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Brachial Plexus Anesthesia: An Analysis of Options

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There are multiple sites at which the brachial plexus block can be induced in selecting regional anesthesia for upper extremity surgical patients. The most frequently used blocks are axillary, infraclavicular, supraclavicular, and interscalene. One must understand brachial plexus anatomy to use these blocks effectively, as well as the practical clinical differences between the blocks. Axillary brachial plexus block is most effective for surgical procedures distal to the elbow. This block is induced at a distance from both the centroneuraxis and the lung; thus, complications in those areas are avoided. Infraclavicular block is often the most effective method of maintaining a continuous block of the brachial plexus, since the catheter is easily secured to the anterior chest. Supraclavicular block provides anesthesia of the entire upper extremity in the most consistent, time-efficient manner of any brachial plexus technique; however, the block needle is necessarily positioned near the lung during injection. Interscalene block is especially effective for surgical procedures involving the shoulder or upper arm because the roots of the brachial plexus are most easily blocked with this technique. The final needle tip position with this block is potentially near the centroneuraxis and arteries perfusing the brain, thus careful aspiration of the needle and incremental injection are important. In summary, when an understanding of brachial plexus anatomy is combined with proper block technique and a patient- and procedure-specific balancing of risk-benefit, our patients and colleagues will be coadvocates of our brachial plexus regional blocks.

"Man uses his arms and hands constantly and as a result he exposes his arms and hands to injury constantly. Man also eats constantly. Man's stomach is never really empty. The combination of man's prehensibility and his unflagging appetite keeps a steady flow of patients with injured upper extremities and full stomachs streaming into hospital emergency rooms. This is why the brachial plexus is so frequently the anesthesiologist's favorite group of nerves [1]."

The late David Little's appropriate observations do not always lead anesthesiologists to choose a regional anesthetic for surgical procedures involving the upper extremity. However, those who do select regional anesthesia recognize that there are multiple sites at which the brachial plexus block can be induced; the most frequently used are axillary, infraclavicular, supraclavicular, and interscalene sites. Effective use of any of these brachial blocks demands that one first understand brachial plexus anatomy.

BRACHIAL PLEXUS ANATOMY

The brachial plexus is formed by the ventral rami of the fifth to eighth cervical nerves and the greater part of the ramus of the first thoracic nerve. Additionally, small contributions may be made by the fourth cervical and the second thoracic nerves. One problem with understanding this anatomy is that the traditional wiring diagram for the brachial plexus may be intimidating. The intimidation stems from the nerve pathways after the ventral rami emerge from between the middle and anterior scalene muscles until they end in the four terminal branches to the upper extremity: the musculocutaneous,

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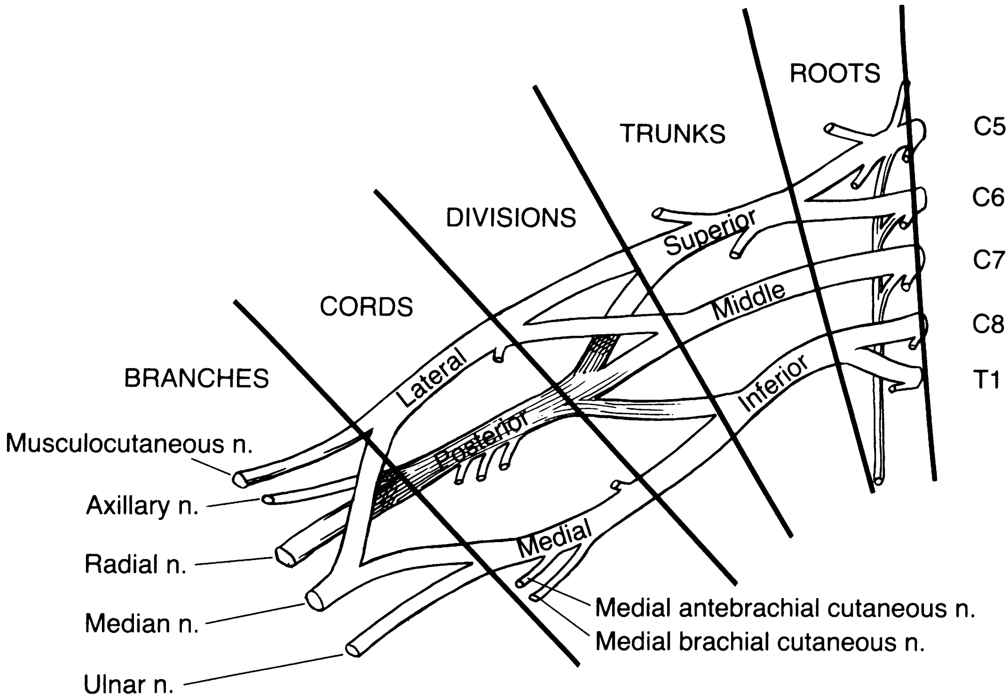

Figure 1. Simplified brachial plexus anatomy: roots, trunks, divisions, cords, and branches. (With permission from ref. 22)

median, ulnar, and radial nerves (Figure 1). Most of the anatomic detail about the transformation of nerve roots to brachial plexus, and then peripheral nerves, is not clinically essential information for an anesthesiologist [2].

After the nerve *roots* pass the lateral margin of the scalene muscles, they reorganize into *trunks* - superior, middle, and inferior. The trunks continue toward the first rib, and at the lateral edge of the first rib, the trunks undergo a primary anatomic *division*; that is, into ventral and dorsal divisions. This is also the point where understanding of brachial plexus anatomy gives way to frustration and often unnecessary complexity. This anatomic division is significant since the nerves destined to supply the originally ventral part of the upper extremity separate from those that supply the dorsal part.

As these brachial plexus divisions enter the axilla, the divisions are transformed into *cords*. The posterior divisions of all three trunks unite to form the posterior cord; the anterior divisions of the superior and middle trunks form the lateral cord; and the medial cord is the nonunited, anterior division of the inferior trunk. These cords are named according to their relationship to the second part of the axillary artery. It is at the lateral border of the pectoralis minor muscle that the three cords reorganize to become the *peripheral nerves* of the upper extremity [3]. Once again, in an effort to simplify brachial plexus anatomy, the *branches* of the lateral and medial cords are all "ventral" nerves to the upper extremity. The posterior cord, in contrast, provides all "dorsal" innervation to the upper extremity. Thus, the radial nerve supplies all the dorsal musculature in the upper extremity below the shoulder. The musculocutaneous nerve supplies muscular innervation in the arm, while providing cutaneous innervation to the forearm. In contrast, the median and ulnar nerves are nerves of passage in the arm, but in the forearm and hand they provide the ventral musculature with motor innervation. These nerves can be further categorized; the median nerve more heavily innervates the forearm, while the ulnar nerve more heavily innervates the hand.

