Pediatric Regional Anesthesia for the Upper Limb

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Interscalene Nerve Block

General Considerations

A well-studied peripheral nerve block that is relatively easy to perform and has a low risk of complications. The interscalene nerve block should be avoided in children with limited respiratory reserve as blockade of the phrenic nerve can significantly impair diaphragmatic muscle use for ventilation. The ulnar nerve is often inconsistently blocked with this technique.

Indication

Suitable for analgesia and surgical anesthesia for shoulder surgery, proximal humerus, and arm. Distal arm procedures will likely require supplementation with ulnar nerve blockade.

Functional Anatomy

After leaving the intervertebral foramina, the roots of the brachial plexus travel between the anterior and middle scalene muscles at the level of the cricoid cartilage (C6). The carotid artery and internal jugular vein will appear more medially, and the sternocleidomastoid muscle lies more super-medially. The interscalene nerve block is performed at this anatomical location at the level of the roots and proximal trunks of the brachial plexus (Fig. 74.1).

Technique

The patient is placed with the head turned approximately 45° away from the side to be blocked with a rolled towel placed underneath the shoulders. The skin is cleaned with antiseptic solution. If ultrasound guidance is used, prepare the probe surface by applying a sterile adhesive dressing. A 50 mm, 22G–25G insulated short-beveled needle is used. Recommended local anesthetics are 0.125–0.25% bupivacaine or 0.1–0.2% ropivacaine. Using 0.25% bupivacaine at 0.2–0.3 mL/kg is a reasonable option for this block. The duration of sensory block averages 15 ± 4.5 h, independent of the type and concentration of the local anesthetic used. Epinephrine 1:200,000 may be added to detect intravascular injection.

Nerve Stimulation

The point of needle insertion is at the level of cricoid cartilage (C6) within the interscalene groove (Fig. 74.2). The interscalene groove is located between the anterior and middle scalene muscles posterior to the lateral border of sternocleidomastoid muscle (SCM), approximately slightly above the point where the sternal and clavicular heads of the SCM

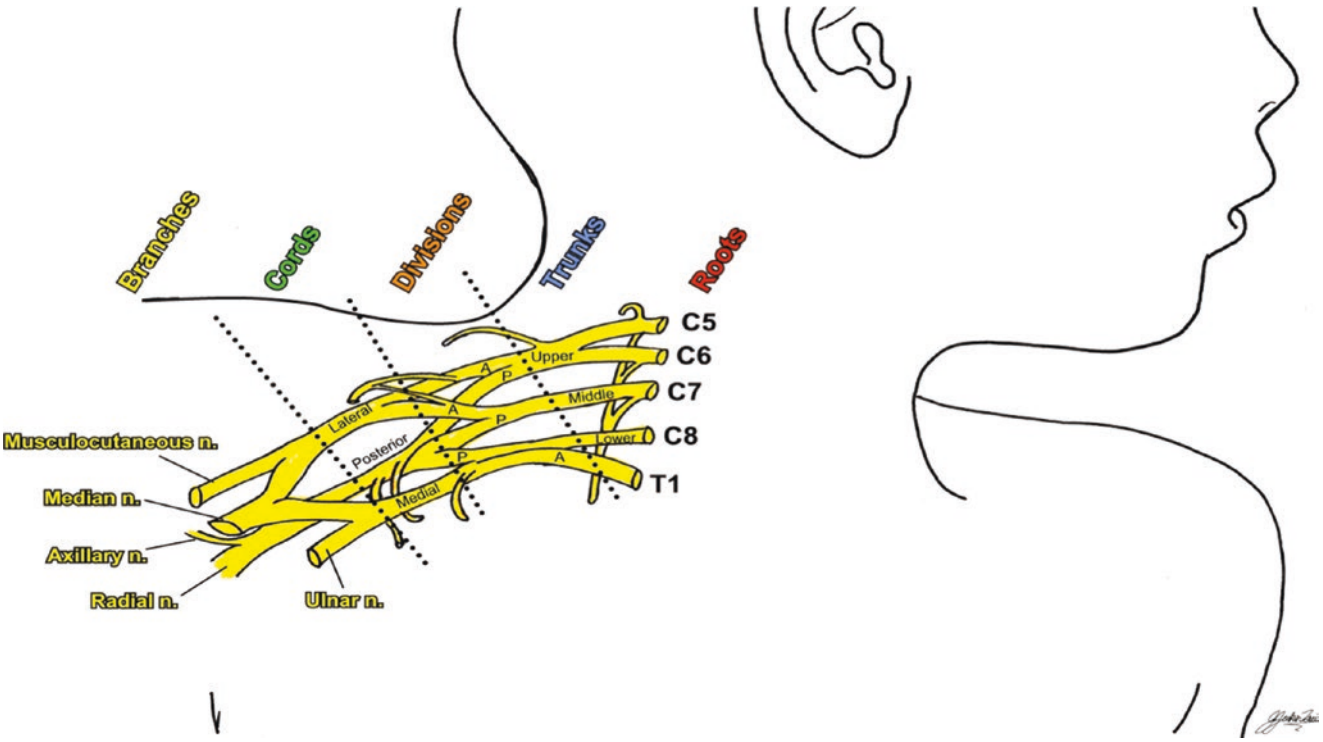

Fig. 74.1 Anatomy of the brachial plexus. *A* anterior divisions, *P* posterior divisions

