CHAPTER 31

Regional Anesthesia for Pediatric Orthopaedic Surgery

SANTHANAM SURESH/ADRIAN T. BÖSENBERG

INTRODUCTION

Regional anesthesia is commonly used as an adjunct to general anesthesia and plays a key role in the multimodal approach to perioperative pain management in children. Its use in pediatric orthopaedic surgery is gaining in popularity, despite concerns from some orthopaedic surgeons that the profound analgesia offered may mask ischemic pain of compartment syndromes.

The worldwide trend toward more day-case surgery and the associated advantages offered has increased the use of regional anesthetic techniques. Furthermore, the advent of more complex and innovative surgical procedures in children has improved outcome but also led to more invasive surgery and consequently more pain in the postoperative period. These factors have provided the impetus for the development of continuous peripheral nerve block techniques that target the site of surgery in both children and adolescents.

The practice of peripheral nerve blockade continues to improve with the development of age-appropriate equipment and the introduction of safer long-acting local anesthetic agents such as ropivacaine and levobupivacaine. Although caudal blockade remains the most popular and frequently used block in infants and small children, the safety of peripheral nerve blocks has been established in large-scale prospective studies in children. Peripheral nerve blocks have consequently been recommended, rather than central neuraxial techniques, where appropriate. The majority of peripheral nerve blocks are performed in the operating room by experienced anesthesiologists, but there are several blocks, such as femoral nerve or digital block, that may be done in the emergency room or even the intensive care unit.

The purpose of this chapter is to outline some methods used to identify and block individual nerves and to consider regional anesthetic techniques that can be used for surgical procedures of the upper and lower limbs in children. The choice of technique may be dictated by the pathology, the extent of surgery, the child’s body habitus, and the presence of contractures. The differences between adults and children are highlighted, together with techniques to improve the success of blocks.

METHODS TO IMPROVE THE ACCURACY OF PERIPHERAL NERVE BLOCKS

Peripheral nerve blocks, particularly in young children, can be difficult. Anatomic landmarks are poorly defined and vary according to the stage of the child’s development, particularly in those with limb defects. The successful placement of peripheral nerve blocks requires an awareness of these differences, knowledge of developmental anatomy, and an understanding of the equipment used. For most of the blocks presented in this chapter, the use of an insulated needle and peripheral nerve stimulator is recommended although successful blocks may also be achieved with noninsulated needles.

Given the difficulty in obtaining cooperation, particularly in young infants, most children are sedated or under...
general anesthesia when nerve blocks are performed. Caution must therefore be exercised while placing the blocks, since paresthesias and pain cannot be elicited.

**Nerve Stimulator**

A number of basic principles need to be emphasized regarding the use of a nerve stimulator (see Chap. 19). In order to locate a peripheral nerve or plexus accurately, neuromuscular blocking agents should be withheld until after completion of the nerve block. The proper functioning of the nerve stimulator, according to the manufacturer’s recommendations, should be understood before it is used. With the many peripheral nerve stimulators currently on the market, it is best to familiarize oneself thoroughly with one particular model and to stick with it.

The negative electrode should be attached to the needle and the positive electrode attached to the patient with a standard electrocardiographic (ECG) skin attachment. Once the appropriate landmarks have been determined or “surface mapped” and the peripheral nerve stimulator initially set at 1 to 1.5 mA, 100 to 300 µs, and 1 to 2 Hz, the needle should be advanced through the skin and underlying tissue planes until appropriate distal muscle contractions are elicited. The current output should then be decreased and the needle moved until a brisk motor response is elicited with the least amount of current; i.e., 0.3 to 0.5 mA. The appropriate dose of local anesthetic should be injected at this point. If the needle is correctly placed, the muscle contractions will immediately cease, indicating that a successful block is likely. Failure to elicit this response requires the needle to be repositioned before repeating the process. At this stage of our knowledge we believe that the local anesthetic should not be injected if intense muscle contractions are elicited at ≤0.2 mA or if there is resistance to injection. Both events suggest that the tip of the needle may be intraneural and that the nerve may be damaged by further injection.

Newer techniques for improving the success of peripheral nerve blocks include surface nerve mapping and ultrasound imaging. Because both methods are particularly useful in small children, who are considered to be a group at greater risk for complications or failure.

**Surface Nerve Mapping**

This is a modification of the standard nerve stimulator technique. The path of a superficial peripheral nerve or plexus can be traced before skin penetration by stimulating the motor component of the nerve transcutaneously. The nerve stimulator’s output is set at 2 to 5 mA at 1 to 2 Hz and the negative electrode is used as the mapping electrode. The current required varies and depends on the depth of the nerve and the moistness of the overlying skin. The point at which the appropriate muscle responses are strongest is marked and used as the landmark for that specific nerve block.

Direct muscle stimulation is finer and more localized and should be recognized as a “false positive” response. Excessive pressure applied over the nerve may inhibit the response. The nerve-mapping technique may be used for various approaches to the brachial plexus as well as for axillary, musculocutaneous, ulnar, median, and radial nerve blocks of the upper limb and femoral, sciatic, and popliteal nerve blocks in the lower limb. Surface nerve mapping is particularly useful when classic anatomic landmarks are absent or difficult to define; for example, in children with arthrogryposis or those with major congenital limb defects.

**Ultrasound Imaging**

Ultrasound is becoming an important adjunct to regional anesthesia. Ultrasoundography is noninvasive, relatively inexpensive, and being used to improve the accuracy of local anesthetic placement. Technological advances have allowed the development of small portable ultrasound equipment that can be taken into the operating theater. Finally, the technique is easily taught.

There are a number of reasons why ultrasonography may be of greater value in pediatric regional anesthesia. In the sedated or anesthetized child, direct visualization of the nerve or neuraxial structures, vessels, tendons, and bones and placement of the local anesthetic is possible. Since, in children, most peripheral nerves lie within range of portable ultrasound probes, good definition can be achieved. Using real-time imaging, ultrasound can verify correct needle and local anesthetic placement around the nerve and reduce the risk of intraneural or intravascular injection. The position of continuous catheters can also be confirmed.

Proponents of ultrasound guidance claim earlier onset times, improved quality and duration of block with smaller volumes of local anesthetic, and fewer complications in children. To date, the use of ultrasound in pediatric regional anesthesia is limited but gaining in popularity, particularly in Europe.

**REGIONAL ANESTHESIA FOR THE UPPER EXTREMITY**

The motor and sensory innervation of the whole upper extremity is supplied by the brachial plexus with the exception of part of the shoulder, which is innervated by the cervical plexus, and the sensory innervation to the medial aspect of the upper arm, which is supplied by the intercostobrachial nerve, a branch of the second intercostal nerve.

** Anatomy of the Brachial Plexus**

The anterior primary rami of C5-8 and the bulk of T1 form the brachial plexus (Fig. 23-1). These five roots emerge.
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from the intervertebral foramina to lie between the scalenus anterior and scalenus medius muscles (which attach to the anterior and posterior tubercles of the transverse process of the cervical vertebrae, respectively). The fascia from these muscles encloses the plexus in a sheath that extends laterally into the axilla. A single injection of local anesthetic within this sheath produces complete plexus blockade by blocking the trunks (supraclavicular approaches) or the cords (infraclavicular approaches).

As the five spinal roots pass between the scalene muscles, they unite to form three trunks: upper C5-6, middle C7, and lower C8-T1 (Fig. 23-4). Emerging from the interscalene groove, the three trunks pass downward and laterally to lie posterolaterally to the subclavian artery as it cross the upper surface of the first rib. The subclavian artery is not as easily palpable above the clavicle in children as it is in adults. At the lateral border of the first rib, each trunk divides into anterior and posterior divisions, which then join to form the three cords, named according to their relationship to the axillary artery: lateral, medial, and posterior. These cords then divide into the nerves of the brachial plexus: musculocutaneous, ulnar, median, and radial (see Chaps. 23 and 24).