A clinical mnemonic that will help anesthesiologists in checking brachial plexus blocks before the initiation of the surgical procedure is the series of "four P's." Using the mnemonic "push, pull, pinch, pinch" an anesthesiologist can easily remember how to check the four peripheral nerves of interest in brachial plexus blockade. By having the patient push (extend) the forearm at the elbow by contracting the triceps muscle, one can assess radial nerve function. Likewise, if the patient attempts to resist a pull (extention) of the forearm away from the upper arm, motor innervation to the biceps muscle can be assessed. If this muscle has been weakened, one can be certain that local anesthetic has reached the musculocutaneous nerve. Finally, if the patient is pinched in the distribution of the ulnar and median nerves, that is, at the base of the fifth and second digit, one can develop a sense of the adequacy of block of both the ulnar and median nerves, respectively. Typically, this maneuver is performed shortly after brachial plexus block, and motor weakness is evident before sensory block. This technique for checking the upper extremity was developed during World War II to give medics a method for quick analysis of injuries to the brachial plexus.

AXILLARY BLOCK

Axillary brachial plexus block is most effective for surgical procedures distal to the elbow. There are patients in whom procedures on the elbow or lower humerus can be performed with an axillary technique, but strong consideration should be given to supraclavicular block for those more proximal procedures. It is discouraging to induce a successful axillary block only to find that the surgical procedure extends outside the area of sensory block. The block is appropriate for hand and forearm surgery; thus, it is often the most appropriate technique for outpatients in a busy hand surgery practice. Because this block is distant from both the centroneuraxis and the lung, complications in those areas are avoided.

Patient selection

For axillary block to be appropriate, patients must be able to abduct their arm at the shoulder. As the anesthesiologist becomes experienced the necessity for ideal positioning of the patient's arm diminishes, but this block cannot be done with the arm at the side. Because the block is most appropriate for surgical procedures on the forearm and hand, it is a rare patient with a surgical condition at those sites who cannot abduct the arm as described.

Pharmacologic choice

Hand and wrist procedures often require less motor blockade than do those on the shoulder. Thus, the concentration of local anesthetic can often be decreased slightly with axillary block, in contrast to supraclavicular or interscalene block. Appropriate drugs are lidocaine (1 to 1.5%), mepivacaine (1 to 1.5%), and bupivacaine (0.5%). Lidocaine and mepivacaine produce from 2 to 3 hrs of surgical anesthesia without epinephrine, and 3 to 5 hrs of surgical anesthesia when epinephrine is added. These drugs can be useful for less involved or outpatient surgical procedures. For more extensive surgical procedures requiring hospital admission, a longer-acting agent, such as bupivacaine, can be used. Bupivacaine alone produces surgical anesthesia lasting from 4 to 6 hrs; the addition of epinephrine can prolong this to 8 to 12 hrs. One must consider the length of local anesthetic effect when prescribing a drug for outpatient axillary block, because blocks lasting as long as 18 to 24 hrs can result from higher concentrations of bupivacaine with epinephrine added.

Axillary block anatomy

At the level of the distal axilla, the axillary artery can be conceptualized as indicating the center of a four-quadrant neurovascular bundle. It is useful to imagine these nerves in a quadrant (or clockface) manner, because multiple injections during axillary block result in more acceptable clinical anesthesia than injection at a single site [4]. The musculocutaneous nerve is found in the 9 to 12 quadrant in the substance of the coracobrachialis muscle. The median nerve is most often in the 12 to 3 quadrant; the ulnar nerve is "inferior" to the median nerve in the 3 to 6 quadrant; and the radial nerve is in the 6 to 9 quadrant (Figure 2). The block does not need to be performed in the axilla and, in fact, needle insertion in the mid-to-lower portion of the axillary hair patch, or even more distal, is effective. Partridge et al. [5] examined 36 axillary specimens and documented that this four-quadrant concept was true for the majority of the anatomic specimens. It seems clear from additional radiographic and anatomic study of the brachial plexus and axilla that separate and distinct sheaths are present [6]. If this concept is kept in mind, it will help to decrease the number of unacceptable blocks.

Technique

The patient is placed supine with the arm forming a 90° angle with the trunk, and the forearm forming a 90° angle with the upper arm. A line should be drawn tracing the course of the artery from the midaxilla to the lower axilla; overlying this line, the index and third fingers of the left hand of the anesthesiologist are used to identify the artery and to minimize the amount of subcutaneous tissue overlying the neurovascular bundle. In this manner, the anesthesiologist can develop a sense of the longitudinal course of the artery which is essential for successful axillary block.

While the axillary artery is identified with two fingers, the syringe needle is inserted and local anesthetic should be injected in each of the quadrants surrounding the axillary

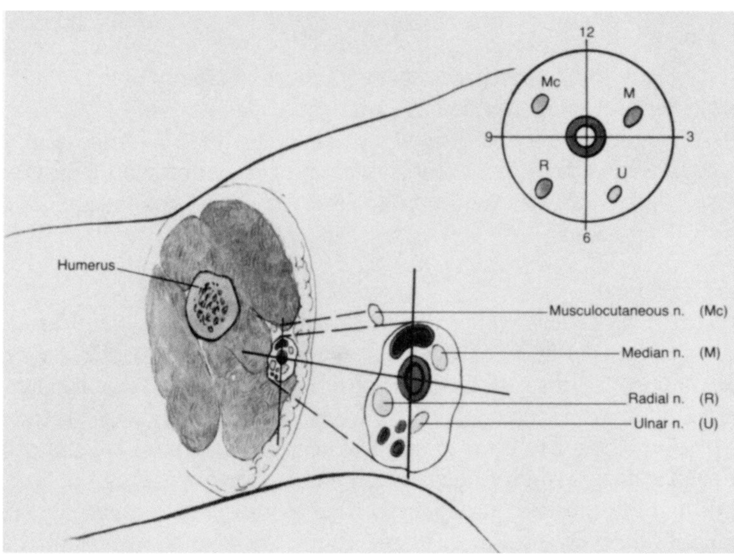

Figure 2. Four-quadrant concept of functional axillary anatomy, illustrating the most common relationship for musculocutaneous, median, ulnar and radial nerves. (With permission from ref. 2., Figure 5-1)

artery. If paresthesia is obtained, that is beneficial, although undue expenditure of time or production of patient discomfort should not occur during attempts to elicit paresthesia. Effective axillary block is produced by utilizing the axillary artery as an anatomic landmark and infiltrating the local anesthetic in a fanlike manner around the artery. Anesthesia of the musculocutaneous nerve is best achieved by infiltrating the drug into the mass of the coracobrachial muscle. This can be done by identifying the coracobrachial muscle and injecting into its substance or by inserting a longer needle until it contacts the humerus and injecting in a fanlike manner (Figure 3).

