward onto the flexed knee as the heel rests on the knee of the dependent nonoperative leg (modified Sims position; Fig. 57-19). A line is drawn to connect the posterior superior iliac spine to the greater trochanter of the femur. A perpendicular line is drawn bisecting the first line and extending 5 cm caudad. A second line is drawn from the greater trochanter to the sacral hiatus. The intersection of this line with the perpendicular line indicates the point of needle entry and falls 3 to 5 cm along the line. A 22-gauge, 10- to 12-cm needle is advanced until a motor response (or paresthesia) is elicited or bone is contacted (Fig. 57-20). Stimulation
of the tibial nerve component produces plantar flexion and inversion of the foot, and common peroneal nerve stimulation produces dorsiflexion and eversion. If bone is encountered, the needle is redirected medially; if blood is aspirated (superior gluteal artery), the needle is redirected laterally. After the needle is placed properly, a total of 20 to 30 mL of local anesthetic is injected.

Subgluteal Approach. With this approach, the patient is positioned laterally in a modified Sims position; the leg to be blocked is rolled forward onto the flexed knee as the heel rests on the knee of the dependent (nonoperative) leg. This approach is based on the bony relationship to the greater trochanter and the ischial tuberosity. The most prominent aspects of the greater trochanter and the ischial tuberosity are identified by palpation, and a line is drawn joining these two points. A perpendicular line is drawn bisecting this line and extending 4 to 6 cm caudad. The second line approximates the location of the sciatic nerve. The site of the needle insertion can be at the intersection of the two lines or as far as 6 cm distally along the second line. A 21-gauge, 10- to 12-cm needle is inserted perpendicularly and advanced until a tibial or peroneal motor response (or paresthesia) in the ankle or foot is elicited, and 20 to 30 mL of local anesthetic is injected incrementally (Fig. 57-21). If no response is elicited, the needle can be redirected 1 to 2 cm medially or laterally to the original direction of the needle. It may be helpful to palpate or visualize the groove on the posterior aspect of the thigh. If bony contact is made, the needle is withdrawn and redirected medially.

Ultrasound Guided. A curvilinear probe is placed just distal to the gluteal cleft and scanned lateral to medial. The sciatic nerve can be identified as a flat hyperechoic structure medial to the greater trochanter and lateral to the hyperechoic border of the ischial tuberosity. The needle is advanced in an out-of-plane approach towards the sciatic nerve (see also Chapter 58).

Anterior Approach. The anterior approach is useful when the patient cannot be positioned for the classic posterior approach because of pain. With the patient in the supine position, a line drawn along the inguinal ligament from the anterior superior iliac crest to the pubic tubercle is trisected. A second line parallel to the inguinal ligament is drawn, beginning at the tuberosity of the greater trochanter. The intersection of this second line with the more medial of the perpendicular lines represents the point of needle entry. A 22-gauge, 10.5- to 12-cm needle is inserted perpendicularly with a slightly lateral angulation at the point where the line representing the juncture of the middle and medial thirds crosses the second line. The needle is advanced until it contacts bone, the lesser trochanter of the femur (Fig. 57-22). The needle is redirected medially past the femur, and a paresthesia or nerve stimulator response is sought at a depth of about 5 cm past the bone. A total of 20 to 25 mL of solution is injected incrementally after careful aspiration.

Other Approaches. The sciatic nerve can also be blocked with the patient in the lateral and lithotomy positions, although these are rarely used clinically.

Side Effects and Complications
Serious complications of sciatic nerve block are rare; however, theoretical concerns regarding muscle trauma and puncture of a variety of vascular structures, must be considered. Sciatic nerve block is primarily a somatic nerve block. It does carry some sympathetic fibers to the extremity,
however, and may therefore allow pooling of small quantities of blood that is usually insufficient to cause significant hypotension. On some occasions, such as limb reimplantations and sympathetically mediated pain conditions, this sympathetic block may be advantageous. Residual dysesthesias for periods of 1 to 3 days are not uncommon, but usually resolve within several months.\textsuperscript{72,86} Importantly, many orthopedic surgical procedures (including total hip and knee replacement) are associated with neuropraxia to one or both components of the sciatic nerve. Thus, thoughtful application of this technique is required to optimize neurologic outcome for patients considered to be at high risk of perioperative nerve injury from surgery or preexisting neurologic dysfunction.

