9 Ultrasound-Guided Peripheral Nerve Blockade

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Introduction

The introduction of ultrasonographic guidance for peripheral nerve blockade has provided today's anesthesiologist with a powerful imaging tool for managing the precision and safety of needle and catheter placement and of local anesthetic injection. Due to the wide range of blocks performed, and the inability to blind observers when studying blocks, it is difficult to determine with certainty if ultrasound-guided blocks are better than other techniques, but numerous studies provide evidence that using ultrasound confers increased efficacy, lower local anesthetic requirements and improved safety compared with landmark or nerve stimulator techniques [1–11]. Randomized, controlled trials have assessed individual ultrasound-guided blocks and suggest a reduced risk of vascular puncture, improved block quality, faster onset time, and reduced time to perform the block [8–10]. Additionally, some investigations have suggested that ultrasound guidance may permit successful blockade with lower volumes of local anesthetics, which might have implications regarding reduced risk for toxicity [12, 13].

Basic principles of ultrasound-guided peripheral nerve blockade require an understanding of nomenclature, physics, and descriptions of probe manipulation and the orientation of the probe relative to the needle. An ultrasound probe uses a cyclic sound pressure beam which penetrates a medium and then measures the reflection signature, creating an image [14]. This permits the operator to visualize the inner structural details of many media, including soft tissue.

When describing an ultrasound image, one uses the terms hyperechoic, hypoechoic, and anechoic. Hyperechoic refers to a bright, white appearance of structures, while hypoechoic refers to a darker, duller appearance of structures. Anechoic refers to a completely dark appearance. Typically, tendons, nerves, and fascia appear as hyperechoic, while fat and muscle appear as heterogeneous, hypoechoic structures. Fluid, which fills the arteries and veins, appears as anechoic. Air produces a bright, hyperechoic image (Fig. 9.1).

In order to optimize images with the tools available on ultrasound machines, one must understand some basic principles. The ultrasound wave frequency can be chosen both by probe selection and by changing the settings on the machine itself. Higher-frequency beams improve axial resolution, which is the ability to distinguish between two objects at different depths in line

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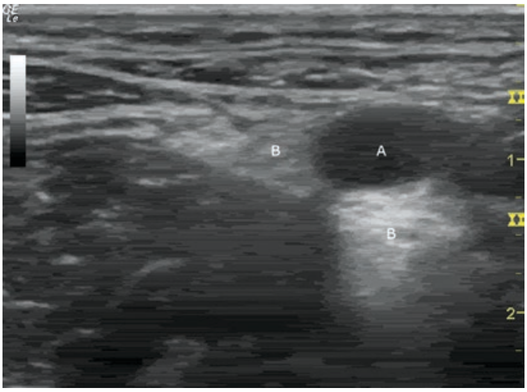

Fig. 9.1 Image of hyper- and hypoechoic. (*A*) The fluid-filled femoral artery appears as a *dark*, anechoic structure, and (*B*) the fascial structure appears *bright* and, as such, is hyperechoic

with the axis of the beam [15]. Thus, increasing the frequency of the ultrasound probe (10–13 MHz) will improve resolution of superficial structures at the expense of visualizing deeper structures. Conversely, a lower frequency will improve image quality of deeper structures at the expense of resolution of more superficial structures. The term "gain" refers to the degree to which the ultrasound machine amplifies returning ultrasound waves, making them appear brighter. Gain will increase the brightness of the entire image, but also increases artifact from background noise. "Time gain compensation" is a form of gain manipulation that allows the operator to adjust the gain at specific depths in the field. Time gain compensation is useful in filtering out background noise and focusing on the depth of the target, though it may make visualization of the needle more difficult. Altering depth penetration also can be used to enhance the image. Once a target is identified, if a greater-than-necessary depth is selected, the target will appear small due to the change in aspect ratio of the image. If the set depth is too shallow, the target may be obscured or fall deeper than the penetration of the ultrasound beam appears on the screen. The final manipulation is "focus," which allows the operator to place the focal zone of the beam at various points in the field to limit beam divergence, thereby improving lateral resolution, which is the ability to distinguish between two structures that sit side by side [16, 17].

In addition to optimizing the machine settings, an image can be enhanced by physical manipulations of the probe by the operator. The basic motions of probe manipulation are pressure, rotation, alignment, and tilt (Fig. 9.2). The needle direction in relation to the ultrasound beam can be described as in-plane or out-of-plane (Fig. 9.3). It is also useful, before needle placement, to establish the ultrasound probe's orientation in relation to the right and left sides of the screen and to center the target in the image on the screen.

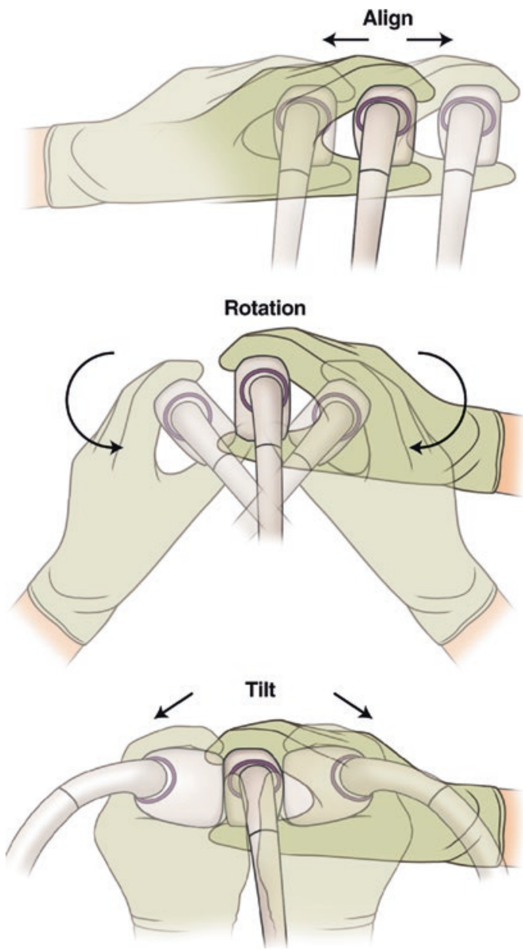

Fig. 9.2 The basic principles of ultrasound probe manipulation are pressure, rotation, alignment, and tilting

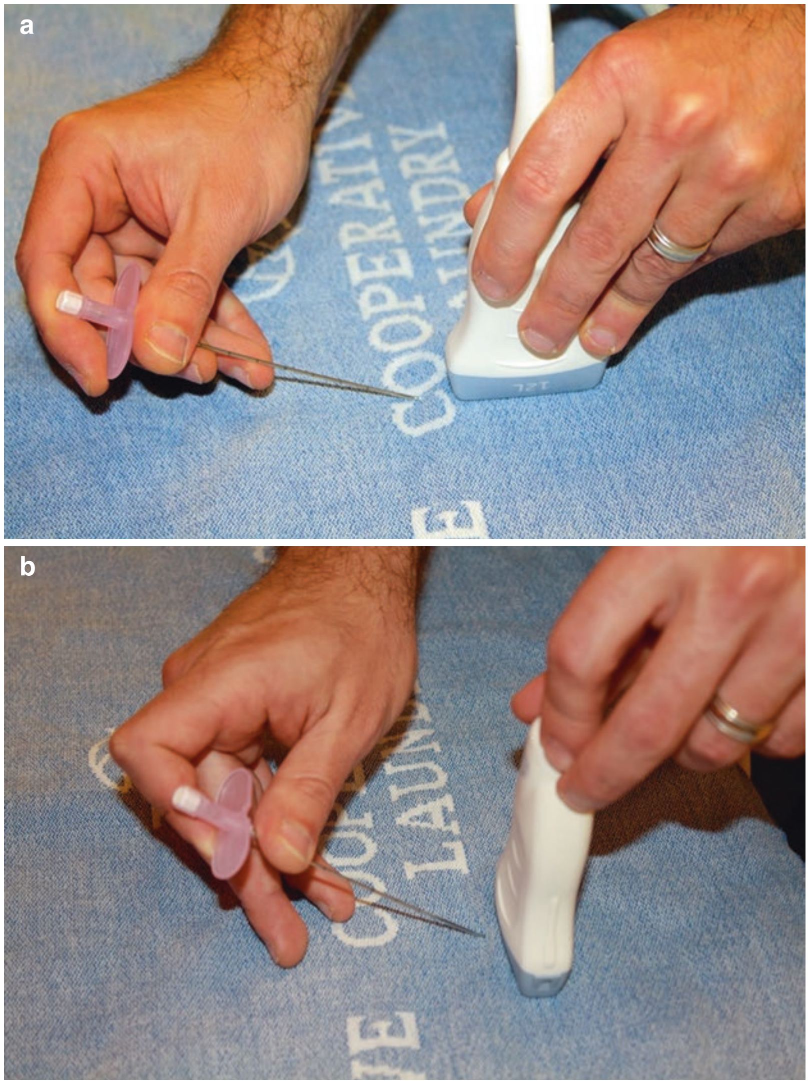

Fig. 9.3 (**a**) The needle is in-plane with the ultrasound probe. (**b**) The needle is out-of-plane with the ultrasound probe

Local Anesthetic Dosing

It is difficult to give absolute dose recommendations for specific blocks. In some cases it appears to be better to use as small a dose of drug as possible, in order to reduce the incidence of side effects (e.g., to reduce diaphragmatic paresis with interscalene block) [5]. For other blocks (e.g., transversus abdominal plane blocks), however, increasing volume while not exceeding the accepted safe limits for toxicity may improve block quality [18]. Many experts, on the basis of both empiric evidence and limited study data, recommend that ultrasound imaging can help guide the adequacy of administered volume by visualizing the spread of injected local anesthetic around the target nerves. General recommendations for average volumes of local anesthetic for specific blocks are found in Table 9.1. In all cases one must never exceed the recommended toxic limits of local anesthetic, which should be calculated in advance and must also take into account

Table 9.1 Dosing

Area of block	Suggested volume (mL/kg)	Postoperative analgesic dose	Anesthetic dose	Max dose (mL)
Above umbilicus	0.2–0.4	0.2% Ropivacaine or 0.25% bupivacaine	0.35% Ropivacaine or 0.375% bupivacaine	30
Below umbilicus	0.3–0.5	0.2% Ropivacaine or 0.25% bupivacaine	0.35% Ropivacaine or 0.375% bupivacaine	40
Compartment block (TAP, quadratus lumborum, paravertebral)	0.25	0.2% Ropivacaine or 0.25% bupivacaine	Surgical anesthetic dose cannot be obtained (not applicable)	40

Table 9.2 Local anesthetic toxic dose limits

Agent	Maximum dose (mg/kg)
Lidocaine	3
Lidocaine with epinephrine	6
Bupivacaine	2
Bupivacaine with epinephrine	2.5
Ropivacaine	3
Ropivacaine with epinephrine	4

any addition local anesthetic dose administered to the patient by the anesthesiologist or surgeon (Table 9.2). Local anesthetic systemic toxicity is a rare event during peripheral nerve blockade but must be assiduously avoided [19].