There are anesthesiologists who advocate use of a single, fixed needle position when carrying out axillary block [7]. If this technique is used, a needle-extension tube-syringe assembly is created, and after abduction of the patient's arm to approximately 90°, a blunt 25-gauge needle is inserted in a perivascular axillary arterial location, as far proximal in the axilla as possible. Some suggest that needle entry into the perivascular "sheath" is identified by noting a click when the blunt needle enters the sheath. At this point, advocates of perivascular axillary block carry out incremental injection of local anesthetic, after aspirating for blood between increments.

Potential problems

Problems with axillary block are infrequent because of the distance from centroneuraxis structures and the lung. One complication that can be minimized by the use of multiple injections, rather than use of a single, fixed perivascular located needle, is the

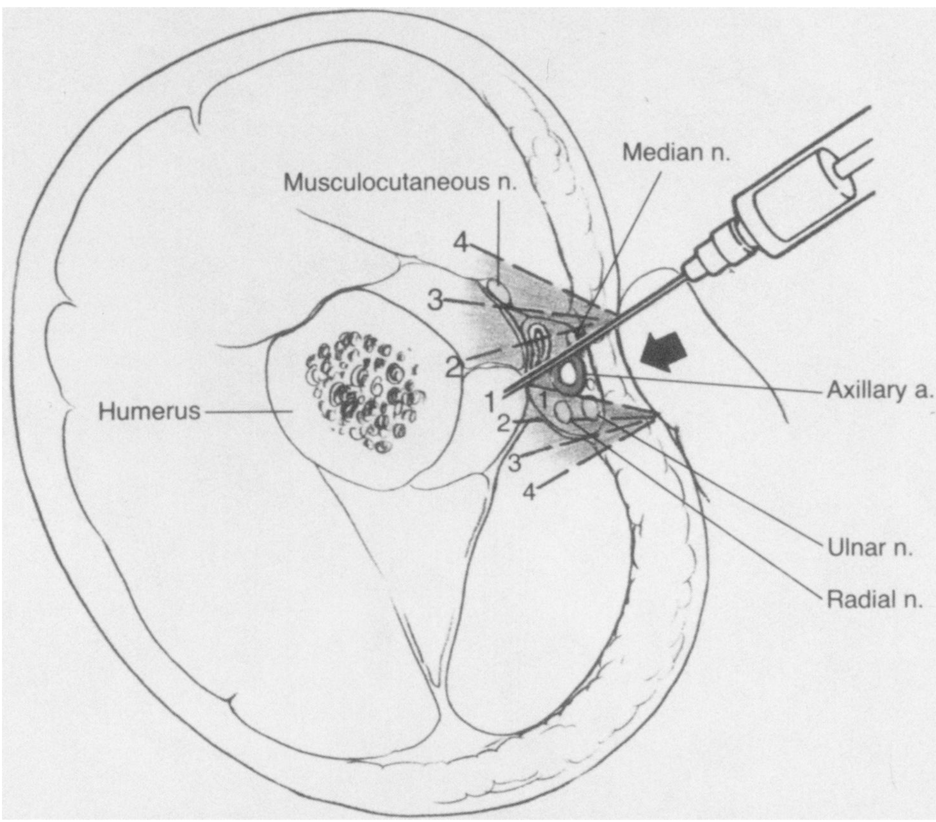

Figure 3. Needle-insertion technique for axillary nerve block that uses fanlike injection with axillary artery as guide. (With permission from ref 2., Figure 5-4)

occasional occurrence of systemic toxicity from axillary block. Any time a single immobile needle is used to inject large volumes of a local anesthetic, the potential for systemic toxicity increases, especially when compared to a technique of using smaller volumes of local anesthetic injected at multiple sites. Another potential problem with axillary block is development of postoperative neuropathy; however, one should not assume that axillary block is the cause of all neuropathies after upper extremity surgery. A logical and systematic approach to determining the cause of a neuropathy is necessary if we are to understand the true incidence and origin of neuropathy after brachial plexus block. Although there are many editorials and reports about avoiding paresthesia as a means of decreasing the incidence of postoperative neuropathy, there are no conclusive data supporting the concept that elicitation of gentle paresthesia is accompanied by an increased incidence of postoperative neuropathy [2, 8, 9, 10].

INFRACLAVICULAR BLOCK

Infraclavicular block is especially effective for continuous analgesic techniques when a brachial plexus catheter needs to be left in place for some days [11]. The block produced with this technique has many clinical similarities to an axillary block if the technique of Raj [12] is utilized, since when the needle tip is located within the axilla during the block. This block can be performed with the arm in almost any position, thus, correct patient positioning of the involved upper extremity is less important than when an axillary block is carried out (Figure 4).

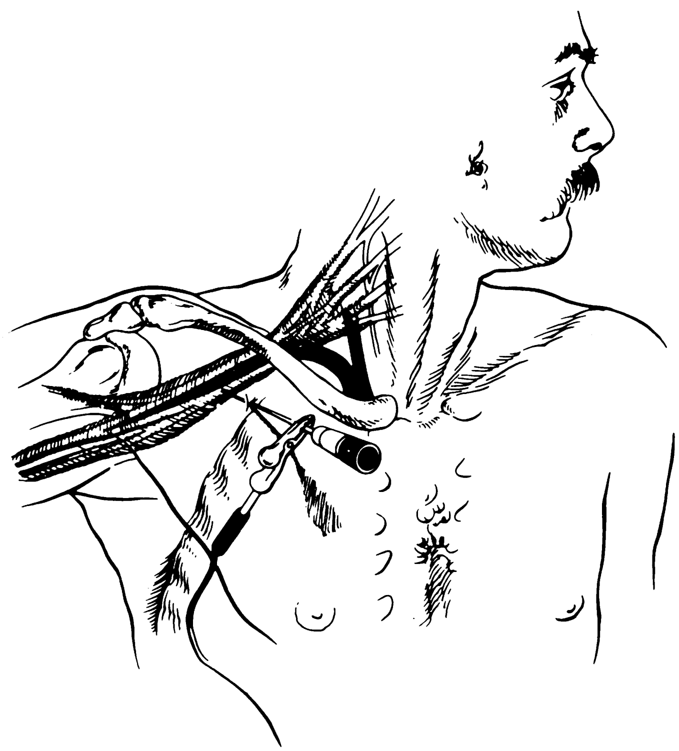

Figure 4. Needle-insertion technique for the infraclavicular block, showing needle insertion at the clavicular mid-point, in a lateral-posterior direction. (With permission from ref. 12, Figure 10)

Patient selection

Patients are candidates for this block whenever an axillary block is indicated. Additionally, patients requiring prolonged upper extremity analgesia often are most comfortable if this block is used as a continuous technique. Patients requiring prolonged central venous catheterization often prefer a subcalvian site over an internal jugular site, since the dressing over the percutaneous subclavian site is much easier to keep clean and secure. Similarly, an infraclavicular catheter location allows patients upper extremity use limited only by motor block produced from the continuous technique, as well as the convenience of a secure catheter location.

