CONTENTS

2.

ANESTHESIA

LOCAL NERVE BLOCKS

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INTRODUCTION

Regional anesthesia refers to the use of local anesthetics to block nerve signals emanating from discrete anatomic areas of the body. It allows surgical procedures to be performed on anesthetized regions of the body without necessarily rendering a patient unconscious. As such, it has many advantages over general anesthesia, as there are less interferences and disturbances of normal homeostasis. This is particularly important for patients with significant medical comorbidities involving the cardiovascular, respiratory, or renal systems. Additionally, regional anesthesia can be performed quickly and is useful in emergency situations without delaying care, such as when a patient may have recently eaten and is at increased risk for general anesthesia due to aspiration. Furthermore, postoperative morbidity, including pulmonary edema, atelectasis, and other respiratory complications related to general anesthesia, can be markedly reduced with the use of regional anesthesia techniques. There can also be a significant benefit from a nursing and medical standpoint corresponding to decreases in after-care requirements when techniques are planned and implemented appropriately.

Regional anesthesia encompasses a broad range of techniques. In its simplest form, infiltration of local tissues with anesthetic agents can provide a small field under which to perform minor surgical procedures. Peripheral nerves of all sizes can also be targeted to render discrete anatomic areas and even entire limbs insensate. In its most complex form, regional anesthesia can be delivered to the central nervous system, blocking entire regions of the body encompassing multiple dermatomal distributions. Regional techniques have even allowed patients to remain awake during major surgery, as evidenced by a recent trend toward "wide awake surgery" being utilized for many plastic surgery procedures.

Local anesthetic agents are essential to create and maintain regional blockades. These drugs fall into two main classifications: esters and amides, with the latter by far the most frequently used. A list of commonly used local anesthetic agents is presented in Table 2.1. Local anesthetic agents are delivered to the target tissues, where they produce a temporary block of nerve conduction by interfering with action potential propagation via their effects on sodium channels. After being taken up by bodily tissues, esters are eliminated locally by plasma pseudocholinesterase, but amides must be absorbed into the systemic circulation to be metabolized by the liver. Use of epinephrine, typically at concentrations of 1:200,000 (or 5 μg/mL), can prolong the expected duration of regional anesthetic blockade. Other techniques employing controlled-release formulations or placement of catheters for continuous infusion of local anesthetics have been described and have further expanded the clinical indications for regional anesthesia.

Local anesthetics, when used in dosages within the normal clinical range, have minimal noxious effects on target tissues. There is negligible neurotoxicity, as exemplified by complete recovery of neural function after regional blocks have been performed. The local adverse effects of anesthetic agents can include manifestations such as prolonged anesthesia (i.e., numbness) and paresthesia (i.e., tingling, feeling of "pins and needles," or strange sensations). These symptoms can be related to damage, usually caused by intraneural injection or expansion of fluid into a closed anatomic space, including untoward sequela such as hematoma. Systemic adverse effects are directly related to circulating plasma levels. Symptoms follow a predictable pattern affecting first peripheral nerves, then the central nervous system, and finally the heart. Side effects on the central nervous system and the heart may be severe and potentially fatal. However, toxicity occurs only at plasma levels that are

TABLE 2.1 LOCAL ANESTHETIC AGENTS

Esters	Amides
Cocaine	Lidocaine (Xylocaine)
Procaine (Novocaine)	Mepivacaine (Carbocaine)
Tetracaine (Pontocaine)	Prilocaine (Citanest)
Chloroprocaine (Nesacaine)	Bupivacaine (Marcaine, Sensorcaine)
Benzocaine (Americaine)	Etidocaine (Duranest)

rarely reached if proper technique is followed. Epinephrine, in addition to prolonging the anesthetic effect via vasoconstriction, can also shift the timeframe for occurrence of peak plasma levels. A detailed discussion of local anesthetic pharmacokinetics is beyond the scope of this chapter, but the characteristics of the commonly used anesthetic agents, including normal dosages, are listed in Table 2.2.

Adverse reactions to local anesthetics are not uncommon, but true allergic reaction remains rare. Allergic reactions occur only with the esters; are usually due to sensitivity to their metabolite, para-aminobenzoic acid (PABA); and do not result in cross-allergy to amide agents. Also, cases of allergy to paraben derivatives occur, which are often added as preservatives to local anesthetic solutions. Methemoglobinemia, a process in which the oxygen-carrying ability of iron in hemoglobin is altered, produces cyanosis and symptoms of hypoxia. Benzocaine, lidocaine, and prilocaine can all produce this effect, especially benzocaine. Thus, a careful medical history should be obtained from every patient, highlighting any previous adverse effect involving local anesthetic agents prior to considering regional anesthesia.

ASSESSMENT OF THE DEFECT

Regional anesthesia is ideal for any surgical procedure being performed on an anatomic site with a pattern of nervous innervation emerging from a point that is accessible for local anesthetic blockade.

INDICATIONS

Regional anesthesia can be used as the sole anesthetic (with or without sedation) or as a supplement to general anesthesia to improve postoperative analgesia. General considerations include (1) suitability for the type of surgery being performed, (2) surgeon's preferences, (3) institutional experience in performing the technique, (4) physiologic and psychologic state of the patient, and (5) patient acceptance of temporary loss of motor/sensory function. Benefits of regional anesthesia can include (1) improved patient satisfaction, (2) less immunosuppression relative to general anesthesia, (3) decreased incidence of postoperative nausea and vomiting, (4) alternative for patients with a history of malignant hyperthermia, (5) alternative for patients who are hemodynamically unstable or too ill to tolerate general anesthesia, (6) superior pain control in the immediate postoperative period, (7) decreased alteration of the patient's cardiopulmonary physiological status, and (8) less postoperative cognitive impairment (especially in the elderly). General risks of regional anesthesia include (1) toxicity of local anesthetics (especially with indwelling catheters), (2) transient or chronic paresthesia, (3) potential nerve damage, (4) intraarterial injection, (5) seizure, (6) cardiac

TABLE 2.2 CHARACTERISTICS OF COMMONLY USED ANESTHETIC DRUGS

Generic Name (Proprietary Name)	Concentrations (mg %)		Maximum Dose[a] (mg/kg)	Approximate Duration (hr)
	Infiltration	*Nerve Block*		
Procaine (Novocaine)	0.75	1.5–3.0	10–14	0.75–1.50
Chloroprocaine (Nesacaine)	0.75	1.5–3.0	12.15	Short-acting
Lidocaine (Xylocaine)	0.50	1.0–2.0	8–11	1.5–3.0
Mepivacaine (Carbocaine)	0.50	1.0–2.0	8–11	Medium duration
Tetracaine (Pontocaine)	0.05	0.15–0.20	2	
Bupivacaine (Marcaine)	0.25	0.25–0.50	2.5–3.5	3.0–10.0
Etidocaine (Duranest)	0.50	0.5–1.0	4.0–5.5	Long-acting
Ropivacaine (Naropin)	0.25	0.25–0.50	2.5–3.5	

[a] Higher dose with the use of 1:200 000 epinephrine.

arrest, (7) block failure and need to supplement and/or convert to general anesthesia, and (8) infection.