Many anatomic landmarks used in adults may be difficult to find in children of different ages, particularly if they are sedated or under anesthesia.9 The younger the child is, the poorer the definition of the muscular landmarks. The interscalene groove is difficult to delineate because the scalenus muscles are poorly developed. The subclavian artery is seldom palpable in the supraclavicular region in infants and preadolescent children.

The brachial plexus can be blocked at various levels.9 The choice of a particular technique is based on the planned surgical procedure, the experience of the anesthesiologist, the presence of contractures, and the potential benefits for the patient, which may include placing a catheter for continuous infusions.

The infraclavicular and the axillary approaches are considered safer and easier for the placement and fixation of an indwelling catheter for continuous peripheral nerve blocks. Although the use of the interscalene approach has been reported for shoulder surgery and for elbow surgery in children,9 it should be used with caution in children because of the increased risk of intravascular or intrathecal injection or temporary phrenic nerve palsy.

**Axillary Approach to the Brachial Plexus**

The axillary block is the most popular approach in children.9-12 It is relatively safe and provides good analgesia for surgery of the forearm and hand. The primary advantages of this block are its easy placement and low risk of complications. Its main limitations are incomplete block of the shoulder and lateral aspect of the forearm onto the thenar eminence (sensory distribution of the musculocutaneous nerve). It may be used for a variety of procedures on the forearm (particularly on the medial aspect) and hand, such as open reduction with internal fixation of a forearm fracture or the repair of congenital anomalies (syndactyly) of the hand (see Chap. 15).12 Vascular insufficiency, finger reimplantation, or closed reduction of forearm fractures (see Chap. 16).11

**Axillary Perivascular Approach**

The patient is positioned supine with the arm abducted 90 degrees, elbow flexed, and hand behind the head. The landmarks are the pectoralis major and coracobrachialis muscles and the axillary artery. Surface nerve mapping, ultrasound, or a nerve stimulator may be used to aid in the correct placement of the block. The dose of local anesthetic is 0.2 to 0.3 mL/kg 0.25 to 0.5% bupivacaine, ropivacaine, or levobupivacaine. Lower concentrations will reduce the degree of motor block if required.

**Technique**

Palpate the axillary artery in the tissues overlying the humerus at the junction of the lower border of pectoralis major and coracobrachialis muscles or as high as possible in the axilla. The nerve stimulator output is set at 1 mA. An insulated needle should be introduced immediately superior to the axillary arterial pulsation at a 45- to 60-degree angle to the skin and directed parallel to the artery or toward the midpoint of the clavicle. Muscle twitches are usually elicited in the areas of median or radial nerve distribution (rarely in the ulnar nerve) as the plexus sheath is penetrated. The output of the nerve stimulator should then be gradually reduced to approximately 0.3 to 0.4 mA while the muscle twitch is maintained by adjusting the position of the needle as needed. Local anesthetic solution can then be injected.

Alternatively, a nerve stimulator set at 3 to 5 mA can be used to map the median, radial, and or musculocutaneous nerve transcutaneously in the axilla on either side of the arterial pulsation. An insulated needle should be inserted at the point where the stimulator causes maximum muscle twitches.

Multiple injection techniques have been described in both adults and children. There is little advantage to multiple injections in children because the loose fascial attachments allow the even spread of the anesthetic. A single-injection can provide adequate blockade of the brachial plexus.

As the local anesthetic solution fills the sheath, a longitudinal swelling may become visible beneath the skin, but it should disappear quickly as the solution spreads proximally. Distal pressure may be applied during and immediately following injection, while the arm should be adducted to release the pressure from the head of the humerus from the fossa in order to facilitate the proximal spread of the solution and facilitate blockade of the musculocutaneous nerve.
The musculocutaneous nerve may be blocked separately to provide reliable analgesia for procedures that involve the lateral forearm (lateral cutaneous nerve of forearm). This should be done by advancing a needle introduced perpendicularly to the skin, just above the axillary artery pulsation, into the coracobrachialis muscle until forearm flexion is elicited by using a nerve stimulator. Then 0.5 to 1 mL of local anesthetic solution should be injected just deep to the fascia.

When long-term pain relief or relief of chronic pain is required, a catheter can be introduced into the axilla for the continuous infusion of a local anesthetic. The immobilization, fixation, and dressing of these catheters are rather difficult in the axilla, but this may be overcome by tunneling the catheter medially onto the chest or laterally over the deltotoid area. After the initial block dose, an infusion rate of 0.2 to 0.4 mg/kg/h should be adequate.

Complications of axillary block are rare but include hematoma from accidental vascular puncture. If the artery is inadvertently punctured, pressure should be applied for at least 5 min to avoid possible vascular insufficiency due to compressive hematoma formation.

Transarterial Approach
The transarterial approach, traditionally used in adults, is not popular for children but is included here for completeness. Proponents of this approach claim greater success with posterior cord (musculocutaneous) blockade. Among the reasons for avoiding the transarterial approach in children is the fact that most soft tissue surgery of the upper extremity (e.g., syndactyly, replants) is vascular in nature; hence it is important to avoid vascular insufficiency caused by vessel spasm or hematoma formation.

The risk of toxicity is also high in children, and even relatively small volumes may produce toxic effects. The detection of intravascular injection and toxicity under general anesthesia is difficult but may be detected by transient changes in the heart rate or ECG. These include changes in the amplitude of T waves or ST segments when using a local anesthetic solution containing epinephrine (usually 1:200,000).

Infraclavicular Approach
The patient’s position is supine with a pillow under the shoulders, the arm extended alongside the body, and the head turned to the opposite side. The landmarks are the midpoint of the clavicle, coracoideus process of the scapula, and axillary artery as it emerges beneath the clavicle. A nerve stimulator, surface mapping, and ultrasound can aid correct placing.

The dose of local anesthetic can be 0.2 to 0.3 mL/kg 0.5% bupivacaine, 0.5% ropivacaine, or 0.5% levobupivacaine. Lower concentrations may reduce the degree of motor block.

Technique
Safety considerations have steered practitioners away from the supraclavicular approach in order to reduce the risk of pneumothorax. A number of infracclavicular approaches have been described. With the child correctly positioned, the clavicle is divided visually into three parts. A mark should be made at the point where the arterial pulsation is felt as it emerges below the clavicle or where any distal flexion or pronation is “mapped” with a nerve stimulator. An insulated needle should be inserted infracclavicularly at the junction of the middle and lateral thirds of the clavicle and directed toward this mark. The needle passes lateral to the cupola of the lung and has little chance of encountering the lung along its course. Pronation or flexion at the elbow should be sought. Once the nerve is located, the nerve stimulator’s current should be reduced to 0.2 to 0.3 mA.

Alternatively, the needle can be inserted at the midpoint of the lower border of the clavicle at a 45-degree angle and directed toward the axilla in the same manner until distal muscle twitches are elicited. A vertical infracervical approach using the coracoid process as a landmark has been described in children. The site of puncture is 1 to 2 cm caudal and 0.5 to 1 cm medial to the coracoid process in the lower part of the deltoid groove. An insulated needle should be inserted perpendicular to the skin until distal muscle twitches are elicited. The brachial plexus may be difficult to locate in some patients, and an ultrasound-guided approach has been recommended. Proponents of this technique claim more effective sensory and motor block than with the axillary approach.

When long-term pain relief or relief of chronic pain is necessary, a catheter for continuous infusion of a local anesthetic solution can be used. Immobilization and fixation of these catheters to the chest is easier than in the axilla, and tunneling is seldom required.

Supraclavicular Approach
The patient’s position is supine, with a pillow under the shoulders, the arm extended alongside the body, and the head turned to the opposite side.

The landmarks are the midpoint of the clavicle, the transverse process of C6 (Chassaignac’s tubercle), the posterior border of the sternoclidomastoid muscle, and the cricoid cartilage.

Surface nerve mapping, nerve stimulator, or ultrasound will aid placement.

