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Anesthesia

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There are several techniques for providing anesthesia for hand surgery. This chapter provides an overview, illustrating the risks and benefits of each. General anesthesia will be briefly discussed, and regional techniques will be addressed, as well as the unique role that regional anesthesia plays in both operative anesthesia and postoperative analgesia for hand surgery.

GENERAL ANESTHESIA

General anesthesia has long been the technique of choice for surgical procedures, using either traditional endotracheal intubation or the newer laryngeal mask airway (LMA). Considered fast and reliable, it is the standard of care at many institutions. Unfortunately, it is associated with complications because the systemic administration of anesthetic medications can cause derangements of other organ systems, including the brain, the heart, the lungs, the airways, and the gastric, endocrine, and renal systems. General anesthesia necessitates airway manipulation, which causes additional associated complications ranging from minor sore throat and hoarseness to more feared, serious complications, including laryngospasm, aspiration, or failed airway. These serious complications are relatively rare; more prevalent are the minor complications of nausea and vomiting, grogginess, or pain requiring further treatment.[1]

REGIONAL ANESTHESIA

Regional anesthesia is the anesthetic of choice at our institution and is especially suited to upper extremity surgery, as most patients are ambulatory. For inpatients, regional anesthesia is associated with less time spent in the recovery room, improved pain control, lower opiate consumption, and less nausea and vomiting.[2] In an effort to reduce nationwide opioid use, the American Society of Anesthesiologists recommends use of regional anesthesia whenever possible.[3] Regional blockade can be used alone as an intraoperative anesthetic or as an analgesic supplement to general anesthesia.

Contraindications

Absolute Contraindications

The two absolute contraindications to regional anesthesia are (1) patient refusal and (2) infection at the site of needle insertion. Often patients refuse regional anesthesia because they have been inadequately educated or are misinformed. However, many common fears regarding regional anesthesia can be dispelled with a forthright discussion.[4] For instance, patient surveys reveal concerns regarding discomfort during needle placement or awareness of the surgical procedure.[5] These concerns are easily allayed with adequate premedication and sedation.

Active infection (such as cellulitis or draining wound) at the site of needle insertion is considered an absolute contraindication to regional anesthesia due to the risk of bacterial translocation from the skin to the bloodstream or nervous system. The risk is even greater with neuraxial anesthesia and continuous nerve catheters compared with a single-injection peripheral nerve blockade. Performance of single-puncture regional techniques on patients with infection elsewhere in the body, while not supported by strong evidence, is not absolutely contraindicated but should still be approached with a thorough risk and benefits assessment.[6]

Relative Contraindications

Need for assessing postoperative nerve status or compartment syndrome. A successful block hinders motor and sensory conduction and negates nerve testing in the immediate postoperative period. Therefore, if an immediate postoperative assessment of nerve function is required, a regional block should not be used. Distal blocks do not, however, preclude hand function. Distal peripheral nerve blocks have the advantage of greater preservation of upper extremity motor function compared with a brachial plexus block and can be considered if the goal is early hand mobilization.[7]

Fear of masking postoperative compartment syndrome is another relative contraindication to regional anesthesia. Compartment syndrome is diagnosed from both subjective and objective findings including compartment pressure measurements.[8] Excessive pain is the hallmark of a compartment syndrome. Pain in the postoperative period is estimated to precede neurovascular changes by 7.3 hours and can theoretically be masked by the use of nerve blockade provided for analgesia. Ischemic pain, however, is largely unaffected by regional anesthesia.[9] Nonetheless, concern for the development of compartment syndrome should be conveyed prior to surgery and an appropriate pain management plan determined at that time. Appropriate vigilance is required and compartment pressures measurements mandatory if there is a suspicion for compartment syndrome, whether or not a nerve block has been performed.

Aggravating a preexisting nerve injury. Another concern is the possibility that regional nerve blockade will incite further nerve injury (double-crush phenomenon) in patients with preexisting nerve injury or paresthesias.[10,11] While this is an understandable theoretical concern, experience has shown that regional nerve blockade remains an appropriate option for patients undergoing uncomplicated procedures such as ulnar nerve transposition[12] and the vast majority of elective upper extremity operations.

At our institution, most surgeons and anesthesiologists, in consultation with the patient, opt for the use of regional nerve blockade in cases of existing nerve injury or dysfunction. The demonstrated safety of newer techniques and benefit of pain control outweigh the unlikely risk of further nerve injury. It is important to discuss the advantages and disadvantages with the patient, allowing him or her to participate in decision making, especially when nerve dysfunction preexists. For patients who appear to fear further nerve injury, we often opt to use general anesthesia with local anesthesia at the surgical site to avoid adding a perceived risk and fear to an already anxious patient.

Anticoagulation therapy. A relative concern among regional anesthesiologists is performing regional blockade in patients on anticoagulation therapy. More and more patients presenting for surgery are taking anticoagulants for treatment of underlying coronary artery disease, atrial fibrillation, or cerebrovascular disease or for prevention or treatment of deep venous thrombosis.

Regional neuraxial (spinal or epidural) anesthesia does not contribute to venous thrombosis in patients. In fact, regional anesthesia has been shown to reduce the rate of blood clots following lower extremity and abdominal surgery, though this advantage has been lessened in recent years with the advent of timely thromboprophylaxis.[13] Postulated mechanisms include sympathetic blockade leading to improved blood flow and decreased sympathetic stimulation, as well as a direct antithrombotic effect of the local anesthetic solution. However, neuraxial regional anesthesia is contraindicated in the fully anticoagulated patient, given the risk of epidural hematoma and subsequent devastating neural injury. Performance of deep plexus blocks in this setting, though, remains practitioner-dependent. There are case reports of retroperitoneal hematoma following deep lumbar plexus blockade in anticoagulated patients; however, the relative safety of this technique was confirmed in a large study of 670 patients who underwent continuous lumbar plexus blockade while anticoagulated with warfarin.[14]

In the anticoagulated patient, a perivascular brachial plexus nerve block has the potential to cause excessive bleeding. Yet several case reports document the safety of peripheral nerve blocks in the anticoagulated patient, particularly when the block is placed under ultrasound guidance.[15] Despite these reassuring findings, the most recent published regional anesthesia guidelines advocate applying the same recommendations for neuraxial anesthesia to anticoagulated patients undergoing deep perivascular nerve blocks, while performance of superficial nerve blocks should be managed based on site compressibility, vascularity, and consequences of bleeding.[16] Patients who have incomplete reversal of their anticoagulation with mild derangements of their coagulation panel must be approached on a case-by-case basis with ample discussion of the risks and benefits.

Bilateral procedures. There may be instances in which regional anesthesia could be used for bilateral procedures; however, there are many risks, and bilateral regional anesthesia should be avoided. The risk of drug toxicity is higher as the dose is nearly doubled. Using a lower amount to avoid toxicity raises the probability of block failure.[17] The type of block also influences the risk. Interscalene nerve block commonly results in phrenic nerve paralysis,[18] so bilateral interscalene nerve block is absolutely contraindicated due to the risk of respiratory failure. Even supraclavicular blockade has an estimated associated risk of transient diaphragmatic paralysis of around 50%.[19] This risk combined with the associated risk of pneumothorax and the necessary high minimum effective dose makes bilateral supraclavicular blockade unreasonable. A safer alternative may be utilization of distal peripheral nerve blockade[20] or performing the blocks using low-volume, short-acting local anesthetics in sequence (i.e., performing the block on the second limb only upon completion of operation on the first limb).[17,21]

Relative Indications

Microvascular Surgery Patients

Regional anesthesia with the use of long-acting blocks or continuous nerve catheter infusion for digital replantation and free flaps is considered standard practice at our institution. Continuous sympathetic blockade causes vasodilation and improves blood flow to the replanted digit(s) or free flap and reduces neurogenically mediated vasospasm.[22] Improved pain control at the graft site via an effective nerve block also reduces pain-induced sympathetic-mediated vasoconstriction.[23] While it remains unclear whether continuous nerve blockade results in improved graft survival,[22] the safety and efficacy of peripheral nerve blockade makes it a desirable anesthetic option in microvascular surgery patients.

Patients with scleroderma and pediatric patients undergoing digital sympathectomy and microvascular reconstruction also benefit from prolonged anesthetic blockade.[24,25] Finally, patients with complex regional pain syndrome who undergo corrective surgery are also likely to benefit from effective prolonged regional anesthesia.[26]

Pediatric Patients

Anesthesia for pediatric patients depends greatly on the age and maturity of the child and the experience of the anesthesiologist. Many techniques combine general anesthesia with regional anesthesia. Many practitioners are comfortable placing blocks in anesthetized children, especially under ultrasound guidance, though the dose of anesthetic agent and the anatomy must be carefully calculated.[27] Recent data from the Pediatric Regional Anesthesia Network including more than 100,000 blocks demonstrated regional anesthesia as a safe and effective form of postoperative pain control in children with very low rates of complications.[28] Ultrasound guidance allows for lower anesthetic volume in nerve blocks while preserving analgesic duration in children.[29] A long-term study looking at the use of continuous peripheral nerve catheters in pediatric patients showed this technique to be a safe and effective way to provide prolonged analgesia.[30]

Pregnant Patients

While elective procedures are generally not performed during pregnancy, circumstances arise that require surgery. When possible, a local or regional technique should be used to minimize the effects on maternal physiology as well as to reduce the possible pharmacologic exposure of the developing fetus. Ideally, surgical procedures should be deferred to the second trimester to minimize teratogen exposure to the fetus during the critical period of organogenesis (15–56 days) and also to limit the risks of preterm labor.[31] We recommend performing regional blockade more caudally along the brachial plexus to decrease the likelihood of hemidiaphragmatic paresis in a parturient.