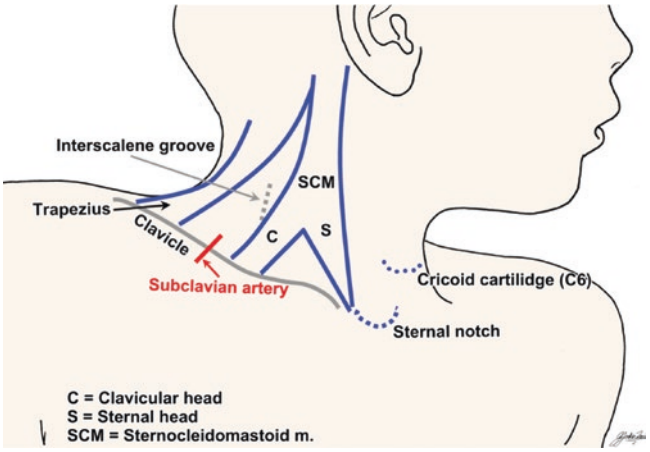

Fig. 74.2 Patient positioning and surface landmarks for interscalene brachial plexus block

separate. The line between the point of needle insertion and the cricoid cartilage should cross the Chassaignac's tubercle (anterior tubercle of the transverse process of the C6 vertebra), which can be felt easily. The needle is inserted at 60° to the skin and directed medially, posteriorly, and caudally to prevent inadvertent puncture of the vertebral artery or epidural/intrathecal space. The initial current is set at 0.8–1.0 mA (2 Hz, 100–300 μs) and then gradually reduced to a threshold current of 0.2–0.4 mA (0.1–0.2 msec) after eliciting appropriate motor responses. Response at a current >0.4 mA indicates that the needle is too far away from the plexus; a current ≤0.2 mA signifies intraneural placement.

Ultrasound-Guided

A high-frequency (13–6 MHz) linear transducer probe is suitable for this block. As shown in Fig. 74.3, the probe is placed on the neck in an axial oblique view at the level of the cricoid cartilage (C6). The anechoic great vessels (common carotid artery and internal jugular vein) and the overlying triangular-shaped sternocleidomastoid muscle are identified first. If necessary, color Doppler can be used to locate the vessels. Move the probe proximally and distally to identify the roots/trunks of the brachial plexus (commonly seen as three round- or oval-shaped hypoechoic structures) in the interscalene groove between the anterior and middle scalene muscles. Occasionally, the vertebral artery can be seen deep to the plexus and anterior to the C6 transverse process. Extra caution should be exercised not to confuse the artery with a nerve and inject into it. Visualization of the neural structures can be difficult in small children, so a "traceback" approach is recommended (Fig. 74.4). In the traceback approach, the probe is placed in a coronal oblique plane at the upper border of the clavicle. The brachial plexus at this point appears as "a bunch of grapes," superolateral to the subclavian artery. The plexus is then traced back to the interscalene region by scanning in a cephalad direction. The needle is inserted either in-plane or out-of-plane, although the in-plane approach is preferred to ensure visualization of the needle, thereby minimizing the risk of complications. For the in-plane approach, the needle is inserted in a lateral-to-medial fashion into the interscalene groove. When using the out-of-plane approach, the plexus is centered in the middle of the screen, and the needle is inserted cranial to the probe at the midline. Direct the needle tip, which appears as bright dot on the screen, in a "walk-down" manner in proximity to the nerves. Nerve structures can be confirmed by nerve stimulation. A test dose with D5W is useful to visualize the spread and confirm nerve localization. After negative aspiration for blood or CSF, local anesthetic is deposited to achieve good spread surrounding the nerves within the interscalene groove. The depth should be less than 1–2 cm, even in teenage adolescents.

Complications

Phrenic nerve block, vertebral artery puncture and injection, epidural or intrathecal injection, Horner's syndrome, recurrent laryngeal nerve blockade, and hematoma formation in the neck due to arterial or venous puncture, block failure, infection, and local anesthetic systemic toxicity (LAST) are possible, but rare, complications.

Practical Tips

- The nerve roots lie anterior to the transverse process.
- If a trapezius muscle twitch is encountered with nerve stimulation, withdraw and angle needle more anteriorly.
- If the carotid artery is punctured, remove needle, and apply pressure. Subsequent attempt should direct needle more posteriorly.

Literature Review

The interscalene nerve block for shoulder surgery in the pediatric population has shown superior postoperative analgesia and minimized inpatient hospital admissions in a retrospective cohort. Case reports of children with acute respiratory tract infections and acute hepatitis needing emergency shoulder surgery have successfully reported on the use of an interscalene nerve block to provide surgical anesthesia while avoiding a general anesthetic.

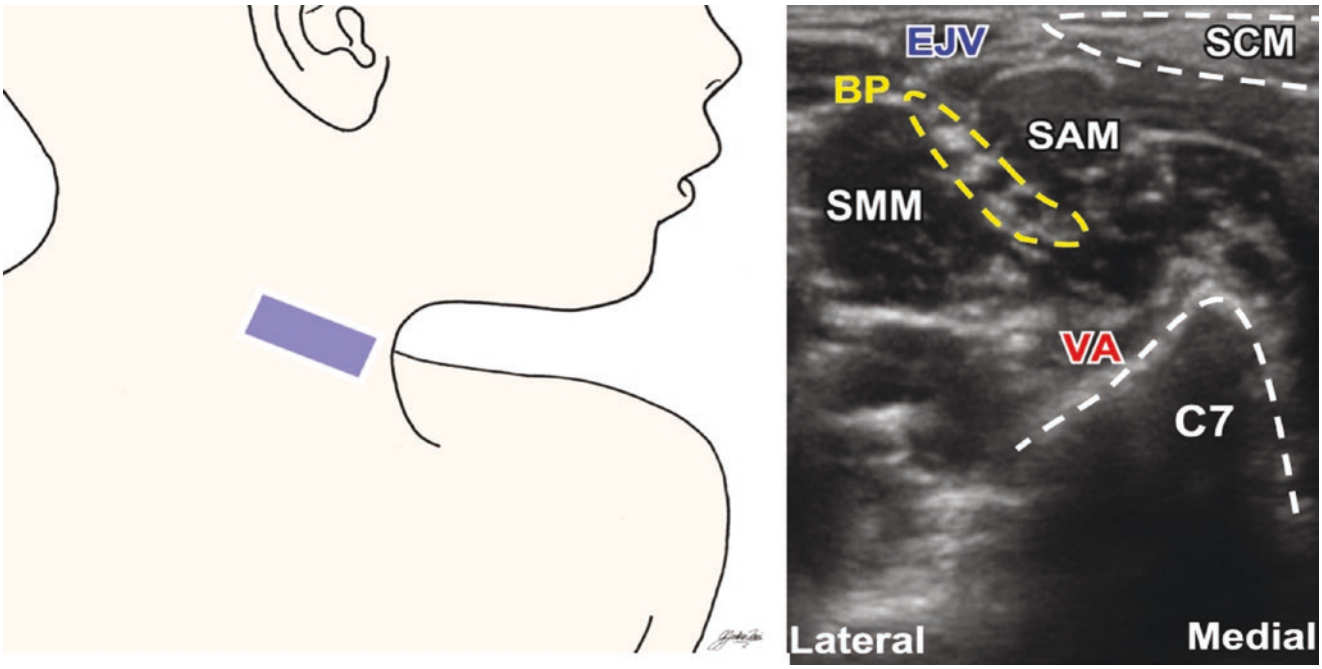

Fig. 74.3 Ultrasound image of the brachial plexus at the interscalene groove. *EJV* external jugular vein, *SCM* sternocleidomastoid muscle, *SAM* scalenus anterior muscle, *SMM* scalenus medius muscle, *VA* vertebral artery, *BP* brachial plexus, *C7* C7 vertebra