The dose of local anesthetic may be 0.2 to 0.3 mL/kg of 0.5% bupivacaine, 0.5% ropivacaine, or 0.5% levobupivacaine; lower concentrations may reduce the degree of motor block.
Technique

Although the reported incidence of pneumothorax in children is low,22 the fear of this complication remains high among most pediatric practitioners. The supraclavicular approach is indicated for all upper extremity surgery, but particularly so if the shoulder is involved. With the patient correctly positioned, the components of the brachial plexus become more superficial and are easily palpable in most children. The site of puncture should be at the junction of the middle third and the lower third of a line joining Chassaignac’s tubercle to the midpoint of the clavicle22 (if Chassaignac’s tubercle cannot be palpated, a line extending from the cricoid cartilage to posterior border of sternocleidomastoid should suffice).

Alternatively, an insulated needle can be inserted perpendicularly to the skin at the stimulation site where the strongest distal muscle contractions (usually flexion or extension at the elbow) can be evoked or simply over the point where the brachial plexus can be palpated subcutaneously with the patient in the supine position.

The success rate is high, but complications caused by faulty technique include pneumothorax, vascular puncture, Horner’s syndrome, and phrenic nerve palsy.7 Nerve damage is possible with injudicious injection against resistance, but the possibility of surgical damage should always be excluded.

When long-term pain relief or relief of chronic pain is necessary, a catheter for the continuous infusion of a local anesthetic solution can be inserted.21 Immobilization and fixation of the catheter can be achieved by tunneling subcutaneously to the chest or shoulder.

Blocks at the Elbow

A single nerve or combination of nerves can be blocked at the elbow to provide analgesia distally. These blocks are particularly useful for pain relief after operations on the forearm or hand without the risks associated with brachial plexus blocks. Four nerves—the median, radial, ulnar, and musculocutaneous nerves—can be located at the elbow. These can be found by surface mapping, using a nerve stimulator capable of generating about 5 mA, as described previously. Once the surface landmark has been mapped, the nerve can be located and blocked using a nerve stimulator and a sheathed needle, thus avoiding multiple skin punctures and reducing the risk of nerve injury.

Median Nerve

The patient’s position is supine with the arm extended and the elbow slightly flexed to accentuate the tendons of the biceps and the brachioradialis. The landmarks are the cubital fossa, brachial artery, and biceps tendon. Surface nerve mapping, ultrasound, or a nerve stimulator can aid placement of the block. The median nerve in the cubital fossa is located medial to the brachial artery and the biceps tendon beneath the deep fascia.

After the median nerve has been located, an insulated needle should be inserted medial to the pulsation of the brachial artery. Pronation of the arm with opposition of the fingers is noted when the median nerve is stimulated. The anesthetic dose is 1 to 2 mL of 0.25 to 0.5% bupivacaine, ropivacaine, or levobupivacaine. The indications for this block are surgery on the volar aspect of the forearm and the palmar portion of the hand. Potential complications include hematoma, paresthesias, and intravascular injection.

Ulnar Nerve

The patient’s position is supine, with the elbow flexed 90 degrees, the arm on the chest, and the hand on the opposite shoulder. The landmark is the olecranon groove, and surface mapping, ultrasound, or nerve stimulator aids placement.

The ulnar nerve lies in the groove posterior to the medial condyle of the humerus midway between the olecranon and the medial epicondyle. The anesthetic dose is 1 to 2 mL of 0.25 to 0.5% bupivacaine, ropivacaine, or levobupivacaine. Indications for this block are surgery in the ulnar distribution of the hand, including the medial aspect of the hand and fingers. The ulnar nerve can easily be blocked at the olecranon groove. A small volume of 0.25% bupivacaine with 1:200,000 epinephrine is injected into the area. Complications are nerve injury and compression of the nerve if an excessive volume of local anesthesia solution is used. Note that the nerve is in a confined space here, and this approach should be used with caution.

Radial Nerve

The patient’s position is supine with the elbow slightly flexed. Landmarks are the biceps tendon and lateral condyle of the humerus. Surface nerve mapping, ultrasound, and the use of a nerve stimulator can aid correct placement. The anesthetic dose is 1 to 2 mL of 0.25 to 0.5% bupivacaine, ropivacaine, or levobupivacaine. The lateral condyle of the humerus and the tendon of the biceps muscle should be identified. The radial nerve lies adjacent to the condyle, lateral to the biceps tendon. With the arm slightly flexed at the elbow, the radial nerve can be stimulated with a mapping probe. Movement of the thumb confirms the location of the radial nerve, and a small volume of local anesthetic can be injected at that point.

Musculocutaneous Nerve

The patient’s arm is either extended or on the abdomen and the landmark is the lateral condyle of the humerus. Surface nerve mapping, ultrasound, or a nerve stimulator can confirm this. The anesthetic dose is 1 to 2 mL of 0.25 to 0.5% bupivacaine, ropivacaine, or levobupivacaine. The musculocutaneous nerve courses superficially along the lateral aspect of the forearm and can easily be...
blocked in this location. A superficial ring of local anesthetic injections (0.1 mL/kg) at the distal end of the lateral condyle of the humerus, along the pronator teres muscle, should block the musculocutaneous nerve. The nerve can be mapped along most of its course.

Wrist Blocks

Analgesia for children undergoing minor surgical procedures of the hand or fingers can be provided by an appropriate nerve block at the wrist. The nerves that can be blocked at this level are the median, ulnar, and radial nerves. Small volumes of local anesthetic (1 to 2 mL) can provide good analgesia for several hours.

Median Nerve

The hand is pronated and the palmaris longus tendon and the volar aspect of the wrist are used as landmarks. Surface nerve mapping aids placement of the block. An anesthetic dose of 0.5 to 1 mL of 0.25 to 0.5% bupivacaine, ropivacaine, or levobupivacaine is used.

The median nerve is the major nerve supplying the hand; most surgical operations of the hand will therefore require a median nerve block at least.

The median nerve is located in a fascial sheath between the palmaris longus tendon and the flexor carpi radialis. Surface nerve mapping with a nerve-stimulating electrode at this point will elicit opposition of the thumb. A bursa that communicates with the neurovascular bundle is located at the ulnar aspect of the palmaris longus tendon. The median nerve can be blocked by injecting local anesthetic into this bursa.

Complications such as carpal tunnel syndrome or injury to the median nerve are rare and can be avoided by using the above technique or restricting the volume of local anesthetic used.

Radial Nerve

The hand is supinated. The landmarks are the anatomic “snuffbox,” styloid process, and radial artery. The anesthetic dose is 1 to 2 mL of 0.25 to 0.5% bupivacaine, ropivacaine, or levobupivacaine.

The radial nerve at the wrist is purely sensory; thus nerve mapping is not possible here. Just above the styloid process, the radial nerve divides into two branches, one supplying the dorsum of the hand and the other supplying the thenar eminence and 1.5 fingers.

The nerve is superficial proximal to the anatomic snuffbox. A wheal of local anesthetic solution should be injected subcutaneously, starting lateral to the radial artery on the lateral aspect of the wrist, using a fine (27-gauge) needle.

Ulnar Nerve

The hand is supinated. The landmarks are the flexor carpi ulnaris tendon and the ulnar artery. Surface nerve mapping and the use of a nerve stimulator aid placement.

The anesthetic dose is 1 to 2 mL of 0.25 to 0.5% bupivacaine, ropivacaine, or levobupivacaine.

The ulnar nerve is located in the palm sheath immediately lateral to the flexor carpi ulnaris tendon but medial to the ulnar artery. Surface nerve mapping with a stimulator at this point will elicit flexion of the little finger. Using a fine needle, 1 to 2 mL of local anesthetic can be injected into the area to provide analgesia for surgery on the ulnar aspect of the hand and the medial 1.5 fingers.

Most lower extremity operations can be performed with a caudal block, the most common block used in children. Some children, particular those of school age, find the altered sensation and bilateral weakness associated with neuraxial blocks disturbing. Peripheral nerve blocks are more specific, can be confined to the site of surgery, and have a longer duration of analgesia. They also avoid the side effects of neuraxial blockade (bilateral motor weakness, urinary retention). For quick discharge, peripheral nerve blocks are therefore better than caudal or other neuraxial blocks.