An anesthetic plan must provide safe anesthesia for both the mother and the fetus. When surgery is unavoidable in a previable fetus, the American College of Obstetricians recommends monitoring the fetal heart rate by Doppler ultrasound before and after surgery. With regard to a viable fetus, fetal heart rate and contraction monitoring should occur before, during, and after the procedure. The patient should have given consent for emergency cesarean section, and obstetric staff should be on standby in the event of fetal distress.[32]

The pregnant patient has an increased cardiac output, increased minute ventilation, increased risk for gastric aspiration, and increased upper airway edema, which can increase the risk of failed intubation. Fetal safety generally relates to avoidance of teratogenicity, avoidance of fetal asphyxia, and avoidance of preterm labor. Randomized controlled trials examining teratogenicity are not ethically or clinically feasible; however, local anesthetics, volatile agents, induction agents, muscle relaxants, and opioids are not considered teratogenic when used in appropriate dosage. Nitrous oxide is best avoided given its effects on DNA synthesis and its teratogenic effects in animals.[33]

Patients With Inflammatory Arthritis

Patients with inflammatory arthritis such as rheumatoid arthritis or psoriatic arthritis are especially suitable candidates for regional anesthesia for upper limb surgery as it decreases the need for airway manipulation and blunts the stress response to surgery. Patients with deformity associated with advanced rheumatoid arthritis require careful positioning on the operating room table to avoid injury to other areas of the body.

This patient population often carries a high potential for airway complications and difficult endotracheal intubation owing to cervical spine immobility, atlantoaxial instability, temporomandibular joint ankylosis, and cricoarytenoid arthritis.[34] Likewise, patients with inflammatory arthritis often have cardiac and pulmonary comorbidities such as accelerated atherosclerosis and pulmonary arterial hypertension, further increasing their risk under anesthesia. Lastly, many patients in this population are prescribed antirheumatic drugs and systemic corticosteroids, which have the potential for causing immunosuppression and a decreased neuroendocrine stress response. Patients consuming 20 mg of prednisone a day for more than 3 weeks are considered at significant risk for hypothalamic-pituitary-adrenal suppression.[35] These patients may require stress dose steroid coverage depending on the invasiveness and stress of the procedure, and steroid treatment should be provided in the event of refractory hypotension.

Advantages and Disadvantages (Box 1.1)

A common concern regarding regional anesthesia is the question of efficacy. Success depends on the experience and confidence of the practitioner performing the block. At our orthopedic hospital, more than 7000 upper extremity blocks are performed annually, and we are able to achieve success in 94% to 98% of patients.[36,37]

While regional blockade can effectively anesthetize the upper extremity and surgical site, this does not ensure patient comfort. Patients asked to lie motionless on a hard operating room bed might be apt to move to relieve discomfort in the back or knees, therefore disturbing the operative field. We place pillows to support the head and under the knees to reduce low-back strain. Even with adequate motor and sensory blockade, some patients will experience vibration or proprioception, and even vague sensations of pressure in the operative limb. Adequate anxiolysis and sedation will minimize the sensation. Access to the airway should be maintained during surgery in case the block is inadequate or other problems ensue. If the patient's position, such as lying prone, precludes this access, preoperative securing of the airway may be a better option.

BOX 1.1 Factors Limiting Use of Regional Anesthesia

In spite of the advantages of regional anesthesia, several factors may prevent its use. Each of these problems can be overcome with appropriate planning.

- Time constraints
- Anesthesiologist's lack of familiarity with the procedure
- Patient's fear of anesthesia failure
- Concern about complications
- Patient's desire to be completely unaware during the procedure

Duration of the neural blockade after single injection is variable, anywhere from 45 minutes to over 24 hours after a single injection, depending on the type of anesthetic and volume used. The duration can be extended with additives in the block solution as well as placing a peripheral nerve catheter for continuous local anesthetic administration.

Prolonged regional anesthetic blockade provides improved pain relief for immediate postoperative physical therapy and does not necessarily inhibit active participation. In a study comparing continuous patient-controlled perineural infusion (0.2% ropivacaine in a patient-controlled opioid analgesic pump) following arthroscopic rotator cuff repair, regional anesthesia resulted in decreased use of pain medications with a comparable incidence of motor weakness.[38] Similarly, selective nerves can be continuously blocked via a tunneled forearm catheter to allow for extended pain-free early active motion after hand surgery.[39,40]

The advantages of regional nerve block have been well demonstrated in the ambulatory surgery population. These advantages include lower pain scores, decreased nausea and vomiting, and shorter stays in the postanesthesia care unit.[38,41,42] While these effects are considerable in the immediate postoperative period, ongoing studies demonstrate long-term outcome differences between different types of anesthesia.[43,44] Evidence supports that in patients undergoing open reduction and internal fixation of displaced distal radius fracture, regional anesthesia provides decreased pain and improved functional outcomes at 3 and 6 months.[45]

Equipment and Pharmacologic Requirements

Medications commonly used in regional anesthesia are listed in Table 1.1.

Regional anesthesia may be administered in a designated block room or the preoperative area, in addition to in the operating room. It is crucial to have available appropriate monitoring and resuscitation equipment, including airway management supplies and resuscitative medication, should an acute complication arise. High-flow oxygen, airway management equipment, and suction capability are crucial for emergency airway management in the event of seizure or high or total spinal block. Medications including inotropes, anticholinergics, and vasopressors should be immediately available to treat symptomatic arrhythmias, bradycardias, and hypotensive episodes. Other available medications should include benzodiazepines or propofol to treat seizures and an intralipid to treat bupivacaine-induced cardiovascular collapse (Box 1.2).[46]

Local Anesthetic Additives

In recent years, the use of additives in local anesthetics to increase efficacy and onset of block, as well as overall block duration, has been readily investigated.[47] Historically, sodium bicarbonate has been used to increase onset of sensory and motor blockade in epidural anesthesia. Sodium bicarbonate raises the pH (alkalinization) of the solution, thereby facilitating passage across lipid membranes. When used perineurally, this advantage appears to be more unpredictable for certain types of blocks and may not be clinically significant.[48] Epinephrine, on the other hand, remains one of the most widely used adjuncts for prolonging the effect of short- and intermediate-acting local anesthetics by decreasing systemic uptake of the local anesthetic through vasoconstriction. Epinephrine is also an excellent marker for detection of intravascular injection. The advantage of epinephrine as an adjunctive in long-acting local anesthetic peripheral nerve blocks is not as apparent, especially when juxtaposed with concerns of neurotoxicity in at-risk patients.[49]

Dexamethasone is another additive that has gained popularity in recent years because of its ability to prolong peripheral nerve blockade.

TABLE 1.1 Characteristics of Commonly Used Drugs

Generic Name (Trade Name)	Concentration (g/dL): Infiltration	Concentration (g/dL): Nerve Block	Maximum Dose (mg/kg)[a]	Approximate Duration
Procaine (Novocain)	0.75	1.5–3	10–14	45–90 min, short-acting
Chloroprocaine (Nesacaine)	0.75	1.5–3	12–15	
Lidocaine (Xylocaine)	0.5	1–2	8–11	1.5–3 h, medium-duration
Mepivacaine (Carbocaine)	0.5	1–2	8–11	
Tetracaine (Pontocaine)	0.05	0.15–0.2	2	
Bupivacaine (Marcaine)	0.25	0.25–0.5	2.5–3.5	3–10 h, long-acting
Ropivacaine (Naropin)	0.25	0.25–0.5	2.5–3.5	

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

BOX 1.2 Prevention of Systemic Toxicity

- Avoid intravascular injection.
- Use epinephrine to slow systemic absorption.
- Use benzodiazepine as a premedication.
- Use ultrasound guidance to fractionate the dose.

Through its proposed ability to inhibit nociceptive C-fibers, dexamethasone has been used with both short- and long-acting local anesthetics in upper extremity surgeries. The reported results indicate some success, though recent randomized trials and metaanalyses suggest that this effect can be achieved just as well via intravenous administration, which has a well-characterized safety profile.[50,51] While investigations into concerns for neurotoxicity with dexamethasone have not yielded conclusive results, we recommend caution when using this adjunct in patients with preexisting nerve injuries.

Alpha-2 selective adrenergic agonists such as clonidine and dexmedetomidine have an analgesic benefit when added to local anesthetics for peripheral blocks.[52-54] These agents inhibit current channels that facilitate neurons to return to normal resting potential from a hyperpolarized state. Clonidine and dexmedetomidine selectively disable C-fiber neurons from generating subsequent action potentials, resulting in analgesia. Disadvantages of using these additives include dose-dependent systemic effects of sedation, bradycardia, and hypotension.

Opioid agonists such as tramadol and buprenorphine are also used as additives to local anesthetics.[55,56] Tramadol, which acts as a weak mu-opioid agonist while stimulating serotonin release and inhibiting reuptake of norepinephrine, prolongs blockade when given perineurally. Tramadol does not reliably have a clear advantage over intravenous (IV) or intramuscular administration.[57,58] Buprenorphine, on the other hand, has been consistently shown to increase block duration and reduce postoperative analgesia when given perineurally, an effect not related to systemic absorption of the drug.[59] The mechanism of action of buprenorphine is an ability to inhibit voltage-gated sodium channels in a fashion similar to local anesthetics.[60] Further studies are needed to elucidate any potential neurotoxic effects of this adjunctive agent.