Supraclavicular Nerve Block

General Considerations

A well-studied peripheral nerve block that is relatively easy to perform and has a low risk of complications. The supraclavicular nerve block is less likely to cause phrenic nerve blockade compared to the interscalene nerve block. Given the proximity of the location of blockade to the pleura, the risk of pneumothorax is present.

Indication

Provides reliable anesthesia and analgesia for surgeries distal to the shoulder involving the entire upper extremity, elbow, forearm, and hand.

Functional Anatomy

The trunks continue to travel between the anterior and middle scalene muscles until they reach the level of the first rib which lies anterior. Superior and posterior to the subclavian artery, the upper, middle, and lower trunks conform tightly and are the ideal location for the supraclavicular nerve block. With the use of ultrasound, the rib and pleura can be seen slightly deeper to the subclavian artery.

Technique

The head of the patient is turned to the contralateral side. The arm is placed on the side, and the shoulder is pushed backward on to the mattress and down toward the feet. The skin is cleaned with antiseptic solution. If the ultrasound approach is used, prepare the probe surface by applying a sterile adhesive dressing.

A 50 mm, 21G–23G insulated needle is used. Depth of insertion is related to the age and weight of the patient in a nonlinear manner. For a 10 kg child, the depth of insertion is about 10 mm. For every 10 kg increase in weight, the depth of insertion increases 3 mm until the child reaches 50 kg. After that, advance 1 mm for every 10 kg increase in weight. The maximum depth should not exceed 35 mm. The required depth of penetration is usually less than 1 cm for children and 1–2 cm for teenagers.

Recommended local anesthetics are 0.25–0.5% bupivacaine, 0.2% ropivacaine, or 2% lidocaine. Blockade at this level can be achieved with volumes as low as 0.15–0.2 mL/kg.

Nerve Stimulation

The needle insertion point is located 1 cm above the midpoint of the clavicle posterolateral to the subclavian artery (Fig. 74.5). The subclavian artery pulsation serves as the landmark for localization of the plexus. The current is initially set at 0.8 mA (2 Hz, 100–300 μs) and then gradually reduced to a threshold current of 0.2–0.4 mA (0.1–0.2 m)