Anatomy of the Lumbar and Sacral Plexus

The motor and sensory innervation of the lower extremity is supplied by the lumbar plexus and the sacral plexus and is more complex than that of the upper extremity (see also Chap. 29). The lumbar plexus is derived from the anterior primary rami of the lumbar nerves from L1 to L4 with a variable contribution from T12 and L5. It is located anterior to the transverse processes of the lumbar vertebrae within the psoas major muscle. The psoas compartment is bordered posteriorly by quadratus lumborum and anteriorly by psoas major muscles. The femoral nerve, lateral cutaneous nerve of the thigh, and obturator nerve are branches of the lumbar plexus and supply the majority of the upper leg, including the thigh and its lateral aspect (Fig. 31-1). The saphenous nerve, the largest sensory branch of the femoral nerve, provides sensory innervation to the medial aspect of the leg below the knee and to the foot.

The sacral plexus is derived from the anterior primary rami of L5, and S1 to S3 with contributions from L4 and S4. The plexus lies anterior to the piriformis muscle behind the pelvic fascia on the posterior wall of the pelvic cavity. The sciatic nerve, the largest nerve of the body, is derived from the sacral plexus and supplies the knee, the leg, and most of the foot except for the medial aspect supplied by the saphenous nerve. A proximal branch of the sciatic nerve, the posterior cutaneous nerve of the thigh, supplies the posterior aspect of the thigh and the hamstring muscles.
The patient is placed in the lateral position with the hips and knees flexed. The landmarks are the posterolateral iliac spine, intercrystal (Toufiier’s) line, and spinous process L4.

A nerve stimulator and ultrasound aid placement of the block.

The anesthetic dose is 0.5 mL/kg of 0.25 to 0.5% bupivacaine, ropivacaine, or levobupivacaine.

The lumbar plexus can be blocked in the psoas compartment within the psoas muscle at the level of the transverse process of L4. It provides a unilateral block of the thigh or hip for congenital dislocation of hip, thigh for open reduction and internal fixation of femoral fractures, or knee surgery.

**TECHNIQUE**

Several approaches that rely on bone contact with the transverse process of L4 have been described in adults. In children, the transverse process is not fully developed, and using it as a guide places the needle far too medially and increases the risk of spinal anesthesia secondary to puncture of the dural cuff on the spinal roots or retrograde epidural spread to the opposite side.

The approach that should be used in children is a modification of Winnie’s approach. With the child in a lateral position, an insulated needle should be inserted perpendicularly to the skin, where a line drawn from the posterior superior iliac spine parallel to the spinous processes of the vertebrae crosses the intercrystal (Toufiier’s) line. The needle should be advanced through the posterior lumbar fascia, paraspinal muscles, anterior lumbar fascia, quadratus lumborum, and into the psoas muscle. Passage through these fascial layers may be detected by distinct “pops” when a short-beveled needle is used. With a nerve stimulator, quadriceps muscle twitches in the ipsilateral thigh will confirm stimulation of the lumbar plexus. If hamstring contractions are observed, the needle should be directed more laterally; if hamstring and quadriceps contractions are observed simultaneously, the needle should be directed more cephalad to isolate the lumbar plexus rather than the sacral plexus.

The depth from the skin to the lumbar plexus is approximately the same distance as the posterior superior iliac spine is to the intercrystal line. The depth of
the needle is emphasized because of the serious complications associated with wayward needle advancement into the peritoneum or retroperitoneum, which may result in renal hematoma, vascular puncture (retroperitoneal hematoma), or even bowel puncture.

Ultrasound-guided psoas compartment blockade is possible but is limited to younger children. In older children, the definition obtained with portable ultrasound units is inadequate for accurate placement.

If long-term pain relief is required, a catheter can be inserted for continuous infusion of a local anesthetic solution. After the initial block, an infusion rate of 0.2 to 0.4 mg/kg/h should be adequate. Immobilization and fixation of these catheters on the back is simple and subcutaneous tunneling is not usually necessary because the large muscle mass anchors the catheter.

**Femoral Nerve Block**

The position is supine with the foot rotated outward. The landmarks are the femoral pulse and the inguinal ligament. Surface nerve mapping, ultrasound, and a nerve stimulator aid placement. The anesthetic dose is 0.2 to 0.3 mL/kg of 0.25 to 0.5% bupivacaine, ropivacaine, or levobupivacaine.

The femoral nerve blocks is probably the most common peripheral nerve block performed in children, its most useful application being for fractured femurs, where it provides for painless transport, radiographic examination, and application of splints. There are several large studies on the use of femoral nerve blocks, alone or in combination with sciatic nerve or lateral cutaneous nerve of thigh block, for postoperative analgesia in lower limb surgery. For surgical procedures on the knee, the femoral nerve block is best used in combination with a sciatic nerve block.

**DEFINITION**

Femoral nerve blocks are performed either as a single shot or as a catheter block for continuous infusion of a local anesthetic. The femoral nerve is usually blocked at its emergence from the lateral border of the psoas major muscle at the level of the inguinal ligament (Poupart’s ligament) on the anterior superior iliac spine (ASIS) medial to the femoral artery. The femoral nerve arises from the lumbar plexus (L2-L3) and is purely sensory.

**TECHNIQUE**

The femoral nerve may be blocked where it emerges from below the inguinal ligament in the femoral canal lateral to the femoral artery in the femoral triangle. The use of a nerve stimulator can make femoral nerve block more successful, but the block can be done without it; e.g., for an unscathed child with a femoral fracture, so that pain caused by muscle contraction can be avoided.

With the child supine and the foot rotated outward, a short-bevel or insulated needle should be inserted approximately 0.5 to 1 cm lateral to the femoral artery pulsation and approximately 0.5 to 1 cm below the inguinal ligament. This distance will vary according to the size of the child; it is therefore better to map the course of the femoral nerve before inserting the needle.

The nerve lies beneath the fascia lata and fascia iliaca, and often two distinct “pops” are felt when a needle pierces these layers. Contraction of the quadriceps, a “patellar kick,” confirms femoral nerve stimulation and should not be confused with direct stimulation of the sartorius muscle. Local anesthetic should be easy to inject into the femoral canal. Resistance to injection suggests intraneural injection; in such an instance the position of the needle should be adjusted until the resistance is lost. Because of the close proximity of femoral vessels, intermittent aspiration for blood is obligatory before and during femoral nerve blockade. In the event of a femoral arterial puncture, pressure should be applied for at least 5 min to prevent hematoma formation.

An appropriate catheter can be inserted into the femoral canal for continuous infusion. After the initial block, an infusion rate of 0.2 to 0.4 mg/kg/h should be adequate. The degree of analgesia obtained is dependent on the final position of the catheter. Immobilization and fixation of these catheters on the thigh is relatively simple, but subcutaneous tunneling may be necessary to reduce the risk of infection when long-term pain relief is required. Psoas abscess is a rare but serious complication associated with femoral nerve catheters that to date has been described only in adults.

A “3 in 1” block is essentially a femoral nerve block that attempts to anesthetize the femoral nerve, lateral cutaneous nerve of the thigh, and obturator nerves with one injection. This is done by promoting retrograde spread of the local anesthetic within the femoral sheath up to the lumbar plexus by applying digital pressure distal to the injection site and increasing the volume of the local anesthetic. The 3-in-1 block has been shown to anesthetize the femoral nerve 100 percent of the time, but it is only 20 percent effective in blocking all three nerves. To do this more reliably, a fascia iliaca or lumbar plexus block should be employed.

**Lateral Femoral Cutaneous Nerve of the Thigh**

The patient is in the supine position. The landmarks are the anterosuperior iliac spine and the inguinal ligament. Ultrasound aids the placement of the block. The anesthetic dose is 1 to 3 mL of 0.25 to 0.5% bupivacaine, ropivacaine, or levobupivacaine.

