Anesthetic Techniques: Regional

13

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Introduction

Regional anesthesia includes a variety of anesthetic approaches such as **neuraxial** (epidural and spinal anesthesia), **peripheral**, and **intravenous** techniques. Regional anesthesia plays an important role both inside and outside of the operating room. In addition to its use for surgical anesthesia, it is also gaining widespread use for perioperative pain control, especially as a key contributor to many opioid-sparing pain management regimens. In this chapter, we will review the basic tenets of neuraxial, peripheral, and intravenous regional anesthesia.

Special thanks to Brian C. McLean, Anthony R. Plunkett and Jesse M. Ehrenfeld for their contribtions as authors of the previous chapter edition.

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J. M. Ehrenfeld et al. (eds.), *Anesthesia Student Survival Guide*,
https://doi.org/10.1007/978-3-030-98675-9_13

Neuraxial Anesthesia

Neuraxial Anatomy

The vertebral column extends from the foramen magnum to the sacral hiatus. The spinal cord is contained within this bony framework. There are 24 vertebrae (7 cervical, 12 thoracic, 5 lumbar, and 5 fused vertebrae forming the sacrum). Each vertebrae is identified via palpation of the lateral transverse processes and a posterior spinous process. The spinous process and transverse process are connected via bilateral lamina, while the transverse process is connected to the vertebral body via the pedicles (see Fig. 13.1).

The spinal cord is contained within the spinal canal and covered by three layers called the meninges. The **pia mater** is closely adherent to the spinal cord and is the deepest layer, while the **arachnoid mater** is more closely adherent to the outermost **dura mater**. Cerebral spinal fluid (CSF) is contained within the space between the pia mater and arachnoid mater, called the **subarachnoid space**. This is the site of injection when performing spinal anesthetic. The spinal cord normally extends from the foramen

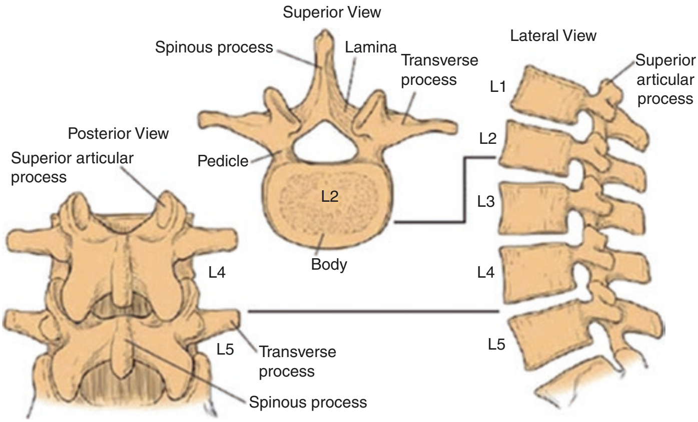

Fig. 13.1 Vertebral anatomy. (Reproduced with permission from Mathias [5])

magnum to the level of L1 in adults and L3 in children, at which point it terminates as the conus medullaris and forms the cauda equina. As a result, performing a spinal (subarachnoid block) or epidural below the level of L3 avoids potential trauma to the spinal cord. An important surface landmark when performing neuraxial anesthesia is the level of the iliac crest, which most commonly corresponds to the level of L4–L5, and additional bony landmarks are illustrated in Fig. 13.2 below.

The spinal cord has a rich vascular supply from a single anterior spinal artery and paired posterior spinal arteries. The anterior spinal artery supplies approximately 2/3 of the spinal cord, while the paired posterior spinal arteries provide the remaining 1/3. There is a prominent feeder artery called the artery of Adamkiewicz or *Radicularis Magna* that provides blood supply to the anterior, lower 2/3 of the spinal cord. Trauma or ischemia of this artery can lead to **anterior spinal artery syndrome**, resulting in bilateral lower extremity paralysis with preservation of proprioception and vibration (as the posterior/dorsal column function is typically preserved).

The spinal nerve roots exit the spinal canal via intervertebral foramen. The nerves arise above their respective vertebrae, but starting at T1, they exit below their vertebrae. As a result, there are eight cervical nerve roots, one more than the number of cervical vertebrae. Each spinal nerve innervates an area of skin referred to as a dermatome (see Fig. 13.3). Keep in mind, these dermatomes

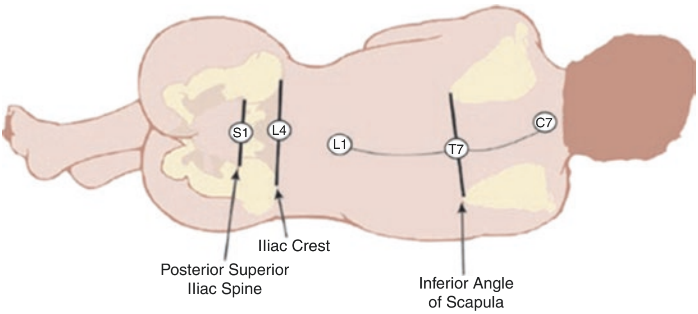

Fig. 13.2 Surface anatomy for neuraxial anesthesia

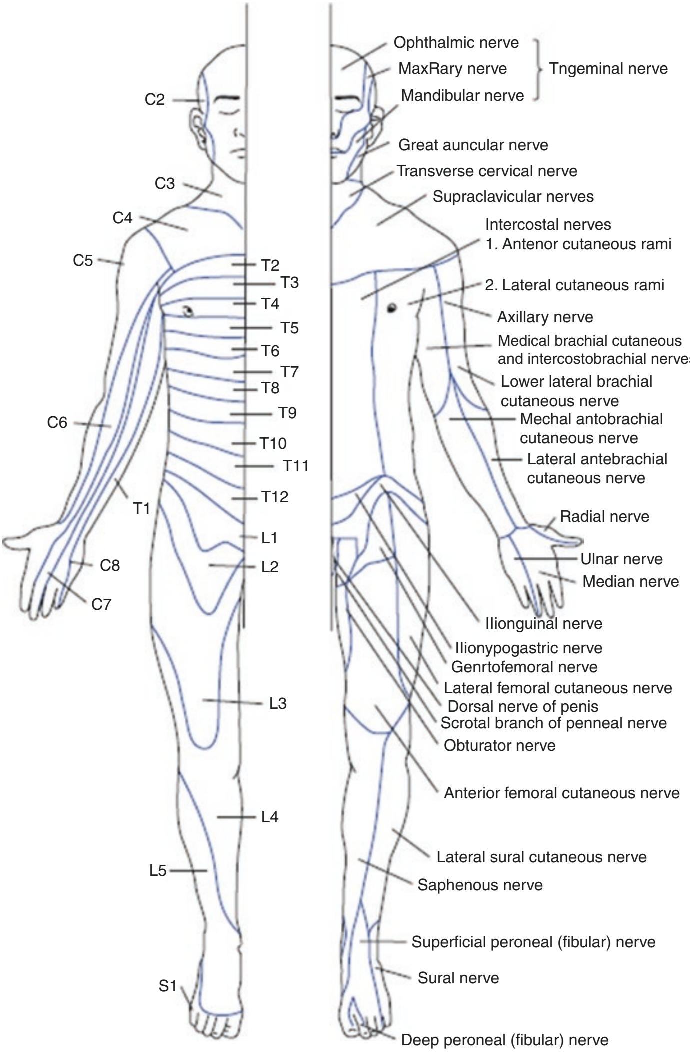

Fig. 13.3 Dermatomes. (Reproduced with permission from Stewart [6])

do not completely match the nerve root innervation of different muscle groups or bones, known as myotomes and osteotomes, respectively.