Interscalene Nerve Block

The use of ultrasound guidance in the placement of interscalene peripheral nerve blockade has been validated by studies addressing success rate, block quality, and time to perform the block [20, 21]. The interscalene nerve block aims to inject local anesthetic at the level of the trunks in the brachial plexus, thereby providing anesthesia to the upper arms and shoulder.

The trunks of the brachial plexus are most effectively accessed at the level of C6, at which location cadaver studies have shown a minimum distance of 23 mm from skin to vertebral foramen [22]. Here, the plexus passes through a compartment formed by the fascia-encased anterior and middle scalene muscles (Fig. 9.4).

To perform an interscalene nerve block with ultrasound guidance, the patient is placed supine with the head rotated between 30 and 45° away from the side of the block. After sterile preparation of the skin and the ultrasound probe, visual inspection reveals the sternocleidomastoid muscle and the thyroid prominence, which is slightly above the C6 level. A linear probe is placed on the skin overlying the sternocleidomastoid at this level in an axial oblique plane in order for the ultrasound beam to transect the plexus (Fig. 9.5). Initial ultrasonographic anatomic landmarks include the sternocleidomastoid, which can be identified by its tapering appearance as one examines more laterally. The carotid artery and jugular artery can be recognized as pulsatile, anechoic, round structures (Fig. 9.6). Moving laterally, the anterior and middle scalene muscles appear in cross section, identifiable by their round, striated nature. In between these two muscles, potentially between their hyperechoic-appearing investing fascia, lay the trunks of the brachial plexus. Adjustments should be made to the ultrasound image in order to maximize frequency and minimize field depth. The trunks appear as round, hypoechoic structures that may be separated by hyperechoic fascial septae (Fig. 9.7). The stacked linear orientation has been described as resembling a snowman.

A 2–4 cm needle is placed at the lateral border of the linear ultrasound probe and advanced medially toward the trunks under constant ultrasound visualization. The needle tip should be visualized passing lateral to the sternocleidomastoid and skirt along the medial border of the middle scalene fascia until it reaches the midpoint of the viewed trunks (Fig. 9.8). After aspiration, a small test dose of local anesthetic should be administered, with good spread being visualized around the trunks and not in muscle or vascular tissue.

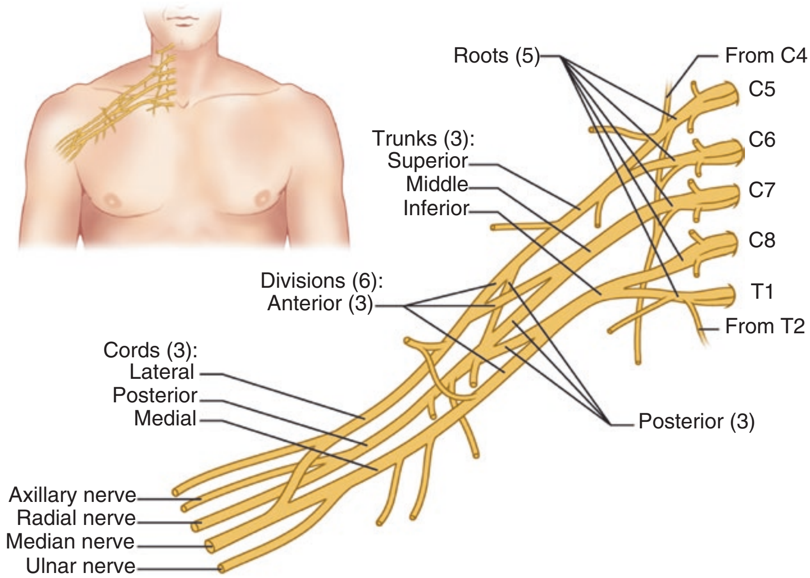

Fig. 9.4 The brachial plexus

Fig. 9.5 Performing an interscalene block

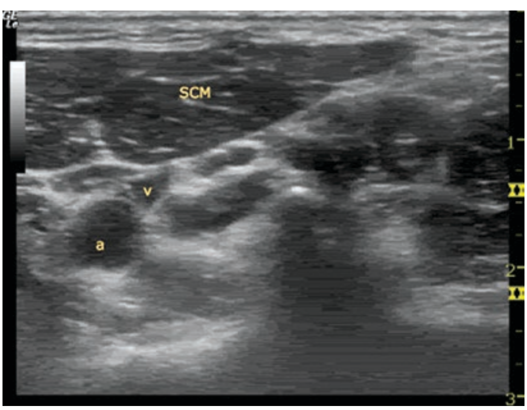

Fig. 9.6 Relationship between the carotid artery (*a*), internal jugular vein (*v*), and sternocleidomastoid (*scm*)

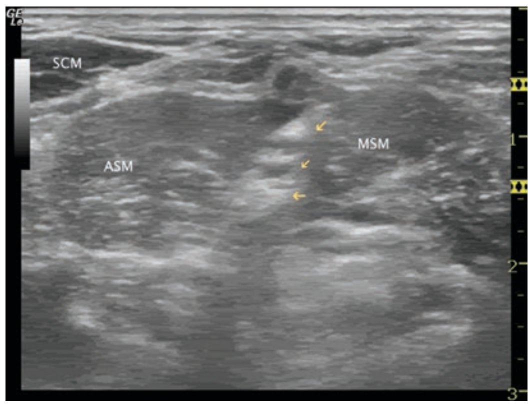

Fig. 9.7 Ultrasound image of the interscalene approach to the brachial plexus showing the trunks of the plexus. Displayed are the sternocleidomastoid (*scm*), the anterior scalene muscle (*asm*), the middle scalene muscle (*msm*), and the trunks of the brachial plexus (arrows)

Complications from interscalene nerve blockade can be dramatic due to the proximity to major vascular and neuraxial structures. Pneumothorax, spinal cord injection with resultant permanent paralysis, epidural injection, intrathecal injection, and intravascular injection are all concerns, and although rare, have been reported [23, 24]. Additionally, neck hematoma and sepsis have been described [25]. Persistent neuropathy after interscalene block has been assessed prospec-

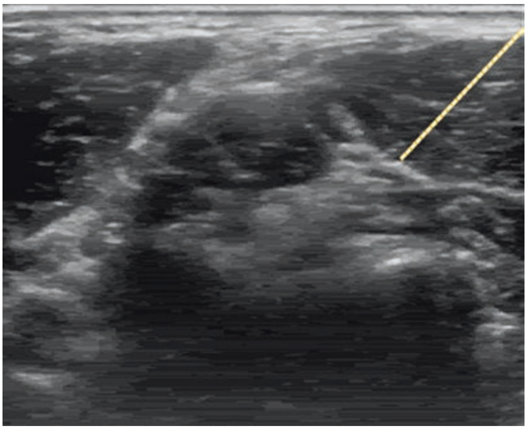

Fig. 9.8 Interscalene injection. Needle trajectory of the interscalene nerve block (dashed line)

tively and does occur with an incidence of between 4 and 16% within the first week after the block but only 0.1–0.2% permanently [6]. These numbers were not different for ultrasound-guided versus nerve stimulator-guided blocks. More common side effects may include a Horner's-type syndrome, transient vocal changes, and transient phrenic blockade. As such, patients should be advised of these phenomena preoperatively, as to alleviate postoperative concerns. Whereas phrenic nerve paresis is nearly universal when nerve stimulation is used to guide needle placement and may produce significant hypoxemia or respiratory insufficiency in susceptible subjects, reports suggest that ultrasound guidance may dramatically reduce its incidence due to the reduction in necessary volume [5].

Of particular note, interscalene nerve blockade has been considered a high-risk (or even contraindicated) procedure in the heavily sedated or anesthetized patient due to the inability of the patient to report paresthesias that could herald entry into the vertebral foramina. Recent results from an analysis of the prospective Pediatric Regional Anesthesia Network database found that the risk of performing this block using ultrasound guidance in anesthetized children bears no greater risk than that reported in awake adults [26]. Comparable data in adults are not yet available.

Supraclavicular Nerve Block

After fading away from the anesthesiologist's armamentarium due to an elevated risk of pneumothorax when performed with surface landmarks, the ultrasound-guided supraclavicular approach to the brachial plexus has gained widespread acceptance due to the ability to easily visualize and inject structures in this area. Subsequent analysis has shown an exceedingly low incidence of pneumothorax when ultrasound is employed [27]. The supraclavicular nerve block aims to anesthetize the divisions of the brachial plexus as they pass over the first rib, under the clavicle (Fig. 9.9). Here, the divisions are located posterolateral to the subclavian artery, medial to the middle scalene muscle, and superior to both the first rib and the pleura [27–29]. The supraclavicular nerve block provides fast-acting and dense anesthesia for procedures distal to the midhumerus.

To perform the block, the operator stands at either the head of the bed or facing the ipsilateral shoulder. The patient's head is turned between 30 and 45° away from the side to be blocked. After sterile preparation of the skin and probe, the supraclavicular fossa is visually identified, noting the sternocleidomastoid muscles, clavicle, and coracoid process. A high-frequency linear probe is placed in a coronal oblique plane, which can be approximated by orienting the probe roughly parallel to the clavicle. Some may find it easiest to "step off" the clavicle and let the probe seat into the supraclavicular fossa (Fig. 9.10).