Regional anesthesia remains the procedure of choice in most patients undergoing upper extremity surgery. Anesthetics can be employed at the level of the brachial plexus, but blocks that anesthetize the entire limb are most commonly carried out in the form of an axillary block. Additionally, blocks can be performed around the elbow or in the forearm, including blocks of the ulnar nerve, medial nerve, radial nerve, and medial and lateral antebrachial cutaneous nerves. Another commonly administered regional block is the wrist block. Wrist blocks are very helpful in producing anesthesia of the palm and in median nerve distribution for carpal tunnel release and release of Guyon's canal. Finally, the most commonly used block in the hand is the digital block, which provides anesthesia to a single digit. This invaluable method of anesthesia for emergency hand surgery is the most common type employed in the management of emergency surgical procedures on the hand.

CONTRAINDICATIONS

There are several factors to consider when choosing anesthetic techniques. Examine the patient for surgical scars, scoliosis, skin lesions, and anatomy that may interfere with nerve blockade. There are no routine preoperative tests for healthy patients undergoing regional anesthesia. However, patients with a history of medications/medical conditions that may increase the risk of bleeding should have coagulation studies and platelet counts drawn. Every patient should be assessed for thrombocytopenia prior to the initiation of spinal anesthesia. The following signs and symptom may indicate bleeding tendencies: (1) blood in the urine, (2) bleeding around the gums, and (3) diffuse petechiae. In addition, the patient should be carefully questioned about tendency to bruise easily and any difficulty forming blood clots or prolonged bleeding.

Contraindications for regional anesthesia can be either relative or absolute. Absolute contraindications include (1) patient refusal, (2) infection at the injection site, (3) a true allergy to local anesthetics, (4) inability to guarantee sterile equipment, and (5) high risk of local anesthetic toxicity (i.e., bilateral axillary block). Relative contraindications include (1) pediatric, combative, and/or demented patients; (2) bleeding disorder, either medication induced (i.e., Coumadin) or genetic (i.e., hemophilia) or acquired (i.e., disseminated intravascular coagulation [DIC]); (3) existing peripheral nerve neuropathies that may increase the risk for permanent nerve damage; (4) severe hypovolemia; (5) anemia; and (6) stenotic heart valve lesions. Careful documentation of any existing sensory and/or motor deficits should occur prior to the initiation of any regional approach. Bleeding disorders are an absolute contraindication for any spinal anesthetic due to the risk of hematoma and subsequent cord compression.

ROOM SETUP AND MARKINGS

The room setup and markings will be specific for each case and the type of regional anesthesia being utilized. Regional anesthetic techniques will most often be employed by the plastic surgeon during upper extremity cases. In such instances, the room should include an operating room table with a hand or arm board coming off at a 90-degree angle for arm positioning, overhead operating room lighting, an arm pneumatic tourniquet, and movable stools around both sides of the arm board. There must also be a place to store the anesthetic agents and sterile supplies, such as gloves, towels, syringes, needles, and tubing. The commonly used needles are 1.5- and 3.8-cm long and either 22 or 25 gauge. The syringes necessary are 5 cc, 10 cc, 30 cc, and 50 cc capacity syringes.

SPECIFIC BLOCKS

AXILLARY BLOCK

The most common technique for providing regional anesthesia of the upper extremity is the axillary block, which blocks the major nerves at the level of the third part of the axillary artery. The artery and major nerves are superficial, permitting consistent anesthesia of the extremity with infiltration of the anesthetic agent.

Anatomy

At the level of the third part of the axillary artery, the brachial plexus cords form three major nerves. Using the axillary artery as a point of reference in the area immediately below the shoulder crease on the medial side of the humerus, the median nerve lies anterior and superficial, the ulnar nerve lies posterior and superficial, and the radial nerve lies deep (Figure 2.1). The artery and vein are enclosed in their own subdivision of the fascial sheath, which envelops the entire brachial plexus. The axillary and musculocutaneous nerves egress from the plexus at the level of the coracoid process

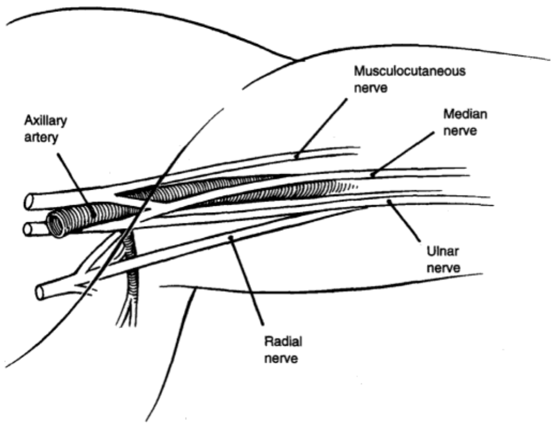


Figure 2.1. Axillary block. Median, ulnar, and radial nerves may be located using axillary artery as point of reference in area immediately below shoulder crease on medial side of humerus.

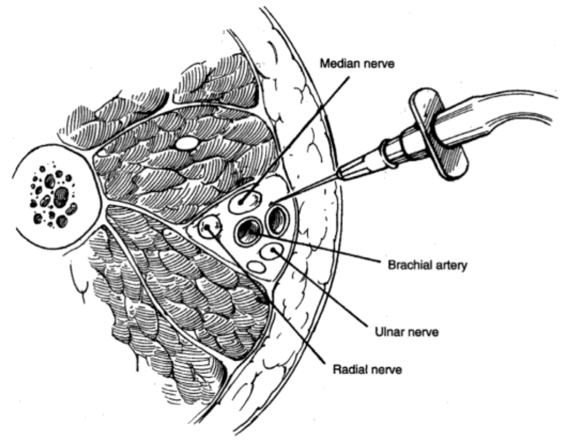


Figure 2.2. Axillary block technique: perivascular approach. Injecting anesthetic agent into sheath above and then below axillary artery.

and are not routinely anesthetized during the performance of an axillary block.

Technique

The original description of the axillary block technique was by Hirshel in 1911. Subsequent to this, all techniques were performed with the arm abducted 90 degrees, with the humerus placed in a position of slight external rotation. Historically, the most common techniques were the arterial puncture and the paresthesia techniques. More recently, the perivascular technique, which is the technique of infiltrating above and below the artery without puncturing the artery or producing paresthesias, has been employed and utilizes ultrasound guidance for delivery of local anesthetic to the axillary sheath.

Since the nerves to be anesthetized surround the axillary artery, the technique of deliberately puncturing the artery with a 22-gauge needle while aspirating blood through the syringe was developed. The needle is advanced through the artery, and an injection is performed only when no further blood can be aspirated. At this point, 40–50 mL of lidocaine or bupivacaine is injected into the sheath surrounding the plexus. It is imperative to hold digital pressure on the area of arterial puncture to prevent hematoma formation, which, if present, may interfere with the production of a satisfactory block.

With the paresthesia technique, the needle is used to explore the region just anterior and just posterior to the axillary artery. It is relatively easy to elicit paresthesias from the median and ulnar nerves since they are superficial, but more difficult to evoke paresthesias from the radial nerve. After paresthesias are noted, approximately 10 mL of local anesthetic agent is injected around each nerve.