Indications and Contraindications

As with any anesthetic procedure, the risks and benefits of neuraxial regional anesthesia must be discussed with the patient. Potential risks are shown in Table 13.1.

Spinal anesthesia is primarily indicated for lower abdominal surgery, the perineum, and lower extremities. Epidural anesthesia is primarily indicated for lower abdominal surgery, thoracic surgery, surgery on the lower extremities, and labor. Epidurals can have sacral nerve root "sparing" and may not be optimal for surgery involving this area. Contraindications to neuraxial anesthesia are listed in Table 13.2.

Mechanism of Action

The most common medication given for neuraxial anesthesia is a local anesthetic. Local anesthetic that has been injected directly into the subarachnoid space (spinal) or that bathes the nerve roots and perhaps also diffused into the subarachnoid space from the

Table 13.1 Risks of neuraxial anesthesia

Bleeding
Infection
Nerve injury
Post-dural puncture headache
Urinary retention
Failure of block to provide adequate anesthesia
Hypotension/hemodynamic changes/cardiac arrest
Total spinal
Transient neurological symptoms
Drug toxicity/LAST (Local Anesthetic Systemic Toxicity)

Table 13.2 Contraindications to neuraxial anesthesia

Absolute contraindications	Relative contraindications
Patient refusal	Bacteremia
Infection in the area of needle puncture	Pre-existing neurologic disease (e.g. multiple sclerosis)
Elevated intracranial pressure	Severe spinal deformity
Severe hypovolemia	Stenotic valvular heart disease
Coagulopathy or bleeding diathesis	LV outflow obstruction (hypertrophic obstructive cardiomyopathy/HOCM)

epidural space (epidural) will inhibit synaptic transmission of action potentials. The effect of local anesthetics on nerve fibers varies according to the size of the nerve fiber, myelination and the concentration of the local anesthetic (also see Chap. 6, Pharmacology of Local Anesthetics). Epidural anesthesia has slower onset (10–20 minutes) compared to spinal anesthesia (typically onset within 60 seconds). Differential blockade (the order of effects among the different nerve types) typically results in sympathetic blockade (often accompanied by change in temperature sensitivity), followed by sensory blockade (pain, light touch), and finally motor blockade (paralysis). A well-placed neuraxial anesthetic can provide total anesthesia for a variety of surgical procedures.

There are a number of other medications that can be used for both spinal and epidural anesthesia. Opioids (e.g., morphine, fentanyl, hydromorphone), alpha-2-receptor agonists (e.g., clonidine), and vasoconstrictors (e.g. epinephrine) have all been given with the effect of enhancing the quality or the duration of the block. Epinephrine can prolong the duration of spinal anesthesia by decreasing the rate of absorption of the local anesthetic.

Epidural Anesthesia

Epidural anesthesia allows the delivery of medication either continuously or intermittently into the epidural space for up to several days after the surgical procedure. Sitting is the most common position in which an epidural is performed. Benefits of the sitting position include better identification of the midline and more flexion of the vertebral column. As the spine is flexed, it helps to open the space between spinous processes, allowing more room for the epidural needle to enter. An epidural may also be performed with the patient in the lateral position. This may increase patient comfort, especially for pregnant patients in active labor. However, the midline may be more difficult to identify, or may be malaligned.

The risks and benefits must be discussed with the patient and informed consent obtained. Standard monitors should be applied including blood pressure, ECG, and pulse oximetry, with end-tidal CO2 and supplemental oxygen if sedation is to be provided.

Technique

A midline or paramedian approach can be used. After infiltration of skin with local anesthetic, the epidural needle is advanced through the skin, subcutaneous tissue, the supraspinous ligament, the interspinous ligament (mostly avoided with paramedian approach, but paraspinal muscles are traversed), and finally into the ligamentum flavum. Identification of the epidural space may be found with a loss of resistance technique or a hanging-drop technique.

With the loss of resistance technique , a syringe containing saline or air or combination of both is attached to the epidural needle. As the needle is slowly advanced, the anesthesiologist places pressure on the syringe. The positive pressure encountered in the supraspinous ligament, interspinous ligament and ligamentum flavum prevents the plunger of the syringe from depressing (see Fig. 13.4). As the needle advances past the ligamentum flavum, a distinct loss of positive pressure is felt, as the plunger gives way and the saline or air or both is injected into the epidural space. A small catheter can then be threaded into the epidural space, usually 3–5 cm past the needle tip. Once the catheter is placed, the catheter is aspirated to ensure no blood or cerebrospinal fluid (CSF) is withdrawn (indicative of an intravascular or intrathecal catheter, respectively), and then a syringe containing a "test dose" of lidocaine with epinephrine 1:200,000 is attached. The test dose, typically 3 mL, is injected through the epidural

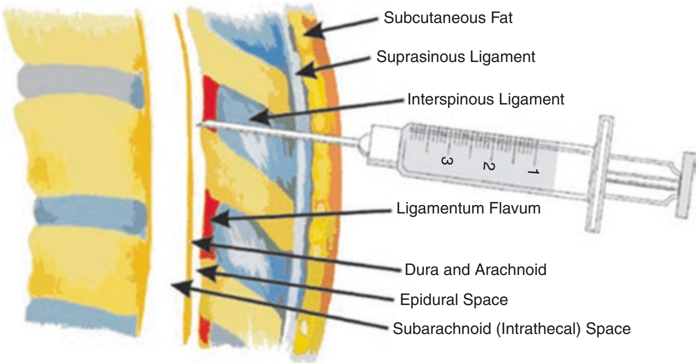

Fig. 13.4 Trajectory of epidural anesthesia. (Image courtesy J. Ehrenfeld, M. D)

catheter. The epinephrine serves as a surrogate marker to ensure the catheter has not threaded into a blood vessel (if positive, one would expect to see an increase in heart rate). The test dose also helps to determine if the catheter is in the subarachnoid space (spinal), which would typically result in rapid onset of sensory or motor changes within 3 min. If negative, the catheter is most likely not in the subarachnoid space.