Ultrasound examination begins by locating the subclavian artery in the short axis view, where, with appropriate rotation and tilting, the artery will appear as a round, pulsating, and anechoic structure. At this point, one will also see the hypoechoic first rib underneath the artery and, possibly, the pleura. Ultrasonographically, the pleura will have a mixed pattern of hyper- and hypoechoic signals due to the presence of air in the interstitium and will move with respiration, while the rib will not. Lateral to the subclavian artery, the operator will appreciate the middle scalene, which is scanned in short axis and is

Fig. 9.9 Passage of the brachial plexus in the supraclavicular area

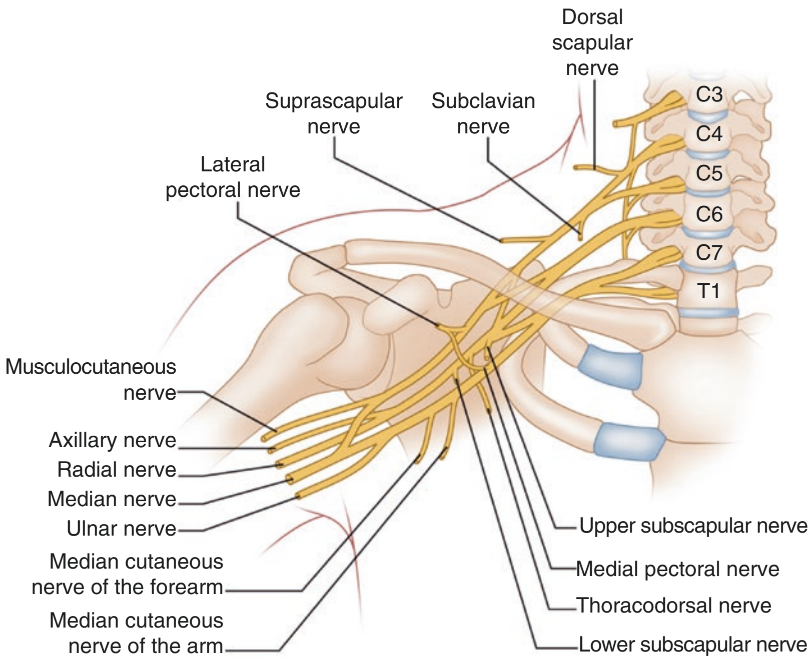

Fig. 9.10 Photo of performance of the supraclavicular block

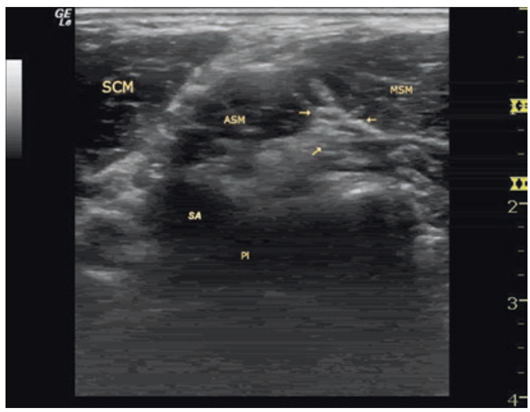

Fig. 9.11 View of the brachial plexus in the supraclavicular fossa. Note the sternocleidomastoid (*scm*), subclavian artery (*SA*), anterior scalene muscle (*asm*), middle scalene muscle (*msm*), first rib shadow and pleura (*pl*), and the brachial plexus divisions (arrows)

notable for its often-striated appearance. In between the subclavian and the middle scalene lie the divisions of the brachial plexus, which appear as a hypoechoic, grape-cluster-like structure (Fig. 9.11).

After identification of the brachial plexus in the supraclavicular fossa, the ultrasound image is optimized by increasing frequency and decreasing image depth to focus on the plexus and the first rib. The block needle is then advanced under constant visualization in an in-plane fashion along the medial border of the middle scalene, toward the lateral portion of the plexus. In order to obtain proper needle position, it is often necessary to pierce the middle scalene muscle (Fig. 9.12). Here, a test dose reveals spread of the anesthesia in the fascial layer surrounding the divisions of the brachial plexus. If indicated, subtle movements can be used to penetrate small fascial layers to provide adequate local anesthetic spread.

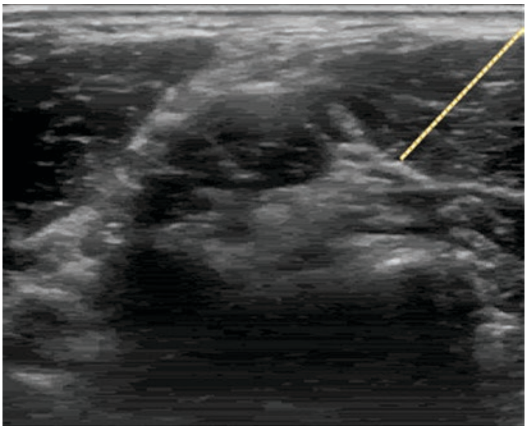

Fig. 9.12 The needle trajectory (yellow dashed line) for supraclavicular nerve block

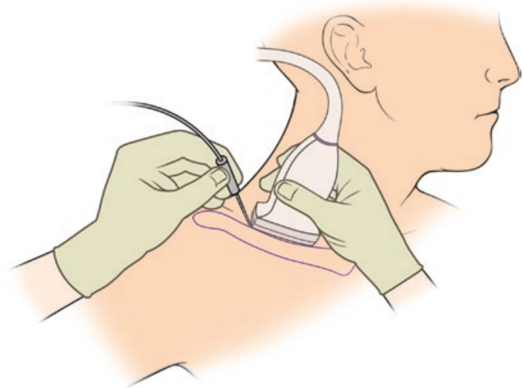

Fig. 9.13 Performing the infraclavicular block

Inherent to the supraclavicular nerve block is the risk of pneumothorax, the risk of which is reduced by cautious and deliberate needle advancement under ultrasound guidance. Other risks include intravascular injection with resultant local anesthetic toxicity, neck hematoma, and abscess. In the largest cohort reported to date, the incidence of accidental vascular puncture and transient sensory deficits were both 0.4%. Horner Syndrome and hemidiaphragmatic paresis occurred in 1% and there were no pneumothoraces [30].

Infraclavicular Nerve Block

The infraclavicular nerve block targets the brachial plexus as it emerges from underneath the clavicle. Here, the lateral, medial, and posterior cords surround the axillary artery and are easily identified by ultrasound examination. This block is utilized in surgeries distal to the midhumerus. Though quite similar to the supraclavicular nerve block, it offers benefits of diminished risk of phrenic nerve blockade and ease of catheter placement [31]. The ultrasound-guided infraclavicular nerve block has shown similar, if not improved, efficacy compared with the axillary approach to the plexus as well as greater patient comfort and willingness to undergo the same procedure when performed in the awake or unsedated subject [32, 33].

To perform the infraclavicular nerve block, the operator preferably stands at the head of the bed. Visual inspection reveals the sternocleidomastoid, the clavicle, and the coracoid process. It may be helpful to mark these points on the patient with a soft-tip marker. Additionally, it may be useful to abduct the arm to 90°, externally rotate the shoulder, and flex the elbow (Fig. 9.13). This action may bring the plexus closer to the skin, allowing the ultrasound image to be optimized [34].

After sterile preparation of the skin, a linear ultrasound probe is placed in the coronal plane in the infraclavicular fossa. Of note, in the larger patient, a lower-frequency (8–10 MHz) ultrasound beam may be required, as it may need to penetrate deeper than for other blocks. The hypoechoic clavicle is identified, and then the axillary artery is visualized in cross section. Rotation and tilting may be used to enhance the artery's round, pulsating image. Once this is achieved, one can appreciate the two muscle layers immediately anterior to the artery, comprised of the pectoralis major and pectoralis minor. The image depth and frequency are then optimized. It is important to orient oneself to the location of the beam, specifically which side is caudal and which is rostral. Another landmark to note may be the heterogeneous lung pleura, which moves with inspiration.

In the infraclavicular fossa, the cords of the brachial plexus appear as hyperechoic star-like structures surrounding the hypoechoic axillary artery. Chan classically described the positions of the nerve cords in relation to the axillary artery in terms of a clock face with the lateral cord located cranially at 09:00 h, the posterior cord between 06:00 and 07:00 h, and the medial cord lying at 04:00–05:00 h, often between the axillary artery and vein (Figs. 9.14 and 9.15) [29, 35].

Using an in-plane approach, a needle is guided from either the rostral or caudal end of the ultrasound probe, under constant visualization. It is often easier to insert the needle at the rostral end of the probe just underneath the clavicle, as a 45° angle is usually sufficient to initially reach the posterior cord, and, after injection, draw back to the lateral cord and inject further local anesthetic. When the needle reaches the posterior cord, injection may result in the "double bubble sign," which consists of the hypoechoic axillary artery anteriorly and the spreading local anesthetic posteriorly [34]. One may see additional spread of the local anesthetic in a u-shaped fashion along the posterior border of the axillary artery.

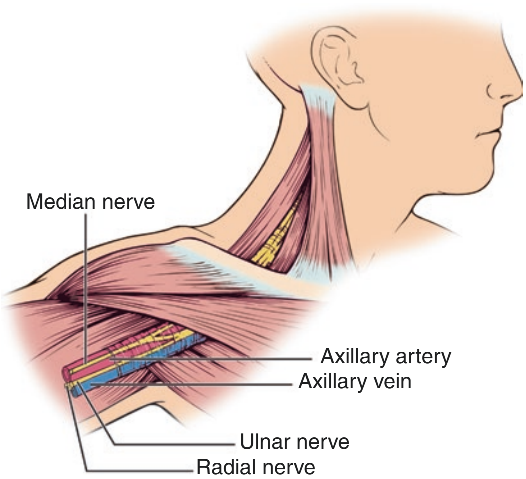

Fig. 9.14 Location of the cords around the axillary artery

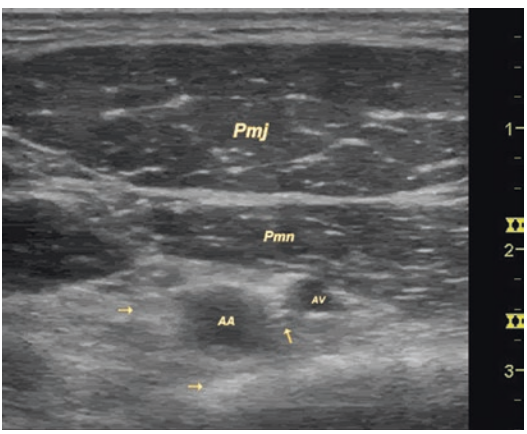

Fig. 9.15 Ultrasound appearance of the approach to the infraclavicular nerve block. The pectoralis major (*pmj*) and pectoralis minor (*pmn*) cover the brachial plexus noted by arrows, which surrounds the axillary artery (*AA*). The small axillary vein (*AV*) is located caudal to the artery

Complications associated with the infraclavicular nerve block include hematoma, infection, vascular puncture, and local anesthetic toxicity. Pneumothorax is avoided by maintaining the needle in the sagittal plane and avoiding medial movement. Minor dysesthesia has been noted in 2% of patients in large cohorts, though permanent nerve injury is only rarely described following this block [31, 33].