The lateral cutaneous nerve of the thigh is derived from the lumbar plexus (L2-L3) and is purely sensory, supplying the anterolateral aspect of the thigh for a variable distance down to the knee. The nerve descends over the iliacus muscle just below the pelvic rim in an aponeurotic canal formed in the fascia lata and enters the thigh close to the anterosuperior iliac spine behind the inguinal ligament. In the thigh, it crosses or passes through the tendinous origin of the sartorius muscle. It divides into anterior and posterior branches.

Blockade of this nerve provides analgesia for plating of the femur, plate removal, drainage of femoral osteitis, harvesting of skin grafts, or obtaining muscle biopsies.
CHAPTER 31 REGIONAL ANESTHESIA FOR PEDIATRIC ORTHOPAEDIC SURGERY

**Technique**
A point 1 to 2 cm below and medial to the origin of the inguinal ligament at the anterosuperior iliac spine is identified. A blunt needle should be inserted perpendicular to the skin until a “pop” is felt as the fascia lata is penetrated and a second “pop” is felt when the fascia iliaca is entered. If bone contact is made, the needle should be withdrawn and redirected. Correct placement of the needle can also be determined with loss of resistance, which is noted when the fascia iliaca compartment is entered. Alternatively, withdraw and redirect the needle laterally and advance deep to the fascia lata in a fan-like manner, or direct the needle laterally in order to make bone contact and deposit the local anesthetic just medial to the anterosuperior iliac spine.

**Fascia Iliaca Compartment Block**
The patient is in the supine position. The landmarks are the anterosuperior iliac spine, the inguinal ligament, and the pubic tubercle. Ultrasound aids placement of the block.

The anesthetic dose is 0.5 to 1 mL/kg of 0.25 to 0.5% bupivacaine, ropivacaine, or levobupivacaine.

A fascia iliaca compartment block in children was originally described by Dalens. It is more effective in blocking the femoral nerve, lateral cutaneous nerve of the thigh, and the obturator nerves than the 3-in-1 block, with a reported success rate of 90 percent, compared to 20 percent for the 3-in-1 block. It is particularly useful for any surgery on the lower extremity above the knee and for femoral shaft fractures.

The aim of a fascia iliaca compartment block is to deliver local anesthetic deep to the fascia iliaca and superficial to the iliacus muscle, where the three nerves of the lumbar plexus emerge from the psoas muscle.

With the child in the supine position and the thigh slightly abducted and externally rotated, a line should be drawn from the pubic tubercle to the anterosuperior iliac spine along the inguinal ligament. A short beveled needle should be inserted perpendicular to the skin 0.5 to 1 cm below the junction of the lateral and middle thirds of this line. Two “pops” are felt as the needle pierces the fascia lata and then the fascia iliaca. A slight loss of resistance may be detected if light pressure is held on the plunger of the syringe. After a negative aspiration test for blood, local anesthetic (0.5 to 1 mL/kg) may be injected. Because the aim is to block all three nerves with one injection, larger volumes of local anesthetic solution are required with this block than with many others. Massaging the area in an upward direction facilitates the upward spread of local anesthetic. A nerve stimulator is of no benefit, since there is no motor nerve that can be directly stimulated at the point of entry.

No significant complications have been described in association with a fascia iliaca compartment block if the needle remains inferior to the inguinal ligament and away from the femoral vessels. Some investigators have shown particularly high blood levels of local anesthetic after a fascia iliaca compartment block, which could be explained by the large surface area available for absorption.

Continuous infusions have been used for femoral lengthening procedures, internal fixation of femoral fractures, and amputations. The degree of analgesia obtained is dependent on the final position of the catheter. After the initial block, an infusion rate of 0.2 to 0.4 mg/kg/h should be adequate. Immobilization and fixation of these catheters on the thigh is simple.

**Obturator Nerve**
An isolated obturator nerve block is seldom performed to provide analgesia for orthopaedic surgery in children. However, the obturator nerve may be included with the lateral femoral cutaneous nerve and the femoral nerve in a 3-in-1 nerve block. The obturator nerve (L2-L4) supplies the motor innervation to the adductors of the leg and sensory innervation to the medial portion of the lower thigh and knee joint. Blockade of this nerve can be considered for pain management after adductor tendon releases in children with spastic cerebral palsy.

**Sciatic Nerve Block**
The sciatic nerve leaves the posterior pelvis through the greater sciatic foramen and the piriformis muscle into the buttock and descends down the midline of the back of the leg to the apex of the popliteal fossa. The sciatic nerve lies midway between the greater trochanter and the ischial tuberosity at the gluteal cleft, where it is palatable in most young children. It divides into the common peroneal and tibial nerves within the popliteal fossa in the majority of children.

The sciatic nerve can be blocked using several different approaches at the hip (anterior, posterior and lateral) or in the popliteal fossa. In children, the posterior approach is more popular than in adults because their smaller limbs are easily lifted. The chosen approach ultimately determines the distribution of motor and sensory blockade. Block of the sciatic nerve at the gluteal level provides anesthesia of the posterior aspect of the thigh (posterior cutaneous nerve of thigh) and leg below the knee but excludes the medial aspect of the lower half of the leg, the medial malleolus, and the medial aspect of the foot.

Sciatic nerve block is suitable for all surgical procedures involving the posterior aspect of the leg, especially below the knee—for example, in lengthening of the Achilles' tendon and clubfoot repair as well as major foot arthrodesis. Sciatic nerve block may need to be supplemented with other blocks, depending on the type of surgery; this would, for example, be the case with knee surgery or tibial osteotomies.
The different approaches to the sciatic nerve in children are described below.

**Posterior Approach to the Sciatic Nerve**

The patient’s position is laterally recumbent with the hip and knee flexed. Landmarks are the coccyx, greater trochanter, and ischial tuberosity. A nerve stimulator aids in placement of the block. The anesthetic dose is 0.2 to 0.3 mL of 0.25 to 0.5% bupivacaine, ropivacaine, or levobupivacaine.

**TECHNIQUE**

A modified posterior approach to the sciatic nerve is easy to use and poses a low risk of complications. With the child in the lateral position, the side to be blocked should be uppermost, with the leg flexed at the hip and knee (modified Sims position); a line is then drawn from the tip of the coccyx to the greater trochanter of the femur. An insulated needle is inserted at the midpoint of this line and directed toward the ischial tuberosity. Nerve mapping is not possible, but a nerve stimulator, set at 0.3 to 0.4 mA, will elicit distal motor responses in the leg, foot, or both (plantar- or dorsiflexion, inversion or eversion) and will confirm stimulation of the sciatic nerve (which supplies all the muscles below the knee). Careful aspiration should be performed before injection of local anesthetic to avoid the risk of intravascular injection.

**Infragluteal Approach to the Sciatic Nerve**

The patient is in the supine or lateral decubitus position with the hip flexed and the knee extended.

Landmarks are the greater trochanter, ischial tuberosity, gluteal crease, and biceps femoris muscle. A nerve stimulator and ultrasound aid in placement of the block.

The anesthetic dose is 0.2 to 0.3 mL/kg of 0.25 to 0.5% bupivacaine, ropivacaine, or levobupivacaine.

**TECHNIQUE**

Raj described an approach that is particularly useful in children. With the hip flexed and knee extended, the sciatic nerve can be approached posteriorly by inserting a needle perpendicular to the skin at a point midway between the ischial tuberosity and greater trochanter on the gluteal crease. With exaggerated hip flexion, the glutei may be flattened, so that the sciatic nerve becomes relatively superficial even in some obese children. The greater trochanter is not easily defined in non-weight-bearing children, but the sciatic nerve may be palpable in the groove lateral to the biceps femoris muscle in children.