Finally, additives such as ketamine, midazolam, and magnesium, while showing some promise, do not have an adequately characterized safety profile perineurally to be recommended as additives to local anesthetics.[61-63]

Historical Techniques

Regional nerve blockade is essentially the deposition of local anesthetic near a nerve. Historically, nerve blocks were blind techniques, performed solely based upon anatomic relationships to superficial landmarks. Practitioners noted that patients would report paresthesias as the needle advanced, leading to development of the paresthesia technique. This technique required a cooperative and conscious patient capable of providing verbal feedback, as the anesthetic practitioner would intentionally attempt to elicit a paresthesia as a means of nerve localization. Others began experimenting with the use of a nerve stimulator, applying a low-current electrical impulse through the needle near a nerve to stimulate muscle contraction.[64] Studies were unable to demonstrate outcome differences.[65] Nerve localization using nerve stimulation was employed to decrease actual needle-to-nerve contact and reduce nerve injury. A randomized prospective trial comparing the two techniques, however, was unable to determine a difference in postoperative neurologic symptoms.[66] Another advantage of the nerve stimulator technique was decreased reliance on patient feedback and allowing the technique to be performed on sedated patients.

Ultrasound was next introduced to improve needle placement. Ultrasound allows visualization of anatomic structures, blood vessels, and nerves, as well as of the advancement of a needle and the distribution of local anesthetic.[67] With satisfactory visualization of target structures, this technique does not require patient feedback and can be used safely in the sedated or anesthetized patient.[68] When target structures are deep, however, needle visualization can be difficult. In such cases, it is safer to engage patient feedback whenever possible. Several studies have demonstrated the advantages of the ultrasound technique including shorter performance time, faster block onset, greater block success, and decreased dosing requirements compared with traditional techniques.[69-71] For practitioners and patients, ultrasound guidance facilitates a steeper learning curve to proficiency, reduces the number of needle passes leading to decreased pain during performance, and increases patient satisfaction.[72] A recent meta-analysis of 16 randomized controlled trials showed that ultrasound decreased the incidence of complete hemidiaphragmatic paresis and vascular punctures and was more likely to result in a successful brachial plexus block compared with the nerve stimulation technique.[73] Despite these benefits, ultrasound-guidance does not appear to decrease the incidence of neurologic injury.[36,73] Certainly, this is an area in need of further study and review as we attempt to minimize risks of anesthetic complications.

Continuous Peripheral Nerve Catheters

The use of continuous peripheral nerve catheters (CPNC) has gained favor both in the inpatient setting and the outpatient setting. Catheters have been successfully inserted along various levels of the brachial plexus depending on the desired location of blockade, from above the clavicle, such as interscalene and supraclavicular locations, to below the clavicle, such as infraclavicular and axillary locations.[42] The advantages include time-extended, opioid-sparing, and site-specific analgesia with only minimal side effects.[74,75] There is also some data to suggest that the incidence of chronic postsurgical pain may be decreased with a short-term postoperative CPNC.[76] Disadvantages include increased anesthesia performance time and catheter dislodgement or misplacement leading to ineffective analgesia. Complications also include ipsilateral diaphragmatic paralysis, technical problems involving the infusion pump leading to dosing inconsistency, infection due to the indwelling catheter, and catheter coiling leading to block failure or catheter retention.[75] Rarely, brachial plexus peripheral nerve catheters have led to epidural and even intrathecal blockade.[77,78] The incidence of brachial plexus catheter failure on postoperative day 1 is between 19% and 26%.[79] The rate of dislodgement is low (<5%) but is directly correlated with the length of time the catheter is maintained and the extent of upper extremity movement.[80] There appears to be a modest clinical benefit to the use of nerve-stimulating catheters over nonstimulating catheters to confirm tip placement; however, this advantage has been largely supplanted by ultrasound guidance, which vastly improves placement accuracy.[81,82] In contrast to epidural catheters, the choice of end-orifice versus multiple-orifice catheters in CPNC does not affect analgesic quality.[83]

Once the patient is at home, peripheral nerve infusion pumps for ambulatory surgery patients are safe and effective for extending the duration of nerve blocks from hours to days. Evidence supports the use of these catheters in children as well as adults.[30]

Minimum Effective Volume

Efforts have been made to determine the minimum effective volume (MEV) of local anesthetic required to produce an adequate block to reduce the dose-dependent adverse effects of neurotoxicity and systemic absorption without sacrificing time to block onset and overall analgesic duration. These efforts have been helped enormously by the use of ultrasound. For the upper extremity, low local anesthetic volumes have been established for interscalene blocks and axillary blocks using ultrasound guidance. Although the absolute effect of type and concentration of local anesthetic on minimal volume has not been elucidated, the MEV to elicit an interscalene blockade that is 95% successful (MEV_{95}) can be less than 1 mL.[69,84] Reducing the anesthetic volume in interscalene blocks has the potential advantage of reducing the incidence of hemidiaphragmatic paresis.[85] For axillary blocks, MEV_{95} averages 2 mL per nerve.[86,87] On the contrary, the MEV_{95} for supraclavicular and infraclavicular blocks ranges from 17 to 32 mL and 23 to 35 mL, respectively.[88-91] We postulate that the higher volume required in the latter blocks may be related to increased variations in injection techniques and nerve anatomy.

Elderly patients generally require lower local anesthetic volumes, an effect likely related to a decrease in the cross-sectional area of the brachial plexus as we age.[92] Similarly, diabetic patients are more likely to have a successful and longer duration nerve block for a given local anesthetic dose.[93,94] The authors postulate that this is due to either an increased sensitivity of diabetic nerve fibers to local anesthetic, an inadvertent intraneural penetration due to a decreased ability to elicit paresthesias, or a preexisting neuropathy leading to decreased baseline sensation to pain. Surprisingly, although associated with a higher performance difficulty, an increased body mass index does not necessitate an increased local anesthetic volume.[95,96]

In general, in the absence of additives, decreasing the dose of local anesthetic in the peripheral block results in a reduction of block duration.[97,98] Despite the advantage of decreasing dose-dependent complications and reducing neurotoxicity, our establishment of the MEV should be tailored with the surgical procedure, the patient's particular risk factors, and the expected postoperative pain. In the end, it is also important to remember that the practitioner and his or her ability to optimally deposit the local anesthetic heavily influence the MEV for any given block.

Brachial Plexus Blocks

The goal of regional anesthesia for upper extremity surgery is to provide anesthesia at the site of surgery. Other potential painful stimuli require consideration, including positioning and the tourniquet. There are many different approaches to nerve blockade, and all involve the brachial plexus that provides sensory and motor innervation to the upper extremity. The brachial plexus is formed by the ventral rami of C5-T1, occasionally with small contributions by C4 and T2 (Fig. 1.1).

There are multiple approaches to blockade of the brachial plexus, beginning proximal at the interscalene interval and moving in a distal direction with the supraclavicular, infraclavicular, axillary, midhumeral, and forearm approaches. The uniting concept is the existence of a sheath encompassing the neurovascular bundle extending from the deep cervical fascia to slightly beyond the borders of the axilla.[99]

Our preferred technique, using ultrasound guidance, involves an in-plane view of the needle at its point of entry just under the skin to its location near the plexus. The needle choice is probably less critical, although we use short bevel, noninsulated needles, which are less likely to injure the nerve and more echogenic. The goal is to get close to the nerve (plexus or cord) without actually contacting the nerve. Once the fascial plane adjacent to the nerve is reached, a small amount of local anesthetic is injected. The anesthetic will hydrodissect the area and demonstrate local filling in the desired location of the nerve.

Interscalene Block

The interscalene block is the most proximal approach, performed as the brachial plexus courses between the anterior and middle scalene muscles, traditionally at the level of the cricoid cartilage (Fig. 1.2).[100] At this level, the nerve roots of C5, C6, and C7 are visualized and course in a longitudinal direction. Between 5 and 10 mL of local anesthetic can be injected between C5 and C6 using a lateral-to-medial approach, avoiding injury to the phrenic nerve. This block is well suited for procedures of the shoulder, the lateral two-thirds of the clavicle, and the proximal humerus. Advantages of this block include rapid and reliable blockade of the shoulder region, as well as relative ease of landmark palpation. Disadvantages of this block traditionally include incomplete coverage of the lower trunk of the plexus (C8 and T1 nerve roots) resulting in insufficient ulnar nerve anesthesia. This problem makes the interscalene block less reliable for forearm or hand procedures. The interscalene block commonly causes transient ipsilateral diaphragmatic paralysis and ipsilateral Horner's syndrome because of the proximity of the phrenic nerve and the cervical sympathetic ganglion, respectively. Rare but serious complications include permanent phrenic nerve palsy and cervical epidural and total spinal blockade.[101]

Selective Superior Trunk Block

In recent years, efforts to increase block target precision for shoulder procedures and reduce the incidence of hemidiaphragmatic paralysis have led to the introduction of selective blockade of the upper trunk.[102] Placement necessitates identification of the upper trunk of the brachial plexus under ultrasound and circumferential injection of 5 to 10 mL of local anesthetic. This technique provides precise motor and sensory blockade to the shoulder while sparing the forearm and hand. Less local anesthetic is injected, which reduces the probability of local toxicity, phrenic nerve paresis, and Horner's syndrome.