Axillary Nerve Block

A time-tested approach to the brachial plexus exists in the axillary nerve block, although with the advent of ultrasound guidance for the previously described brachial plexus techniques, this block has become less frequently performed. Here, the brachial plexus is blocked at the level of terminal nerves as they pass through the axilla. This technique lends itself to ultrasound guidance due to the superficial orientation of the plexus. Of note, this is an excellent "starter" block for newcomers to ultrasound-guided blocks, due to the easy visualization of structures, the ability to handle the needle with multiple passes under ultrasound guidance, and the lack of critical structures to avoid. Much like the infraclavicular block, the axillary nerve block provides anesthesia for extremities distal to the midhumerus.

To perform the axillary nerve block, the arm is abducted to 90° and externally rotated. After sterile preparation, a linear probe is placed in a parasagittal orientation in the axilla (Fig. 9.16). On initial exam, one notices the striated biceps and triceps muscles and the pulsating axillary artery. As the probe is centered over the axillary artery, the image is optimized by increasing

Fig. 9.16 Performing the axillary nerve block

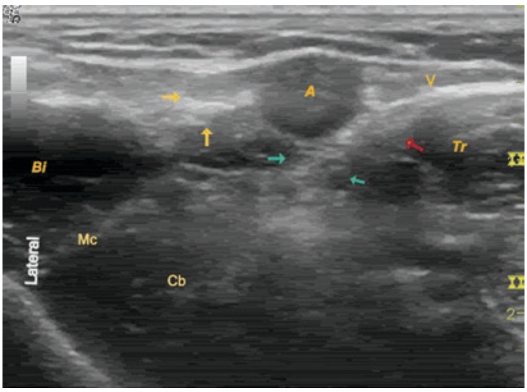

Fig. 9.17 The ultrasonography of the axillary nerve block. The axillary artery (*A*) is located centrally, bounded laterally by the biceps muscle (*Bi*) and medially by the triceps muscle (*Tr*) and compressible axillary vein (*V*). The terminal nerves surrounding the artery are the median nerve (yellow arrows), the radial nerve (blue arrows), and the ulnar nerve (red arrow). The musculocutaneous nerve (*Mc*) is separately blocked as it runs in between the biceps and the coracobrachialis (*Cb*)

frequency, adjusting gain, and reducing depth. The median, radial, and ulnar nerves are visualized as heterogeneous, typically honeycomb-shaped structures around the artery. While there does tend to be variation in location of the nerves, the median nerve is located most laterally, in close proximity to the biceps; the radial nerve tends to lie deep to the axillary artery; and the ulnar nerve lies medially, close to both the triceps muscle and the axillary vein (Fig. 9.17) [36].

An in-plane approach is used to guide a needle to the plexus. There is consensus among some experts that multiple injection passes are needed to provide adequate anesthesia to the distal upper extremity [37–39]. Typically, one may insert the needle from the lateral aspect of the brachial plexus and advance the needle to the radial nerve, which lies underneath the axillary artery, typically at a 06:00 h position. The needle is then withdrawn to the 09:00 h position, where the median nerve is injected. The current evidence suggests that selective ulnar nerve injection is not necessary for block success because diffusion of the solution within tissue planes will produce adequate blockade of that nerve [37]. Block success seems to be improved when it is easy to visualize the spread of hypoechoic local anesthetic around the nerve bundles [40].

A specific problem frequently encountered with the axillary plexus block is the early (proximal) exit of the musculocutaneous nerve, which innervates the surface of the medial arm. This frequently necessitates the direct blocking of the musculocutaneous nerve, which courses through the body of the coracobrachialis muscle. To block the nerve here, one simply places the probe on the coracobrachialis muscle in a cross-sectional fashion and finds the nerve by its hyperechoic signature within the muscle mass. This can be achieved with distal and superior scanning of the ultrasound probe on the arm. A small volume of local anesthetic then is placed at this site [41].

Complications of the axillary nerve block include hematoma, infection, vascular puncture, and local anesthetic toxicity. Nerve injury from this block is exceedingly rare [39].

Femoral Nerve Block

The femoral nerve block is utilized for procedures involving the anterior thigh and knee. This block is easy to perform given the size of the nerve sheath and its adjacent structures and finds many uses in orthopedic practice. The femoral nerve is blocked in the proximal thigh as it exits below the inguinal ligament and above both the psoas and iliacus muscles. It is easily identifiable as it courses lateral to the femoral artery, surrounded in a triangular fashion by the artery and iliopectineal ligament medially, fascia lata

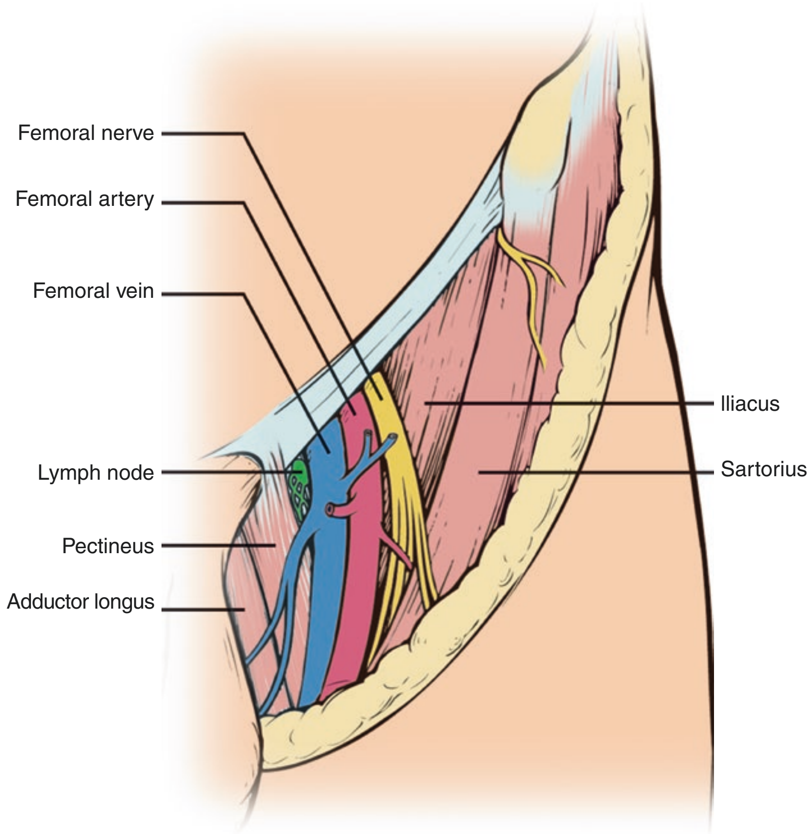

Fig. 9.18 The femoral nerve and its relation to the artery and vein

superiorly, and iliacus muscle and its investing fascia inferiorly (Fig. 9.18).

To perform the block, the patient is placed supine, with the legs in a neutral position. After sterile preparation, a linear probe is placed in a transverse orientation just distal to the inguinal ligament (Fig. 9.19). The first and most prominent landmark is the pulsating, anechoic femoral artery. The operator then moves the probe distally to observe the takeoff of the profunda femoris artery from the femoral artery. Blockade of the femoral nerve should be proximal to this landmark. The nerve is identified as a hyperechoic, heterogeneous structure located lateral to the artery. It often appears as a "comet trail," which is due to its surrounding fascia lata and iliacus muscle. If difficulty is encountered visualizing the nerve, the probe can be tilted in a caudal-rostral fashion until the image improves (Fig. 9.20) [42].

The image is optimized using frequencies between 8 and 10 MHz, by adjusting depth and gain. In an in-plane approach, the needle is passed to the inferolateral border of the "comet tail." Here, local anesthetic is deposited. Frequently, with injection the round, hyperechoic nerve becomes more visible as the local anesthetic surrounds the nerve. If there is inadequate spread of local anesthetic medially, one can

Fig. 9.19 Performing the femoral nerve block

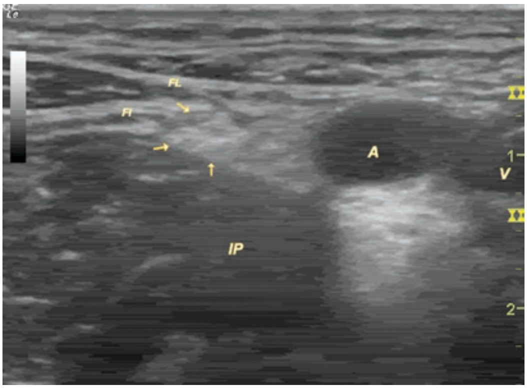

Fig. 9.20 Ultrasonographic appearance of the femoral nerve. The femoral nerve (arrows) is observed superior to the iliopsoas muscle (*IP*) and lateral to the femoral artery (*A*) and femoral vein (*V*). It is encased by the fascia iliaca (*FI*) and bounded superiorly by the fascia lata (*FL*)

reposition the needle on top of the nerve and continue injection, though it is wise to stay below the hyperechoic, linear-appearing fascia iliaca.

Complications of the femoral nerve block include hematoma, abscess, vascular puncture, and local anesthetic toxicity. Transient and permanent nerve injury after femoral nerve blockade is exceedingly rare [31].