An alternative approach that can also be applied in children has recently been described. The surface landmarks are the gluteal crease and the lateral border of the biceps femoris muscle. An insulated needle is inserted at an angle of 70 to 80 degrees 1 cm distal to the gluteal crease along the lateral border of the biceps femoris muscle. The needle should be directed cephalad with an anterior orientation in the parasagittal plane. Plantarflexion, inversion, or dorsiflexion at 0.3 to 0.4 mA confirms sciatic nerve stimulation. If bone contact is made before a motor response is elicited, the needle should be withdrawn and redirected. The posterior cutaneous nerve of the thigh can be missed, since it may separate more proximally in the thigh.

**Posterior Midthigh Approach to the Sciatic Nerve**

The patient’s position is supine, with the hip flexed and the knee flexed or extended.

Landmarks are the ischial tuberosity and the head of the fibula. Surface nerve mapping, ultrasound, and a nerve stimulator aid in placement of the block.

The anesthetic dose is 0.2 to 0.3 mL/kg of 0.25 to 0.5% bupivacaine, ropivacaine, or levobupivacaine.

**TECHNIQUE**

An insulated needle is inserted perpendicular to the skin at the midpoint of a line drawn from the head of the fibula to the ischial tuberosity in the posterior thigh. The nerve is surrounded by the hamstring muscles at this point, and this compartment can be detected using a loss of resistance technique as the needle tip emerges from the deep surface of the biceps femoris. A more accurate location of the nerve may be obtained by a distal motor response in the ankle or foot or simply the big toe (plantarflexion, inversion, eversion, or dorsiflexion). The posterior cutaneous nerve of the thigh is missed at this level.

**Lateral Approach to the Sciatic Nerve at the Thigh**

The patient’s position is prone, lateral, or supine. A nerve stimulator aids placement of the block. The anesthetic dose is 0.2 mL/kg of 0.25 to 0.5% bupivacaine, ropivacaine, or levobupivacaine.

**TECHNIQUE**

An insulated needle is inserted 0.5 to 1 cm below the greater trochanter and advanced toward the posterior border of the femur. With this approach, the broadest aspect of the nerve is targeted. If bone contact is made, the needle can be “walked off” the femur posteriorly or withdrawn and redirected until muscle twitches are elicited in the lower leg or foot. Continuous catheters...
have been placed using this technique, but their fixation is difficult unless the leg is immobilized.

**Sciatic Nerve Block at the Popliteal Fossa**

The patient’s position is prone, lateral, or supine. The landmark is the apex of the popliteal fossa. Surface nerve mapping, ultrasound, and a nerve stimulator aid in placement of the block. The anesthetic dose is 1 to 2 mL of 0.25 to 0.5% bupivacaine, ropivacaine, or levobupivacaine.

The sciatic nerve may be blocked where it courses through the popliteal fossa behind the knee for operations on the distal lower extremity. The boundaries of the popliteal fossa are formed by the semimembranosus and semitendinosus tendons medially, the biceps femoris tendon laterally, and the popliteal crease between the femoral condyles inferiorly.

Near the popliteal fossa, the sciatic nerve divides into two branches: the common peroneal and the posterior tibial nerves. The exact location of this division varies, but in the majority of children it is within the popliteal fossa. The common peroneal nerve then runs laterally medial to the biceps femoris tendon before passing over the lateral head of the gastrocnemius muscle and around the head of the fibula. The posterior tibial nerve extends down the midline of the posterior aspect of the lower leg in close proximity but superficial to the popliteal artery within the popliteal fossa.

Although the nerves branch, there is a common epineural sheath that envelopes both the posterior tibial and the common peroneal nerves. For this reason a high rate of success can be achieved even when the motor response of only one branch is elicited. Stimulation of the common peroneal nerve will cause dorsiflexion and evasion of the foot, while stimulation of the posterior tibial nerve will elicit inversion and plantarflexion of the foot. (Internal nerve; i.e., posterior tibial nerve results in inversion of the foot; external nerve; i.e., common peroneal nerve results in evasion of the foot.) The nerves are superficial enough to be “surface mapped” individually, particularly in young infants.

Various landmarks have been described for the insertion of the needle. Konrad and Johr base their point of insertion on the weight of the child. For each 10 kg body weight, the needle insertion is moved 1 cm further above the popliteal crease just lateral to the midline. Alternatively, an insulated needle may be inserted midway between the intercondylar line and the apex of the popliteal fossa to block the posterior tibial nerve and then directed laterally at the same level to block the common peroneal nerve. In small children, the block can also be performed with the patient lying supine by elevating the limb; in older children, this can be done by resting the foot on the operator’s shoulders while accessing the popliteal fossa.

More recently, ultrasonography has been utilized to determine the exact location of the bifurcation. With this information, the nerves can be blocked individually below the bifurcation or simultaneously above the bifurcation of the sciatic nerve. Surface mapping may be used in thin children to achieve similar results. Complications are rare, but care should be taken to avoid intravascular injection (the popliteal artery lies deep to the nerves in the popliteal fossa).

**Lateral Approach to Sciatic Nerve at the Knee**

The patient’s position is supine. The landmark is the biceps femoris tendon. A nerve stimulator aids in placement of the block.

The anesthetic dose is 0.1 mL/kg of 0.25 to 0.5% bupivacaine, ropivacaine, or levobupivacaine.

**Technique**

A lateral approach to the popliteal fossa, originally described in adults, has recently been described in children. The advantage of this approach is that it can be performed on a supine patient. The biceps femoris tendon is identified on the posterolateral aspect of the knee. A point 4 to 6 cm above the crease of the popliteal fossa is identified. An insulated needle is then inserted anterior to the biceps femoris tendon until it contacts the shaft of the femur. At this point, the needle is gently walked off the femur posteriorly and, using a nerve stimulator, is slowly inserted until a motor response is elicited with a current of 0.3 to 0.4 mA. Dorsiflexion or plantarflexion along with eversion is desirable. Careful aspiration for blood should be carried out to avoid intravascular injection.

**Anterior Approach to the Sciatic Nerve**

The patient’s position is supine. The landmarks are the anterosuperior iliac spine, pubic tubercle, and greater trochanter. A nerve stimulator aids in placement of the block. The anesthetic dose is 0.1 to 0.2 mL of 0.25 to 0.5% bupivacaine, ropivacaine, or levobupivacaine.

**Technique**

The anterior approach is less commonly used but has the advantage that the patient need not be turned. The need for only one sterile area is a further advantage when this approach is combined with a femoral or saphenous nerve block for lower limb surgery.

A line drawn from the pubic tubercle to the anterosuperior iliac spine (inguinal ligament) is divided into thirds. A perpendicular line is then drawn from the junction of the inner and middle thirds onto a line drawn parallel to the inguinal ligament through the greater trochanter. Using a
nerve stimulator, an insulated needle is inserted perpendicular to the skin until contact is made with the femur of the femur. The needle is then “walked off” the lesser trochanter posteriorly and advanced about 1 cm or until distal motor responses are elicited. A loss of resistance can also be detected as the needle passes through the posterior aspect of the adductor magnus muscle.43

Saphenous Nerve Block

The patient is supine and the landmarks are the femoral artery, sartorius muscle, and inguinal ligament. A nerve stimulator and ultrasound are used to aid in placement of the block.

The anesthetic dose is 0.1 to 0.2 mL/kg of 0.25 to 0.5% bupivacaine, ropivacaine, or levobupivacaine.

TECHNIQUE

The saphenous nerve runs along the medial aspect of the thigh just lateral to and within the same fascial sheath as the motor nerve supplying the vastus medialis. The main indication for blocking this nerve is to complement a sciatic nerve block for surgery on the medial aspect of the lower limb or foot.

The nerve to the vastus medialis muscle can be located using a nerve stimulator. With the child in the supine position, an insulated needle is inserted perpendicularly to the skin 0.5 cm lateral to the point where the femoral artery crosses the medial border of the sartorius muscle in the anterior thigh. Muscle twitches of the sartorius muscle confirm the close proximity to the saphenous nerve at this level. The distance from the inguinal ligament (3 to 5 cm) varies with age, as does the depth of the nerve (0.5 to 3 cm). An advantage of this block over a femoral block is that motor activity in the remainder of the quadriceps is spared.