**POPLITEAL FOSSA BLOCK**

The posterior muscles of the thigh are the biceps femoris, the semimembranosus, semitendinosus, and the posterior portion of the adductor magnus. As these muscles are traced distally from their origin on the ischial tuberosity, they separate into medial (semimembranosus, semitendinosus) and lateral (biceps) musculature, and they form the upper border of the popliteal fossa. The lower border of the popliteal fossa is defined by the two heads of the gastrocnemius. In the upper part of the popliteal fossa, the sciatic nerve lies posterolateral to the popliteal vessels. The popliteal fossa is defined by the two heads of the gastrocnemius. In the upper part of the popliteal fossa, the sciatic nerve lies posterolateral to the popliteal vessels. The popliteal vein is medial to the nerve, and the popliteal artery is most anterior, lying on the popliteal surface of the femur. Near the upper border of the popliteal fossa, the two components of the sciatic nerve separate. The peroneal nerve diverges laterally, and the larger tibial branch descends almost straight down through the fossa. The tibial nerve and popliteal vessels then disappear deep to the converging heads of the gastrocnemius muscle.
Clinical Applications

This block is chiefly used for foot and ankle surgery. Popliteal fossa block is preferable to ankle block for surgical procedures requiring the use of a calf tourniquet. The components of the sciatic nerve may be blocked at the level of the popliteal fossa through posterior or lateral approaches. Supplemental block of the saphenous nerve is required for surgical procedures to the medial aspect of the leg or when a calf tourniquet or Esmarch bandage are used.

Technique

**Posterior Approach: Peripheral Nerve Stimulation or Paresthesia.** The classic approach to the popliteal fossa is posteriorly, with the patient positioned prone. However, access can also occur with the patient in the lateral position (operative side nondependent) or supine position (with leg flexed at the hip and knee).

The borders of the popliteal fossa are identified by flexing the knee joint. A triangle is constructed, with the base consisting of the skin crease behind the knee, and the two sides composed of the semimembranosus (medially) and the biceps (laterally). A bisecting line is drawn from the apex to the base of the triangle, and a 5-cm needle is inserted at a site 5 to 10 cm above the skin fold and 0.5 to 1 cm lateral to the bisecting line (Fig. 57-23, A). Classically, the 5-cm distance was described; however, in an attempt to block the sciatic nerve before its division, a 7- to 10-cm distance has been recommended. The needle is advanced at a 45-degree angle until a motor response (or paresthesia) is elicited. With a nerve stimulator technique, inversion is the motor response that best predicts complete neural block of the foot. Injection of approximately 30 mL of local anesthetic solution is sufficient.

The success rate is typically 90% to 95%. No formal comparison between paresthesia and nerve stimulator techniques has been performed to assess efficacy and complications. It is believed that incomplete block is the result of poor diffusion (because of the size of the sciatic nerve), the separate fascial coverings of the tibial and peroneal nerves, or blockade of only a single component of the sciatic nerve. Identification of the tibial and peroneal components decreases onset time and improves the success rate.

![Figure 57-23.](image)

**Figure 57-23.** A, Anatomic landmarks for the posterior approach to the sciatic nerve in the popliteal fossa. B, Anatomic landmarks for the lateral approach to the sciatic nerve in the popliteal fossa.
Ultrasound Guided. The use of ultrasound can help identify the point of divergence of the sciatic nerve into the peroneal and tibial branches. Blockade at this level allows for a single (rather than a double) injection with comparable success90 (see Figs. 57-23 and 57-24).

Lateral Approach. A lateral approach to blockade of the sciatic nerve in the popliteal fossa has been described.91 Although block time is somewhat longer, onset and quality of block are similar to the posterior approach.92 The lateral approach allows the patient to be positioned supine and eliminates the need for repositioning. The patient’s leg is extended, with the long axis of the foot at a 90-degree angle to the table. The site of insertion is the intersection of the vertical line drawn from the upper edge of the patella and the groove between the lateral border of the biceps femoris and vastus lateralis. A 10-cm needle is advanced at a 30-degree angle posterior to the horizontal plane (see Fig. 57-23, B). Because the common peroneal nerve is located lateral to the tibial nerve, the stimulating needle often encounters the common peroneal nerve first with the lateral approach. As with the classic posterior approach, a tibial response is sought.93 If a response associated with common peroneal nerve stimulation (e.g., eversion) is elicited, the needle is redirected more posteriorly.

Side Effects and Complications
Intravascular injection can occur because of the presence of vascular structures within the popliteal fossa. Performance of popliteal fossa block in patients with previous total knee arthroplasty or vascular bypass (femoral-popliteal) obviously should be performed extremely carefully. However, there have been no cases of graft disruption or joint infections related to needle placement in these patients.

NERVE BLOCKS AT THE ANKLE
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 posterior tibial, sural, superficial peroneal, and deep peroneal branches. The sciatic nerve divides at or above the apex of the popliteal fossa to form the common peroneal and tibial nerves. The common peroneal nerve descends laterally around the head of the fibula, where it divides into the superficial and deep peroneal nerves.