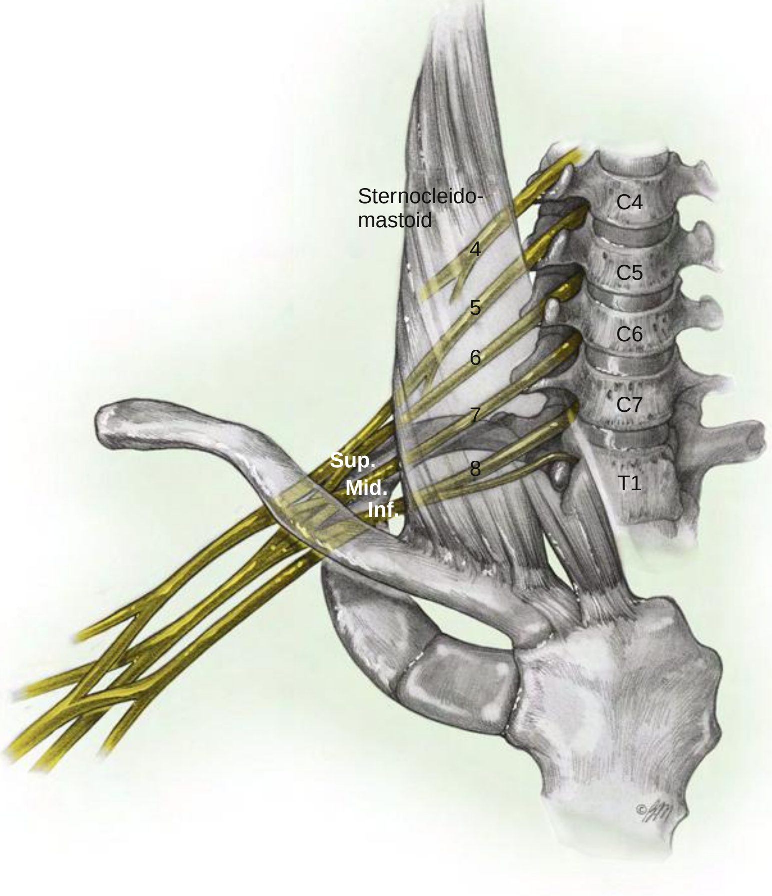

Fig. 1.1 Brachial plexus, showing the relationship of the roots, trunks, divisions, and cords to bony landmarks. *Inf.,* Inferior; *Mid.,* middle; *Sup.,* superior. (Copyright Elizabeth Martin.)

Supraclavicular Block

A supraclavicular approach to the brachial plexus provides profound anesthesia for the entire arm, making it a versatile block for most upper extremity procedures. Past approaches have used surface landmarks, generally lateral to the lateral border of the sternocleidomastoid muscle and superior to the clavicle, considering the first rib as the safety margin for the cupola of the lung.[103] Concern regarding the risk for pneumothorax with traditional techniques led to the development of an ultrasound-guided technique for supraclavicular brachial plexus blockade, which has decreased the incidence of pneumothorax from 4% to 0.4%.[67,104] Ultrasound guidance allows the practitioner to visualize the first rib and the border of the pleura, thereby being able to watch the approach of the needle to help ensure an appropriate distance.[105] For the supraclavicular block, the needle is placed just inferior and posterolateral to the plexus, as in "eight ball in the corner pocket" (Fig. 1.3).[105] Advantages include a compact formation of the plexus at this level and resultant dense blockade of the entire upper extremity. Disadvantages include phrenic nerve paresis and suprascapular nerve palsy.[106]

Infraclavicular Block

The infraclavicular (or coracoid) approach is more distal and at the level of the cords, which course circumferentially around the subclavian artery. The infraclavicular block provides dense anesthesia to the entire arm to the fingers. This block does not adequately anesthetize the shoulder but has become our block of choice for elbow, wrist, and hand surgery. Initial techniques based needle placement on anatomic landmarks and nerve localization with a nerve stimulator,[107] but more recent approaches favor an ultrasound-guided approach (Figs. 1.4 and 1.5).[108] The preferred position of the infraclavicular block is the 6 o'clock location relative to the subclavian artery. The lower anatomic location of this block negates the possibility of a phrenic nerve block and therefore can be considered for bilateral procedures. Disadvantages include risk of pneumothorax, which can be minimized by performing the block in a more lateral position along the clavicle.[109] There is concern for accidental subclavian artery puncture that would be difficult to apply compression to tamponade the bleeding.

Axillary Block

The axillary block, the most distal of the brachial plexus blocks before the nerves leave the sheath and divide into their terminal branches, is perhaps one of the oldest and most traditional regional blocks for hand and wrist surgery. Various guidance techniques are described, including ultrasound, anatomic (either transarterial or paresthesia), or nerve stimulator techniques. All begin with palpation of the axillary nerve in the apex of the axilla, with consideration of the reliable

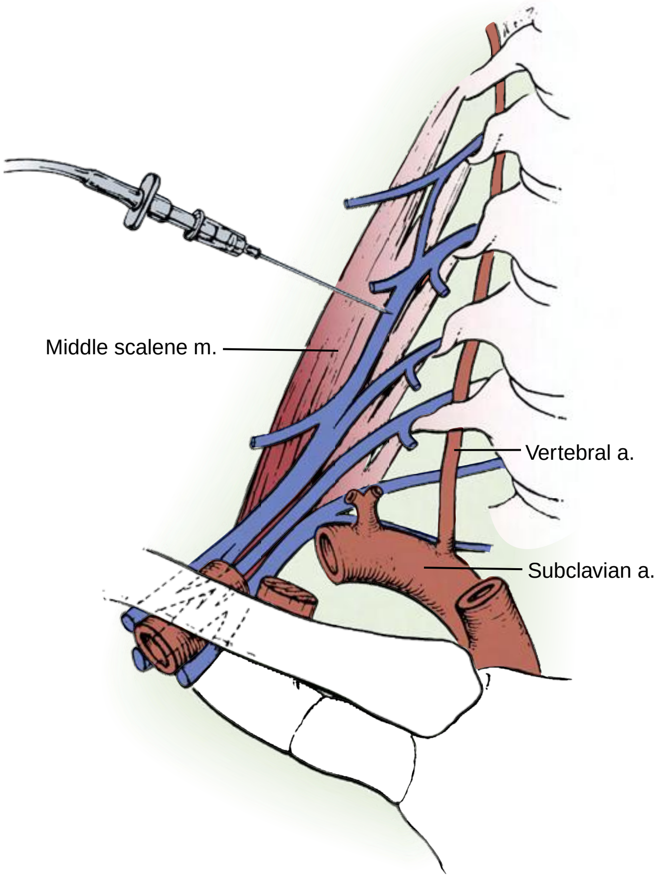

Fig. 1.2 Interscalene technique. (From Winnie AP. Regional anesthesia. *Surg Clin North Am.* 1975;55(4):861–892.)

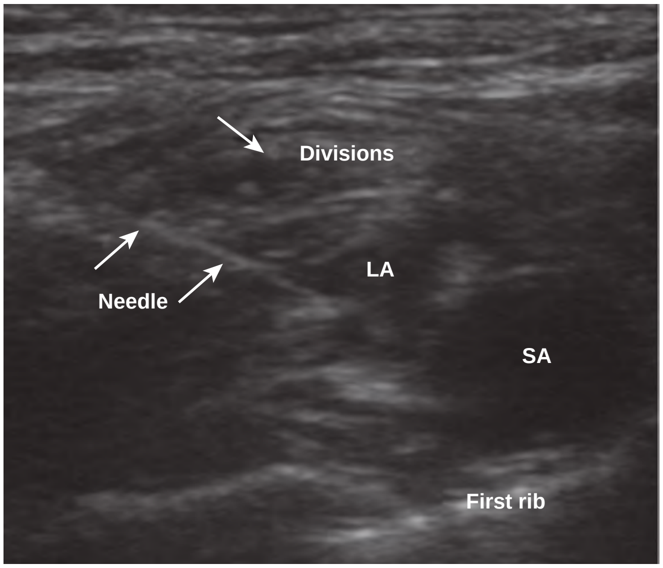

Fig. 1.3 Ultrasound-guided supraclavicular nerve block. The brachial plexus is approached at the level of the divisions; the needle is entering the view from the lateral aspect at the top left of the screen. The pulsations of the subclavian artery *(SA)* are visualized, as is the spread of local anesthetic *(LA)*.

anatomic relationship of the nerves to this arterial landmark (Fig. 1.6). The musculocutaneous nerve frequently leaves the sheath proximal to the intended insertion point of this block; therefore a supplemental injection into the body of the coracobrachialis muscle is often needed, especially if a tourniquet is used. This can be done easily with a blind

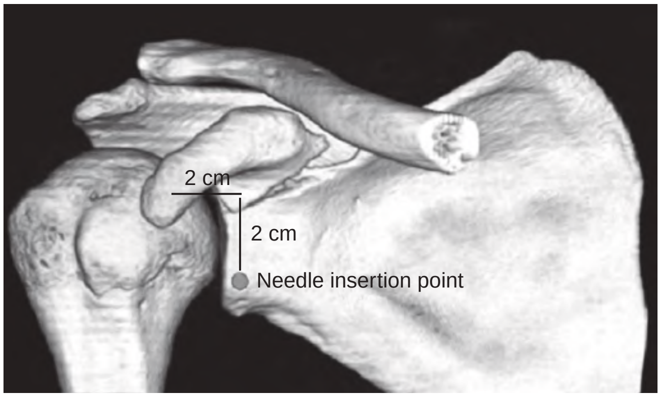

Fig. 1.4 Landmarks for infraclavicular block.