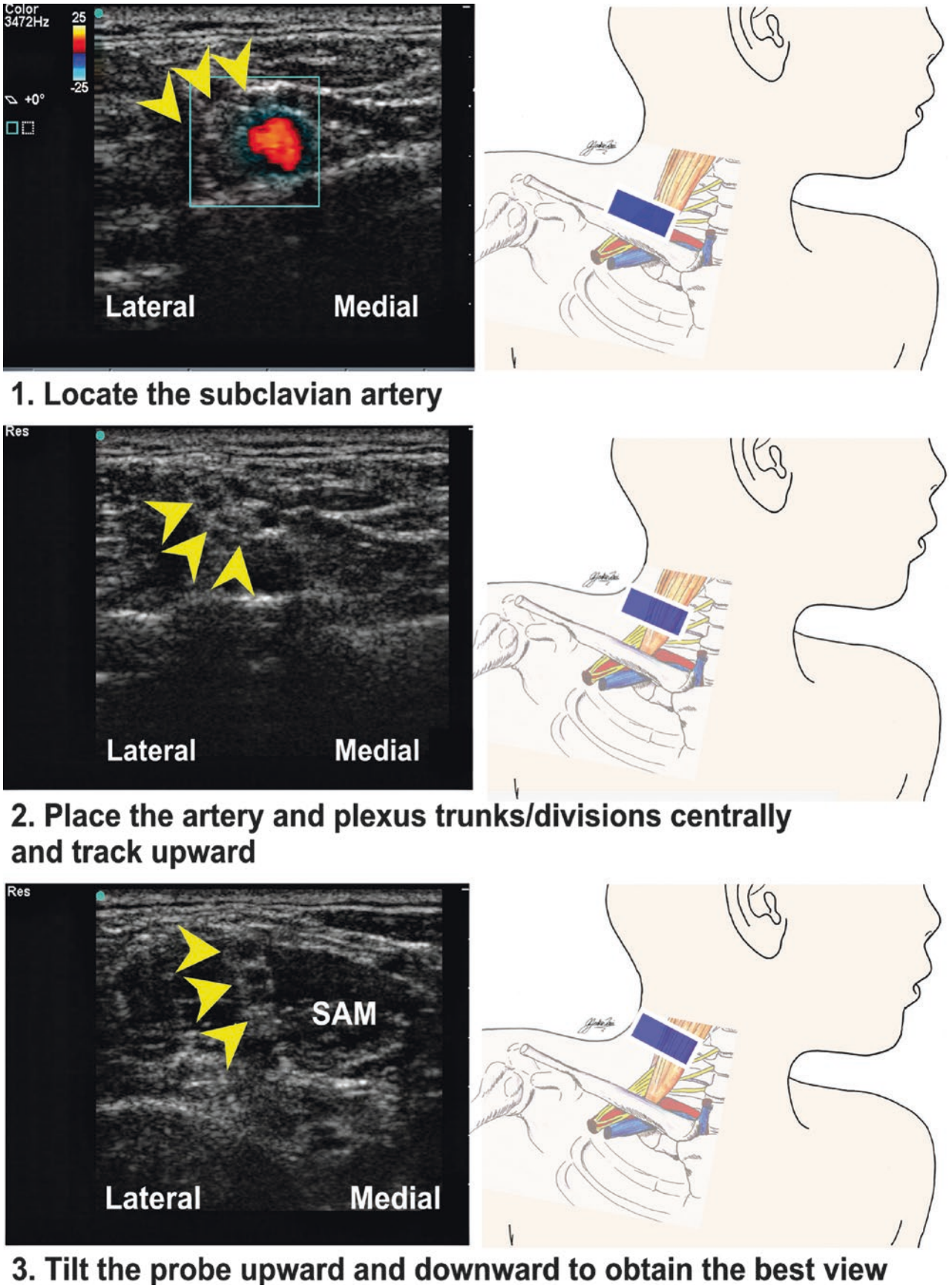

Fig. 74.4 Ultrasound traceback approach for interscalene block. *SAM* scalenus anterior muscle; arrowheads show location of brachial plexus

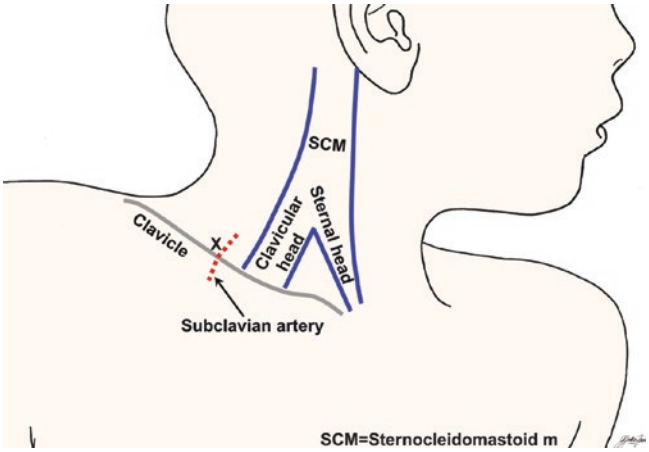

Fig. 74.5 Patient positioning and surface landmarks for supraclavicular brachial plexus block

after obtaining appropriate response. Motor response at a current ≤0.2 mA indicates intraneural placement, and the needle should be withdrawn. The spread of local anesthetic solution in children may be greater than for adults since, in children, the fascia adheres less to the nerve trunks. This increases the likelihood of a successful block with any motor response.

Ultrasound-Guided

A high-frequency (13–6 MHz) hockey stick probe is ideal for small children. For older and/or obese children, a small footprint curved array probe is a better option. The probe is first placed in a coronal oblique plane at the lateral end of the upper border of the clavicle (Fig. 74.6). It is then moved medially until the subclavian artery is seen. The subclavian artery is anechoic, hypodense, pulsatile, and round; its identity can be confirmed by color Doppler. The plexus is located superior and lateral to the artery above the first rib and appears as a "bunch of grapes" outlined by a hyperechoic fascia sheath. Below the artery, the first rib appears as a hyperechoic structure with a hypoechoic acoustic shadow, while the lung pleura is accompanied by a hyperechoic shadow due to air artifacts.

The needle is inserted immediately above the clavicle in a lateral-to-medial direction at a shallow angle. An in-plane approach is strongly recommended, to ensure visualization of the needle tip, at all times, so as to minimize the risks of pneumothorax and vascular puncture. A test dose of D5W is used to visualize the spread and confirm nerve localization. Local anesthetic is first deposited into the "corner pocket" (the corner between the subclavian artery and the first rib). This way, the plexus is often raised away from the pleura so as to reduce the chance of pleural puncture upon subsequent injection. The needle may then be repositioned to achieve good local anesthetic spread around the nerves within the fascia.

Complications

Pneumothorax, phrenic nerve block, subclavian artery puncture and injection, epidural or intrathecal injection, Horner's syndrome, recurrent laryngeal nerve blockade, and hematoma formation in the neck due to arterial or venous puncture, block failure, infection, and local anesthetic systemic toxicity (LAST) are possible, but rare, complications.

Practical Tips

- The use of Doppler to identify vascular structures (i.e., suprascapular artery and transverse cervical artery) in the vicinity of the brachial plexus at this location is recommended.
- If a pneumothorax occurs, the clinical presentation is often delayed as opposed to immediate.

Literature Review

The use of single shot and continuous infusion supraclavicular nerve blocks in children have been reported for both sole surgical anesthesia and postoperative analgesia of upper extremity orthopedic surgery.

Infraclavicular Nerve Block

General Considerations

A well-studied brachial plexus block that is moderately challenging to perform given the depth of the brachial plexus divisions at this location. The risk of complications is low, and this block is preferable in children with respiratory compromise who are dependent on diaphragmatic muscle use for respiration.

Indication

This block is indicated for surgery on the upper arm, elbow, forearm, and hand. Continuous infusion of local anesthetic via an infraclavicular catheter provides excellent postoperative analgesia for major upper limb surgery and is preferred over supraclavicular and axillary catheters because of ease of placement and securement.