Pharmacologic choice

Continuous analgesic techniques often require much less motor blockade than necessary for surgical anesthesia. Thus, the concentration of local anesthetic can often be decreased significantly with a continuous infraclavicular block. The most used drug is bupivacaine (0.125 – 0.25%), administered at a rate varying from 5 to 10 mL/hr. If a traditional surgical anesthetic is planned, the drug prescription can use the criteria outlined for drug selection during axillary block.

Infraclavicular block anatomy

The axilla is a pyramid-shaped space located between the lateral chest wall and the medial portion of the upper arm (Figure 5). This infraclavicular space has an apex, base,

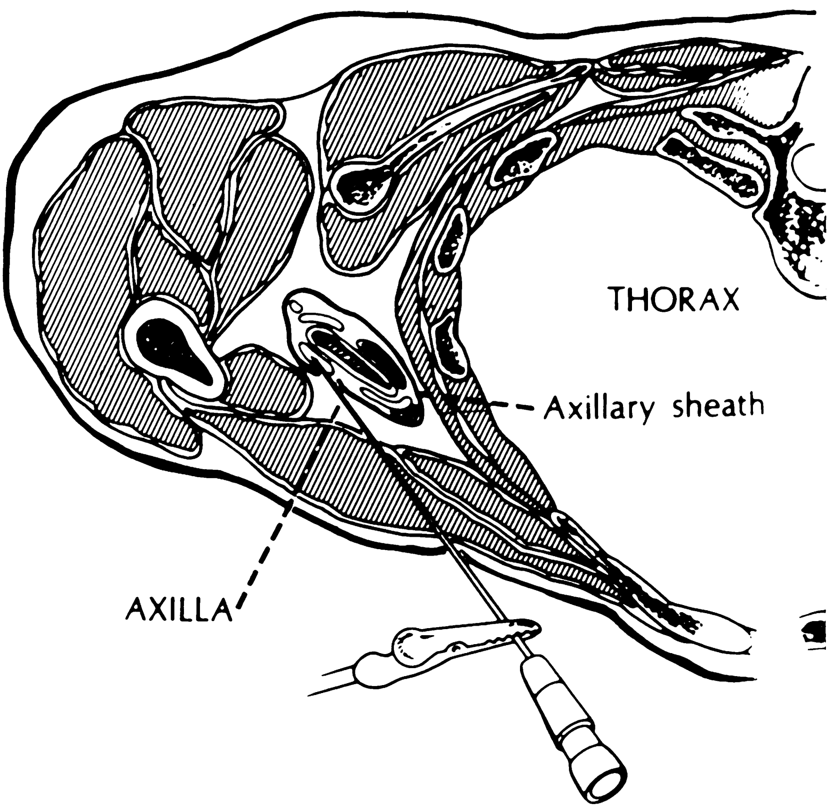

Figure 5. An oblique cross-section of the thorax and upper arm, highlighting the boundaries of the axilla, and location of brachial plexus and axillary vessels within the axilla. (With permission from ref. 12, Figure 2)

and four walls. The apex is limited by the outer border of the first rib, the superior aspect of the scapula, and the posterior surface of the clavicle. The base consists of the skin and soft tissue of the axilla. The anterior wall is formed by pectoralis major and minor muscles, while the subscapularis, teres major, and latissimus dorsi muscles make up the posterior wall. The medial wall is formed by the lateral chest wall, while the lateral wall is formed by the medial aspect of the upper arm. Within the axilla are the axillary blood vessels, the brachial plexus, and a significant amount of soft tissue, consisting of lymph nodes, and adipose and areolar tissue [12].

Technique

The patient is positioned supine with the head turned away from the side to be blocked. The arm may be abducted to 90°, although this is not absolutely necessary if the abducted position causes the patient pain. The clavicle is outlined, and its mid-point is marked. Approximately one cm caudad to the clavicular mid-point a local anesthetic skin wheal is raised in preparation for needle insertion. If a continuous technique is contemplated, a needle of large enough diameter to accept a catheter is chosen, such as an 18- to 20-gauge, 6 to 9 cm needle. It is then inserted in a lateral-posterior direction with aid of a peripheral nerve stimulator or the use of a paresthesia seeking technique. The needle direction can be adjusted by reinserting the needle in a parasagittal plane from more cephalad to caudad in the axilla [12]. Effort should be made not to allow the needle to assume a too posterior orientation, since the chest wall can be penetrated if a direct anterior-posterior needle orientation is maintained. When a catheter is planned and the needle is confidently located near the brachial plexus by either paresthesia or nerve stimulator repsonse, 10 mL of saline is injected *via* the needle in an effort to ease catheter insertion. The catheter is then inserted approximately 5 cm past the needle tip and the needle withdrawn over the catheter. The catheter is then secured to the chest wall with either a suture or sterile adhesive tape (Steri-Strips®). If a continuous analgesic technique is planned, a loading dose of local anesthetic is injected (e.g., 10 – 15 mL of 0.25% bupivacaine), and the infusion pump is attached to the catheter, and begun at 5 to 10 mL/hr. If a surgical anesthetic is planned, the blunt, 22-gauge, 6 to 9 cm needle is positioned as outlined, and the local anesthetic is then incrementally injected.

Potential problems

If the needle is not allowed to assume too much of an anterior-posterior orientation, the complications associated with this block should be the same as those accompanying axillary nerve block. If the chest wall is entered by a misdirected needle, a pneumothorax is possible, although maintenence of the correct needle orientation makes this unlikely (Figure 6). This complication may occur more frequently when the infraclavicular technique of Labat [13] is used. In this situation, the needle entry site remains infraclavicular; however, the needle is directed toward the base of the neck rather than toward the arm.