Currently, the most popular technique of achieving an axillary block is the perivascular approach (Figure 2.2). In this method, the penetration of the axillary sheath by the injecting needle is noted when a "click" is felt just above and just below the artery. Approximately 40 mL of anesthetic agent is injected into the sheath, and again digital pressure is applied after completion of the injection. The arm is then adducted, and this maneuver, along with the digital pressure, promotes central and proximal migration of the anesthetic solution. This block is relatively simple and is consistently attainable with experience; ultrasound guidance is routinely used to enhance accuracy of this technique.

Precautions

The technique cannot be used when it is not possible to abduct the arm. When using the paresthesia technique, there has been some concern regarding neuritis following injection, especially when epinephrine is added to the local anesthetic. With these concerns in mind, the axillary block remains the technique of choice for regional anesthesia of the upper extremity.

BLOCKS AROUND THE ELBOW

Blocks around the elbow are not frequently performed since there is significant overlap of the distribution of the ulnar, median, and radial nerves, and the variation of this distribution necessitates multiple blocks. Therefore, instead of performing the necessary multiple blocks at the elbow level, it is easier to achieve whole-arm anesthesia with an axillary block. Individual nerve blocks at the elbow are most often used to supplement an axillary block. However, diagnostic nerve blocks at the elbow are useful in the evaluation of pathologic nerve lesions, such as neuromas, or to investigate pain syndromes of the forearm, wrist, and hand.

ULNAR NERVE BLOCK

Technique

The ulnar nerve passes from the posterior aspect of the upper arm to the anterior aspect of the forearm at the elbow, running through the groove between the olecranon and the medial epicondyle. It can be palpated at this level and is anesthetized by the placement of 5 mL of 2% lidocaine solution administered through a 1.5-cm, 25-gauge needle.

Precautions

It is imperative to avoid injection of the local anesthetic directly into the ulnar nerve, which is quite superficial.

RADIAL NERVE BLOCK

Technique

The radial nerve travels on the lateral aspect of the upper arm in the interval between the brachialis and brachioradialis muscles. The nerve is blocked two fingerbreadths above this landmark in the interval between the two muscle bellies, using a 3- to 8-cm, 25-gauge needle. Paresthesias should be sought, and once obtained, 5–10 mL of 2% lidocaine solution is infused.

The medial and lateral antebrachial cutaneous (MAC and LAC) nerves can be blocked distal to the elbow. The MAC runs just lateral to the medial basilic vein, and the LAC runs just medial to the cephalic vein. Approximately 3–5 mL of local anesthetic can be placed into this location, or, alternatively, a subcutaneous ring of local anesthetic can be injected just distal to the elbow flexion crease.

WRIST BLOCKS

Wrist blocks are very valuable and used often in hand surgery. They are safe, well tolerated by the patient, and simple to perform.

MEDIAN NERVE BLOCK

Anatomy

Anesthesia of the median nerve is critical in the performance of carpal tunnel release. This nerve is readily accessible to the infiltration of local anesthetic in the form of either lidocaine or bupivacaine.

The nerve is derived from the medial cord of the brachial plexus. It runs on the anterior aspect of the upper arm and then in the plane between the flexor digitorum superficialis and flexor digitorum profundus in the upper forearm. At approximately the distal third of the forearm, the nerve becomes relatively superficial. Just above the wrist flexion crease, it lies in a position between the flexor carpi radialis (FCR) and the palmaris longus (PL). At this level, it can be anesthetized by the infiltration of local anesthesia.

Technique

Routinely, the patient is asked to oppose the tip of the ring finger to the tip of the thumb. This allows careful and precise location of the PL tendon. The PL lies on the ulnar side of the median nerve. Local anesthetic can then be injected radial to this landmark along the nerve (Figure 2.3). An injection of the nerve in the carpal tunnel

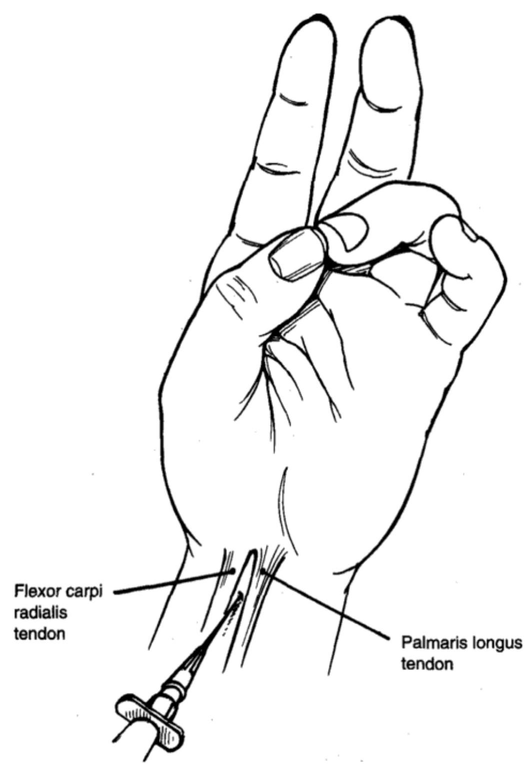


Figure 2.3. Median nerve block. Injecting local anesthetic radial to palmaris longus along nerve.

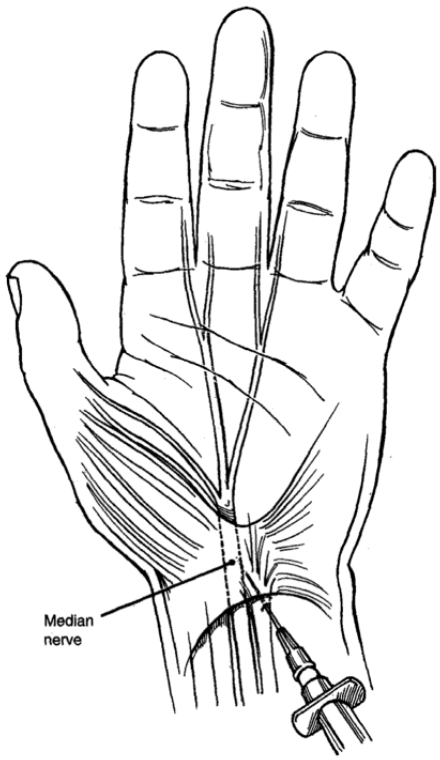


Figure 2.4. Median nerve block. Injecting local anesthetic in carpal tunnel with entrance ulnar to palmaris longus.