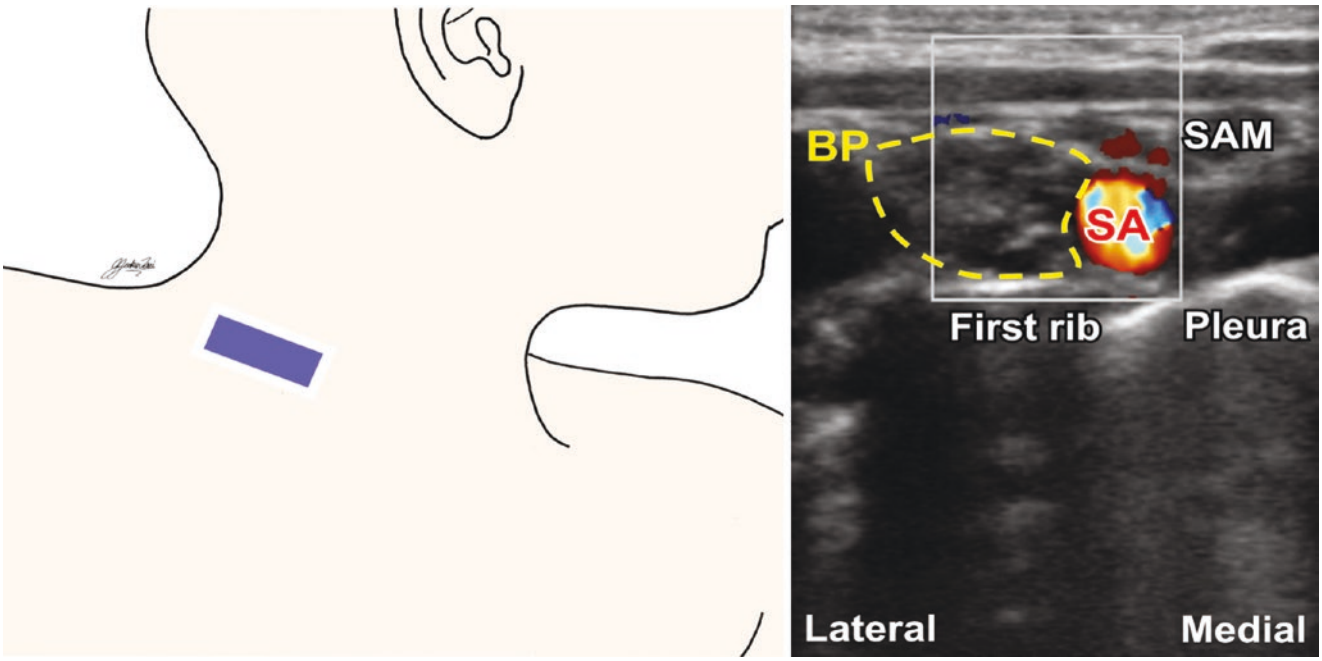

Fig. 74.6 Ultrasound image of the brachial plexus at the supraclavicular level. *BP* brachial plexus, *SAM* scalenus anterior muscle, *SA* subclavian artery

Functional Anatomy

As the trunks of the brachial plexus pass over the lateral border of the first rib heading toward the axilla, they become anterior and posterior divisions. In the infraclavicular region, near the lateral chest wall, the infraclavicular plexus block is performed to anesthetize the lateral, medial, and posterior cords that surround the axillary artery. The pectoralis major and minor muscles lie superficial to the cords, while the axillary vein is deep to the cords.

Technique

A pillow is placed underneath the patient's shoulder. The elbow is flexed with the hand resting on the abdomen or with the arm resting at the side. Alternatively, the arm can be abducted and externally rotated with the elbow flexed. This maneuver has the advantage of stretching the cords and bringing them closer to the surface, enhancing the ultrasonographic appearance as well as facilitating local anesthetic spread. The skin is cleaned with antiseptic solution. If ultrasound guidance is used, prepare the probe surface by applying a sterile adhesive dressing.

A 50 mm, 21G–24G needle is commonly used for this block. An insulated needle should be chosen if nerve stimulation is used. The depth of penetration is usually within 2–3 cm at a lateral location inferior to the coracoid process. Recommended local anesthetic doses are 0.5 mL/kg of 0.2–0.5% ropivacaine or 0.25–0.5% bupivacaine. Concentrations may need to be reduced in small children to obtain a volume of at least 5 mL for this block.

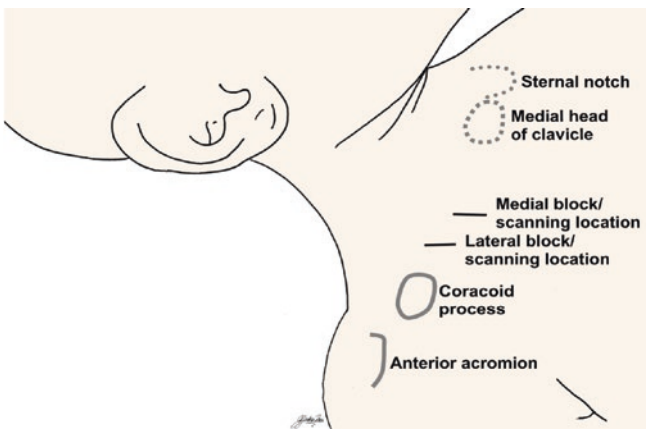

Fig. 74.7 Patient positioning and surface landmarks for infraclavicular brachial plexus block

Nerve Stimulation Technique

A lateral approach is recommended, where the point of needle insertion is approximately 0.5–1 cm inferior and slightly medial to the coracoid process (Fig. 74.7). At this point, the pleura is further away so the risk of pneumothorax is lower compared to a more medial injection site. The needle is advanced in a vertical direction until distal motor response (hand or wrist flexion) is obtained. The current is initially set