INTERSCALENE BLOCK

Interscalene block is especially effective for surgical procedures involving the shoulder or upper arm because the roots of the brachial plexus are most easily blocked with this technique [14]. There is frequently sparing of the ulnar nerve and its more peripheral distribution in the hand, unless one makes a special effort to inject local anesthetic caudad to the site of the initial paresthesia [15]. This block is ideal for reduction of a dislocated shoulder and can often be achieved with as little as 10 to 15 mL of local anesthetic. This block can also be performed with the arm in almost any position and, thus, can be useful when brachial plexus block needs to be repeated during a prolonged upper extrem-

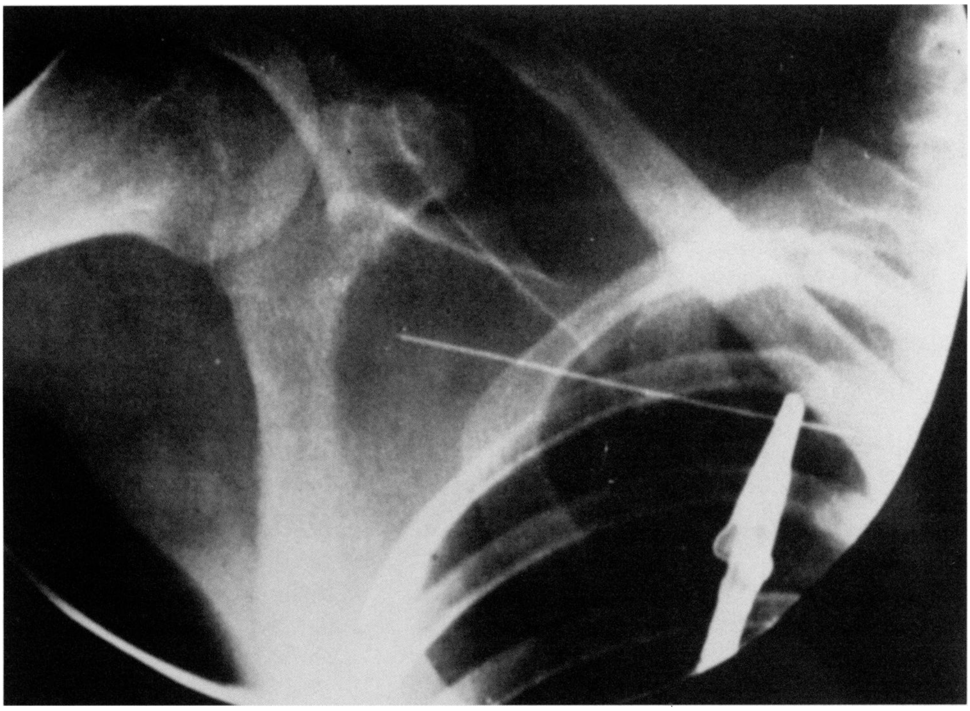

Figure 6. A Radiograph showing correct needle placement for the infraclavicular block, i.e. the needle is directed lateral and posterior, and away from the lung. (With permission from ref. 12, Figure 8)

ity procedure.

Patient selection

Interscalene block is appropriate for nearly all patients, because even obese patients usually have identifiable scalene and vertebral body anatomy. One group of patients in which interscalene block should be avoided includes those with significantly impaired pulmonary function [16]. This point is likely not relevant if one is planning to use a combined regional and general anesthetic technique which allows control of ventilation intraoperatively. Even when a long-acting local anesthetic is chosen for the interscalene technique, usually by the time the surgical procedure is completed, clinical pulmonary function has returned to a level that patients will tolerate if a low concentration of local anesthetic is chosen for the block.

Pharmacologic choice

Useful agents for interscalene block are primarily the amino amides. Lidocaine and mepivacaine produce from 2 to 3 hrs of surgical anesthesia without epinephrine and 3 to 5 hrs of surgical anesthesia when epinephrine is added. These drugs can be useful for less involved or outpatient surgical procedures. For more extensive surgical procedures requiring hospital admission, a longer-acting agent such as bupivacaine can be chosen.

The more complex surgical procedures on the shoulder often require muscle relaxation; thus, bupivacaine concentrations of at least 0.5% are needed. Bupivacaine alone produces surgical anesthesia lasting from 4 to 6 hrs, whereas the addition of epinephrine may prolong this to 8 to 12 hrs, with analgesia lasting 18 to 24 hrs.

Anatomy

Surface anatomy of importance to anesthesiologists involves the larynx, sternocleidomastoid muscle, and external jugular vein. Interscalene block is most often performed at the level of the C-6 vertebral body which is at the level of the cricoid cartilage [17] (Figure 7). Thus, by projecting a line laterally from the cricoid cartilage, the level can be identified at which one should roll the fingers off the sternocleidomastoid muscle onto the belly of the anterior scalene and then into the interscalene groove. With firm pressure, in most individuals it is possible to feel the transverse process of C-6, and in some, it is possible to elicit a paresthesia by deep palpation. It is always important to visualize what lies under the palpating fingers, and, again, the key to performing successful interscalene block is the identification of the interscalene groove.

Technique

The patient lies supine with the neck in the neutral position and the head turned slightly away from the site to be blocked. The anesthesiologist then asks the patient to lift the head off the table in order to tense the sternocleidomastoid muscle and to allow iden-

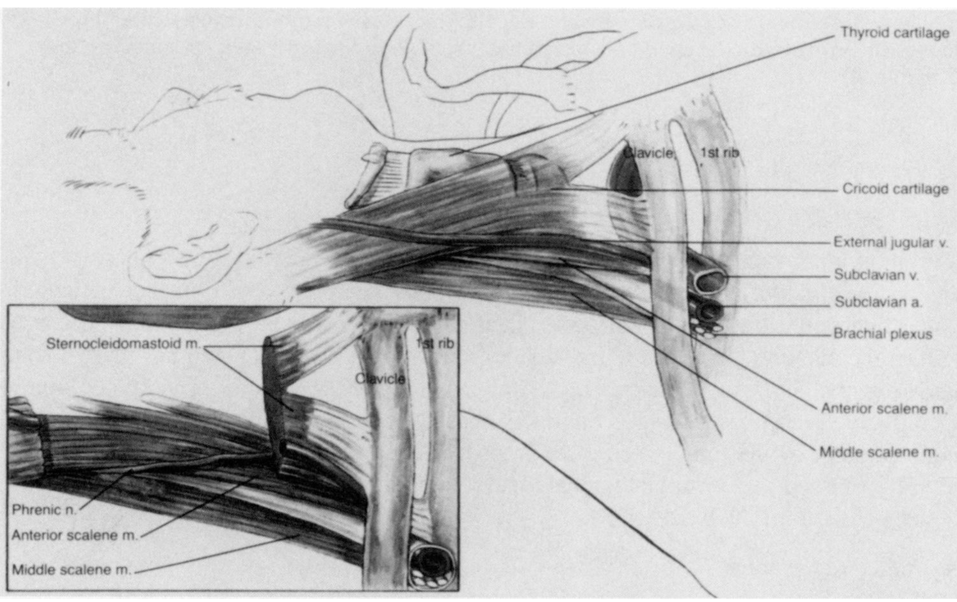

Figure 7. Interscalene block functional anatomy: the level of C-6 is the classic position for needle insertion. At that level, the scalene muscles (middle and anterior) travel with a slight oblique orientation compared to the posterior border of the sternocleidomastoid muscle, with the latter inserting onto the clavicle and the former two inserting onto the first rib. (With permission from ref. 2, Figure 3-2)

tification of its lateral border. The fingers then roll onto the belly of the anterior scalene muscle and, subsequently, into the interscalene groove. This should all be done in the horizontal plane through the cricoid cartilage at the level of C-6.