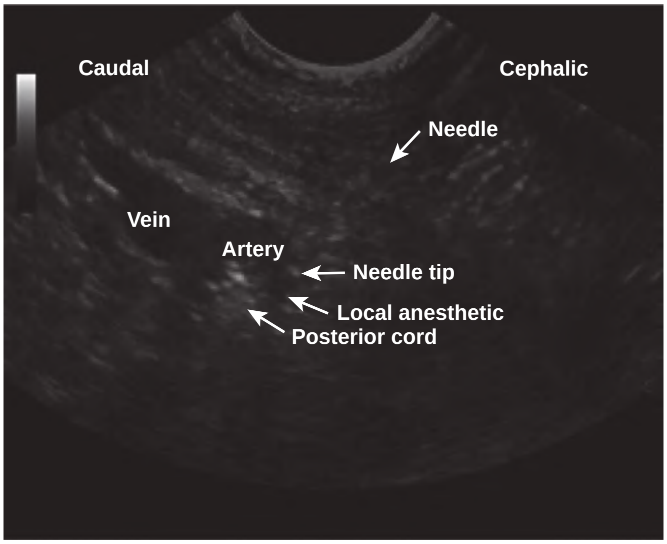

Fig. 1.5 Ultrasound-guided infraclavicular nerve block; note the perivascular spread of local anesthetic.

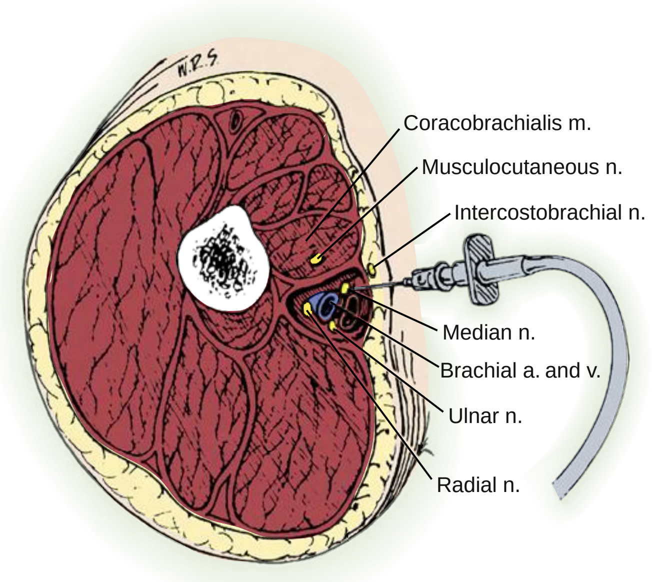

Fig. 1.6 Cross-sectional view of the axillary nerve block. (From Winnie AP. Regional anesthesia. *Surg Clin North Am.* 1975;55[4]:861–892.)

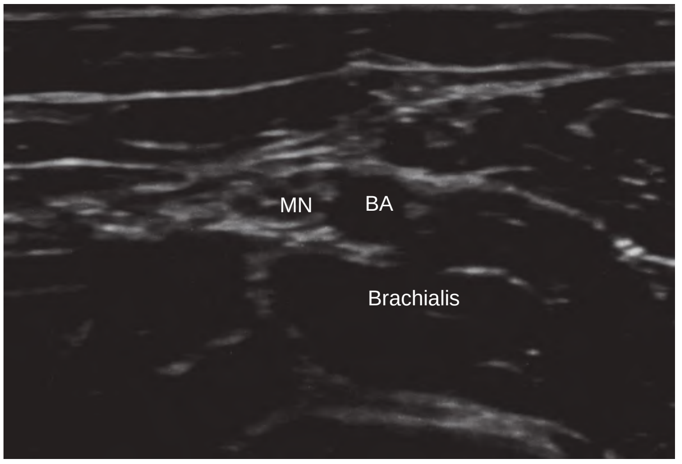

Fig. 1.7 Ultrasound image of median nerve *(MN)* at the level of the elbow.

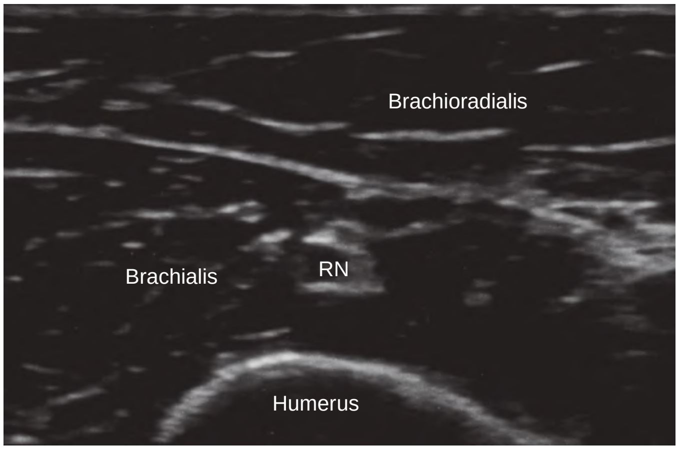

Fig. 1.8 Ultrasound image of radial nerve *(RN)* at the level of the elbow.

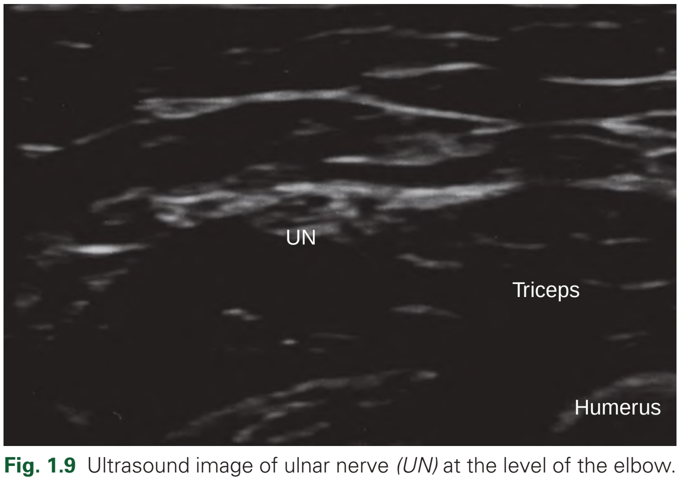

Fig. 1.9 Ultrasound image of ulnar nerve *(UN)* at the level of the elbow.

technique as well as with ultrasound guidance, as the nerve courses in the fascial plane between the coracobrachialis and the bicep muscles. Major risks for the axillary block are largely related to the close proximity of the axillary artery. Risks for minor bruising and tenderness are higher with transarterial techniques, although the risk of hematoma is lower, reported from 0.2%[110] to 8%.[111] Another concern is anesthetic toxicity related to either intraarterial injection or rapid systemic absorption after injection near an arterial puncture. Rates of systemic toxicity are reported around 0.2%.[110]

Elbow Block

The intercostobrachial nerve arises from T1-T3 and travels superiorly to provide cutaneous sensory innervation to the medial and posterior upper arm.[112] Because this innervation is not part of the brachial plexus, additional blockade in the form of a field block is used for surgery around the medial aspect of the elbow extending to the armpit. Subcutaneous distribution of 5 to 10 mL of local anesthetic along the distal portion of the axillary crease will effectively anesthetize the intercostobrachial nerve.

In the past, anesthetic blocks about the elbow were less frequently performed as a primary technique because the overlap and variability of nerve distribution necessitates multiple injections to obtain sufficient anesthesia. As a result, elbow blocks were mainly used to supplement incomplete brachial plexus nerve blockade. The advent of ultrasound guidance has vastly increased the efficacy and ease of placement of these blocks. The median, radial, and ulnar nerves are easily visualized using ultrasound as they course from the elbow to the wrist.[113]

The median nerve may be blocked as it traverses posteromedial to the brachial artery, just superior to the antecubital fossa (Fig. 1.7). The nerve is superficial at this location and can be easily visualized overlying the brachialis muscle. An injection of 5 mL of local anesthetic injected slightly superior to a line connecting the epicondyles provides a sufficient block.

The radial nerve can be blocked 3 to 4 cm above the lateral epicondyle. Under ultrasound, the nerve is seen between the extensor carpi radialis longus and brachioradialis muscles (Fig. 1.8). After the needle pierces the lateral intramuscular septum, paresthesias or a nerve stimulator can be used to further localize the nerve. An injection of 5 mL of local anesthetic provides a sufficient block.

The ulnar nerve is frequently missed in an interscalene block, so supplementation is often necessary for complete arm anesthesia. The nerve is usually blocked behind the medial epicondyle, deep to the brachial fascia and superficial to the triceps muscle (Fig. 1.9). Injection of 3 to 5 mL of local anesthetic is performed between the olecranon and the medial epicondyle. Caution is necessary to avoid nerve compression between the medial epicondyle and olecranon.[114]

Forearm Block

The use of forearm blocks, also known as distal peripheral nerve blocks, as a primary anesthetic for hand and wrist surgery has gained popularity. An advantage of the forearm block compared with the more proximal brachial plexus block is the greater preservation of upper extremity function. This benefit can be useful in tendon repair surgery, allowing gentle hand movement to assess the tenorrhaphy site, which may improve functional outcome.[7,20] Potential limitations include inadequate anesthetic coverage of the forearm or wrist and pain associated with prolonged tourniquet application. A more distal forearm block can be performed. The nerves are identified under ultrasound at the level of the elbow as described above, and the probe is moved down the long axis following the nerve toward the wrist crease. Approximately 5 cm from the proximal wrist crease, an injection of 5 to 10 mL of local anesthetic around each nerve, will provide adequate coverage without overly compromising handgrip.