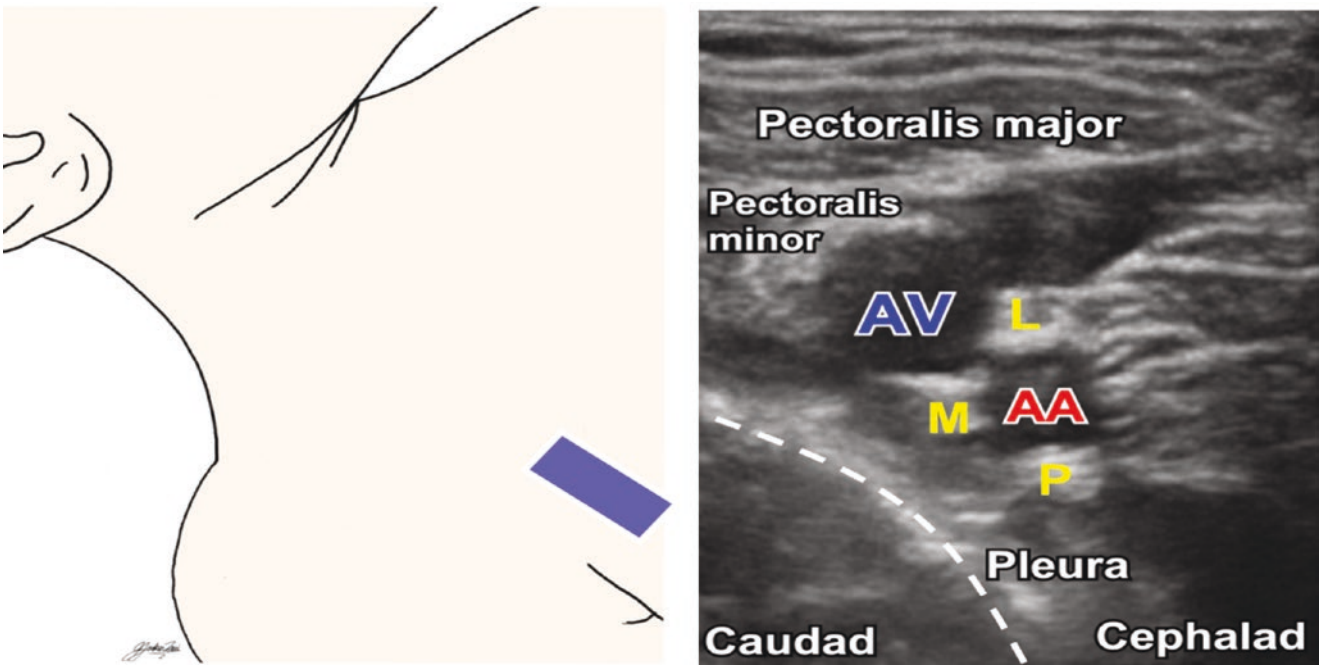

Fig. 74.8 Ultrasound image of the brachial plexus at the infraclavicular level at a lateral scanning location. *AV* axillary vein, *AA* axillary artery, *L* lateral cord, *M* medial cord, *P* posterior cord

at 0.8 mA (2 Hz, 100–300 μs) and then gradually reduced to a threshold current of 0.2–0.4 mA. Twitching of the pectoralis muscles indicates the needle is too shallow, while bone (rib) contact means it is too deep, and appropriate needle adjustment should be made. Careful aspiration is crucial to rule out pneumothorax or arterial/venous puncture.

Ultrasound-Guided Technique

A small footprint linear array transducer (13–6 MHz frequency) is ideal for young children. In older or larger children, a curved array transducer (5–2 MHz frequency) is desirable to allow greater depth of penetration.

A lateral block location is recommended. The probe is placed in a parasagittal plane below and slightly medial to the coracoid process. Scan medially and laterally to locate the axillary neurovascular bundle, which sits underneath the pectoralis major and minor muscles (Fig. 74.8). The axillary artery can be identified as a round- or oval-shaped pulsatile structure. The axillary vein is almost always medial and caudad to the artery and is irregularly shaped. Color Doppler can be used to identify the vessel in cases of doubt. At this point, the cords, which are seen as hyperechoic oval structures, can be found posterolateral to the artery. The medial cord may be difficult to identify because it may be hidden between the axillary artery and vein and can be posterior or even slightly cephalad to the artery.

If a medial approach is to be used, the probe is positioned at the midpoint of the line between the anterior acromion and jugular notch. It is important to maintain the pleura and needle in view at all times during the time of needle insertion. The pleura usually appears as a hypoechoic cavity outlined by a hyperechoic line and is often located proximal to the vessels and plexus (Fig. 74.9).

Both in-plane and out-of-plane approaches can be used for this block. The in-plane approach is strongly recommended, especially when a more medial block location is chosen, because it allows visualization of the needle tip and shaft, thereby minimizing the risk of pleural puncture. The needle is inserted at the cephalad end of the probe at a 45–60° angle to the skin and advanced caudally. The needle is then directed to the posterior cord, and local anesthetic is deposited around it. This often results in a "U-shaped" spread around the artery and hence complete blockade of the plexus. If the spread is deemed inadequate, a further dose of local anesthetic is deposited as the needle is withdrawn to the lateral cord position. Another injection between the artery and the vein may be needed to ensure blockade of the medial cord. Nerve stimulation offers additional confirmation of the neural structure and is recommended. A test dose of D5W prior to injection of local anesthetic can visualize spread and confirm nerve localization.

Occasionally, the out-of-plane approach is required when there is not enough space for the in-plane needle insertion between the probe and the clavicle, especially in very small children. This approach also has the advantage of a reduced length of needle path for better patient comfort if the block is to be performed on a conscious child. A 45°-angled needle insertion is used so that the distances between the needle