When the interscalene groove has been identified and the operator's fingers are firmly pressing in the interscalene groove, the needle is inserted in a slightly caudad and slightly posterior direction (Figure 8). If a paresthesia is not elicited on insertion while maintaining the same needle angulation, the needle is "walked" in a plane joining the cricoid cartilage to the C-6 transverse process. Because the brachial plexus is traversing the neck at virtually a right angle to this plane, if small enough steps of needle reinsertion are used, a paresthesia is almost guaranteed. If the block is being induced for shoulder surgery, this is probably the one brachial plexus block in which a large volume of local anesthetic, coupled with a single needle position, allows effective anesthesia. For shoulder surgery, 30 to 40 mL of lidocaine, mepivacaine, or bupivacaine can be used.

Potential problems

Problems that can arise from interscalene block include subarachnoid injection, epidural blockade, intravascular injection (especially in the vertebral artery), pneumothorax, and phrenic block [18].

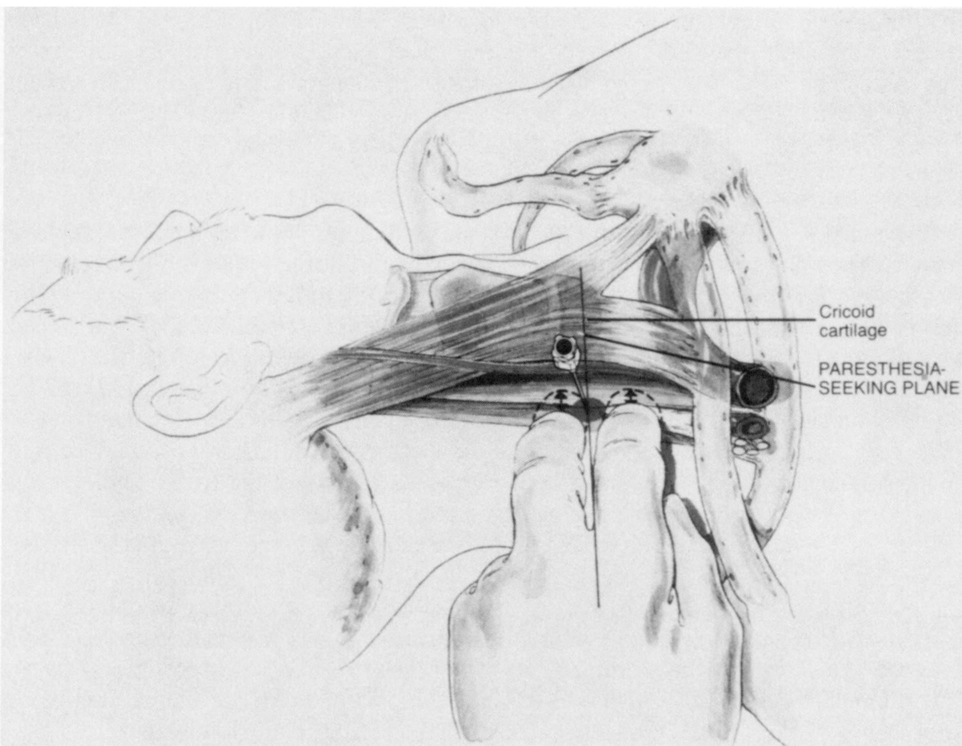

Figure 8. Interscalene block is performed by clearly identifying the interscalene groove and inserting the needle at the level of C-6 in a slightly caudad and posterior direction. If paresthesia is not elicited on initial needle insertion, the needle is reinserted in a parallel plane, while the fingers are rolled anterior or posterior along a line constructed at a 90° angle to the route of travel of the brachial plexus. (With permission from ref. 2, Figure 3-5)

SUPRACLAVICULAR BLOCK

Supraclavicular block provides anesthesia of the entire upper extremity in the most consistent, time-efficient manner of any brachial plexus technique [15]. It is the single, most effective block for all portions of the upper extremity and is performed at the division level of the brachial plexus. Perhaps this is why there is often little or no sparing of peripheral nerves if an "adequate" paresthesia is obtained. If this block is used for shoulder surgery, it should be supplemented with a superficial cervical plexus block to block the cutaneous innervation overlying the shoulder.

Patient selection

Almost all patients are candidates for this block, with the exception of those who are uncooperative. Additionally, in less experienced hands, supraclavicular block may be inappropriate for outpatients. Although pneumothorax is an infrequent complication of the block, it often becomes apparent only after delay of several hours when an outpatient might already be at home [19].

Pharmacologic choice

As with other brachial plexus blocks, the prime consideration of drug selection should be length of the procedure and the degree of motor block desired. Again, mepivacaine (1 to 1.5%), lidocaine (1 to 1.5%), and bupivacaine (0.5%) are all applicable to brachial plexus block. Lidocaine and mepivacaine produce from 2 to 3 hr of surgical anesthesia without epinephrine and from 3 to 5 hrs when epinephrine is added. These drugs can be useful for less-involved or outpatient surgical procedures. For more extensive surgical procedures requiring hospital admission, a longer-acting agent, such as bupivacaine, can be chosen. Bupivacaine alone produces surgical anesthesia lasting from 4 to 6 hrs, and the addition of epinephrine may prolong this to 8 to 12 hrs.

Anatomy

The anatomy of interest for this block is the relationship between the brachial plexus and the first rib, the subclavian artery, and the cupula of the lung. My experience suggests that this block is more difficult to teach than many of the other regional blocks, and for that reason, I will illustrate two approaches to the supraclavicular block: the classic Kulenkampff approach [20] and the "plumb-bob" approach [21]. The plumb-bob approach was developed in an attempt to overcome the difficulty in learning the classic supraclavicular block and to decrease the incidence of pneumothorax accompanying the technique. In spite of that caution, either of the techniques is clinically useful once mastered. As the subclavian artery and brachial plexus pass over the first rib, they do so between the insertion of the anterior and middle scalene muscles onto the first rib (Figure 9). The nerves lie in a cephaloposterior relationship to the artery; thus, paresthesia can be elicited before the needle contacts the first rib. At the point where the artery and plexus cross the first rib, the first rib is broad and flat, sloping in a caudad direction as it moves from posterior to anterior; although the rib is a curved structure, there is a distance of 1 to 2 cm in which a needle can be "walked" in an anterior-posterior direction [22]. Immediately medial to this first rib is the cupula of the lung, and pneumothorax from this block most often results when too medial a needle angulation is used.