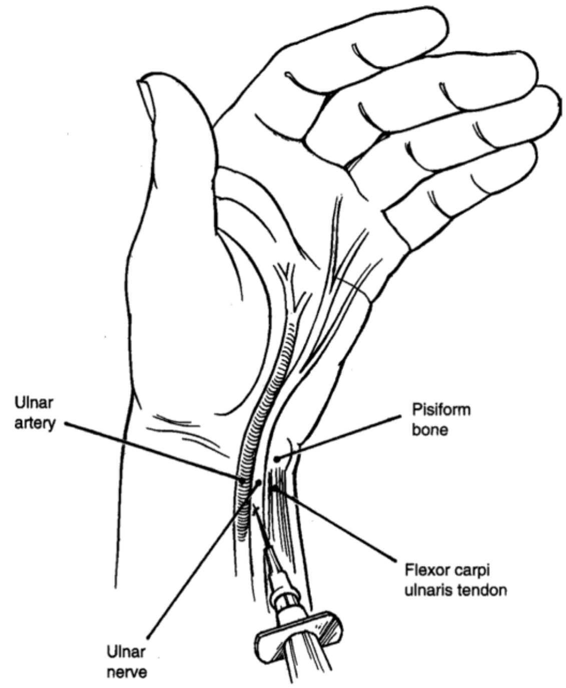


Figure 2.5. Ulnar nerve block. Injection proximal to wrist flexion crease and just radial to flexor carpi ulnaris tendon.

can also be performed (Figure 2.4). A 2% solution of lidocaine is customarily used. The palmar cutaneous branch of the median nerve arises approximately 6 cm proximal to the wrist flexion crease on the radial side of the nerve. It, too, can undergo anesthesia by infiltrating the local anesthetic in a wheal just proximal to the wrist flexion crease. Using 2% lidocaine solution without epinephrine, a 4-cm, 25-gauge needle is inserted between the FCR and PL tendons (Figure 2.3). At the first sign of paresthesias, 5 mL of local anesthetic is slowly injected. It is imperative not to inject the local directly into the nerve, but rather around it. This infiltration produces anesthesia in the median nerve proper and the palmar cutaneous bands with a maximum duration of 2 hours. If a longer effect is desired, the surgeon may infiltrate bupivacaine into the region.

ULNAR NERVE BLOCK

Anatomy

The ulnar nerve is also superficial in its position: it lies radial to the flexor carpi ulnaris tendon, which inserts into the pisiform bone (Figure 2.5). This pisiform bone is readily palpated at the wrist. The ulnar artery lies radial to the ulnar nerve (Figure 2.5), and the surgeon must not inject local anesthesia into the artery. The dorsal sensory branch of the ulnar nerve exits 6 cm proximal to the wrist, passing over the ulnar aspect of the forearm.

Technique

The pisiform bone is palpated on the palmar aspect of the wrist, and the patient is asked to flex and deviate the wrist toward the ulna, allowing precise identification of the flexor carpi ulnaris (FCU) tendon. Next, a 4- cm, 25-gauge needle, which is attached to a syringe containing 2% lidocaine solution, is passed just radial to the FCU tendon until paresthesias are sensed. At this point, the needle is slightly withdrawn so as to not directly inject the nerve, and 5 mL of the lidocaine is injected slowly (Figure 2.5). To obtain a block of the dorsal sensory branch of the ulnar nerve, an additional 5 mL of lidocaine is injected 6 cm proximal to the wrist flexion crease on the ulnar and dorsal aspect of the forearm in the subcutaneous tissue.

RADIAL NERVE BLOCK

Anatomy

The radial nerve is a pure sensory nerve after giving rise to the posterior interosseous nerve in the proximal forearm. It runs on the volar aspect of the forearm deep to the brachioradialis muscle and emerges through this muscle 8–10 cm proximal to the wrist. It then passes radial and dorsal at a point 6 cm proximal to the wrist flexion crease (Figure 2.6) to supply sensory innervation to the dorsoradial aspect of the hand and radial digits (thumb through ring finger).

Technique

The radial nerve is readily blocked at the level of the wrist by placing 5–8 mL of 2% lidocaine solution in the subcutaneous tissues 6 cm proximal to the wrist flexion crease on the radial and dorsoradial aspect of the forearm.

DIGITAL NERVE BLOCK

Perhaps the most frequently used nerve block for surgery on the hand is the digital nerve block. It is easy to administer, well tolerated by the patient, and invaluable for many of the outpatient emergency procedures performed on the digit. Historically, it has been taught to never inject local anesthetic agents containing epinephrine when performing this block.

Anatomy

Each digit is supplied by four nerve branches. Two of these run on the palmar aspect of the finger and are commonly

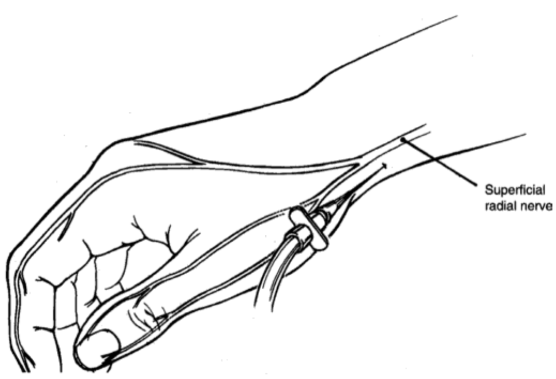


Figure 2.6. Radial nerve block. Subcutaneous injection along radial side of forearm 5 cm proximal to wrist flexion crease.

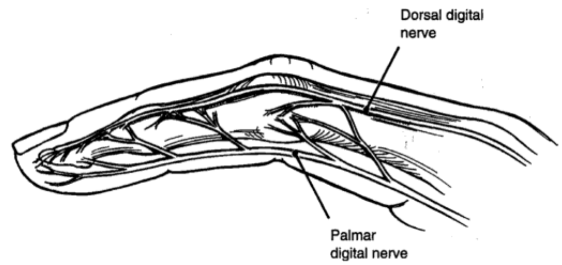


Figure 2.7. Digital nerve block. Dorsal and palmar digital nerve anatomy.

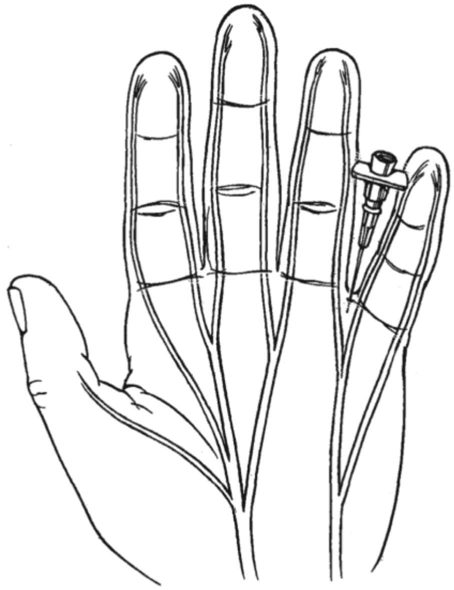
referred to as the digital nerves. They arise from either the median nerve (thumb, index, and middle fingers and radial aspect of the ring finger) or the ulnar nerve (ulnar side of ring and small finger in the proximal portion of the palm). The two corresponding dorsal sensory branches to the digits arise from either the dorsal radial nerve or the dorsal ulnar nerve (Figure 2.7).