With the hanging-drop technique, a small drop of saline is placed at the hub of the needle. As the needle passes through the positive pressure structures stated above, the drop of saline will remain at the hub of the needle. Once the needle contacts and passes through the ligamentum flavum, the drop of saline is retracted back into the needle as the negative pressure of the epidural space is encountered. The catheter is then placed, as above.

Pharmacology of Epidural Anesthesia

Similar local anestheticscan be used for both epidural and spinal anesthesia. Chloroprocaine, lidocaine, and mepivacaine are fast onset medications with a short duration of action, while bupivacaine and ropivacaine have a slower onset and longer duration.

Unlike spinal anesthesia, the level of anesthesia in an epidural is not influenced by baricity or position of the patient immediately after injection (see below), but, rather, injectate volume (typically 1–2 ml per segment to be blocked). Concentration of local anesthetic used also affects density of block, and can be chosen based on the epidural indication (eg., surgical anesthetic versus analgesic block). Only preservative-free local anesthetic solutions and medications are used.

The amount of local anesthetic required to produce surgical anesthesia with an epidural is significantly more than with a spinal, as the local anesthetic must traverse more layers to act on the nerve roots. The addition of epinephrine can prolong the effect of local anesthetic by decreasing vascular uptake, allowing more time for the medication to act on the nerve roots. Opioids, such as morphine or fentanyl, can also be added to an epidural. They help to enhance the quality of the epidural as well as provide postoperative pain control.

Spinal Anesthesia

As with general anesthesia, prior to starting a spinal anesthetic, standard patient monitors should be applied (blood pressure, pulse oximeter, and ECG). Supplemental oxygen is often administered, with EtCO2 monitoring. Intravenous access also must be established. In some situations, the patient may be sedated as patient comfort will help in both positioning and anxiolysis while performing the spinal. As with an epidural, a spinal may be placed in either the sitting or lateral position.

The spinal cord typically ends at the level of L1 in adults and L3 in children. Placing the spinal needle below the level of L3 provides an additional margin of safety by decreasing the likelihood of any spinal cord penetration. The iliac crest has been traditionally used as an anatomic landmark corresponding with an L4–L5 interspace (see Fig. 13.2).

Technique

There are two main techniques for performing a spinal anesthetic, midline and paramedian, similar to that of an epidural anesthetic as outlined above. As with epidural anesthetic, the patient is positioned and interspace identified, skin cleaned and prepared with antiseptic solution, local anesthesia is infiltrated in the skin and subcutaneous tissues. With the **midline approach**, the spinal needle is first introduced into the skin between the upper and lower spinous processes at the desired interspace. After passing through the skin, the needle continues to pass through subcutaneous tissue, the supraspinous ligament, the interspinous ligament, the ligamentum flavum, and finally advancing through the epidural space into the subarachnoid space (Fig. 13.4). Often a distinct "pop" is felt by the anesthesiologist as the needle penetrates the ligamentum flavum. Correct identification of the subarachnoid space is confirmed by free flow of CSF out of the hub of the needle.

The **paramedian approach** is used in patients where the midline may be difficult to identify (e.g., scoliosis) or the interspace may be challenging to pass a needle through (e.g., thoracic level for epidural placement, elderly patients with calcified ligaments or loss of disc space). Needle insertion is typically 1 cm from the midline. After the transverse process is contacted, and the needle is redirected cephalad and medial to pass through the interlaminar space. One of the main differences between the paramedian and midline approach is that the ligamentum flavum is the first resistance encountered with the paramedian approach. Again, correct identification of the subarachnoid space is confirmed by free flow of CSF out of the hub of the needle.

Assuming there is no blood exiting the needle and the patient has not experienced a paresthesia, administration of the local anesthetic can proceed, and the specific local anesthetic is chosen based upon characteristics which affect onset, duration, and potential for toxicity (see Chap. 6, Pharmacology of Local Anesthetics). Before injection of the local anesthetic, one confirms intrathecal position via aspiration of a small amount of CSF, visualized as a CSF “swirl” when mixing with the local anesthetic in the syringe. The local anesthetic is injected slowly over 3–5 seconds. CSF can be aspirated in the middle and at the end of the injection as well to confirm the needle has not moved from the spinal space while injecting.

Factors Effecting Level and Duration of Local Anesthesia

Two of the most important factors determining the distribution of local anesthetic in the subarachnoid space are the **baricity** of the solution (density compared to CSF) and the **position** of the patient immediately after injection of the solution. Addition of a vasoconstrictor (e.g., epinephrine) and the type of local anesthetic selected may influence the onset and duration of the spinal block.

Hyperbaric solutions usually contain glucose/dextrose. They allow for a more controlled spread of the local anesthetic. If a higher dermatomal level is needed, the patient may be placed in a head-down (Trendelenburg) position, allowing the hyperbaric solution to migrate cephalad. Likewise, if the surgery requires dense lumbosacral anesthesia (such as for a perineal procedure), the patient may be left in a sitting position for several minutes after completion of the spinal (commonly referred to as a “saddle block”). Hyperbaric solutions can also be administered in a lateral position, which results in a unilateral block of the dependent side.

Hypobaric solutions are used less commonly in clinical practice. A patient undergoing hip arthroplasty may benefit from having the hypobaric solution “float up” to the operative side. Hypobaric solutions can be made by mixing the local anesthetic with sterile water, or normal saline.

Isobaric solutions tend to have limited spread within the subarachnoid space and are thought to produce a more profound motor block and longer duration of action. Isobaric solutions can be prepared by mixing the local anesthetic with normal saline or the patient’s CSF.

Addition of epinephrine (0.1–0.2 mg) or phenylephrine (2–5 mg) to the local anesthetic solution increases the duration of the spinal block. The resultant decrease in spinal cord blood flow and uptake of the local anesthetic prolongs the exposure to the nerve roots of the local anesthetic.

Caudal Anesthesia

This type of regional anesthetic is most commonly performed in pediatric patients. After induction of general anesthesia the child is placed in the lateral position. The sacral cornu are identified as well as the sacral hiatus. The skin is prepared in sterile fashion. A needle is introduced perpendicular to the skin through the sacrococcygeal ligament (beneath the sacral hiatus), advanced slightly, then the angle is dropped and the needle is advanced slightly further into the epidural caudal canal. Confirmation of proper needle position can be obtained by rapidly injecting 3–5 mL of air or saline while the anesthesiologist's fingers are palpating the skin directly over the needle. Skin swelling or crepitus indicates the needle has not penetrated the epidural space. Once proper position is confirmed, a syringe is connected to the end of the needle and aspirated to ensure no blood or CSF is obtained. Local anesthetic is then injected in slow 3–5 mL aliquots. Dosing is typically 0.5–1.0 ml/kg of 0.125% or 0.25% bupivacaine or ropivacaine, and may include epinephrine, opioids, or alpha-2-agonists, as discussed previously.