Sciatic Nerve Block

While it is a large nerve, ultrasound imaging of the sciatic nerve is impeded by its depth and by the large amounts of tissues that surround it in its proximal region. For this reason, one must consider whether a proximal or distal sciatic nerve block is appropriate. If anesthesia of the posterior thigh is required, a proximal sciatic block should be performed. If anesthesia is only required at and below the knee, a popliteal fossa sciatic nerve block is sufficient.

The sciatic nerve is formed from the L4, L5, and S1–S3 nerve roots, leaving the pelvis via the greater sciatic foramen, deep to the gluteus maximus, and along the medial side of the femur [43]. The sciatic nerve splits in the popliteal fossa to form the tibial and peroneal nerves, which provides innervation to the lower extremity distal to the knee. As such, the sciatic nerve can be blocked proximally, near the gluteus maximus, or distally in the popliteal fossa.

Sciatic nerve blockade near the gluteus maximus poses challenges of depth to anesthesia guidance. To perform the block at this level, the patient is placed in a lateral position with the hips and knees flexed. To obtain an image, a lower-frequency (2–5 MHz) curved array probe is placed just inferior to the buttock in line with the ischial tuberosity and greater trochanter [44]. Here the sciatic nerve will be found deep to the gluteus maximus and medial to the ischial tuberosity. The depth of the nerve varies between 3 and 5 cm. The nerve appears as an elliptical hyperechoic structure that may be difficult to distinguish from the fascia surrounding the gluteus maximus (Fig. 9.21). For this reason, a stimulating needle may be of benefit in confirming its position [45]. Using an in-plane or out-of-plane technique, an insulated stimulating needle is passed to the nerve. It is wise to anticipate that a longer-length needle may be needed. Once the needle has reached the sciatic nerve, neurostimulation may reveal the need for readjustment.

At the midthigh, the sciatic nerve becomes more superficial, though it may still be difficult to see in patients with more muscle or adipose mass. In this setting, a lower-frequency (6–10 MHz) linear probe is used. The patient's leg is flexed at the knee and positioned so that the posterior

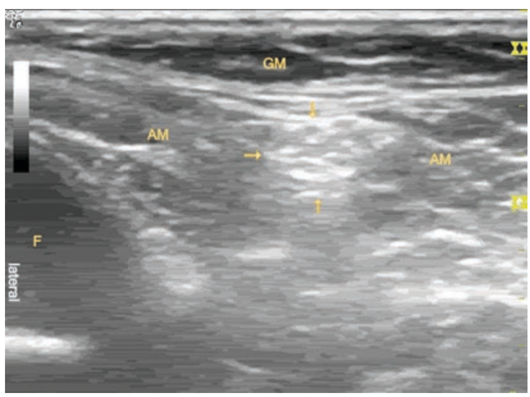

Fig. 9.21 The proximal sciatic nerve. The sciatic nerve (arrows) is bounded superficially by the gluteus maximus (*GM*) and deeper by the adductor magnus muscles (*AM*). The hypoechoic femur (*F*) serves as the lateral point of reference

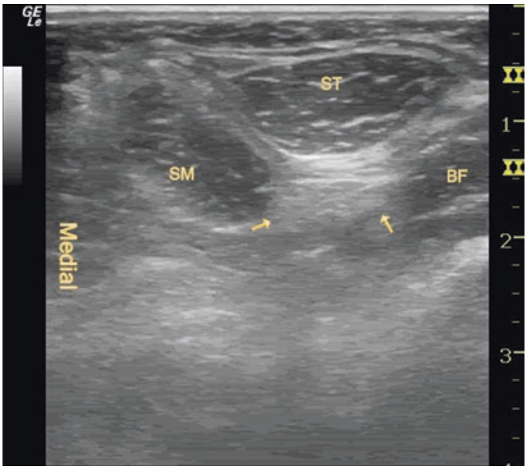

Fig. 9.22 The midthigh sciatic nerve. The sciatic nerve (arrows) lying deep to the semimembranosus (*SM*), semitendinosus (*ST*), and biceps femoris (*BF*)

aspect of the thigh is accessible to probe placement. The probe is then applied laterally to the posterior aspect of the thigh. Anatomic structures of note in the view are the biceps femoris, adductor magnus, semitendinosus muscle, and semitendinosus muscle (Fig. 9.22). The sciatic nerve appears as a honeycombed oval or elliptical structure deep to these muscles [45, 46]. If further confirmation is needed, one can use the "scan down-scan up" technique in which the operator scans, in the same plane, distally to observe the bifurcation of the sciatic nerve into the tibial and peroneal nerves. The "scan back" portion then tracks the nerve proximally and proceeds with needle placement. Needle insertion can be in-plane or out-of-plane. It is often useful to use an in-plane, trans-vastus lateralis approach. For this technique, the needle is inserted in-plane and passed in a lateral fashion from the side of the thigh (Fig. 9.23). An advantage of the trans-vastus approach is that the needle angle remains constant, allowing the operator to optimize the needle image and then advance in that optimized plane.

The popliteal fossa provides an easy location to perform sciatic nerve blockade, though it will not provide anesthesia to the posterior thigh proximally to the popliteal fossa. Here, the thick muscular tissues part, allowing easy visualization

Fig. 9.23 The trans-vastus approach for needle placement

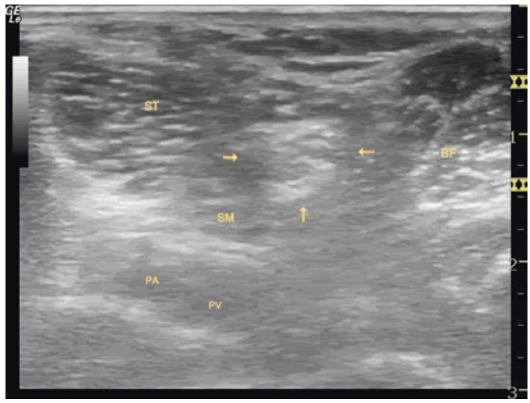

Fig. 9.24 The popliteal fossa. The sciatic nerve (arrows) is bounded laterally by the semitendinosus (*ST*) and semimembranosus (*SM*) muscles and medially by the biceps femoris muscles (*BF*). The popliteal artery (*PA*) and popliteal vein (*PV*) are also seen

of the sciatic nerve. The patient is placed in either a lateral position or a supine position with the hip flexed and the knee flexed. An 8- to 10-MHz probe is placed transversely at the posterior portion of the popliteal crease. The tendons of the semimembranosus and semitendinosus are identified medially, and the biceps femoris is located laterally. Additional landmarks noted by ultrasound exam include the anechoic, the pulsatile popliteal artery, and the compressible popliteal vein. The vessels are located medially to the sciatic nerve, which appears as a hyperechoic, round structure with hypoechoic honeycombing (Fig. 9.24) [28]. Needle choice is made, and the needle can be introduced in an in-plane or out-of-plane fashion. Again, as in the midthigh region,

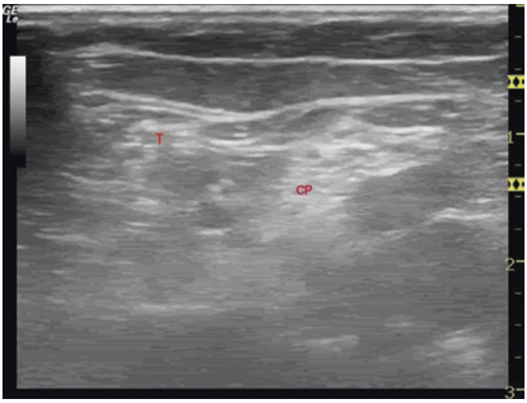

Fig. 9.25 The bifurcation of the sciatic nerve into the common peroneal (*CP*) and tibial nerves (*T*)

the in-plane needle insertion can be performed in a trans-vastus approach or in an angular approach from the side of the probe. The "scan back" technique is often useful for this approach as well, noting the separate tibial and peroneal nerves and then moving the transducer proximally until their point of bifurcation from the single sciatic nerve is identified (Fig. 9.25).

Complications

Complications of the sciatic nerve block include hematoma, abscess, vascular puncture, and local anesthetic toxicity. Transient and permanent nerve injury after sciatic nerve blockade is exceedingly rare [3, 31].

Saphenous Nerve Block/Adductor Canal Block

The saphenous nerve, a terminal sensory branch of the posterior division of the femoral nerve, provides innervation to the medial aspect of the upper thigh, lower leg, ankle, and foot. As the nerve exits the adductor canal, it courses along with the saphenous branch of the descending genicular artery [47, 48]. The nerve then gives off an infrapatellar branch innervating the knee, and a sartorial branch, which courses to the posterior portion of the knee.

The saphenous nerve is easily blocked in the midthigh, owing to its course along with the sartorius muscle, the femoral artery, and, more distally, the descending genicular artery. The patient is placed supine, and after sterile preparation, the probe is placed in a transverse fashion on the anterior thigh, midway between the inguinal crease and knee. Typically, owing to the deeper location of the nerve, a frequency between 6 and 1 MHz is selected. Initial ultrasound examination will identify, most superficially and medially, the sartorius muscle and, laterally and deeper, the vastus medialis. The nerve can be identified as it courses laterally and deep to the sartorius muscle, in an anterolateral relation to the femoral artery. Here, the nerve will appear as a hyperechoic, star-like structure that directly abuts the artery (Fig. 9.26). If difficulty is encountered, the probe can be moved more distally in order to attempt to image the nerve as it exits the adductor canal, though it may change its orientation to both the sartorius and the descending genicular artery in

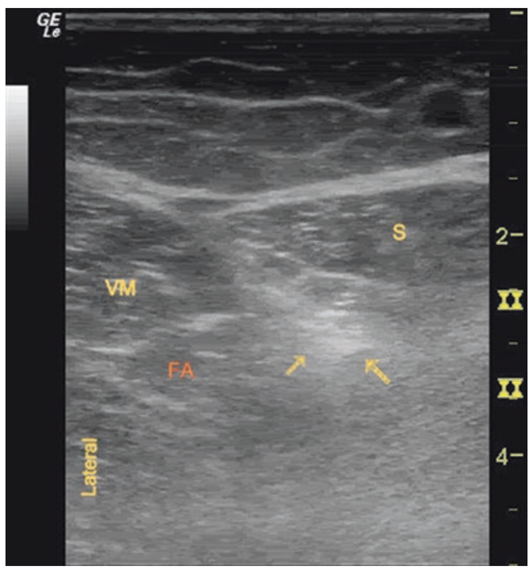

Fig. 9.26 The trans-sartorial saphenous block. The saphenous nerve (arrows) in relation to the vastus medialis (*VM*), the femoral artery (*FA*), and the sartorius (*S*)

this view. The nerve can also be identified by a "scan back technique" in which the operator locates the femoral nerve and artery in the inguinal crease and then traces these structures down to the midthigh, thereby identifying the saphenous nerve [49].