Wrist Block

Hand surgeons frequently use wrist blocks to produce anesthesia for surgery or to supplement brachial plexus nerve blocks. Wrist blocks are relatively simple and reliable to perform based on external landmarks. The nerve supply of the extrinsic muscles of the hand is preserved, thus allowing the patient to move the fingers of the hand, but the intrinsic

Fig. 1.10 Surface anatomy for median nerve block at the wrist. (Reproduced with permission from Chung KC, ed. *Operative Techniques: Hand and Wrist Surgery.* Philadelphia: Saunders; 2008, p 5.)

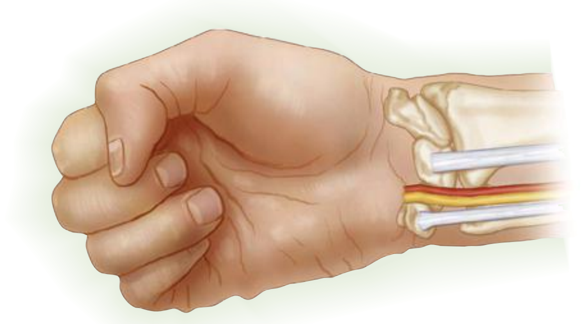

Fig. 1.11 Surface anatomy for ulnar nerve block at the wrist. (Reproduced with permission from Chung KC, ed. *Operative Techniques: Hand and Wrist Surgery.* Philadelphia: Saunders; 2008, p 6.)

muscles are paralyzed. Whereas this can be an advantage in a cooperative patient, it is a potential disadvantage in an uncooperative patient. Additionally, the need for a forearm tourniquet limits the duration of surgery to 20 to 30 minutes in most instances. These blocks are especially efficacious for carpal tunnel release.[115,116]

The median nerve can be blocked as it courses between the palmaris longus and flexor carpi radialis tendons (Fig. 1.10). A 1.5-cm, 25-gauge needle is inserted just proximal or distal to the wrist crease. In the absence of the palmaris longus tendon, the needle is inserted on the ulnar side of the flexor carpi radialis tendon. After penetration through the flexor retinaculum at a depth of approximately 1 cm, 5 mL of local anesthetic is injected. Injecting 1 mL of local anesthetic above the retinaculum as the needle is withdrawn can block a superficial palmar branch supplying the skin over the thenar eminence.[114,117]

The ulnar nerve is blocked at the wrist at either the radial or the ulnar side of the flexor carpi ulnaris tendon (Fig. 1.11). The ulnar approach is preferred to avoid intravascular injection, given the location of the ulnar artery on the radial side of the tendon. At the level of the distal ulna, the needle is introduced on the dorsoulnar side of the flexor carpi ulnaris. Subsequent injection of 5 mL of local anesthetic under the flexor carpi ulnaris will result in anesthesia of this distribution. Additional subcutaneous infiltration of the dorsoulnar area of the wrist blocks the dorsal cutaneous branch of the ulnar nerve.[117]

The radial nerve is superficial and divided into branches running in the subcutaneous fat at the level of the radial styloid process (Fig. 1.12). The radial nerve can be blocked using 5 to 10 mL of local anesthetic injected in a subcutaneous field block at the level of the radial styloid. The initial injection is just lateral to the radial artery at the level of the proximal wrist crease using 2 to 3 mL of local anesthetic. The needle is then redirected and advanced within the subcutaneous tissue injecting 5 to 7 mL of local anesthetic across the proximal border of the snuffbox to the midpoint of the dorsal wrist. Several separate injections may be necessary to follow the curvature of the wrist and block the numerous superficial branches.[114]

Fig. 1.12 Surface anatomy for radial nerve block at the wrist. (Reproduced with permission from Chung KC, ed. *Operative Techniques: Hand and Wrist Surgery.* Philadelphia: Saunders; 2008, p 7.)

Digital Block

There are dorsal and volar digital nerves that supply sensation to the digits. The dorsal aspect of the proximal phalanges is supplied by the terminal branches of the radial and ulnar nerves. The dorsal aspect of the middle and distal phalanges is supplied by dorsal branches emanating from the proper digital nerves. Hence, a digital nerve block will anesthetize the volar aspect of the finger and the dorsal aspect distal to the proximal interphalangeal joint (Fig. 1.13). There are three main recommended approaches for performing digital nerve block: transthecal, transmetacarpal, and subcutaneous. A circumferential ring block along the base of the digit is not recommended because of the possibility of arterial compression.

Transthecal digital nerve block uses the flexor tendon sheath for anesthetic infusion. At the level of the palmar digital crease, the needle enters the flexor tendon sheath until bony contact is made (Fig. 1.14). The needle is then withdrawn slightly and slowly until the local anesthetic solution can be injected easily into the space between the bone and the flexor tendon. For digital anesthesia, 2 mL of local anesthetic is injected. Advantages of this approach include a single injection and rapid onset.[118] Patients can complain of prolonged finger discomfort after this technique.[119]

Transmetacarpal block is performed at the level of the distal palmar crease. The insertion site is approximately 1 cm proximal to the metacarpophalangeal joint, traditionally on the volar side of the hand (Fig. 1.15), though some favor entering the thinner dorsal side or the web space for patient comfort. An injection of 2 mL of local anesthetic on each side of the metacarpal neck effectively anesthetizes the common digital nerves supplying the finger.[120]

The dorsal nerves supplying the skin along the proximal phalanges are blocked using a subcutaneous technique. The needle is inserted in a vertical direction and 2 mL of local anesthetic is injected at each location (Fig. 1.16). Alternatively, injection can be performed just proximal to the web of the finger using a 1.5-cm, 25-gauge needle, creating a skin wheal superficial to the extensor hood to block the dorsal nerve. The needle can then be advanced toward the palm and an additional 1 mL injection performed just under the volar skin to anesthetize the volar digital nerve. The needle can be withdrawn to the skin and redirected toward the opposite side of the finger to place a superficial skin wheal or the process simply repeated on the other side of the digit. Small volumes of local anesthetic are preferred to avoid creating a circumferential ring.

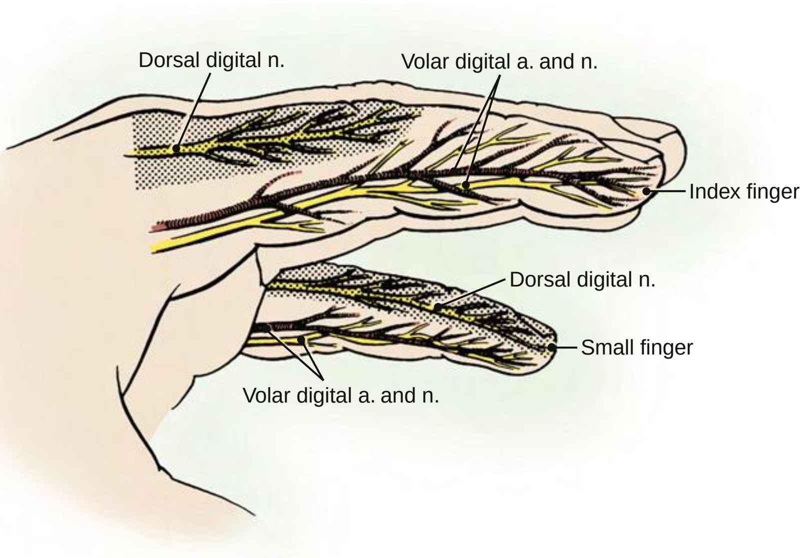

Fig. 1.13 Relationship and distribution of the digital nerves. Note that in the small finger, the dorsal digital nerve extends to the top of the digit; in the median nerve distribution, the volar nerve supplies the dorsum of the digit distal to the proximal interphalangeal joint. (Copyright Elizabeth Martin.)

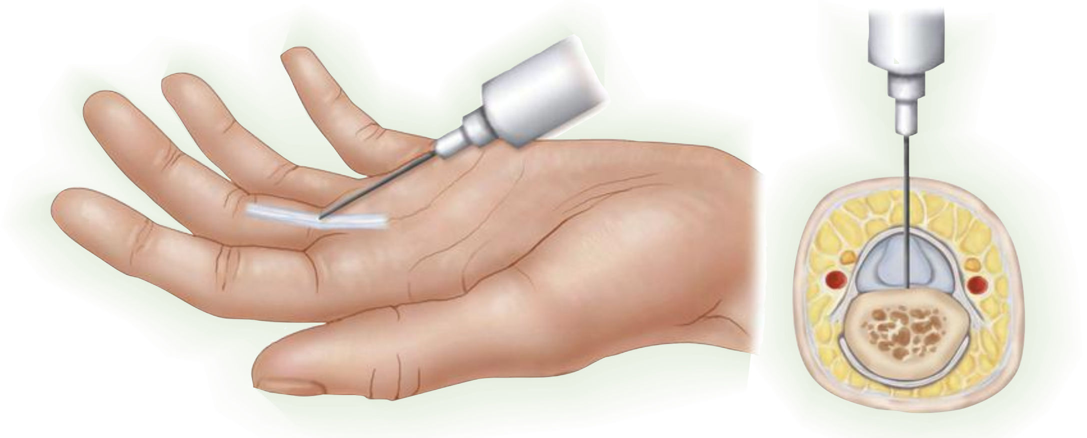

Fig. 1.14 Transthecal digital nerve block. Needle is advanced into the flexor tendon sheath **(A)** until it contacts the bony surface **(B)**. (Reproduced with permission from Chung KC, ed. *Operative Techniques: Hand and Wrist Surgery.* Philadelphia: Saunders; 2008, p 13.)