Technique

Either of two techniques is used to achieve anesthesia in the distribution of the proper digital nerves from either the main median or ulnar nerve. The preferred method starts with the dorsal skin surface as a reference, where a 25-gauge needle is inserted into the interdigital web two-thirds of the way toward the palm. The needle is inserted approximately 2 cm deep, and 3–4 mL of 2% lidocaine solution is injected (Figure 2.8A). The same maneuver is performed on the opposite side of the digit. Next, additional local anesthetic is injected subcutaneously over the dorsum of the base of the digit from the site of the first injection to the site of the second injection (Figure 2.8B).

An alternative to injecting the interdigital web space to achieve a block of the proper digital nerves is to begin the injection on the dorsum of the hand in the distal hand at a level corresponding to the distal palmar crease on either side of the metacarpal ray. A 4-cm, 25-gauge needle is introduced through the dorsal skin of hand. A small amount of 2% lidocaine solution is injected into the subcutaneous tissue, and the needle is further inserted toward the palmar skin. Contact with the dermis on the palm side will produce discomfort: at this time the needle is withdrawn slightly, and 3 mL of the lidocaine solution is injected on one side of the metacarpal ray; then the procedure is repeated on the other side of this metacarpal. Again, it is also necessary to inject local anesthesia into the subcutaneous tissues over

(A)



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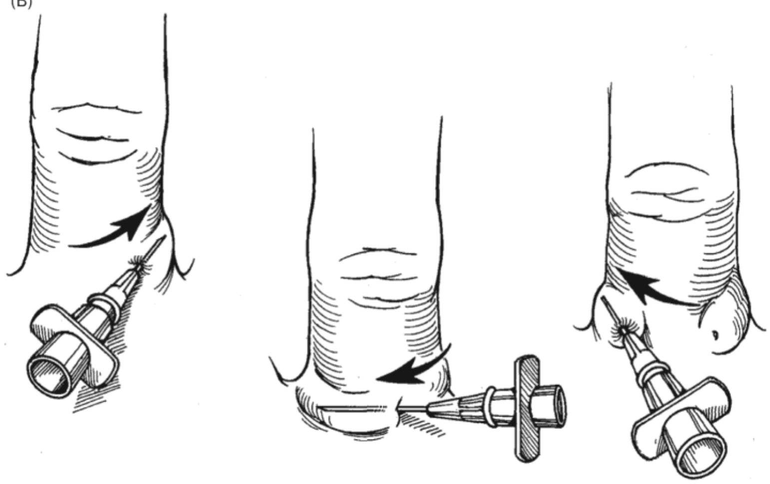

Figure 2.8. Digital nerve block technique. (A) A 25-gauge needle is inserted approximately two-thirds of way into interdigital web toward palm, and 3–4 mL of lidocaine solution is injected. (B) Additional local anesthetic is injected subcutaneously over dorsum of base of digit from site of first injection to site of second injection.

the entire dorsum of the digit to block the dorsal sensory nerves.

FACIAL BLOCKS

Facial blocks are very valuable and used often in plastic surgery to facilitate simple office procedures or allow for emergent repair of injuries. They are safe, well tolerated by the patient, and simple to perform.

LIP BLOCK

The lips surround the entrance to the oral cavity. They function to provide competence to the oral cavity during mastication and at rest. The lips affect uttered sounds that facilitate spoken language and provide changes of facial expression that facilitate unspoken language. They provide sensory information about food prior to its placement in the oral cavity. To accomplish the multitude of functions, lips require a complex system of muscles and supporting structures.

Anatomy

The sensory innervation to the perioral region is from the maxillary and mandibular branches of the fifth cranial nerve. The infraorbital nerve, which is a terminal branch of the maxillary nerve, innervates the upper lip. This nerve exits the infraorbital foramen 4–7 mm below the inferior orbital rim on a vertical line that descends from the medial limbus of the iris. The nerve runs beneath the levator labii superioris and superficial to the levator anguli oris to supply the lateral nasal sidewall, ala, columella, medial cheek, and upper lip.

The lower lip and chin receive sensory innervation from branches of the mandibular nerve. The inferior alveolar nerve, a branch of the mandibular nerve, forms the nerve to the mylohyoid just proximal to entering the lingula of the mandible. The inferior alveolar nerve travels through the body of the mandible to exit from the mental foramen. The mental foramen is located below the apex of the second mandibular bicuspid with 6–10 mm of lateral variability. The mental nerve ramifies to supply the lower lip skin down to the labiomental fold and, occasionally, down the chin as well. The nerve is located in the submucosa as it exits the foramen and frequently is visible in its location.

Technique

Either an intraoral or extraoral approach can be used to block the infraorbital nerve, while the mental nerve is routinely blocked from within the oral cavity at its location within the lower gingival buccal sulcus (Figure 2.9). When blocking the infraorbital nerve via an intraoral approach, a finger should be placed over the infraorbital rim to protect the globe from accidental puncture. The cheek is retracted on the desired side and a 4-cm, 25-gauge needle is introduced into the mucosa comprising the upper gingival buccal sulcus above the second premolar. The needle is kept parallel with the long axis of the second premolar until it is palpated through the skin near the foramen lying approximately 2.5 cm cephalad. If the needle is extended too far superiorly and posteriorly, the orbit may be entered. Once the needle is positioned properly, aspirate to ensure that the needle is not within a vessel and inject 2.3 mL of anesthetic solution adjacent to the foramen. For the extraoral approach to the infraorbital nerve, a finger is again placed on the infraorbital rim to protect the globe. The skin is pierced with a 4-cm, 25-gauge needle perpendicular to the skin surface one fingerbreadth below the infraorbital rim in a position directly below the later corneal limbus. Again, 2.3 mL of local anesthetic solution is injected around the foramen.

For blocking the mental nerve, the cheek is retracted laterally. The mental nerve foramen is located approximately 2 cm below the alveolar ridge in line with the second premolar in adults. The needle is inserted into the lower gingival buccal sulcus directly under the second premolar and 2–3 mL of local anesthetic solution is injected around the foramen.

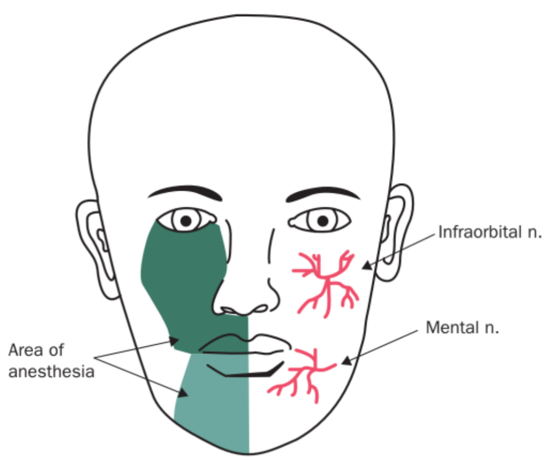

Figure 2.9. Sensory innervation to the periorbital region arises from the infraorbital and mental nerves.

NASAL BLOCK

Nasal anesthesia is required for the management of common routine and emergency procedures including management of nasal and facial trauma. General anesthesia may not be an option because of the emergent need for intervention, medical risk factors, or operating room availability.