Needle selection is based on the depth of the nerve on ultrasound examination, and an in-plane approach is used from the lateral edge of the ultrasound probe. After the needle reaches the saphenous nerve, aspiration is performed to exclude vascular placement, and local anesthetic is injected incrementally. At times, the needle may be repositioned to ensure injection within the fascial sheath running in between the vastus medialis and the sartorius.

Use of the term "adductor canal block" has become more frequent in relation to surgeries of the lower extremity. This block is performed in the same fashion as the saphenous nerve block, but a higher volume of injectate is utilized [50, 51]. The higher volume of local anesthesia may provide additional proximal spread to cover the vastus medialis nerve, the middle femoral cutaneous nerve, articular branches of the obturator nerve, and the medial retinacular nerve, thereby providing sensory block to the medial and anterior aspects of the knee and the upper tibia [47, 48, 52].

Truncal Blocks

Ilioinguinal-Iliohypogastric Nerve Block

The ilioinguinal nerve innervates the upper medial part of the thigh and the upper part of the genitalia, while the iliohypogastric nerve provides sensation to the buttock and abdominal wall above the pubis. As such, the ilioinguinal-iliohypogastric nerve block (IIIHNB) can provide analgesia for procedures including inguinal hernia repair, orchiopexy, and hydrocele repair [53]. The ilioinguinal and iliohypogastric nerves are terminal portions of the L1 root that emerge from the lateral border of the psoas major muscle, cross the quadratus lumborum muscle obliquely, and perforate the transverse abdominis muscle, where they course together in the plane between the internal oblique and transverse abdominis (Fig. 9.27) [44].

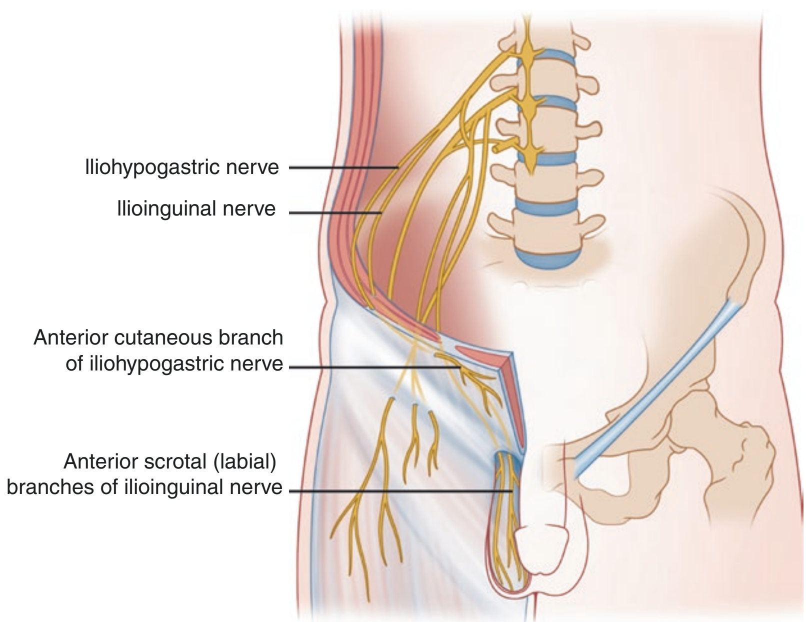

Fig. 9.27 The course of the ilioinguinal and iliohypogastric nerves

The nerve block is performed with the patient supine. After sterile preparation of the skin and probe, the probe is placed in a transverse orientation directly medial to the anterior superior iliac spine (ASIS). Here it is useful to tilt and rotate the probe so that it runs parallel to a line drawn between the ASIS and umbilicus. The operator then gently moves the probe medially, "rolling off" the ASIS. Ultrasound examination will reveal laterally the hypoechoic shadow of the ASIS and the three layers of abdominal musculature: the external oblique, internal oblique, and transverse abdominis. Below the transverse abdominis, the bowel can be seen. The ilioinguinal and iliohypogastric nerves can be visualized as elliptical honeycomb structures that run between the internal oblique and transverse abdominis (Fig. 9.28). They may often be mistaken for vascular structures due to their round, hypoechoic centers.

After frequency, depth, and gain are adjusted to optimize the image, a needle is passed from the lateral border of the probe toward the nerve (Fig. 9.29). After an aspiration is performed to rule out vascular placement of the needle, a small test dose is injected. Ultrasound examination of correct placement reveals a lemon-shaped appearance of local spread around the nerve bundle. Incorrect placement of the needle will often result in a round appearance of local anesthetic spread, typical of intramuscular injection.

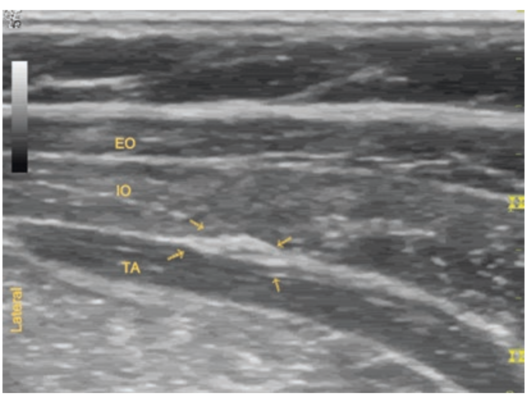

Fig. 9.28 Ultrasound of the ilioinguinal and iliohypogastric nerves. The ilioinguinal and iliohypogastric nerves (arrows) lie in between the internal oblique (*IO*) and transverse abdominis muscles (*TA*). Also pictured is the more superficial external oblique

Fig. 9.29 Performing the ilioinguinal-iliohypogastric nerve block

Specific complications associated with IIIHNB are bowel hematoma, bowel puncture, pelvic hematoma, femoral nerve block, and local anesthetic toxicity [53]. As such, it is prudent to constantly visualize the tip of the needle with specific attention to the depth of both the needle and the location of the intraperitoneal contents.

Transverse Abdominis Plane Block

The transverse abdominis plane (TAP) block can be used as an analgesic supplement in procedures involving the abdominal wall and anterior parietal peritoneum [53]. The transverse abdominis plane exists between the internal oblique and transverse abdominis muscles and consists of an interconnected plexus of nerves comprised of the somatic afferents of T8–L1 (Fig. 9.30) [53, 54]. It should be noted that this block will not provide analgesia of the deep intraperitoneal structures.

To perform the TAP block, a linear probe is selected. After sterile preparation, the probe is placed on the abdomen, approximately at the level of the planned incision, in a transverse fashion just lateral to midline. Initial ultrasound examination will identify the large, ellipse-like muscular structure of the rectus abdominis muscles (Fig. 9.31). Once this is identified, the probe is moved laterally, noting the edge of the rectus abdominis muscle. Directly adjacent to the lateral

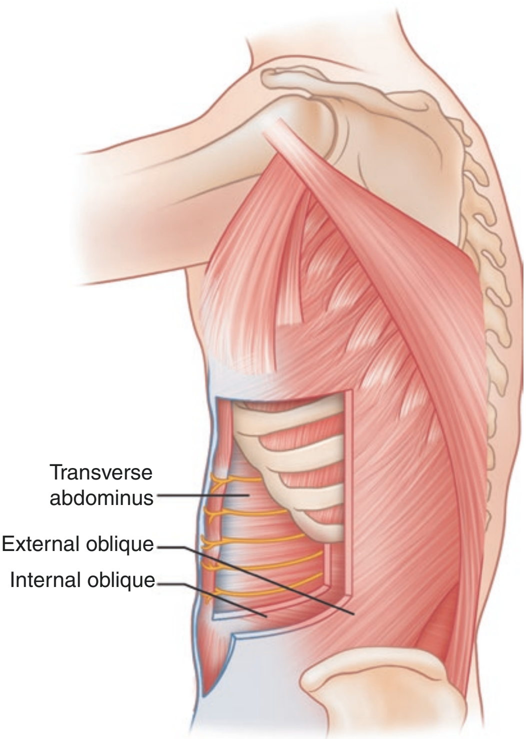

Fig. 9.30 The TAP plexus

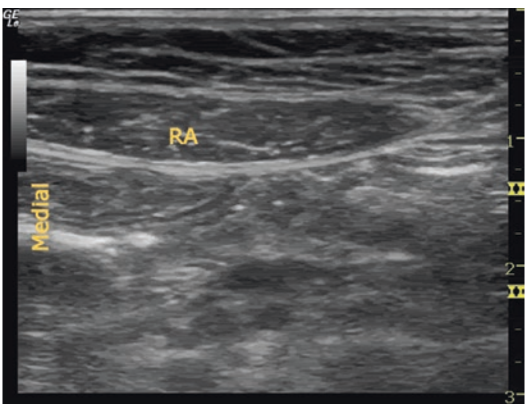

Fig. 9.31 The cross-sectional ultrasonographic appearance of the rectus abdominis

edge of the rectus abdominis muscle, the three linear layers of muscle can be visualized, consisting of the external oblique most superficially, then the internal oblique, and, deepest, the transverse abdominis (Fig. 9.32). Once identified, depth, focus, and frequency (typically 12–14 MHz) are adjusted to optimize the image.