The saphenous nerve is a purely sensory nerve at the knee. It is therefore difficult to identify it with a nerve stimulator, making blockade at this level unreliable. At the level of the tibial plateau, the saphenous nerve perforates the fascia lata between the sartorius and gracilis muscles, where it lies subcutaneously in close proximity to the long saphenous vein.

A deep linear subcutaneous infiltration below and lateral to the insertion of the sartorius tendon (medial surface of the tibia) is performed where the nerve lies in a subcutaneous length immediately in front of the upper part of the medial head of the gastrocnemius muscle. Intermittent aspiration tests for blood will reduce the risk of injection into the long saphenous vein.

Ankle Block

The patient’s position is supine or prone. The landmarks are the medial and lateral malleolus, extensor hallucis longus tendon, Achilles’ tendon, and dorsalis pedis pulse.

The anesthetic dose is 0.1 mL/kg of 0.25 to 0.5% bupivacaine, ropivacaine, or levobupivacaine.

An ankle block can be used for procedures confined to the foot, including distal phalangeal amputations, foreign-body removal, and simple reconstructive surgery including syndactyly or polydactyly repair. The peripheral nerves blocked at this level are the terminal branches of both the sciatic (posterior tibial, superficial peroneal, deep peroneal, and sural nerves) and femoral (saphenous) nerves. There is considerable variation in the branching and sensory distribution of these nerves, and for this reason block of all five nerves is advocated.

An ankle block is relatively easy to perform by injecting local anesthetic solution subcutaneously in a ring-like fashion at the ankle. It is important to avoid using local anesthetics that contain epinephrine, since the end arteries in the foot may be compromised. Each nerve should be blocked separately for best results (Figs. 28-1 to 28-3 and Fig. 31-1).

1. The tibial nerve innervates the sole of the foot and medial aspect of the heel and is located between the medial malleolus and the calcaneum deep to the flexor retinaculum immediately posterior to the posterior tibial artery. Local anesthetic injected through a needle inserted posteriorly and medially to the Achilles’ tendon and directed toward the pulsation of the artery should block the tibial nerve.

2. The superficial peroneal nerve supplies the dorsum of the foot. A subcutaneous injection across the dorsum of the foot between the lateral malleolus and the extensor hallucis longus tendon will block the nerve. Sometimes it is useful to perform this block with a 25-gauge spinal needle, since the entire block can be achieved by using one needle puncture.

3. The deep peroneal nerve innervates the first web space between the first and the second toe. A needle is passed medial to the extensor hallucis longus tendon along the pulsation of the anterior tibial artery until contact with the tibia is made. The needle should then be withdrawn a few millimeters and the local anesthetic solution injected.

4. The sural nerve innervates the lateral aspect of the foot. A needle is introduced posteriorly and laterally to the Achilles’ tendon between the lateral malleolus and the calcaneum until contact with the calcaneum is made. The needle is then withdrawn a few millimeters and the local anesthetic solution injected.

5. The saphenous nerve innervates the medial aspect of the ankle and foot and lies in close proximity to the saphenous vein. It is located on the medial side of the dorsum of the foot anterior
to the medial malleolus. A subcutaneous injection of local anesthetic from the medial malleolus along the anterior aspect of the ankle toward the saphenous vein using a fine needle will effectively block the nerve.

**METHODS FOR PROLONGING DURATION OF NERVE BLOCKS**

**Continuous Peripheral Nerve Blocks**

Catheters for continuous peripheral nerve blocks have not been readily available for use in children until recently (see also Chap. 20). A variety of improvised methods, some of which formed the basis for the development of the modern “designer” catheters, were used. As the appropriate equipment has become available, an increasing number of reports of their use for continuous postoperative pain management or therapeutic care have been published.19,23,30,44–50

The main indications for continuous blocks have been for children who undergo procedures, or have procedures that are associated with significant or prolonged postoperative pain; or to improve peripheral perfusion in microvascular surgery or in vasospastic disorders involving the limbs. In selected cases, patient-controlled analgesia is also feasible. Continuous infusions have also been used to provide analgesia and to allow physical therapy in chronic regional pain syndromes. Blood levels reached during continuous brachial plexus infusions are less than those attained during continuous epidural analgesia.

For the lower extremity, the main indication has been the management of femoral fracture30,45 or major trauma. Catheters have also been placed in the lumbar plexus (psoas compartment)46 or fascia iliaca compartments47 to provide unilateral analgesia of the hip or thigh. The psoas compartment block provides a more reliable block of all three nerves of the lumbar plexus. Fixation of the catheters for continuous use is considered easier on the lower extremity, particularly for psoas compartment blocks.

Ideally, a commercially available kit should be used, since it allows a nerve stimulator to identify the correct nerve sheath before placement of the catheter. Several manufacturers now provide insulated Tuohy needles of “child friendly” length through which an appropriate sized catheter can be passed. Research on the role of stimulating versus nonstimulating catheters for continuous peripheral nerve blocks is continuing.

Instead of stimulating catheters, one could improvise with a modification of the Seldinger technique. With this technique, the nerve to be blocked is stimulated via a guidewire passed through a needle or intravenous cannula. The needle is then removed and a catheter placed over the wire or threaded through the cannula. These improvised methods are very reliable for accurate catheter placement; radiographic confirmation may be required.

The dosage recommended for continuous infusions after an initial bolus dose are 0.1 to 0.2 mL/kg/h of either bupivacaine or levobupivacaine (0.125 to 0.25%) or ropivacaine (0.15 to 0.2%). The lower rates are generally used for upper extremity catheters and the higher rates for lower extremity plexus analgesia. The infusion rate may be adjusted as needed up to the maximum recommended rates of 0.2 mg/kg/h for infants less than 6 months of age and 0.4 mg/kg/h in children older than 6 months.48 Disposable infusion pumps, which may be programmed to deliver local anesthetic based on a child’s weight, are currently available and may offer an option for pain control in outpatients in the future.49

To date the reported incidence of complications has been low. They include catheter-induced infection, particularly in immunocompromised patients, as well as hematoma formation, catheter breakage, or knot formation on removal.

**Additives and Adjuvants**

Additives are used to prolong the duration of analgesia and improve safety by reducing the dose of local anesthetic required. By reducing the concentration, some of the unwanted side effects, such as motor blockade, can be eliminated.

A variety of additives has been studied in adults; these include opiates (morphine, fentanyl, sufentanil, buprenorphine) ketamine, neostigmine, ketorolac, hyaluronidase, and clonidine. One of the advantages of regional anesthesia is the low incidence of nausea and vomiting, but this advantage is lost with some additives without any convincing evidence that they enhance analgesia in acute pain.

Clonidine (0.5 to 1 mL/kg) may have a peripherally mediated effect. It seems to be effective in prolonging the duration of the shorter-acting agents (e.g., mepivacaine after single-injection peripheral nerve blocks) but is less effective when used with bupivacaine or ropivacaine. Research in this area is ongoing, as the clinical efficacy of peripheral clonidine remains unresolved. Studies in children are limited.51

**CAUDAL BLOCK**

Caudal anesthesia is the most useful technique in children for operations below the umbilicus.52–55 Its popularity stems from its simplicity, safety, and efficacy in all pediatric age groups, and it is extensively used in conjunction with light general anesthesia for postoperative pain relief for orthopaedic procedures on the lower extremities.
Anatomy

The sacral hiatus is formed as a result of failure of fusion of the fifth sacral vertebral arches. The remnants of the arch are represented by two prominences, the sacral cornua, on either side of the hiatus. The sacral cornua are approximately 0.5 to 1 cm apart, depending on the age of the child. The sacral hiatus extends from the sacral cornu to the fused arch of the fourth sacral vertebra. The sacrococcygeal membrane covers the sacral hiatus, separating the caudal space from the subcutaneous tissue. In some individuals, the fourth and even the third sacral vertebral arch may not be fused.