Anatomy

The understanding of nasal innervation can be simplified by dividing it into the internal and external aspects of the nose. The external nose is innervated by the ophthalmic (V1) and maxillary (V2) nerves, which are the first two divisions of the trigeminal nerve (cranial nerve V). The anterior-superior aspect of the nose, including the tip, is supplied by the infratrochlear nerve (V1), the supratrochlear nerve (V1), and the external nasal branch of the anterior ethmoid nerve (V1). The infraorbital nerve (V2) supplies the inferior and lateral aspects of the nose, extending to the lower eyelids.

The internal nasal cavity may be subdivided into the nasal septum, the lateral walls, and the cribriform plate. The superior inner aspect of the lateral nasal wall is supplied by the anterior and posterior ethmoid nerves (V1). The sphenopalatine ganglion (V2) is located at the posterior end of the middle turbinate and innervates the posterior nasal cavity. The anterior and posterior ethmoid nerves (V1) and the sphenopalatine ganglion (through the nasopalatine nerve) provide sensation to most of the septum. The cribriform plate contains the special sensory branches of the olfactory nerve.

Technique

For a comprehensive nerve block, a series of injections is performed. The practitioner must attempt to limit the number of times the needle is inserted into the skin by performing a series of sequential injections. First, block the external nasal nerve with an intercartilaginous injection of the nasal dorsum from the region of the rhinion to the supratip region. Next, block the nasopalatine nerve with an injection at the base of the columella and nasal tip. Inject the other side in a similar fashion. Next, pass the needle through the vestibule into the facial soft tissue to a point just below the mid-orbital rim to anesthetize the infraorbital nerve.

EAR BLOCK

Anesthesia of the ear is useful for repair of lacerations, hematoma incision and drainage, and other painful procedures of the ear.

Anatomy

Four sensory nerves supply the external ear: (1) greater auricular nerve, (2) lesser occipital nerve, (3) auricular branch of the vagus nerve (i.e., Arnold's nerve), and (4) auriculotemporal nerve. The greater auricular nerve is a branch of the cervical plexus. It innervates the posteromedial, posterolateral, and inferior auricle (lower two-thirds both anteriorly and posteriorly). The lesser occipital nerve innervates a small portion of the helix. The auricular branch of the vagus nerve innervates the concha and most of the area around the auditory meatus. The auriculotemporal nerve originates from the mandibular branch of the trigeminal nerve. It innervates the anterosuperior and anteromedial aspects of the auricle.

Technique

The choice of technique depends on the area of the ear that requires anesthesia. The ring block around the entire ear can anesthetize the entire ear, excluding the concha and external auditory canal. To perform this technique, insert a 4-cm, 25-gauge needle into the skin just inferior to the attachment of the earlobe caudally. Advance the needle just anterior to the tragus, aspirating as the needle advances. Aspirate and then inject 2.3 mL of anesthetic while withdrawing the needle slowly back toward the puncture site without removing it from the skin. Once back at the puncture site, redirect and advance the needle posteriorly along the inferior posterior auricular sulcus, again aspirating as it is advanced. Then inject 2.3 mL of anesthetic while withdrawing the needle Figure 2.10.

The needle is then removed and reinserted just superior to the attachment of the helix to the scalp. Direct and advance the needle just anterior to the tragus, aspirating as it is advanced. Aspirate and inject 2.3 mL of anesthetic

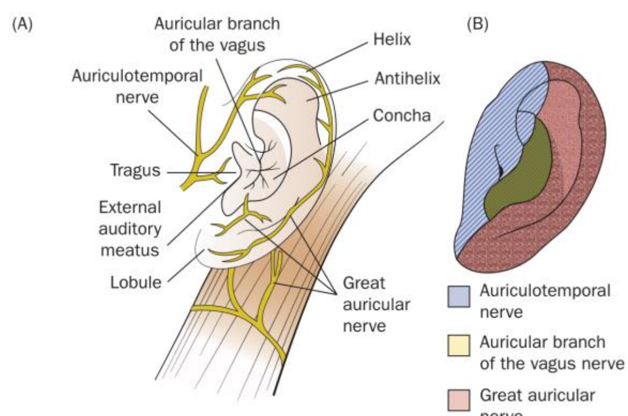

Figure 2.10. Sensory innervation to the ear arises from four distinct sources: (1) greater auricular nerve, (2) lesser occipital nerve, (3) auricular branch of the vagus nerve (i.e., Arnold's nerve), and (4) auriculotemporal nerve.

while withdrawing the needle toward the skin puncture site without removing it. Be cognizant to inject the subcutaneous tissue, not the ear cartilage. Once just under the skin at the needle puncture site, redirect and advance the needle posteriorly along the superior posterior auricular sulcus, aspirating as it is advanced. Again aspirate and inject 2.3 mL of anesthetic while withdrawing the needle. Be mindful of the superficial temporal artery, located anterior to the ear as it crosses over the zygomatic arch. The concha and ear canal can be difficult to anesthetize due to the sensation arising from the auricular branch of the vagus nerve.

INTRAVENOUS REGIONAL ANESTHESIA

Intravenous regional anesthesia, also known as a Bier block, is a very simple technique that is increasingly being used for hand surgery procedures and for fracture reduction procedures in the upper extremity.

TECHNIQUE

A double tourniquet is placed on the upper arm and each of the dual compartments is carefully checked. An intravenous line is started in the arm to be anesthetized, using a 20- or 22-gauge venous cannula, and it is taped securely. The arm is elevated and exsanguinated with an Esmarch bandage from the digital tips to the tourniquet; this exsanguination must be thorough. After this maneuver, the proximal tourniquet is inflated. Next, the intravenous infusion of lidocaine without epinephrine is begun using 0.5% lidocaine solution. A dose of 3 mg/kg is administered through the intravenous line. Anesthesia in the extremity is noted approximately 4 minutes after the infusion. The proximal tourniquet is left up until the patient senses discomfort (usually 20–30 minutes) and then the distal cuff of the tourniquet is inflated. The proximal cuff is deflated when it is ascertained that the distal cuff is stable. The distal cuff can remain inflated for up to 40 minutes without producing significant discomfort.

At the completion of the procedure, the tourniquet is released for short intervals of approximately 15 seconds and then reinflated. This procedure is repeated four times if the procedure was less than 10 minutes in duration, three times if it was less than 20 minutes in duration, and two times if it was less than 40 minutes in duration. This prevents a bolus of lidocaine from entering the circulation. Fifty percent of the local anesthetic is still bound to the tissues for 30 minutes. If additional anesthesia is needed within 30 minutes after deflation of the tourniquet, additional lidocaine can be administered in half of the original dose.

The advantages of this procedure are that it is very easy to perform, and it is safe and effective for outpatient surgery. Rapid return of motor function occurs after tourniquet release, allowing the surgeon to evaluate tendon and joint motion in cases of tenolysis. Disadvantages of this technique include the potential for tourniquet pain, especially if the procedure lasts longer than 1 hour. Other potential problems include lack of anesthesia after cuff deflation, lack of muscle relaxation, equipment problems, and problems with tourniquet release.

FIELD BLOCK ANESTHESIA

This type of anesthesia has limited application in hand surgery, but it is valuable for certain procedures, including carpal tunnel release, trigger finger release, and release of the second extensor compartment for de Quervain's tenosynovitis. For surgery on the preceding three conditions, a field block-type anesthesia is effective and facilitates rapid recovery when these surgical procedures are performed under sedative anesthesia.