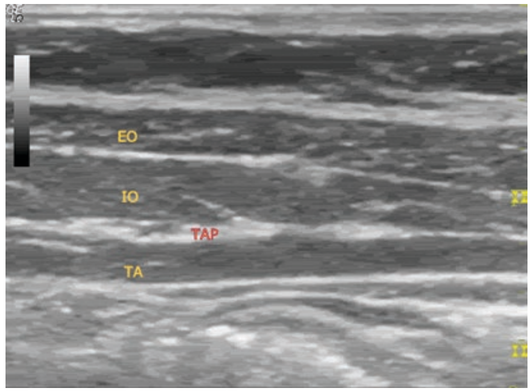

Fig. 9.32 TAP block. The external oblique muscle (*EO*), internal oblique muscle (*IO*), and transverse abdominis muscle (*TA*) are visualized. The transverse abdominis plane (*TAP*) lies between the internal oblique and transverse abdominis muscle

The needle is introduced in-plane from the medial edge of the ultrasound probe. Under constant visualization, it is passed into the hyperechoic fascial layer between the internal oblique muscle and the transverse abdominis muscle. After aspiration, a test dose injection is performed. Ideal visualization of local spread will show a "lemon"-shaped spread of local anesthetic between fascial planes, as opposed to the more circular-shaped appearance of an intramuscular injection [55].

Potential complications of the TAP block include intravascular injection, local anesthetic toxicity, peritoneal puncture with or without visceral injury, and infection at the injection site [56–58].

Rectus Sheath Block

The rectus sheath block can provide analgesia for procedures involving the anterior abdominal wall such as vertical midline laparotomy and laparoscopy. Its advantages include the large and recognizable size of the rectus muscle and lack of large vascular structures in that area [59].

The ventral roots of T6–L1 innervate the central portion of the abdominal wall and lie between the belly of the rectus abdominis muscle and, posteriorly, the fascia of the rectus sheath. Here,

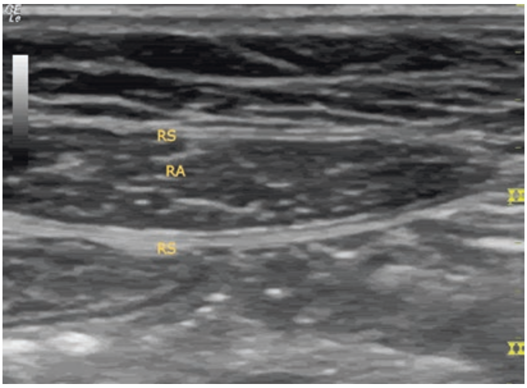

Fig. 9.33 The rectus sheath (*RM*) is encapsulated anteriorly and posteriorly by the rectus sheath (*RS*)

an injection of local anesthetic will spread in a caudocephalad manner, anesthetizing the terminal branches of the nerves [60].

To perform the nerve block, the patient is placed supine. A linear probe is selected, with typical frequency ranging from 10 to 12 MHz. After sterile preparation of the skin and probe, the probe is placed in a transverse fashion along the lateral edge of the umbilicus. Here, the rectus abdominis muscle is identified in cross section, and the image is optimized by decreasing depth and selecting the best focus depth and frequency. The probe is then directed laterally to identify the lateral, beak-like border of the rectus muscle. Directly posterior to the muscle lies the hyperechoic fascia of the rectus sheath (Fig. 9.33).

Needle selection is based on the depth of the border of the rectus muscle and rectus sheath. In an in-plane fashion, a needle is introduced from the lateral edge of the rectus muscle and is placed between the rectus muscle and the posterior rectus sheath fascia. After aspirating to rule out intravascular needle placement, a test dose injection will reveal an ellipse-like spread of local anesthetic in the fascial plane. Incorrect intramuscular placement of the needle will result in the local anesthetic injection forming a circular appearance. Once correct needle placement is confirmed, the remaining local anesthetic is injected with the goal of separating the rectus muscle and sheath [61].

Potential complications of the rectus sheath block include intravascular injection, local anesthetic toxicity, rectus sheath hematoma, peritoneal puncture with or without visceral injury, and infection at the injection site.

Quadratus Lumborum Block

The quadratus lumborum block aims to deposit local anesthetic in a similar fascial plane as the TAP block, only more dorsally in the abdominal wall (Fig. 9.34). The aim of the block is to anesthetize the ventral rami of the spinal nerve roots as they course anterior to the quadratus lumborum muscle [62]. The block may impart both a longer duration of sensory block, as well as a more complete spread of sensory block over the upper and lower abdomen [63, 64]. The block is thus ideal for surgeries that involve more extensive somatic pain over the abdominal wall, such as laparoscopic surgeries with multiple ports.

To perform the block, a linear probe is selected. After sterile prep, the probe is placed on the lateral abdomen, similar to the TAP block. The external oblique, internal oblique, and transverse abdominis are identified just as in the TAP block. The probe is then moved laterally, following the transverse abdominis to its lateral border, where it comes to a point. Below the tip of the

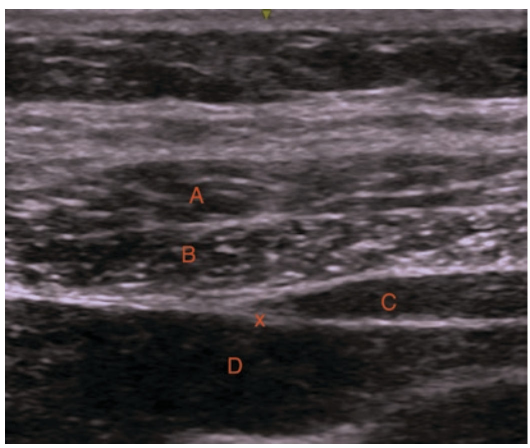

Fig. 9.34 The quadratus lumborum block: similar to the TAP block, the external oblique (*A*), internal oblique (*B*), and transversus abdominis muscles (*C*) are identified. Below the transversus abdominis lies the quadratus lumborum (*D*). Injection occurs at the conjunction of the transversus abdominis and the quadratus lumborum (*x*)

transverse abdominis lies the quadratus lumborum muscle, which is surrounded by a hyperechoic, thick thoracolumbar fascia [62]. It is important to ensure that the kidney is not mistaken for the quadratus lumborum, and as such, Doppler interrogation of the target is prudent. The needle is introduced medially and directed laterally, with the goal of placement directly under the thoracolumbar fascia encasing the quadratus lumborum muscle. Once test dose reveals subfascial injection, injection of a larger volume of more dilute local anesthetic will result in a successful block.

Potential complications of the quadratus lumborum block include intravascular injection, local anesthetic toxicity, peritoneal puncture with or without visceral injury, kidney injury, and infection at the injection site [65].

Thoracic Paravertebral Block

The thoracic paravertebral space provides an area to perform unilateral somatic and sympathetic nervous blockade to the chest and abdominal wall (Fig. 9.35). Continued experience with ultrasound guidance has popularized this technique. Its potential benefits over thoracic epidural blockade include hemodynamic stability with more dense blockade, ability to ambulate, no risk of urinary retention, thereby eliminating the need for Foley catheter placement, and the ability to perform neurologic examination of the lower extremities [66].

The thoracic paravertebral space is bounded medially by the vertebral bodies, though it maintains a connection to the epidural space [67]. Laterally, the paravertebral space tapers and becomes the intercostal space. The posterior border of the thoracic paravertebral space is the superior costotransverse ligament, while the anterior border is the parietal pleura. Interconnectivity exists at the anteromedial border of the paravertebral space, allowing spread of the injectate to multiple levels [68].

Two methods exist for ultrasound visualization of the thoracic paravertebral space: sagittal and transverse. In the sagittal view, a linear probe is placed on the midline of the selected level of blockade. The spinous processes are identified, specifically noted by their "mountain chain" appearance. The probe is the moved laterally, and utilizing tilt, the hypoechoic transverse processes surrounding the hypoechoic paravertebral space are visualized (Fig. 9.36). Some have likened this image to "Mickey Mouse ears." Of note, the paravertebral space is superiorly bordered by the costotransverse ligament in this view, which appears

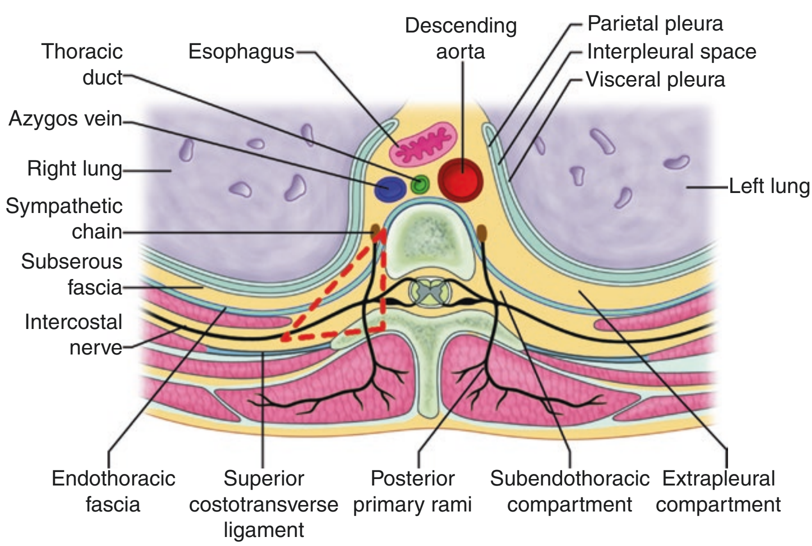

Fig. 9.35 The thoracic paravertebral space (red dashed line)

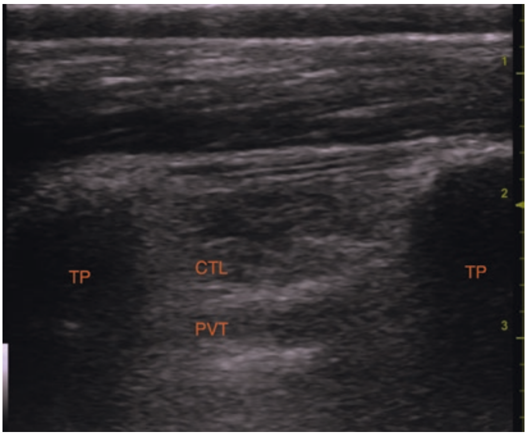

Fig. 9.36 The sagittal view of the thoracic paravertebral space. The transverse processes (TP) about the hypoechoic paravertebral space (PVT) superiorly bordered by the costotransverse ligament (CTL). Injection of the paravertebral space will lead to a round increasing size of the paravertebral space and a depression of the hyperechoic pleura below

as a more hyperechoic but heterogenous layer. The paravertebral space will be a hypoechoic linear space directly below this layer, connecting the "Mickey Mouse ears." Of note, the parietal pleura is also seen here as a hyperechoic linear and dynamic structure moving with respiration.