Use of epinephrine in digital nerve blockade. There has been a long-standing debate regarding the use of epinephrine in digital nerve blocks because of concern regarding vasoconstriction and subsequent ischemia and necrosis. The advantages include improved hemostasis and decreased need for tourniquet placement. Several studies and reviews have addressed this issue and deemed the use of epinephrine in a digital block safe.[121] Chowdhry and colleagues published a retrospective review in 2010 that reported no adverse events involving digital gangrene in 1111 patients.[122]

Intravenous Regional Block

Intravenous regional block, or Bier block, was one of the first techniques of regional blockade, introduced in 1908.[123] Bier block can be used for brief surgical procedures or manipulation of the distal upper extremity. Advantages include ease of use and rapid onset of anesthesia. Disadvantages include the lack of postoperative analgesia and necessity of using a pneumatic tourniquet as patients tend to complain of tourniquet pain after 30 minutes. Adding a second distal tourniquet allows prolongation of the block up to 1 hour.[124] After tourniquet pain is experienced with the proximal tourniquet, the distal tourniquet is inflated.

This technique involves placement of an IV catheter in the dorsum of the hand, followed by exsanguination of the upper extremity and inflation of a pneumatic tourniquet. Subsequent injection of local anesthetic into the venous system by means of the IV catheter results in rapid and profound sensory blockade. Plain lidocaine 0.5% in a dose of 3 mg/kg is the typical agent of choice, which requires a volume of 40 mL for the average adult.[123] Other agents such as prilocaine may be used instead[125]; however, bupivacaine is contraindicated in Bier block because of potential cardiac toxicity.

Contraindications include crush injuries or compound fractures that may damage the venous system or in the extremity difficult to exsanguinate. Bier block should also not be performed in patients in whom tourniquet use is contraindicated, in patients with local skin infections or cellulitis, or in patients with an allergy to local anesthetics.

Complications associated with Bier block are mainly related to drug effects of the local anesthetic, mainly when there is mechanical tourniquet failure leading to early deflation. It is recommended that the tourniquet remain inflated for 20 to 30 minutes after injection to allow metabolism of the local anesthetic and minimize systemic effects, particularly cardiovascular and respiratory events.[125] Incremental deflation, inflation, and deflation has been described to allow gradual release of the local anesthetic.

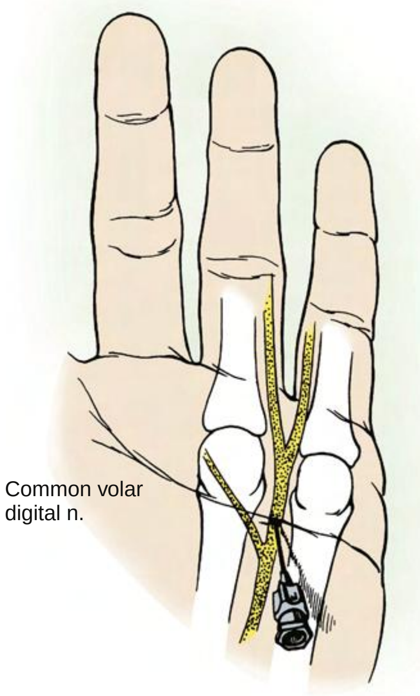

Fig. 1.15 Transmetacarpal digital nerve block. (Copyright Elizabeth Martin.)

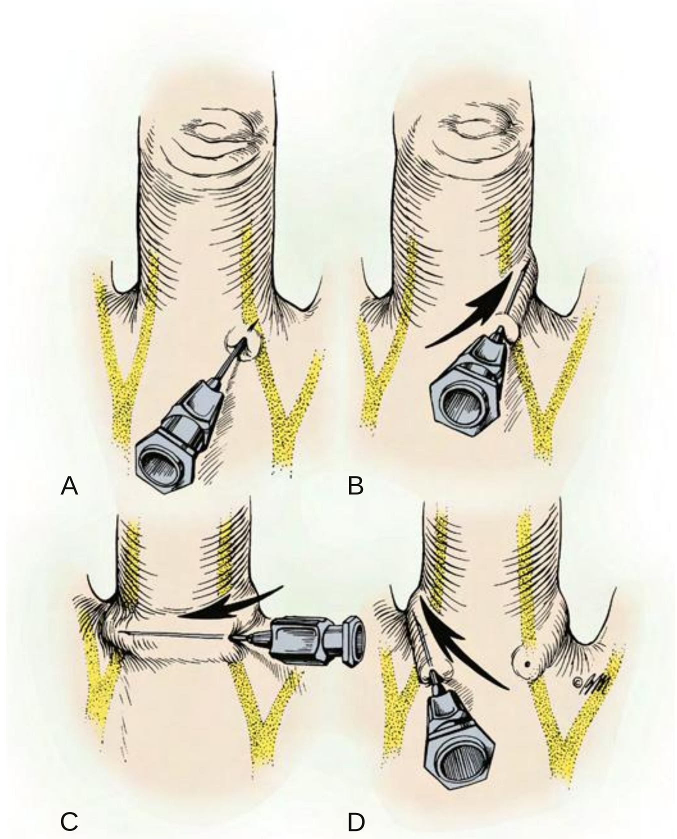

Fig. 1.16 Subcutaneous digital nerve block. **A,** The needle is inserted along one side of the flexor tendon sheath to block the volar nerve **(B)**. **C,** The dorsal digital nerve is anesthetized with a superficial skin wheal. **D,** The opposite volar nerve is blocked using the same technique. Care is taken to ensure that local anesthetic is not injected fully circumferentially around the finger. (Copyright Elizabeth Martin.)

Wide Awake Local Anesthesia No Tourniquet Technique

An alternative approach to anesthesia of the hand has been popularized by Don Lalonde, MD, using tumescent local anesthesia or the injection of local anesthetic with dilute epinephrine into the subcutaneous fat (see the online chapter Tumescent Local Anesthesia for Wide-Awake Hand & Upper Extremity Surgery, available on ExpertConsult.com). The effect of epinephrine allows for vasoconstriction ("blanching") over the injected site and results in bloodless surgery without the use of a tourniquet. Depending on the type of surgery planned and the weight of the patient, a predetermined amount of local (usually lidocaine) mixed with epinephrine is prepared and very slowly injected into the intended incisional site through a 27 g or 30 g needle. The local is then allowed to "set up" over 30 to 60 minutes prior to incision. The need for any systemic or regional anesthetic is eliminated, which allows this tumescent local anesthesia to be performed safely in an unmonitored procedure room. The surgery is performed without an IV. Tumescent local anesthesia is particularly useful in tendon repairs or transfers where the patient can actively move and the status or the repair or transfer assessed and adjusted if necessary. Tumescent local anesthesia also saves substantial monies and is being implemented in low- and middle-income countries as a way to provide safe and affordable surgical care. Patients with severe anxiety or cognitive impairment, young children, and patients with extremely poor capillary refill in their fingers may not be suitable candidates for wide awake local anesthesia no tourniquet (WALANT).

AUTHOR'S PREFERRED METHOD OF TREATMENT: REGIONAL ANESTHESIA

For surgery of the upper extremity, regional anesthesia is our standard method. Regional anesthesia is associated with decreased morbidity, shorter stays in the postanesthesia care unit, great patient satisfaction, and a low complication rate.[2,38,41,42] Presently, the American Academy of Orthopaedic Surgeons recommends the use of peripheral nerve blocks as a safe and effective anesthetic option for upper-extremity procedures.[44]

Our preferred blocks for regional anesthesia of the upper extremity are ultrasound-guided supraclavicular and infraclavicular blocks. They are often faster to perform in less experienced hands, have a faster onset, and allow smaller anesthetic volumes to be used.[69,70,126] Each year over 4200 supraclavicular and infraclavicular blocks are performed at our institution. Almost all of the blocks are performed using ultrasound guidance. These blocks have proven to be safe, rapid, and highly successful.

The type of ultrasound-guided block chosen depends on the surgery. For surgery from the shoulder to the elbow and occasionally from the elbow to the hand, our block of choice is the ultrasound-guided supraclavicular block. For surgery on the more distal upper extremity, our block of choice is most frequently the ultrasound-guided infraclavicular block.

Complications

Neurapraxia (Box 1.3)

Incidence. Temporary postoperative paresthesia, or temporary sensory or motor deficit, is relatively uncommon. Injury can result from the administration of anesthesia related to needle trauma and local anesthetic irritation. Injury can also be related to patient positioning, tourniquet compression, and/or surgical manipulation.