ANATOMY

Carpal tunnel release is performed using an incision ulnar to and parallel with the thenar flexion crease. The transverse carpal ligament is released from the superficial palmar arch to the volar carpal ligament. The characteristic incision varies from 3–5 cm in length.

Technique

Using 1% lidocaine solution without epinephrine, 2 mL is injected proximal in the wrist flexion crease after intravenous sedation has been administered. Next, an additional 8 mL of 1% lidocaine solution is injected into the subcutaneous tissues, both immediately below the dermis and immediately above the palmar fascia in the line of intended incision. This provides excellent anesthesia in the hand, and the operation can be performed with the assistance of either a forearm or upper arm tourniquet.

For trigger finger release operations or for release of the first extensor compartments to treat de Quervain's disease, the local anesthetic is instilled into the intended line of incision, and, again, either a forearm or upper arm tourniquet is used.

STELLATE GANGLION BLOCK

This is a special block designed to interrupt the sympathetic innervation of the extremity, which is used to treat the early phases of a reflex pain syndrome. It can be very useful in the treatment of reflex sympathetic dystrophy. If the initial block is successful, repeated blocks are also likely to be successful.

TECHNIQUE

The most commonly used technique is the paratracheal approach, for which the patient is placed in the supine position. The sternoclavicular junction is palpated and the sternocleidomastoid muscle is displaced laterally. A 4-cm, 22-gauge needle is inserted two fingerbreadths above and lateral to the sternoclavicular junction until the seventh transverse process is contacted (Figure 2.11). After aspiration, the needle is withdrawn 2 mm and 10–15 mL of 1% lidocaine solution is injected. The development of Horner's syndrome is observed within a few minutes. Increased skin temperature and the absence of swelling are evidence that the sympathetic input has been blocked.

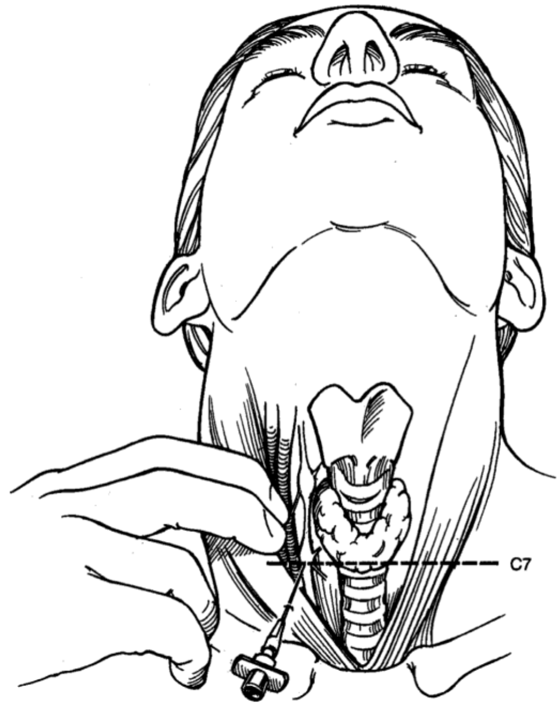

Figure 2.11. (A) Stellate ganglion block. A 3.8 cm, 22-gauge needle is inserted two fingers' breadth above and lateral to sternoclavicular junction until the seventh transverse process is contacted; needle is withdrawn 2 mm and 10–15 mL of 1% lidocaine solution is injected. Disadvantages of this technique include the potential for tourniquet pain, especially if the procedure lasts longer than 1 hour. Other potential problems include lack of anesthesia after cuff deflation, lack of muscle relaxation, equipment problems, and problems with tourniquet release.

INTERCOSTAL NERVE BLOCK

Intercostal block produces discrete band-like segmental anesthesia in the chosen levels. The intercostal block is an excellent analgesic option for a variety of surgical procedures. The beneficial effect of intercostal blockade on respiratory function following thoracic or upper abdominal surgery, or following chest wall trauma, is well documented. Although similar in many ways to the paravertebral block, intercostal blocks are generally simpler to perform because the osseous landmarks are more readily palpable. However, the risks of pneumothorax and local anesthetic systemic toxicity are present, and care must be taken to prevent these potentially serious complications.

ANATOMY

After emerging from their respective intervertebral foramina, the thoracic nerve roots divide into dorsal and ventral rami. The dorsal ramus provides innervation to the skin and muscle of the paravertebral region; the ventral ramus continues laterally as the intercostal nerve. This nerve then pierces the posterior intercostal membrane approximately 3 cm lateral to the intervertebral foramen and enters the subcostal groove of the rib, where it travels inferiorly to the intercostal artery and vein. Initially, the nerve lies between the parietal pleura and the inner most intercostal muscle. Immediately proximal to the angle of the rib, it passes into the space between the innermost and internal intercostal muscles, where it remains for much of the remainder of its course. At the midaxillary line, the intercostal nerve gives rise to the lateral cutaneous branch, which pierces the internal and external intercostal muscles and supplies the muscles and skin of the lateral trunk. The continuation of the intercostal nerve terminates as the anterior cutaneous branch, which supplies the skin and muscles of the anterior trunk, including the skin overlying the sternum and rectus abdominis.

Intercostal blocks can be more challenging to perform above the level of T7 because the scapula prevents access to the ribs. Although an intercostal block is an excellent choice for analgesic purposes, it is often inadequate as a complete surgical anesthesia. For this application, supplementation with another anesthesia technique usually is required.

TECHNIQUE

After cleaning the skin with an antiseptic solution, 1–2 mL of dilute local anesthetic is infiltrated subcutaneously at each planned level injection site. The fingers of the palpating hand should straddle the insertion site at the inferior border of the rib and fix the skin to avoid unwanted skin movement. A 2-cm, 22-gauge needle is introduced through the skin and contact with the rib should be made. While maintaining the same angle of insertion, the needle is walked off the inferior border of the rib. Then the needle is advanced 3 mm below the inferior margin of the rib, with the goal of placing the tip in the space containing the neurovascular bundle between the internal and innermost intercostal muscles. The end point for advancement should be the predetermined distance (3 mm). Following negative aspiration for blood or air, 3–5 mL of local anesthetic is injected. The process is repeated for the remaining levels of blockade.

TRANSVERSUS ABDOMINIS PLANE BLOCK

The transverse abdominis plane (TAP) block is a peripheral nerve block designed to anesthetize the nerves supplying the anterior abdominal wall (T6–L1). It was first described in 2001 by Rafi as a traditional blind landmark technique using the lumbar triangle of Petit. In recent studies, the TAP block was shown to reduce the need for postoperative opioid use, increase the time to first request for further analgesia, and provide more effective pain relief while decreasing opioid-related side effects such as sedation and postoperative nausea and vomiting. The introduction of ultrasound has allowed providers to identify the appropriate tissue plane and perform this block with greater accuracy under direct visualization. Often, the plastic surgeon will have direct access to the abdominal wall through a lower abdominal incision.