The tibial nerve divides into the posterior tibial and sural nerves in the lower leg. The posterior tibial nerve becomes superficial at the medial border of the Achilles tendon near the artery of the same name, and the sural nerve emerges laterally to the Achilles tendon.

Clinical Applications
Ankle blocks are simple to perform and offer adequate anesthesia for surgical procedures of the foot not requiring a tourniquet above the ankle.

Technique
Posterior Tibial Nerve. The posterior tibial nerve can be blocked with the patient in either the prone or the supine positions. The posterior tibial artery is palpated, and a 25-gauge, 3-cm needle is inserted posterolateral to the artery at the level of the medial malleolus (see Fig. 57-24, A, 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 back from the posterior aspect of the tibia. Blockade of the posterior 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 posterior tibial nerve can shorten onset time94 (Fig. 57-25).

Sural Nerve. 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 (Fig. 57-26, A, C). 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 Nerves. The deep peroneal, superficial peroneal, and saphenous nerves can be blocked through a single needle entry site (see Fig. 57-26). 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 pulsation between the two tendons on the intermalleolar line. A 25-gauge, 3-cm needle is advanced perpendicular to 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 some techniques, resulting in discomfort for the patient. Persisting paresthesias can occur, but they are self-limited. The presence of edema or induration in the area of the ankle block can make palpation of landmarks difficult. Intravascular injection is possible but unlikely if aspiration for blood is negative. The volume of local anesthetic used is small, thereby decreasing the risk of local anesthetic toxicity.

CONTINUOUS CATHETER TECHNIQUES

The advantages cited for continuous nerve blockade include prolongation of surgical anesthesia, decreased risk of toxicity because of lower incremental doses, and 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. 57-27).95 Although concern regarding accurate catheter placement and maintenance still exists, the use of stimulating catheters and radiographic confirmation may further improve the functionality.96 Overall, continuous peripheral nerve block provides superior analgesia compared with conventional opioid therapy. Minor technical problems such as catheter kinking, displacement...
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24 hours often occurs with long-acting local anesthetics important (see Chapter 36). Prolonged blockade for up to the surgical procedure, although other factors are also calculated for each patient and should be kept within safe limits (see Chapter 36 for details).

The choice of local anesthetic for a peripheral nerve obviously depends on some degree on the duration of the surgical procedure, although other factors are also important (see Chapter 36). Prolonged blockade for up to 24 hours often occurs with long-acting local anesthetics such as bupivacaine or ropivacaine. Although this feature results in superb postoperative pain relief for the inpatient, it may be undesirable for the ambulatory patient 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 in the outpatient setting (see Chapter 89). Whatever drug is chosen, the total dosage should be kept within safe limits (see Chapter 36 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 clonidine, opioids, and ketamine, have been reported to enhance or prolong local anesthetic peripheral nerve blockade.41,64

**COMPPLICATIONS**

Nerve injury is a recognized complication of peripheral neural blockade. Although needle gauge, type (i.e., short versus 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 imaging would allow a high success rate without increasing the risk of neurologic complications, but this has not been established.11

**CHOICE OF LOCAL ANESTHETIC**

The choice of local anesthetic for a peripheral nerve block obviously depends on some degree on the duration of the surgical procedure, although other factors are also important (see Chapter 36). Prolonged blockade for up to 24 hours often occurs with long-acting local anesthetics such as bupivacaine or ropivacaine. Although this feature
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.100

Hemorrhagic complications have been described with nearly every peripheral technique and range from localized bruising and tenderness to severe hematomas or hemorrhagic complications. Patients who are receiving hemostasis-altering medications (e.g., low-molecular-weight heparin, warfarin, antiplatelet or antithrombotic medications) are at the highest risk. The risk of hematoma in anticoagulated patients undergoing peripheral nerve blockade is less clear than the risk of spinal hematoma in anticoagulated patients undergoing neuraxial blockade. 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 (lumbar plexus) or in a location where a hematoma could compress the airway (interscalene).73

Infectious complications can be caused by exogenous (contaminated medication or equipment) or endogenous sources.101 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.97

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.

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, depending on the type of block.99 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 will 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 a lipid infusion improves success of resuscitation from cardiac arrest due to local anesthetic toxicity if given immediately after a local anesthetic overdose.102

**SUMMARY**

It is possible to perform all surgical procedures while the patient is under general anesthesia, but the addition of peripheral nerve block techniques adds flexibility and skills that 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 64 and 98).

Complete references available online at expertconsult.com
References