Technique

The patient lies supine without a pillow, and the head is turned away from the side to be blocked. The patient's arms are at the sides, and the anesthesiologist can stand either at the head of the table or along side the patient near the arm to be blocked for the classic

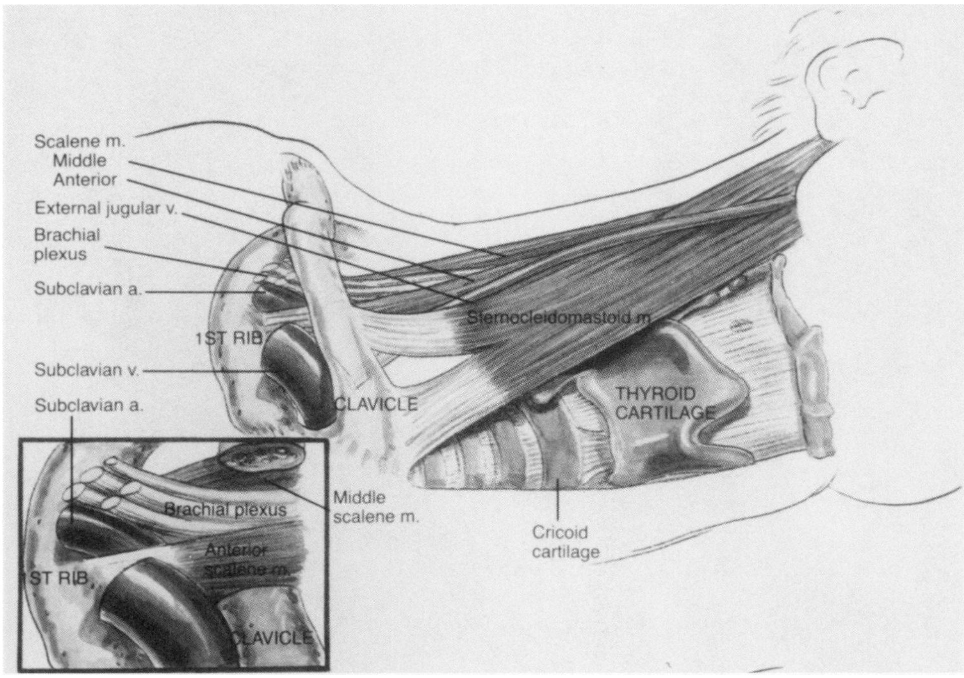

Figure 9. Basic supraclavicular anatomy of the brachial plexus at the level of the first rib. (With permission from ref 2, Figure 4-2)

approach and lateral to the patient at the level of the patient's upper arm for the plumb-bob technique.

Classic. In the classic approach, the needle insertion site is approximately 1 cm superior to the clavicle at the clavicular midpoint. This entry site is closer to the middle of the clavicle than to the junction of the middle and medial third, as often described. From this point, the syringe needle is inserted in a plane approximately parallel to the patient's neck and head, taking care that the axis of syringe and needle does not aim medially toward the cupula of the lung (Figure 10).

Plumb-Bob. Patients are asked to raise their head slightly off the block table so that the lateral border of the sternocleidomastoid muscle can be marked as it inserts onto the clavicle. From that point, a "mental" plane is created that runs parasagittally through that site. The name "plumb-bob" was chosen for this block concept because if one suspends a plumb-bob over the entry site, needle insertion through that point results in contact with the brachial plexus in most patients [21] (Figure 11). Once this skin mark has been placed immediately superior to the clavicle at the lateral border of the sternocleidomastoid muscle as it inserts onto the clavicle, the needle is inserted in the parasagittal plane at a 90° angle to the tabletop. If paresthesia is not elicited on the first pass, the needle and syringe are redirected cephalad in small steps through an arc of approximately 30°. If a paresthesia still has not been achieved, the syringe and needle is reinserted at the starting position

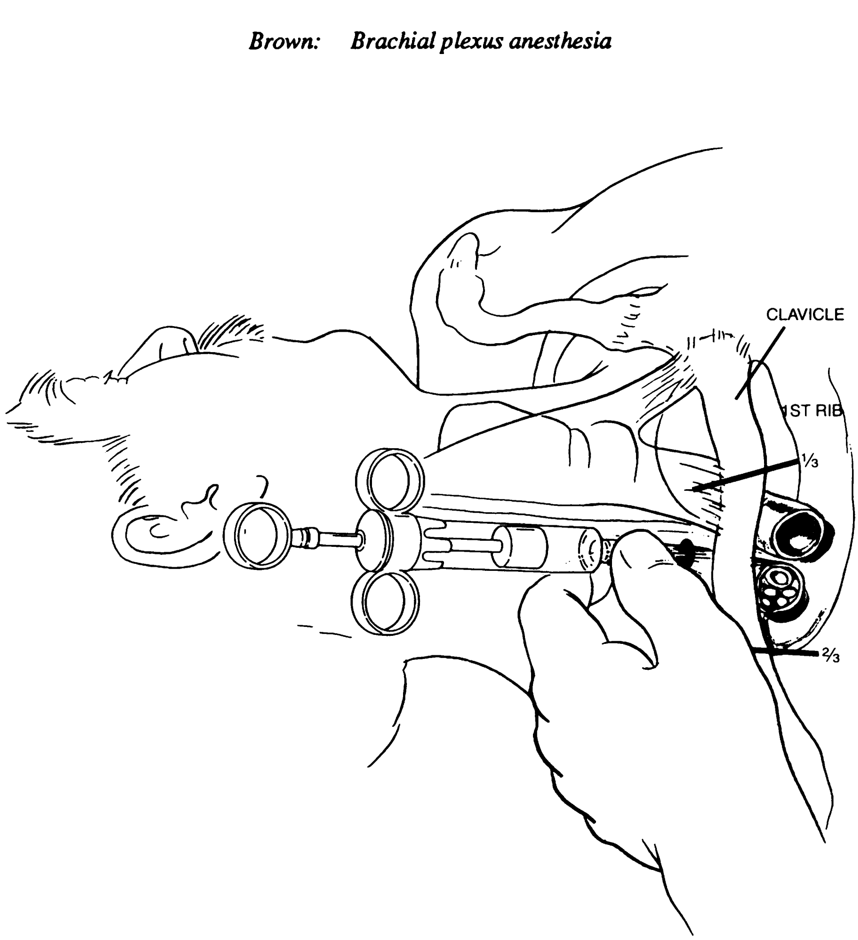

Figure 10. Supraclavicular block, classic technique. The needle insertion site is approximately1-cm superior to the clavicle at the cavlicular midpoint. The needle and syringe assembly are then inserted in a plane parallel to the patient's head and neck and reinserted along an anterior-posterior line in small steps until a paresthesia is evoked. Care is taken to avoid letting the needle drift medially toward the cupula of the lung. (With permission from ref. 2, Figure 4-3)

and then moved in small steps through an arc of approximately 30° in a caudad direction. Because the brachial plexus lies cephaloposterior to the artery as it crosses the first rib, often a paresthesia can be elicited before contacting either the artery or the first rib. If that occurs, approximately 30 mL of local anesthetic is injected at this single site. If a paresthesia is not elicited with the maneuvers described, but the first rib is contacted, the block is performed as in the classic approach, "walking" along the first rib until paresthesia is elicited. As in the classic approach, care should be taken not to allow the syringe and needle assembly to aim medially toward the cupula of the lung.