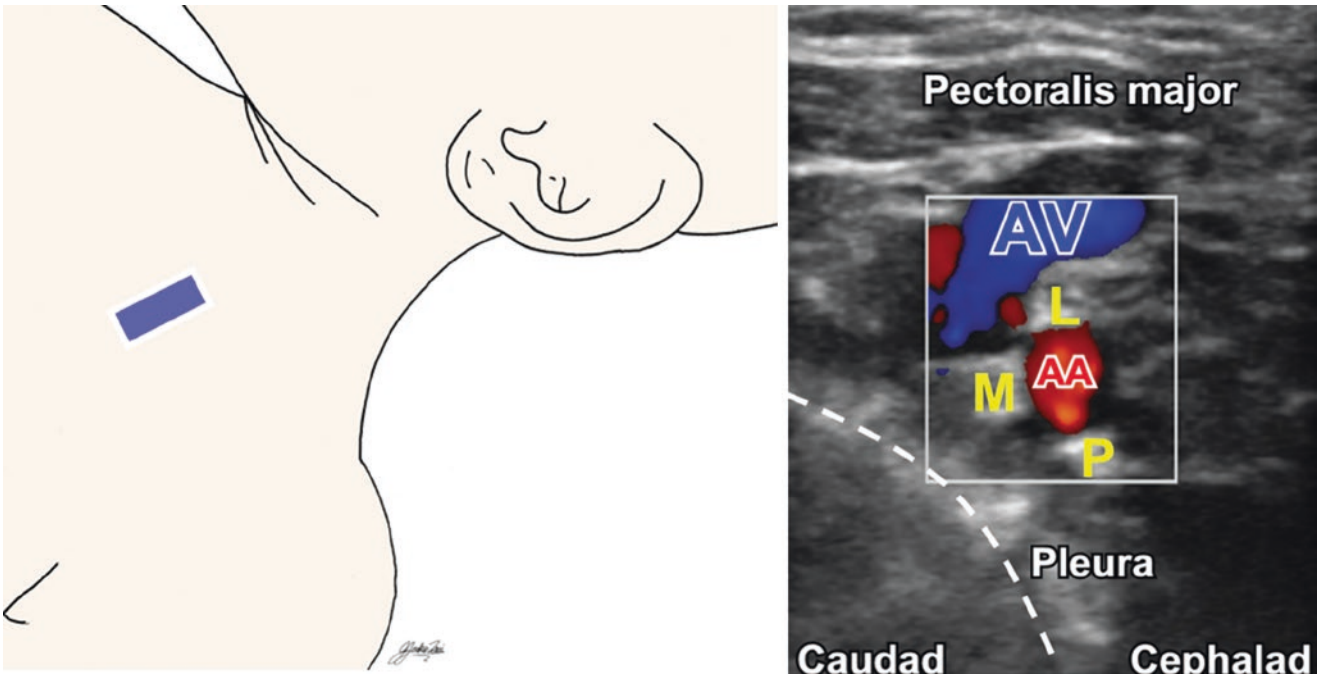

Fig. 74.9 Ultrasound image of the brachial plexus at the infraclavicular level at a medial scanning location. *AV* axillary vein, *AA* axillary artery, *L* lateral cord, *M* medial cord, *P* posterior cord

insertion point, probe, and brachial plexus are equal (i.e., forming a right-angled triangle). The needle then "walks down" to reach the posterior cord while the needle tip is being tracked.

Complications

Axillary artery puncture and injection, hematoma formation in the neck due to arterial or venous puncture, block failure, infection, local anesthetic systemic toxicity (LAST), and pneumothorax are possible, but rare, complications.

Practical Tips

- Common causes of pneumothorax with the infraclavicular nerve block can occur with medial insertion of needle, excessive medial redirection of needle, and deep needle placement.
- The ultrasound probe should be placed medial to the coracoid process, an easy-to-palpate bony landmark.
- The lateral cord is cephalad, posterior cord is posterior, and medial cord is caudad to the axillary artery.

Literature Review

The infraclavicular brachial plexus has been reported in children requiring upper extremity forearm and elbow surgery. Relative to the supraclavicular nerve block, it is reported as having a slightly higher incidence of arterial puncture and lower risk of pneumothorax and requiring longer to perform. The duration of motor block and analgesia with the two techniques is similar. Continuous infraclavicular catheter placement in children has been described with good success.

Axillary Nerve Block

General Considerations

Prior to routine use of ultrasound, the axillary nerve block was the most commonly performed brachial plexus block in children given the low risk of complications. Though quite consistent in its sensory and motor blockade, limitations of arm positioning in a sedated child who is in pain and sparing of the musculocutaneous nerve make it less ideal.

Indication

Elbow, forearm, wrist, and hand surgery below the level of the antecubital fossa.

Functional Anatomy

At the apex of the axilla, the axillary artery continues its trajectory along with three of the terminal branches of the brachial plexus: the ulnar, median, and radial nerves. The other two terminal branches (axillary and musculocutaneous) arise earlier in the brachial plexus and follow a different trajectory such that they are not within the neurovascular sheath of the axillary artery.

Technique

The arm of the patient is abducted 70–80° and externally rotated. The skin is cleaned with antiseptic solution. If ultrasound is used, prepare the probe surface by applying a sterile adhesive dressing.

A 50 mm, 22–24G insulated needle is typically used. The recommended dose of local anesthetic for an ultrasound-guided technique is 0.2–0.3 mL/kg of 0.25–0.5% bupivacaine, ropivacaine, or levobupivacaine and 0.5–1.0 mL for the musculocutaneous nerve. Higher volumes are needed if nerve stimulation is used.

Nerve Stimulation Technique

The axillary artery is first palpated at the apex of axilla. The needle is introduced at an approximately 45° angle to the skin at the upper edge of the axillary artery, pointing cephalad toward the midpoint of clavicle (Fig. 74.10). Advance the needle until a "pop" or "give" is felt as the needle enters the neurovascular sheath. Pulsations in the needle indicate that the needle tip is in immediate vicinity of the artery. An initial current is applied at 0.8 mA (2 Hz, 100 μs) and then gradually reduced to a threshold current of 0.4 mA (0.1 ms) after obtaining a distal motor response in the hand, wrist, or forearm. Local anesthetic is deposited after careful aspiration to rule out any intra-arterial/intravenous placement. A second injection can be made at the lower edge of the artery in a similar fashion ("two-puncture technique").

To block the musculocutaneous nerve, direct the needle (using the same needle insertion site) toward the belly of the coracobrachialis muscle, and inject local anesthetic. Elbow flexion can be elicited if nerve simulation is used.

If a tourniquet is required for the surgery, the intercostobrachial nerve should be blocked; this can be done by subcutaneous injection of local anesthetic across the medial surface of the upper arm.

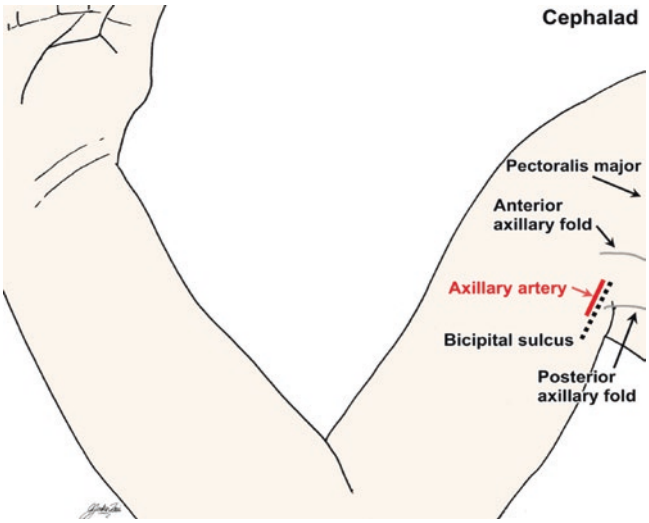

Fig. 74.10 Patient positioning and surface landmarks for axillary block of the brachial plexus