Combined Spinal–Epidural

The last technique for neuraxial anesthesia combines the advantageous qualities of both a spinal (fast, dense onset of anesthesia) and an epidural (placement of a catheter for continuous medication infusion). A special combined spinal–epidural kit is often used that contains an epidural needle with a small hole at the tip to allow passage of a spinal needle. An epidural technique is performed. Once the needle has reached the epidural space, the spinal needle is then introduced through the epidural needle until it pierces the dura, allowing free flow of CSF back through the needle. Local anesthetic is injected into the spinal space, the spinal needle is withdrawn, and the epidural catheter is then threaded through the epidural needle. Catheter placement should be confirmed with aspiration and a test dose, as above. While this technique combines advantages of both spinal and epidural anesthesia, it also exposes a patient to the risks of both. Combined spinal–epidural anesthesia is often used in obstetrics.

Complications and Side Effects: Spinal and Epidural Anesthesia

Cauda Equina Syndrome (CES)

There have been some reports of permanent neurologic injury when using lidocaine for spinal anesthesia. This was first associated with high doses of medication being administered through a continuous spinal catheter, but has also been reported with single-dose injections. It is reported more commonly with higher-concentration local anesthetic injection. The patient develops bowel and bladder dysfunction as well as lower extremity paralysis.

Transient Neurologic Syndrome (TNS)

TNS (or transient radicular irritation) results in pain in the back, buttocks, and lower extremities without motor or sensory deficit, occurring after resolution of spinal anesthesia and resolving within several days. Most reported cases involved high doselidocaine, but has also been reported with other local anesthetics and has even been reported with epidural anesthesia. The incidence is increased when patients are placed in the lithotomy position and when large doses of local anesthetic are used.

Cardiovascular Changes

As a result of sympathetic nervous system blockade, spinal anesthesia and epidural anesthesia can cause hypotension. Treatment centers around volume replacement to restore adequate venous return and cardiac output. The anesthesiologist may also need to administer vasoconstrictor medications (e.g., ephedrine, phenylephrine) to raise blood pressure.

As the level of blockade rises, there is an increased risk of bradycardia. The **cardioaccelerator fibers** originate at the T1–T4 level and may be blocked by neuraxial anesthesia approaching this level. Again, treatment centers around volume replacement to restore preload, but may also require atropine or ephedrine. There is a risk of cardiac arrest following spinal anesthetic, and this is usually preceeded by bradycardia and/or hypotension, thus these symptoms should be promptly treated.

Post-dural Puncture Headache (PDPH)

When the dura mater is violated (as with spinal anesthesia and unintentionally during epidural anesthesia), CSF is allowed to leak through the dural defect faster than it is being produced. This causes traction on the structures supporting the brain, including the meninges, dura, and tentorium, and may result in a headache. Dural puncture with a larger needle (smaller gauge number) leads to higher rates of PDPH, as the result of a larger defect resulting in greater rate of CSF flow. The pathognomonic feature of PDPH is a headache that worsens with sitting or standing and is relieved by lying flat (postural component). Patients may also experience nausea, vomiting, and vision changes. Children and elderly patients have the lowest risk of PDPH, while risk increases with needle size, certain needle types (cutting needles greater risk than pencip point), female sex, young age, and pregnancy. Conservative treatment focuses on bed rest, fluid replacement, caffeine, analgesics, and recumbent positioning. Additional treatment includes sphenopalatine ganglion block, occipital nerve block, and epidural blood patch. Epidural blood patch involves injection of approximately 20 mL of the patient's blood into the epidural space at the same level or one interspace below the level of dural puncture, resulting in near immediate relief.

High/Total Spinal Anesthesia

Total spinal anesthesia refers to excessive sensory and motor anesthesia associated with loss of consciousness, severe hypotension, bradycardia, and loss of respiratory drive. This may occur due to accidental intrathecal injection or overdose of medication. Apnea results from severe sustained hypotension and medullary hypoperfusion, and occasionally through blockade of C3-C5 nerve roots (which contain the phrenic nerve innervation). Treatment focuses on the "ABCs" (Airway, Breathing, Circulation) and tracheal intubation is often necessary until block resolves.

Urinary Retention

Blockade of S2–S4 nerve roots can decrease bladder tone and inhibit the voiding reflex. Most patients that have neuraxial anesthesia require a catheter in the bladder to avoid bladder distention, but this can be avoided with block distribution above the level of sacral nerve roots (such as mid to high thoracic epidural anesthesia for rib fracture analgesia).

Intravascular Injection/LAST (Local Anesthetic Systemic Toxicity)

Since the total dosage of drug administered in a spinal is relatively small, complications resulting from intravascular injection typically occur with epidural anesthesia where volumes are much higher. Local anesthetic may be injected via the needle or a catheter that has been inadvertently threaded into a vessel. Frequent aspiration, administration of a "test dose" (addition of epinephrine), and slow, incremental injections of local anesthetic all help to minimize the chance of intravascular injection. Accidental intravascular injection may result in toxic blood levels of local anesthetic. This can result in effects on the central nervous system (unconsciousness, seizure) and cardiovascular system (hypotension, reduced contractility, arrhythmias). Early signs include tinnitus, metallic taste in the mouth, and ear ringing. Mainstay of treatment is cessation of further local anesthetic injection and administration of a 20% lipid emulsion given via bolus followed by infusion.

Spinal/Epidural Hematoma

The incidence of hematoma after an epidural is commonly cited as approximately 1/150,000 and 1/200,000 after a spinal. Most cases occurr in patients that have abnormal coagulation profiles, including thrombocytopenia, platelet dysfunction, or administration of anti-platelet and anti-coagulant medications. The mass effect of the evolving hematoma causes injury via direct pressure and ischemia. Immediate recognition is paramount to avoid permanent neurologic insult. Symptoms usually include sharp back pain with progression to sensory and motor deficit. An MRI and a neurosurgical consult should be obtained as soon as possible. Emergent surgical decompression of the spine is required and can prevent permanent neurologic damage if performed early.

Epidural Abscess

Abscess formation is a potentially devastating complication of an epidural. The average time frame for the development of symptoms is 5–14 days after catheter placement. There is a progression of symptoms that typically result in back pain exacerbated by percussion over the epidural insertion site, followed by the development of radicular pain, then motor or sensory deficit, and finally paraplegia. As with spinal hematoma, an imaging study and a neurosurgical consultation should be obtained as soon as possible.

Peripheral Nerve Blocks

Peripheral nerve blocks (PNB) and peripheral nerve catheters are common. PNBs are effective for postoperative analgesia and can allow earlier, more intense participation in rehabilitation. Furthermore, regional anesthesia can contribute to reductions in the stress response of a patient associated with surgery or acute pain/trauma, potentially decrease systemic analgesic needs (especially opioid analgesics and their associated side effects), general anesthesia requirements, and even serve as primary anesthetic techniques, providing an alternative to general anesthesia in many cases. The placement of a peripheral nerve catheter can also allow the continued administration of local anesthetic, thus allowing for prolonged blockade well beyond the duration that a "single shot" block would allow. Novel medications utilizing liposomal formulations of local anesthetics have been developed with the potential benefit of prolonged single shot block duration. As with neuraxial anesthesia, the patient must be made aware of the risks and benefits of PNB. Patient refusal, infection at the insertion site, lack of patient cooperation, and coagulopathy are relative or absolute contraindications. As with neuraxial anesthesia, regional anesthetic techniques should only be administered where standard monitors, supplemental oxygen, and resuscitative equipment and medications are available, including those required to treat LAST. While there are many types of PNBs, and many more novel techniques that are increasily described in the literature, we will focus on a few of the most commonly performed for both upper and lower extremity surgery.