The sacral bones are not completely ossified in neonates and infants. The cortex of the sacral bones is wafer-thin and the risk of interosseous injection is high, particularly in this age group. Ossification of the sacrum starts in the teens and is complete by the end of the second decade. As a result, a sacrointervertebral block can be performed in young children, and this is a useful alternative when the caudal approach is not possible.

There is considerable variation in the sacral hiatal anatomy, mainly due to incomplete posterior fusion of the sacral vertebrae and ossification that starts at about age 7. However, a few important surface landmarks need to be identified to enhance the success of the block in both normal and abnormal sacra. The sacral hiatus lies at the apex of an equilateral triangle that has the line drawn between the posterior superior iliac spines as its base. Furthermore, a line drawn from the patella through the greater trochanter with the hips flexed will transect a line drawn down the vertebral column at the sacral hiatus. This landmark is useful when the sacral cornua are covered by adipose tissue and difficult to identify, particularly toddlers and prepubertal children.

The distance between dural sac and the sacral hiatus is extremely variable. The dural sac ends at S3-S4 in newborns and is usually situated at S2 in adults. Individual variation occurs and the dural sac may even extend down into the caudal canal in 1 to 2 percent of the population.

The caudal space contains the cauda equina (sacral nerves), blood vessels, lymphatics, fat, and connective tissue. The consistency of the fat and connective tissue varies with age; the connective tissue is loose and the fat less gelatinous in infants and small children.

Technique

Caudal block is performed in the lateral decubitus position with both knees drawn up. The prone or knee-chest position has also been described but is usually reserved for small infants and neonates. The sacral hiatus and cornua are identified by palpation and feel similar to a metacarpal interspace. Under sterile conditions, a short beveled needle held gently between the thumb and index finger is introduced at approximately 30 to 45 degrees to the skin (i.e., with the bevel parallel to the skin) at the sacral hiatus and advanced until it pierces the sacrococcygeal ligament. This can be detected by a distinct “give” as it enters the caudal epidural space and may be confirmed by loss of resistance. Changing the angle and advancing the needle as described in adults is unnecessary. This maneuver would simply increase the risk of dural puncture or a bloody tap without improving the success of the block.

Styletted needles are considered mandatory in some institutions to reduce the risk of an epidermal inclusion cyst, which may be caused by introducing a skin plug into the epidural space. Others prefer to use an intravenous cannula.

Penetration of the sacrococcygeal membrane just above the sacral cornua is associated with a lower incidence of bloody tap. The caudal space at this point is deeper than below the cornua, where it narrows significantly and makes identification of the narrower space difficult. An approach that is too low is one of the commonest reasons for failure.

Failure to obtain loss of resistance after the sacrococcygeal ligament has been penetrated may indicate that the bevel is lying directly up against the anterior wall of the caudal space. This may be overcome by simply rotating the needle through 180 degrees.

Once the needle position is confirmed and aspiration for blood and CSF has been negative, the appropriate volume of local anesthetic can be injected. Confirming the correct placement of the caudal needle with the “whoosh test,” whereby the injection of air into the epidural space is confirmed by auscultation, is potentially dangerous (air embolus) and should be avoided.

A test dose has been advocated to detect the possibility of intravascular injection. The standard test dose contains 0.5 to 1 μg/kg epinephrine and is defined as an increase in heart rate (10 to 20 beats per minute) or systolic blood pressure (10 percent) following intravenous injection in awake patients. The reliability of the test dose is reduced under general anesthesia and varies under different anesthetic conditions.

The use of epinephrine-containing solutions as a test dose in children under anesthesia may, but does not always, produce an increase in heart rate when injected intravascularly. Atropine administered prior to the test dose improves reliability. Halothane, sevoflurane, and isoflurane attenuate the tachycardic response to epinephrine. Atropine administered prior to test dose may improve the sensitivity under halothane anesthesia.

Careful observation of the electrocardiogram (ECG), particularly an increase in T-wave amplitude, ST-segment elevation, or any other arrhythmia, is more sensitive in detecting an intravascular injection of bupivacaine with epinephrine.
Dosage

The most commonly used drugs for caudal block are bupivacaine,52-55 lignocaine,56 and more recently ropivacaine57 and levobupivacaine.63 The most practical formula is that suggested by Armitage: 0.5 mL/kg of local anesthetic for sacrolumbar dermatomes, 1 mL/kg for lumbar thoracic dermatomes (subumbilical), and 1.25 mL/kg for midthoracic dermatomes (upper abdominal), respectively.64

The duration of analgesia is dependent on the drug and dose administered, the age of the patient, the site of surgery, and whether epinephrine is used. Bupivacaine 0.125 to 0.25% and ropivacaine 0.2% are effective for 4 to 6 h of analgesia. Increasing the concentration does not offer any additional advantage but may increase the incidence of motor blockade and urinary retention.65,66

Adjuvants

Various agents have been added to prolong the analgesic effect of the local anesthetics or to reduce the side effects during caudal block. Opiates (morphine, fentanyl, sufentanil) are effective but unwanted side effects (pruritus, nausea and vomiting, and respiratory depression) have limited their use in the day care setting and prompted the search for alternatives. Clonidine, an alpha2-adrenoreceptor agonist, has been shown to be effective.67,68 No significant hypotension and minimal sedation is apparent when the dose is limited to 1 to 2 µg/kg. Ketamine, an NMDA receptor antagonist, is also effective in prolonging the duration of analgesia: 0.5 to 1 mg/kg has been used with minimal side effects.

Continuous Caudal Block

Continuous caudal catheter techniques are also used to prolong the duration of analgesia.69 Several kits are now marketed for caudal catheter placement. Essentially all that is required is an intravenous cannula, which is introduced through the sacrococcygeal ligament and into the caudal space; an epidural catheter can pass through this cannula to facilitate the continuous infusion of local anesthetic agents.7 The catheter need only be introduced a short distance for surgery on the lower extremities. Because of its proximity to the anus, care must be taken to protect the catheter site from fecal contamination. To reduce the risk of contamination or infection, the catheter should be removed after 48 to 72 h or if the dressings become soiled.

Complications

These are uncommon but are usually caused by misplacement of the needle. Systemic toxicity may manifest as arrhythmia, cardiovascular collapse, or convulsions following accidental intravascular or sacral interosseous injections. The incidence of bloody tap (2 to 10 percent) varies with experience, the age of the patient, and the equipment used.

Urinary retention and delayed micturition are related not only to the duration of preoperative starvation but also to the concentration of the local anesthetic solution. The incidence is negligible when 0.25% bupivacaine or 0.2% ropivacaine or lower concentrations are used. Motor blockade and inability to walk is also concentration-dependent.

Total spinal anesthesia may occur following an undetected dural puncture. Supportive management until the return of diaphragmatic function and spontaneous respiration should be instituted. Nerve injury and neurologic defects have been reported but are extremely uncommon following caudal blockade. Intrapelvic injections have also been reported but should not occur.

CONCLUSION

There are a variety of reasons why regional anesthesia, particularly peripheral nerve blocks, is advantageous for children who undergo elective or emergency orthopaedic surgery. Regional anesthesia provides good pain relief without the need for additional analgesia in both healthy children as well as those with compromised respiratory function or increased sensitivity to opiates (muscle disorders, mucopolysaccharidoses, cerebral palsy, kyphoscoliosis). The reduction of unwanted side effects such as nausea and vomiting can aid in the “fast tracking” (early discharge) of day-stay patients and improve the quality of care of hospitalized patients.

As better techniques are developed, the utilization of peripheral nerve blocks in children should gradually increase. Surface nerve mapping and more recently portable ultrasound are promising developments. These should encourage skilled practitioners to improve their success rates and inexperience practitioners to develop their skills.

Further development of continuous peripheral nerve blocks will enhance patient comfort for longer into the postoperative period. Their use in children to date has been confined to special circumstances. It is too early to judge the risk-benefit ratio, but it seems likely that they will find a place, particularly in children with associated diseases.

REFERENCES