ANATOMY

The abdominal wall is composed of five paired muscles: two midline vertical muscles (the rectus abdominis and the pyramidalis) and three lateral layered flat muscles (external abdominal oblique, the internal abdominal oblique, and the transversus abdominis muscles). The internal oblique muscle is the intermediate layer of the three lateral abdominal muscles. It originates broadly from the anterior portion of the iliac crest, lateral half of the inguinal ligament, and thoracolumbar fascia. The internal oblique inserts on the inferior border of the 10th–12th ribs, the linea alba, and the pubic crest via the conjoint tendon. The muscle fibers of the internal abdominal oblique course upward in a superomedial orientation, perpendicular to the muscle fibers of the external abdominal oblique.

The transversus abdominis muscle is the deepest of the three paired, flat abdominal muscles. It originates on the internal surfaces of the 7th–12th costal cartilages, thoracolumbar fascia, anterior three-fourths of the iliac crest, and lateral third of the inguinal ligament. As with the other flat muscles, the transversus abdominis forms a broad aponeurosis that helps make up the rectus sheath before it fuses in the midline to the linea alba. Above the arcuate line, the transversus abdominis aponeurosis contributes to the posterior rectus sheath. Below the arcuate line, it is fused with the other flat muscles as the anterior rectus sheath.

TECHNIQUE

In the traditional blind approach, the lumbar triangle of Petit is identified. The triangle of Petit is formed by the iliac crest as the base, the external oblique muscle as the anterior border, and the latissimus dorsi muscle as the posterior border. The floor of the triangle is made up of the fascia from both the external and internal oblique muscles. A needle is inserted perpendicular to the skin just cephalad to the iliac crest near the mid-axillary line. The TAP is identified using a "two-pop" sensation or loss of resistance. The first pop indicates penetration of the fascia of the external oblique muscle, and the second indicates penetration of the fascia of the internal oblique muscle. Local anesthetic is then injected with multiple aspirations. Recently, ultrasound has eliminated the blind approach and has greatly enhanced both the safety and efficacy of the TAP block.

PERTINENT DRESSINGS

There are no special dressings required. However, sterile gauze should be available to hold pressure on the site of infiltration or local anesthetic infusion.

UNIQUE ASPECTS OF POSTOPERATIVE CARE

The performance of surgery under regional anesthesia routinely results in a rapid return of motor and sensory function dependent upon the type of local anesthesia used. Sometimes the goal of regional anesthesia is not only to provide surgical anesthesia, but to provide pain control for many hours after surgery. This type of anesthesia does not interfere in any way with the application of the desired dressing or splint, with the necessary arm and hand positioning, or with subsequent therapy.

CAVEATS

Consistency with regional anesthesia requires a thorough knowledge of anatomy and experience in administering the respective blocks.

SELECTED READINGS

Adams JP, Dealy EJ, Kenmore PI. Intravenous regional anesthesia in hand surgery. *J Bone Joint Surg* 1964;46A:811–816.

Adrani J. *Nerve Blocks: A Manual of Regional Anesthesia for Practitioners of Medicine*. Springfield, IL: Charles C Thomas, 1954.

Bier A. Uber einen leg local Anesthetie in den Gleidmassen zu erzeugen. *Arch Klin Chir* 1908;86:1007–1016.

Graham WP III. Intravenous regional anesthesia for outpatient operations on the upper extremity. *Industrial Med* 1970;39:213–214.

Hadzic A. *Textbook of Regional Anesthesia and Acute Pain Management.* McGraw-Hill Education, 2016.

Malamed SF. *Handbook of Local Anesthesia*. Elsevier Health Sciences, 2014.

Mustoe TA, Buck DW, Lalonde DH. The safe management of anesthesia, sedation, and pain in plastic surgery. *Plast Reconstruct Surg* 2010;126(4): 165e–176e.

Ramamurthy S, Hickey R. Anesthesia. In: Green DP, ed. *Operative Hand Surgery*. New York: Churchill Livingstone, 1993.

Winnie AP, Ramamurthy S, Durrani Z. Diagnostic and therapeutic nerve blocks: recent advances in techniques. In: Bonica JJ, ed. *Advances in Neurology*. Vol 4. New York: Raven Press, 1974.

Winnie AP, Tay CH, Patel KP, et al. Pharmacokinetics of local anesthetics during plexus blocks. *Anesth Analg* 1977;56:852–861.

3.

WOUND CLOSURE

David A. Daar and Maristella S. Evangelista

The main duty of plastic surgeons is to restore form and function to their patients. Wound closure is the principal means of accomplishing this task. In order to successfully allow for healing, proper wound assessment and planning are of paramount importance. Successful closure of a wound cannot be achieved with a simple algorithm; rather, it involves a decision made after consideration of wound characteristics, patient characteristics, and reconstructive options.

ASSESSMENT OF THE DEFECT

A thorough history is always the first step in the assessment of a wound. Understanding of the mechanism of injury, chronicity of the wound, and associated symptoms can signal important considerations such as the potential for contamination, infection, or other disease processes. Patient factors such as age, medical history, family history, and social history will also be important in the management of their wounds and will be discussed in more detail in subsequent sections.

On physical exam, assess the location and characteristics of the defect, including size, shape, depth, and color. Is there active drainage or discharge? Does the area have good blood flow? One should consider the anatomy in the area and look for damage to or exposure of surrounding structures, including vessels, nerves, tendons, joints, muscle, or bone.[1] If structures are not visible, their function should still be evaluated as this may indicate a concealed or ongoing process.

Healthy tissue will appear red or pink and may have punctate bleeding. Devitalized tissue may appear gray, purple, or black. Infected wounds may be malodorous or have purulent drainage. Other nonhealing wounds may show hardened fibrotic tissue or yellow debris. Chronic nonhealing wounds should heighten suspicion for chronic patient factors and potentially even malignancy. In traumatic injuries, consider the potential for contamination or retained foreign bodies. Sharp lacerations tend to be confined to the area of the wound, whereas avulsion injuries and blast injuries will create zones of injury beyond initial assessment.

INDICATIONS FOR SURGICAL CLOSURE

In traumatic injuries, the urgency of closure is something to quickly evaluate. Leaving wounds open may increase the risk of infection. Are critical structures exposed or damaged? Is there active bleeding? Is the wound contaminated? Closure performed in the emergency room may be easier and faster but will require good local anesthetic and patient cooperation. Going to the operating room is a more involved process but offers better light, specialized instruments, and greater ability to manipulate, repair, and debride tissue. In times of uncontrolled bleeding, damage to critical structures, evidence of joint or bone involvement, high contamination, high complexity, and/or uncooperative or high-risk patients, the operating room is indicated. Patient safety and comfort is the primary concern—if there is any doubt, manage the patient in the operating room.

Barring contraindications, traumatic wounds should be closed within 6 hours to minimize infection.[2] Open fractures should undergo thorough irrigation and debridement within 8 hours to decrease infection risk.[3,4] Closure may be delayed if further debridement of ischemic or contaminated tissue is needed. The advent of negative pressure wound therapy (NWPT) has revolutionized management of open fractures and allowed for safe delay of closure