Identification of the Target Nerve

There are four major techniques used to identify the desired neural structure: **paresthesias**, **nerve stimulation**, **field block**, and **ultrasound**. Paresthesias are radiating electric shock-like sensations that can occur as a needle contacts or comes very close to a nerve. Due to potential for nerve injury, this is rarely done in current practice. Nerve stimulation (Fig. 13.5) elicits a motor

Fig. 13.5 Nerve stimulation setup for peripheral nerve block. (Reproduced with permission from Tsui [7])

response from a peripheral nerve as the stimulating needle approaches closer to the nerve. A motor response maintained at a current of less than 0.4 mA is thought to indicate close enough proximity to the target nerve to produce anesthesia. Motor response at a current of 0.2 mA or less may indicate needle placement directly in the nerve (intraneural) and injection should only proceed following repositioning of the needle to elicit a less sensitive response. Field block involves injection of local anesthetic targeting cutaneous nerves, and is frequently utilized for minor procedures. Finally, ultrasound uses high-frequency sound waves which are reflected back when they encounter different types of tissue. Different tissues have different degrees of echogenicity and thus reflect the sound waves at different speeds. The resulting image provides varying shades that helps distinguish the tissue types. Nerves can be seen as round, oval, or triangular shaped structures and can be hyperechoic (light) or hypoechoic (dark). For example, nerves visualized above the clavicle tend to be hypoechoic, while those below tend to be hyperechoic. Color flow Doppler can be applied to distinguish blood vessels from other structures. This allows the provider to directly visualize peripheral nerves, adjacent structures, and the needle itself. This allows the provider the ability to both avoid structures that would potentially cause serious harm if punctured (such as lung pleura, peritoneum, and blood vessels), as well as directly visualize spread of local anesthetic to ensure deposition of drug at the desired location for highest rate of block success (and potentially reduce the required volume of administered drug).

Brachial Plexus and Upper Extremity Blocks

The brachial plexus is formed from the anterior rami of cervical nerves C5–C8 and T1 (Figs. 13.6 and 13.7). The brachial plexus runs through the groove formed by the middle and anterior scalene muscles. The plexus initially emerges as the cervical roots, then forms three trunks, six divisions, three cords, and finally the terminal branches that innervate almost all of the upper extremity. A mnemonic sometimes used is "**R**andy **T**ravis **D**rinks **C**old **B**eer" with the first letters of each word standing for **r**oots, **t**runks, **d**ivisions, **c**ords, and terminal **b**ranches.

Interscalene Block

Interscalene block is performed for procedures involving the shoulder and upper arm, as it primarily targets roots C5–7. The block is performed under nerve stimulation by identifying the interscalene groove. To do so, a line is drawn laterally from the cricoid cartilage (the level of the transverse process of C6). The interscalene groove (between the anterior and middle scalene muscle) is palpated (see Fig. 13.8). The brachial plexus is superficial at this level and a nerve block needle is typically inserted only 1–2 cm. Optimal motor response should involve deltoid or biceps, with diaphragm or trapezius response indicationg a position too anterior or posterior, respectively.

Ultrasound guided interscalene block (Fig. 13.9) involves identification of the brachial plexus between the scalene muscles

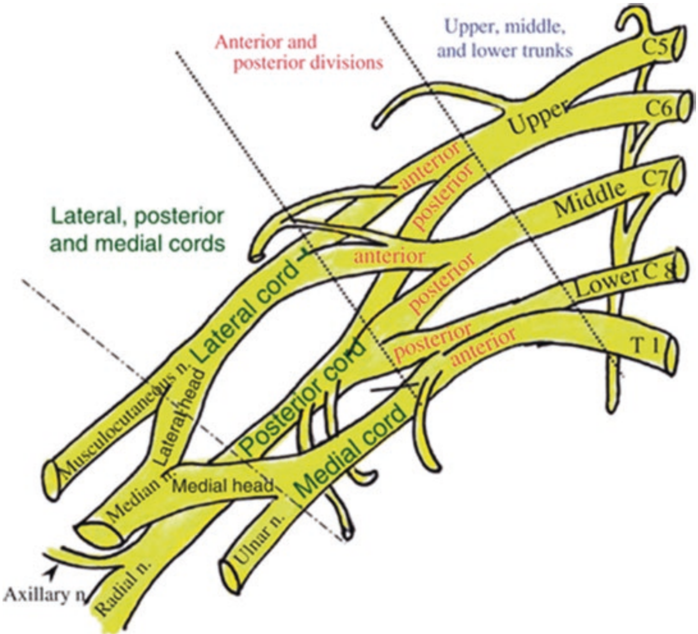

Fig. 13.6 Brachial plexus anatomy. (Reproduced with permission from Tsui [7])

at the level of approximately C6, visualized as a "stop-light sign" as shown in the image above, with the "lights" comprised of three to five hypoechoic circles that are the target roots of the brachial plexus.

An interscalene PNB will often miss the inferior trunk (C8 and T1) and is thus not appropriate for lower arm and hand surgery. Hemidiaphragmatic paralysis via blockade of the ipsilateral phrenic nerve is a side effect in nearly 100% of patients. In a patient with normal respiratory function, this hemidiaphragmatic paralysis is not a concern. Blockade of sympathetic nerves can also produce an ipsilateral Horner's syndrome (ptosis, anhidrosis, miosis, enophthamos, and nasal congestion). Other risks include, vertebral or carotid artery puncture and neuraxial injection.