Potential problems

The most noted complication of this block is pneumothorax. The principal cause of this is needle-syringe angles that "aim" toward the cupula of the lung. Special attention should be directed toward "walking" the needle in a strict anterior-posterior direction. Phrenic nerve block does occur, probably in about 50% of patients, and its use in patients with significant impairment of pulmonary function patients must be considered carefully. The development of hematoma after supraclavicular block, as a result of puncture of the subclavian artery, usually requires only observation.

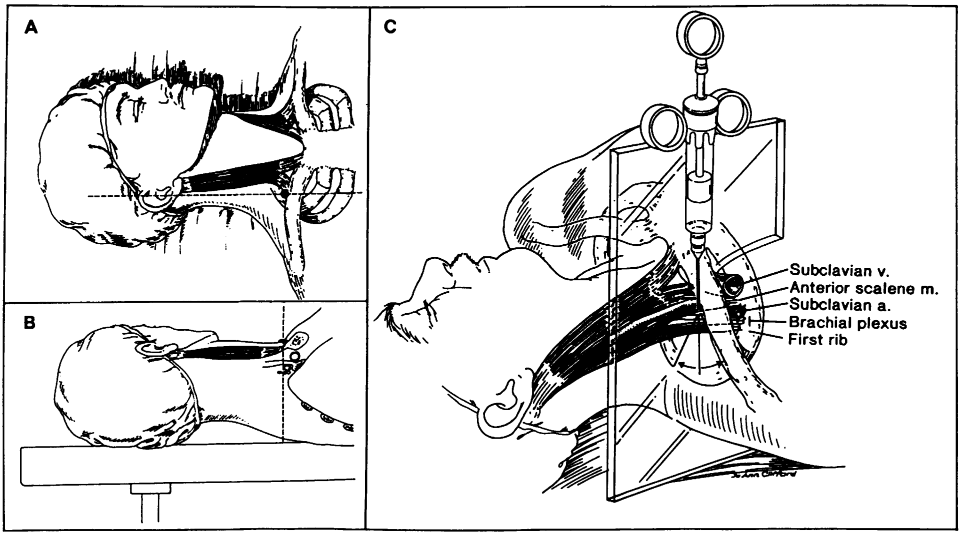

Figure 11. Supraclavicular block, plumb-bob technique. A. Needle entry site (black dot on dotted line) shown immediately lateral to insertion of clavicular head of sternocleidomastoid muscle onto clavicle. **B.** Parasagittal plane shows vertical orientation of needle path (black dot on dotted line) from a position immediately superior to clavicle. **C.** Right oblique view of the modifie d supraclavicular nerve block, with a "pane of glass" outlining the parasagittal plane in which the simulated needle-syringe assembly is moved through 30° arcs to seek paresthesia. (With permission from ref. 17, Figure 1)

NERVE STIMULATION

There are anesthesiologists who suggest brachial plexus block needle insertion is facilitated by the use of a peripheral nerve stimulator. The primary impediment to successfully using a nerve stimulator in a clinical practice is that it becomes at least a three-handed and two-individual technique. Nevertheless, there are circumstances in which nerve stimulation can be helpful, although there is no information available demonstrating block outcome is improved.

Nevertheless, when utilizing nerve stimulation during regional block, insulated needles seem to be the most appropriate since the current from such a needle results in a sphere around the needle tip, while uninsulated needles emit current both at their tip as well as along the shaft resulting in less precise needle location. A peripheral nerve stimulator should allow between 0.1 to 10 milliamps of current in pulses lasting approximately 200 milliseconds at a frequency of 1 pulse/sec. The peripheral nerve stimulator chosen should also have a digital display of the current delivered with each pulse. This facilitates generalized location of the nerve while stimulating at 3 milliamps, and refinement of needle positioning as the current pulse is reduced to 0.5 to 0.1 milliamp. The nerve stimulator should also have stimulator terminals clearly identified since peripheral nerves are most effectively stimulated by using the needle as the cathode. If the circuit is established in reverse with the needle as anode, approximately four times as much current is necessary for stimulation. Thus, the positive lead of the stimulator should be established remote from the site of stimulation by connecting the lead to a common electrocardiographic electrode [2].

One important caution in utilizing the nerve stimulator is to approach the nerve block as if the nerve stimulator were not going to be used; that is, as much attention should be paid to the anatomy and technique when using a nerve stimulator as without its use. Only after you approach the block in that manner should the nerve stimulator be utilized for "fine tuning" the block. When the stimulator is used, the current should be adjusted to a level of approximately 3 milliamps, and the needle slowly advanced toward the nerve. If you are stimulating a mixed nerve, muscle stimulation will be observed when the needle is 1–2 cm from the nerve. Since large myelinated motor fibers are stimulated by less current than smaller and unmyelinated fibers, muscle contraction is most often produced prior to patient discomfort. The needle should be repositioned at a point where muscle contraction can be elicited with 0.5 to 0.1 milliamps. If a pure sensory nerve is to be blocked, a similar procedure is followed; however, localization will require the patient to report a sense of pulsed "tingling or burning" over the cutaneous distribution of the sensory nerve. Once the needle is in final position and stimulation is achieved with 0.5 to 0.1 milliamps, 1 mL of local anesthetic should be injected through the needle. If the needle is accurately positioned, this amount of solution should abolish the muscle contraction and/or sensation with pulsed current [2].

SUMMARY

The use of brachial plexus blocks provides anesthesiologists with a choice of techniques which may be useful in providing anesthesia and analgesia during upper extremity surgery. Most often the techniques are administered as a single injection; however, there may be some patients who benefit from a continuous infusion *via* a catheter technique. For comprehensive anesthesia and analgesia care to be available to more of our patients, the techniques of brachial block should be mastered. If an understanding of brachial plexus anatomic principles is combined with proper block technique and adequate perioperative sedation, patients, surgeons, and anesthesiologists will become coadvocates of brachial plexus regional block.

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