Ultrasound-Guided Technique

A high-frequency (13–6 MHz) linear probe is suitable for this block. In small children, a small footprint ("hockey stick") probe is desirable. The probe is placed in a transverse plane along the axillary crease and scanned as proximally as possible to obtain the best transverse view of the neurovascular bundle surrounded by the biceps brachii, coracobrachialis, and triceps muscles. The anechoic axillary artery can be identified as pulsatile circular structure, while the anechoic axillary vein(s) is/are irregular in shape, compressible, and usually more superficial. The nerves, which appear as round- or oval-shaped structures with a honeycomb-like appearance, are situated around the artery (Fig. 74.11). The median nerve can be found between the artery and biceps brachii muscle and is located superficial to the artery. The ulnar nerve lies between the artery and the triceps muscle and is also superficial to the artery. The radial nerve is deep to the artery at the midline and can sometimes be difficult to locate. The musculocutaneous nerve, whose appearance can vary from round or oval to flat, can usually be found in the plane between the biceps and the coracobrachialis muscles. If necessary, each of these terminal branches can be traced distally for confirmation. The use of nerve stimulation can also help identify individual nerves according to the corresponding motor responses.

The needle is inserted either in-plane or out-of-plane in relation to the probe. Commonly, multiple injections and needle redirections are required to ensure circumferential spread of local anesthetic around each individual nerve. For the in-plane approach, the needle is inserted at an acute angle (20–30°) to the skin in a superior-to-inferior direction in parallel to the long axis of the probe. The needle is initially directed underneath the artery to reach the radial nerve. It is

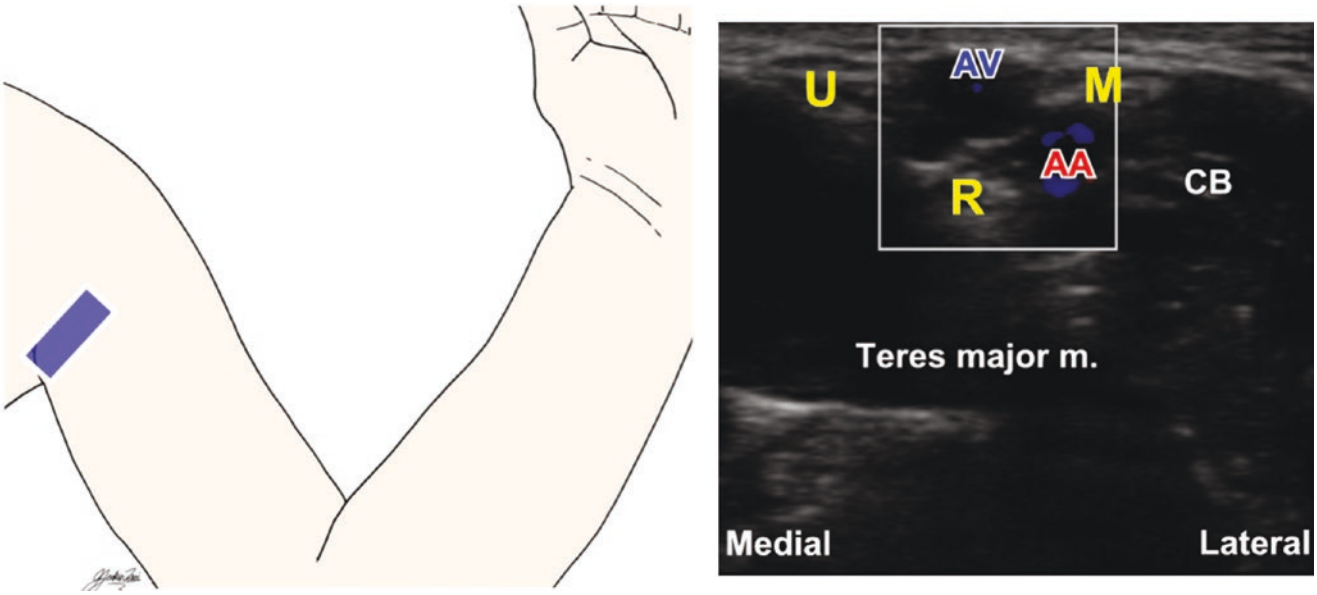

Fig. 74.11 Ultrasound image of the brachial plexus at the axilla. *AV* axillary vein, *AA* axillary artery, *CB* coracobrachialis, *U* ulnar nerve, *R* radial nerve, *M* median nerve

recommended to block the radial nerve first to minimize image distortion from the spread of local anesthetic. After that, the needle is withdrawn and redirected to deposit local anesthetic around the ulnar and the median nerves. A test dose with D5W is useful to visualize the spread and confirm nerve localization prior to injection of local anesthetic. If an out-of-plane approach is used, the needle is inserted approximately 1 cm away from the midpoint of the probe at a 30–45° angle from the skin to reach the nerves.

Complications

Axillary artery puncture and injection, hematoma formation, block failure, infection, and local anesthetic systemic toxicity (LAST) are possible, but rare, complications.

Practical Tips

- Procedures of the forearm require musculocutaneous nerve block supplementation.
- Though the exact orientation of the nerves vary, in general, the median nerve may be identified lateral and superficial to the axillary artery, the ulnar nerve is typically medial and superficial to the artery, and the radial nerve location is posterior to the artery.
- Make sure to identify the axillary vein medial to the axillary artery as it can be easily compressed and potentially serve as a location for intravascular injection.

Literature Review

Unlike in adults, where multiple injections during performance of an axillary nerve block may improve quality of sensory and motor blockade, in children, a single injection is sufficient.

Distal Nerve Blocks of the Upper Extremity

The terminal nerves of the upper extremity including the median, ulnar, and radial nerve can be blocked with local anesthetic either individually or in combination. Though the technique is well described and reported in the adult literature, utility of distal nerve blocks of the upper extremity has not been reported. Further, in common pediatric anesthesia practice, these blocks are rarely performed by the anesthesiologist. As such, the reader is directed to the "Regional Anesthesia for the Upper Limb in Adults" chapter for further description of these blocks.

Suggested Reading

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