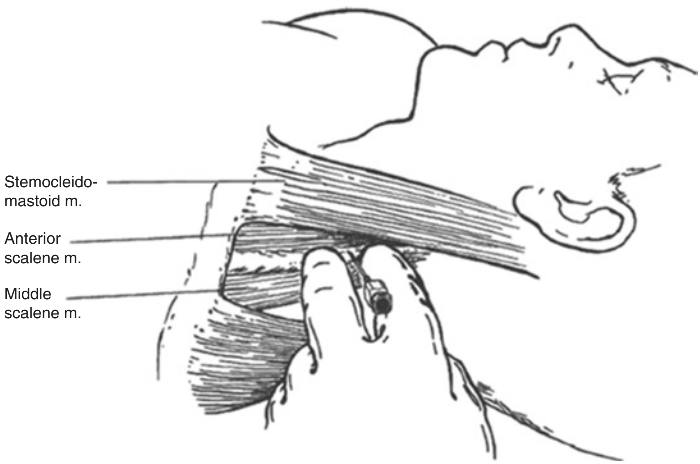

Fig. 13.7 Interscalene nerve block. (Reproduced with permission from Twersky and Philip [8])

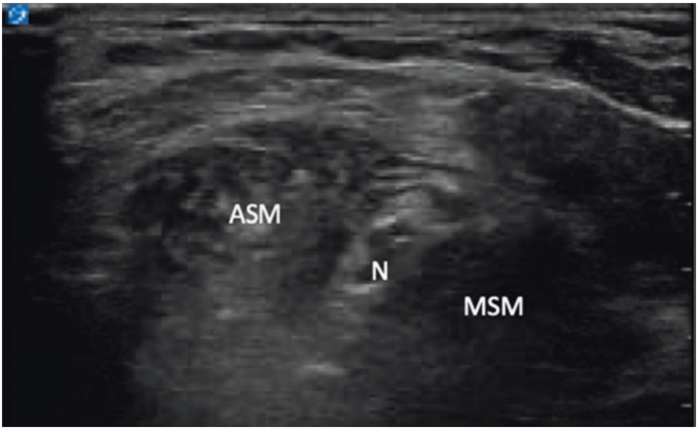

Fig. 13.8 Interscalene block, ultrasound image. ASM anterior scalene muscle, MSM middle scalene muscle, N brachial plexus nerve roots

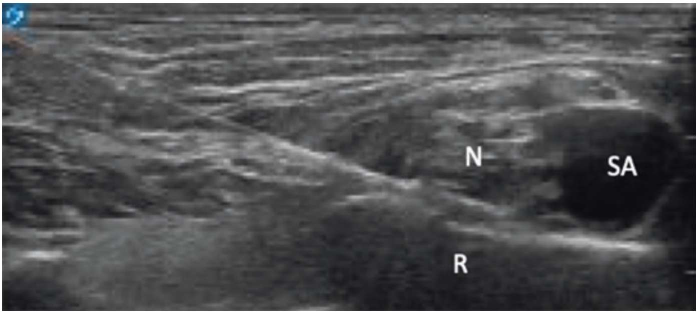

Fig. 13.9 Supraclavicular block, ultrasound image. SA subclavian artery, N brachial plexus nerves, R rib

Supraclavicular Block

A supraclavicular PNB is an excellent choice for surgery of the arm or hand (but is not reliable for shoulder surgery given frequent sparing of axillary and suprascapular nerves), and is often referred to as the "spinal of the arm" given its rapid onset and predictability. Once the interscalene groove is palpated, the groove is followed down the neck to the clavicle. Approximately 1 cm above the clavicle is the insertion point for the block needle. Under ultrasound guidance, the brachial plexus appears as a "cluster of grapes" lateral to the subclavian artery (Fig. 13.10), and use of ultrasound can reduce risk of pneumothorax and subclavian artery puncture. The most common serious complication is pneumothroax, which can occur in 1% of cases.

Infraclavicular Block

An infraclavicular PNB is a good block for surgery of the lower arm and hand (again sparing the shoulder). As the brachial plexus passes under the clavicle, the plexus forms three cords (lateral, posterior, and medial) surrounding the axillary artery. The nerve block needle is further removed from the pleura and the neuraxis and the risk of pneumothorax or neuraxial anesthesia is low. There

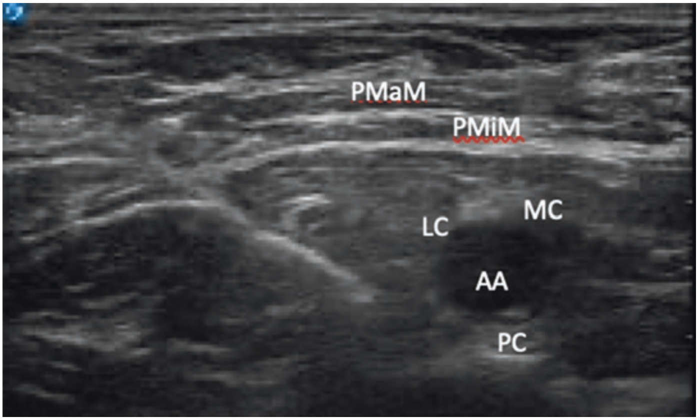

Fig. 13.10 Infraclavicular block, ultrasound image. Brachial plexus surrounding axillary artery at the level of cords. AA axillary artery, MC medial cord, PC posterior cord, LC lateral cord, PMaM pectoralis major muscle, PMiM pectoralis minor muscle

are several approaches to the infraclavicular PNB. The most common approach is ultrasound guided where the probe is placed parasagittaly and allows identification of the three cords and axillary artery to be seen. The block is completed with injection of local anesthetic surrounding the axillary artery and three surrounding cords. If using nerve stimulation, the approach is 2 cm below and 2 cm medial of the acromion. A motor response is usually sought in the hand (finger flexion or extension) with a current <0.4 mA.

Axillary Block

Axillary PNBs are used for surgery involving the lower arm and hand. It offers the advantage of being performed off the chest with minimal risk of phrenic nerve blockade or pneumothorax. As the brachial plexus enters the axilla, the three cords become the terminal branches surrounding the axillary artery. Under ultrasound guidance, the brachial plexus (as the three terminal branches,

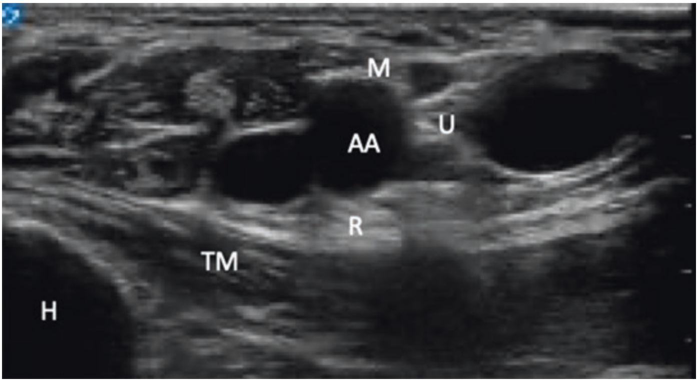

Fig. 13.11 Axillary block, ultrasound image. Brachial plexus surrounding axillary artery at the level of the branches. AA, axillary artery. M median nerve, U ulnar nerve, R radial nerve, TM triceps muscle, H humerus

referred to as the radial, ulnar, and median nerves) is visualized surrounding the axillary artery (Figs. 13.11 and 13.12) Approximately 10 ml of local anesthetic is injected around each nerve. The musculocutaneous nerve is a terminal branch that exits very proximal from the brachial plexus and must be blocked separately. This nerve can be visualized directly under ultrasound and injected, if required for the procedure. As the brachial plexus runs more distal from the roots, the time to onset increases. The axillary PNB takes the longest time to set up of all the upper extremity blocks. Table 13.3 provides a summary of upper extremity peripheral nerve blocks.