Studies have been inconclusive regarding the relationship between neural anatomy and nerve injury (mainly attempting to correlate epineural and intraneural injections with neurologic sequelae).[127] Early transient postoperative neurologic symptoms (PONSs) are common in the first month after peripheral nerve blockade (3%–8%), but rarely persist thereafter (0% to 2.2% at 3 months, 0% to 0.8% at 6 months, and 0% to 0.2% at 1 year).[128,129] Certain patient risk factors may increase the risk of neurologic injury after peripheral nerve blockade. These include old age, the use of chemotherapy, and the presence preexisting neuropathies (diabetes mellitus, cervical myelopathy, multiple sclerosis) and underlying vascular disease.[130] Droog et al.[131] reported that the incidence of new onset nerve injury after elective distal upper extremity surgery was 4.7% regardless of the anesthetic used. No risk factors could be identified. The authors concluded that patients who received a peripheral nerve block were not at an increased risk for nerve injury compared with those patients who underwent general anesthesia.[131] Interestingly, the use of ultrasound guidance rather than the nerve-stimulator technique has not led to a decrease in the incidence of neurologic complications after peripheral nerve blockade.[132-134]

BOX 1.3 Neurologic Complications

- Neurologic complications can occur after regional or general anesthesia.
- Use of ultrasound does not appear to minimize this risk.
- The mechanisms of injury are sometimes obscure.
- With appropriate precautions, the frequency of nerve injury after nerve blocks is quite low.

Management (Fig. 1.17). The surgeon usually discovers the nerve injury after surgery. Management of the patient's concerns and

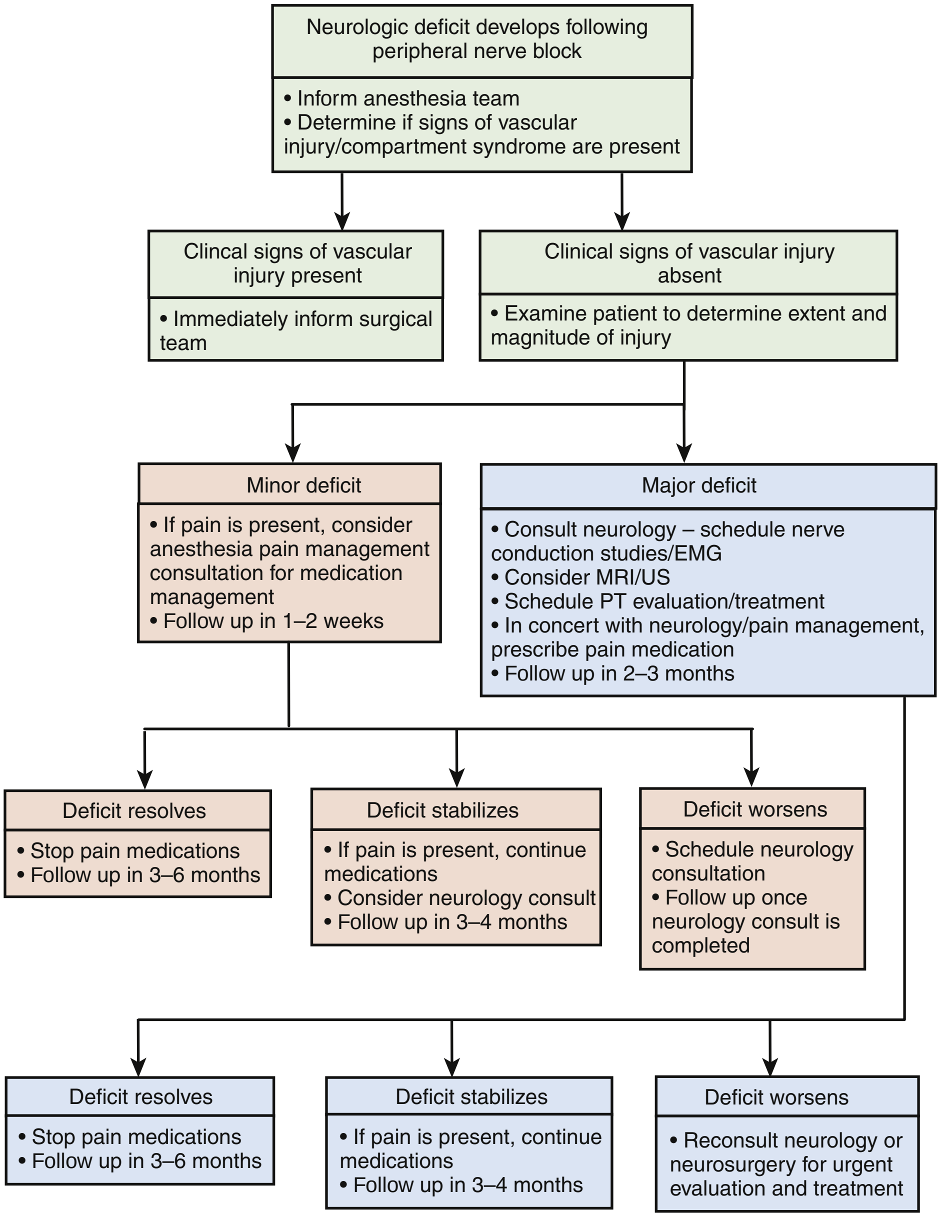

Fig. 1.17 Management of neurologic deficit following peripheral nerve block. *EMG,* Electromyography; *MRI,* magnetic resonance imaging; *PT,* physical therapy; *US,* ultrasound. (Reproduced and modified with permission from Hadzic A, ed. *Textbook of Regional Anesthesia and Acute Pain Management*. New York: McGraw-Hill; 2007, p 989.)

potential injury requires thorough communication between the surgeon, anesthesiologist, and patient. A thorough history coupled with a meticulous physical examination is required to determine the duration and types of symptoms, the dermatomal distribution, and any motor deficit. The surgeon and anesthesiologist must investigate other confounding factors such as postoperative pain, immobility, edema, positioning, and dressings/casting.

We divide the findings into minor or major deficits. Minor deficits include positional paresthesias, defined as changes in temperature or light touch sensation without loss of motor function, for example, a burning sensation in a dermatomal distribution. For minor deficits, reassurance that the deficit will likely resolve in a few weeks will often allay the patient's anxiety. The patient must be followed closely to ensure resolution of symptoms, provide reassurance, and allow early detection of a more serious problem.

Major deficits, such as complete or nearly complete nerve palsy, should prompt heightened concern. Early diagnostic testing and treatment may be required. For example, compression detected via ultrasound or magnetic resonance imaging requires prompt surgical decompression.[130] Pain medication should be prescribed to lessen the nerve pain and decrease the potential for the development of complex regional pain. Nerve conduction studies (NCSs) may or may not be necessary. NCSs are often inconclusive when the patient's only symptom is pain. A decrease in conduction velocity indicates myelin damage, whereas a decrease in amplitude indicates axonal damage. If the initial NCS is normal, the patient likely has injury to the unmyelinated nerve fibers, and the pain should resolve with time. If the initial NCS is abnormal, the injury is at least a neurapraxia, and electromyography (EMG) is often warranted. EMG changes in the muscle appear 2 to 4 weeks following injury. Many centers perform an initial EMG at the same time as the NCS to obtain a baseline. Subsequently, EMG should be performed 2 to 4 weeks after injury to define the muscle involvement and facilitate identification of the injury site.[135]

Allergy and Sepsis

Local anesthetics are categorized into two groups, esters and amides, based on their chemical structure. Esters are rapidly metabolized by plasma pseudocholinesterase, while amides are metabolized intracellularly by the liver. True allergic responses to local anesthetics are rare.[136,137] Patients often claim they are allergic, but a careful history elicits a tachycardic response to the added epinephrine. True allergies are more likely to be due to the ester group. Some patients are allergic to methylparaben, which is a preservative added to multidose vials of amide anesthetic. There is no evidence for cross-reactivity between the two esters and amides groups due to the vastly different chemical structures.

Any injection through the skin raises concerns for infection, and regional nerve blockade is no exception. Aseptic technique is recommended, including thorough hand washing and skin cleansing with either povidone-iodine solution or chlorhexidine.[138] The rate of infection is exceptionally low for single-shot techniques, though there are sporadic case reports. Indwelling catheters have the potential for colonization; however, the rate of clinical infection that correlates with catheter duration is negligible.[138] There are efforts to establish quality assessment surveillance systems for detection and management of infections after regional anesthesia.[139]

CRITICAL POINTS

Regional Anesthesia

- Regional anesthesia for upper extremity surgery may improve the control of postoperative pain, lower opiate consumption, decrease nausea and vomiting, and decrease the hospital stay.
- Among the regional anesthesia techniques of nerve stimulator–guided, paresthesia-guided, or ultrasound-guided nerve block, there is no demonstrated improvement in outcome with any particular technique. However, ultrasound-guided blocks have been shown to improve onset and decrease dosage requirements compared with traditional techniques.
- Absolute contraindications to regional anesthesia are infection at the site of injection and patient refusal. Patient refusal often stems from unsubstantiated fears. These concerns can often be dispelled with a promise of adequate sedation prior to administering the block and a forthright discussion of the procedure.
- The use of additives to local anesthetics can prolong block duration and analgesia while reducing overall local anesthetic dose, but agents should be chosen judiciously to avoid neurotoxicity.
- Continuous peripheral nerve catheters are safe and effective for extending opioid-sparing, site-specific analgesia for adult and pediatric patients in both the inpatient and outpatient settings.
- The incidence of temporary postoperative paresthesias is between 3% and 8% and most resolve within 4 weeks.
- Prolonged neurapraxias are extremely rare, with an incidence of between 0.04% and 0.8%. In the event of a neurapraxia, a coordinated effort between the anesthesiologist and surgeon is required, as well as thorough communication with the patient.

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