Lower Extremity Peripheral Nerve Block

The lumbosacral plexus, comprised of the lumbar plexus (typically L1-L4) and sacral plexus (L4–5 and S1–4), provides lower extremity innervation, and many unique approaches allow for targeted anesthesia of the lower extremity. Figures 13.12 and 13.13 illustrate the sensory distributions of lower extremity nerves. Understanding of these distrubutions is critical to choosing the

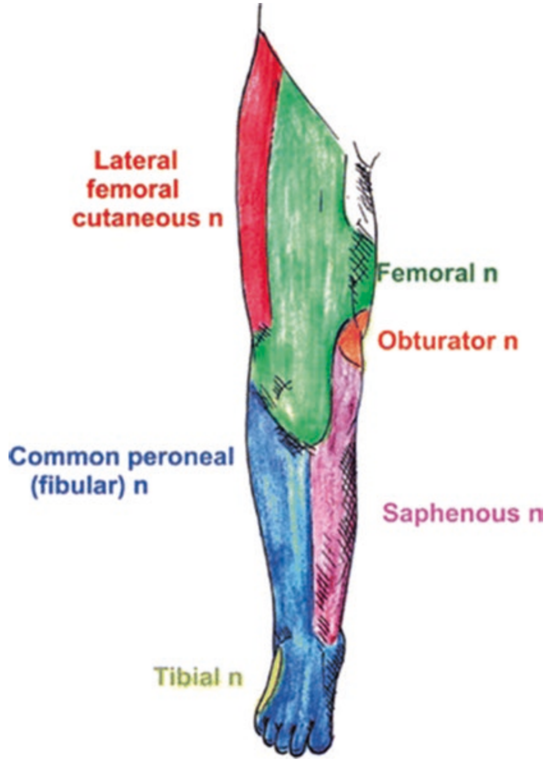

Fig. 13.12 Cutaneous distribution of peripheral nerves. (Reproduced with permission from Tsui [7])

correct peripheral block for a desired analgesic effect. Only a select few will be discussed below.

Femoral Nerve Block

To perform a femoral nerve block, indicated for anesthesia of the hip, thigh, and distribution of the saphenous nerve (medial leg and ankle joint), the patient is placed in the supine position. A line drawn from the anterior superior iliac spine to the pubic tubercle

Table 13.3 Summary of upper extremity nerve blocks

Type of nerve block	Indications	Anatomical landmarks	Potential complications
Interscalene	Shoulder; distal clavicle, upper arm	Between middle and anterior scalene muscles at the level of C6 (cricoid cartilage)	Hemi-diaphragmatic paralysis; Horner's syndrome; epidural spread; intravascular injection; ulnar nerve sparing
Supraclavicular	Upper and lower arm; hand	Between the middle and anterior scalene muscles, 1 cm above the clavicle	Pneumothorax (1% incidence); intravascular injection, may still get hemidiaphragmatic paralysis
Infraclavicular	Upper and lower arm; hand	2–3 cm caudad from the midpoint of the clavicle	Pneumothorax,intravascular injection
Axillary	Lower arm; hand	Brachial artery pulsation	Intravascular injection; prolonged set-up time; miss the musculocutaneous nerve

represents the inguinal ligament. The femoral artery is then palpated along this line and marked. The block needle is inserted 1–2 cm lateral to the femoral artery pulse. The desired motor response is a quadriceps twitch. Under ultrasound guidance, the femoral nerve is visualized over the inguinal crease, just lateral to the femoral artery and deep to the fascia iliaca. Femoral nerve PNB can be used for surgery involving the knee, anterior thigh, and medial portion of the lower leg. Since the femoral nerve is located in close proximity to the femoral artery, careful aspiration is important to avoid intravascular injection of local anesthetic.

The femoral nerve and its branches can be blocked at more distal locations to preferentially provide analgesia of more distal portions of the leg with sparing of quadriceps muscle weakness.

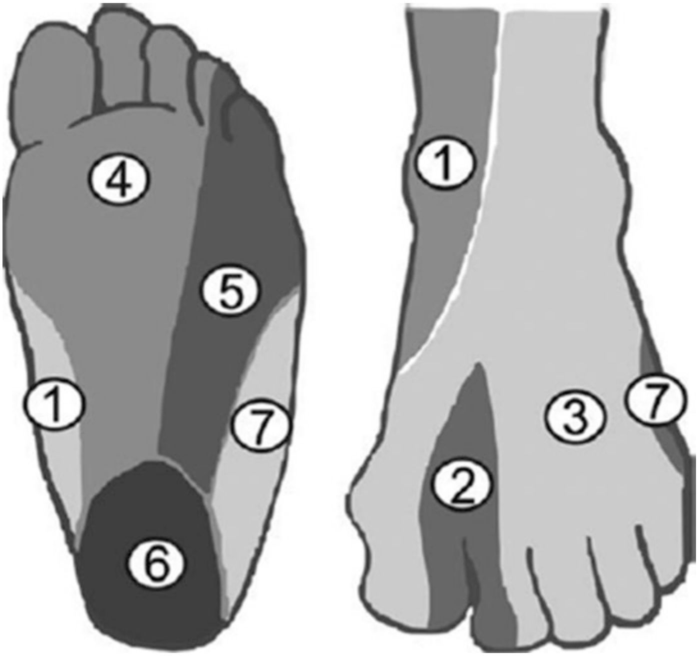

Fig. 13.13 Innervation of the foot. *Plantar surface*: 1 Saphenous nerve; 2 Deep peroneal nerve; 3 Superficial peroneal nerve; 4 Medial planar nerve. *Dorsal surface*; 5 Lateral plantar nerve; 6 Tibial nerve (calcaneal branch); 7 Sural nerve. (Image courtesy J. Ehrenfeld)

The adductor canal block is an option for analgesia of the knee and medial leg, and saphenous nerve block can provide analgesia of the medial leg and ankle joint.

Sciatic Nerve Block

The sciatic nerve is formed from the L4–L5 and S1–S3 nerve roots, and can be blocked anywhere along its course (including posterior, subgluteal, and popliteal approaches). For a posterior (or classical) approach, the patient is placed in the lateral position with the operative side up. The operative leg is flexed at the knee, while the nonoperative leg remains straight. A line is drawn between the greater trochanter and the posterior superior iliac spine. A second line can be drawn from the greater trochanter to the sacral hiatus. A third line is drawn from the mid-point of the first line, intersecting the second line. This is the point of needle entry. The needle is inserted perpendicular to all planes with the desired motor response of plantar or dorsiflexion of the foot. Using ultrasound guidance, the subgluteal approach is usually chosen, and and positioning of the probe is identified using the landmarks of the greater trochanter and ischial tuberosity. The nerve, triangular in appearance, is often visible deep to the gluteal muscles and allows for injection of local anesthetic surrounding the nerve, although nerve stimulation is frequently used in conjunction with ultrasound to confirm proper placement of local anesthetic (see image below). A sciatic nerve block can be used for surgery below the knee (with the exception of the medial portion of the lower leg innervated by a branch of the femoral nerve), although it is also used commonly in addition to femoral blockade for anesthesia of the hip, thigh, and knee. When combined with a lumbar plexus block, it can provide complete anesthesia to the entire leg.

Ankle Block

Five nerves supply sensation to the foot (Fig. 13.10). Four of the five nerves are branches of the sciatic nerve, while one is a branch of the femoral nerve. The **saphenous nerve** (branch of the femoral nerve) provides sensation to the anteromedial aspect of the foot. It can be blocked by infiltrating local anesthetic just anterior to the medial malleolus. The **deep peroneal nerve** provides sensation to the webspace between the first two digits. It can be blocked by infiltrating local anesthetic lateral to the dorsalis pedis artery, and by ultrasound identification of the nerve or the adjacent artery. The **superficial peroneal nerve** provides sensation to the dorsum of the foot and all five digits. It can be blocked by administering local anesthetic from the anterior border of the tibia to the lateral malleolus. The **sural nerve** provides sensation to the lateral aspect of the foot. It can be blocked by injection of local anesthetic just lateral to the Achilles tendon, toward the lateral malleolus. Finally, the **posterior tibial nerve** provides sensation to the heel. The nerve can be blocked by injection of local anesthetic posterior to the medial malleolus, and can again be identified under ultrasound. Approximately 5–8 mL of local anesthetic is injected for each nerve.

Peripheral Nerve Catheters

Placement of a peripheral nerve catheter, or continuous peripheral nerve block, involves identification of a peripheral nerve, placement of a percutaneous catheter adjacent to the nerve, and allows continuous administration of local anesthetic to the area surrounding the nerve. This technique allows for prolonged analgesia from a single procedure, including the possibility of discharging a patient to the home with a continuous infusion of medication. Administration via a continuous nerve block has been shown to potentially decrease rates of chronic postsurgical pain. Potential complications include LAST, nerve injury, infection, hematoma, and intervascular placement of catheter, although these are relatively rare.

Intravenous Regional Anesthesia (Bier Block)

A Bier block is a fairly simple block to perform and can produce profound anesthesia and analgesia. It is often used for short surgical procedures of the hand or forearm (e.g., carpal tunnel), although it is decreasing in popularity with the increasing use of ultrasound guided brachial plexus blocks. To perform the block, a peripheral intravenous line is started and a double pneumatic tourniquet is placed on the arm. The arm is exsanguinated and the proximal cuff on the double tourniquet is inflated. Approximately 25–50 mL of 0.5% lidocaine is injected into the IV and the IV is removed.

If the patient begins to complain about tourniquet pain, the distal cuff can be inflated and the proximal cuff deflated. If the surgical procedure is extremely short, the tourniquet must still be left in place for at least 20 min to avoid rapid systemic absorption of a high concentration of local anesthetic. Due to concern of inadvertent early tourniquet deflation and systemic absorption, long-acting local anesthetics, such as bupivacaine, are not recommended for intravenous regional blocks.

Case Study

A 58-year-old man is to undergo right total knee replacement (TKR/TKA). After a thorough H&P and consultation, he elects to have the procedure under regional anesthesia. He is otherwise healthy, though he smokes a pack of cigarettes a day and does not exercise regularly due to his arthritic knee. He takes an NSAID daily for pain and lately has been taking oxycodone and acetaminophen for worsening pain.

Which dermatomes or nerves will you need to block to perform a total knee replacement comfortably?

The anterior portion of the thigh and leg are innervated by the L3, L4, and L5 dermatomes. The back of the knee, though not in the incision, is stimulated nonetheless in TKR, and is innervated by S2. In addition, a thigh tourniquet is usually employed to prevent blood loss, so L2 and possibly L1 should be blocked. In practice, the femoral, lateral femoral cutaneous, obturator, and portions of the sciatic nerve need to be blocked.

Which regional anesthetic techniques are suitable for total knee replacement? Which will you choose?

In theory, several techniques are possible. Spinal anesthesia will reliably block all the involved nerve roots, whether a plain solution or hyperbaric solution containing glucose is used. Hyperbaric solutions may produce higher levels than are necessary, so plain solutions may be favored for the lower incidence of hypotension. Epidural anesthesia can be used for TKR and allows titration of local anesthetic to the desired level. Disadvantages include a 5–10% incidence of failed or inadequate block (asymmetric anesthesia or incomplete sacral nerve blockade). An additional advantage is the ability to extend the block for either prolonged surgery or for postoperative analgesia. Peripheral nerve blocks may also be used. Individual nerve blocks can provide surgical anesthesia. It is more practical to perform a lumbar plexus or three-in-one block (which will cover the femoral, lateral femoral cutaneous, and obturator nerves with a single injection or catheter). A separate sciatic block, or a spinal or general anesthetic may then be added to complete the anesthetic.

If you choose spinal analgesia, how will you locate the intrathecal space?

Standard monitors are placed and an IV is inserted. The patient can be seated or lying on his side; many find the sitting position easier to locate the midline. The back is sterilely prepped and draped and local anesthetic is infiltrated in a lumbar interspace, typically L3–L4 or L2–L3. With the **midline approach**, the spinal needle is passed through the skin, subcutaneous tissue, the supraspinous ligament, the interspinous ligament, the ligamentum flavum, and finally advancing through the epidural space into the subarachnoid space (Fig. 13.4). Often a distinct "pop" is felt by the anesthesiologist as the needle penetrates the ligamentum flavum. Correct identification of the subarachnoid space is confirmed by free flow of CSF out of the hub of the needle.

If choosing spinal anesthesia, what are the potential benefits, when compared to general anesthesia? Which of the available regional blocks should be considered to help provide post-operative analgesia? What are potential negative implications of choosing these blocks?

The use of neuraxial anesthesia has been associated with improved outcomes following TKA, with potential benefits including decreased hospital length of stay (LOS), decreased OR times, improved 30-day mortality rates, and decreased blood loss. Regional anesthesia techniques provide the opportunity for improved post-operative pain relief, and may reduced pain scores and opioid requirements, as well as shorten hospital LOS. Consideration should be given to single-shot or continuous adductor canal/saphenous block, femoral nerve block, or sciatic nerve block. Adductor canal block attempts to block the sensory branch of the saphenous nerve and provide analgesia to the medial and anterolateral knee below the patella while avoiding motor weakness, but will not provide anesthesia to the posterior aspect of the knee. Femoral nerve block can provide analgesia to the anterior knee, and sciatic block can be used in conjunction to adequately anesthetize the posterior knee, but both will result in likely motor weakness that can potentially result in falls, or delayed participation in rehabilitation exercises.

Suggested Further Reading

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