To inject the paravertebral space in the sagittal view, the patient is placed either lateral or prone. A linear probe is selected, with typical frequency ranging from 8 to 12 MHz. After sterile preparation of the skin and probe, the probe is placed as above. Once the paravertebral space is identified, the needle is passed in an in-plane fashion between the acoustic images of the transverse processes to the hypoechoic paravertebral space. Often, a distinct pop is felt when the needle passes through the costotransverse ligament. It is prudent to intermittently hydrodissect as the needle is advanced to avoid entry into the pleural cavity. Once the paravertebral space is entered with the needle, injection will increase the area of the hypoechoic paravertebral space, also depressing the hyperechoic parietal pleura. If difficulty is encountered guiding the needle to the paravertebral space, one can perform the "off-sides" maneuver of Abdallah and Brull, in which the paravertebral space is placed "off-sides" to the lateral side of the ultrasound screen allowing for a steeper angle of the needle to reach the paravertebral space. This cephalad or caudad translational movement of the linear transducer slows the needle to clear the transverse process and permits easier access to the paravertebral space [69].

The transverse view technique for thoracic paravertebral blockade utilizes the same anatomy, but only focuses on one transverse process at a time. To obtain an image of the thoracic paravertebral space, the probe is initially placed midline to view the spinous process, which appears similar to a mountain peak (Fig. 9.37). The probe is the slid laterally to view the transverse process (Fig. 9.38). Beneath the transverse

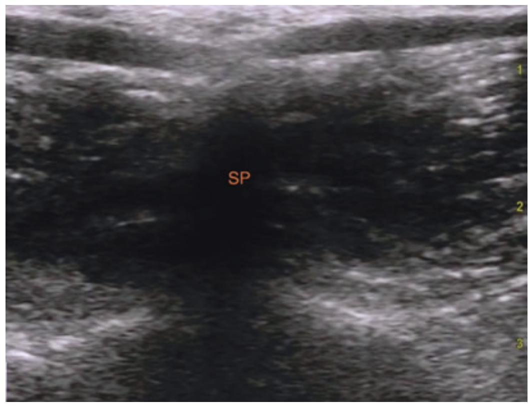

Fig. 9.37 The transverse view of the thoracic vertebrae. Note the hypoechoic "mountain peak" signature of the spinous process (SP)

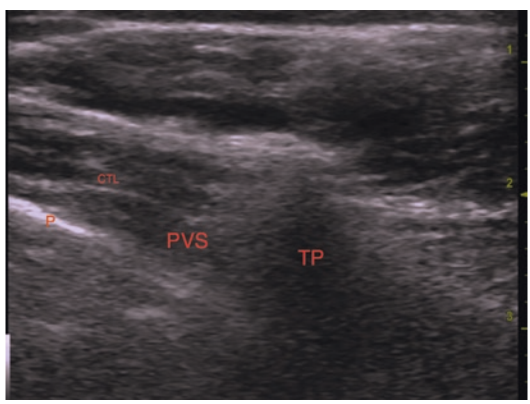

Fig. 9.38 The transverse approach to the thoracic paravertebral block. The hypoechoic transverse process (TP) is bordered laterally by the paravertebral space (PVS). Note the hyperechoic pleura (P) and superiorly bordering costotransverse ligament (CTL)

process lies the wedge shaped, hypoechoic paravertebral space overlying the hyperechoic and dynamic parietal pleura. Inserting a needle in-plane from the lateral side, the needle is advanced to the paravertebral space with hydrodissection to avoid intrapleural injection. As in the sagittal technique, injection into the paravertebral space will result in depression of the parietal pleura [68].

Peripheral Nerve Blockade in Children

Peripheral nerve blockade in the pediatric setting has undergone a slower evolution when compared with the adult world. Before the development of ultrasound-guided peripheral nerve blockade techniques, significant challenges in pediatric patients included the difficulty in targeting nerve structures that course dangerously closely to other critical structures, the constant risk of local anesthetic toxicity with smaller children and higher volume blocks, and the concern of nerve injury when performing a nerve block on a heavily sedated or completely anesthetized patient [70]. The development of ultrasound-guided techniques and subsequent large-scale evaluation of outcomes have led to both increased numbers of peripheral nerve blocks performed in children and clinical data proving efficacy and safety [1, 3]. Performing peripheral nerve blocks with ultrasound on anesthetized children is now generally well accepted and has led to an increase in practice [71].

The pediatric patient offers several advantages over the adult patient in relation to ultrasonography. Typically, the child has less adipose tissue and has smaller structures, which allows the operator to utilize higher frequencies and improve resolution and image quality of blocks that are often difficult in adults. Secondly peripheral nerve blocks in a heavily sedated or anesthetized child have been shown to be safe, which provides the operator with an immobile patient [26, 72]. A disadvantage encountered when performing ultrasound-guided regional nerve blocks on children is related mainly to size. In this setting, smaller, more specific equipment may be needed, including “hockey stick” probes with higher available frequencies and short block needles. Additionally, there is often limited application space for ultrasound probe placement on the skin in small children.

Performing nerve blocks provides an excellent analgesic alternative to systemic pain medication. Considering the fragile nature of infants and children, peripheral nerve blockade can provide a safe, long-lasting analgesic devoid of the risk of respiratory depression and hemodynamic instability. Current trends support this claim, as the gap between neuraxial blockade, once the most commonly practiced regional anesthetic option, and peripheral nerve blockade in pediatric patients narrows [1, 3].

Systemic local anesthetic toxicity has always been a concern when placing regional blocks in infants and children. Ultrasound guidance has been shown to reduce the volume of local anesthetic needed for block success, thereby significantly reducing this risk to an acceptable level [3, 73].

Clinical Pearls

Interscalene Block

- The trunks of the plexus lie lateral to the easily identifiable sternocleidomastoid (SCM). The tapered tip of the SCM lies directly above and medial to the anterior scalene muscle.
- It is easy to mistake the lateral border of the SCM for the brachial plexus. This can be avoided by identification of the anterior scalene muscle.
- The anterior scalene muscle can be small as the probe is moved rostrally. It may be beneficial to move the probe caudally in order to identify it.
- If the brachial plexus is not visualized in the interscalene position, gently roll the probe down to the supraclavicular position, and then trace the plexus back to the interscalene position.

Supraclavicular Nerve Block

- The plexus at this level appears as a "bunch of grapes" as opposed to the more linear, "snowman" appearance in the interscalene block.
- The probe should be tilted to transect the brachial plexus at this level.
- It is often easy to mistake the fascia enveloping the sternocleidomastoid for the brachial plexus. It is important, here, to visualize the SCM, the anterior scalene, and the middle scalene to correctly identify the brachial plexus lying between the anterior and middle scalene.

Infraclavicular Nerve Block

- This is a deeper block; therefore, a curvilinear probe with lower frequencies may be necessary to penetrate tissue.
- If there is difficulty in locating the brachial plexus in the infraclavicular fossa, it is often helpful to identify the brachial plexus in the supraclavicular fossa and then mark on the skin where the plexus is located there. This surface landmark can now serve as the medial border of the area to scan in the infraclavicular fossa.
- In children, it may be difficult to pass a needle at a correct angle in between the probe and the clavicle, particularly with larger probes. If this is the case, it is acceptable to use an in-plane needle placement from the inferior edge of the probe. A hockey stick probe is often beneficial.

Femoral Nerve Block

- The optimal block location is proximal to the femoral artery bifurcation.
- Pressure on the transducer is often useful in obtaining the image of the femoral artery.
- The point of injection must always be below the fascia lata.
- A small amount of rostral tilt may improve the image.

Sciatic Nerve Block

- Lower-frequency probes may be useful when the block is performed more proximally.
- When introducing the needle from the lateral thigh, first measure the depth of the nerve itself, and then use that distance from the probe as the insertion site on the lateral thigh.
- Probe tilting may improve the image as you are "transecting" the nerve at different points of the thigh.
- The bifurcation of the sciatic nerve into the tibial and peroneal nerves should be visualized first during the popliteal fossa block (Fig. 9.25). The nerve should be traced back and blocked proximal to this bifurcation, or the common peroneal and tibial nerves should be blocked with separate injections.

Ilioinguinal-Iliohypogastric Nerve Block

- It is often useful to "roll off" the iliac crest in order to situate the probe in its proper alignment.
- Useful landmarks may include the thick iliacus muscles which lie below the transverse abdominis muscles.
- The nerves may appear similar to vasculature. Doppler interrogation may be used to determine whether it is a vascular or nervous structure.

Transverse Abdominis Plane Block

- The TAP block provides analgesia for abdominal wall and peritoneal pain. Supplementation with NSAIDs and opiates should be added for visceral pain.
- Higher-frequency probes will improve the resolution of the image to the superficial nature.
- The TAP block should be performed as lateral as possible on the abdominal wall, specifically where the latissimus dorsi muscle begins to obscure the three muscle layers.

- The rectus abdominis muscle can serve as an excellent landmark medially because this is where the three muscle layers become evident.

Rectus Sheath Block

- The rectus sheath is easily visualized in the midline.
- A lateral approach may be easier as it allows the operator to avoid the thick rectus muscle.

Review Questions

1. Axial resolution refers to:
   (a) The ability to distinguish two points side by side
   (b) The ability to distinguish two points in the same line of axis
   (c) The ability to minimize background noise
   (d) The optimal depth in order to visualize a structure
2. The interscalene block aims to inject the brachial plexus between:
   (a) The sternocleidomastoid and the first rib
   (b) The omohyoid muscle and the sternocleidomastoid
   (c) The anterior and middle scalene muscles
   (d) The pectoralis minor and axillary artery
3. When placing an ultrasound-guided supraclavicular nerve block, the pulsating artery found at the inferior portion of the target area is the:
   (a) Subclavian artery
   (b) External carotid artery
   (c) Internal carotid artery
   (d) Vertebral artery
4. After placing an axillary nerve block, the patient has sensory sparing of the medial upper arm. The nerve responsible for this is:
   (a) The radial nerve
   (b) The ulnar nerve
   (c) The median nerve
   (d) The musculocutaneous nerve
5. The femoral nerve is bounded medially by the femoral artery, inferiorly by the iliacus muscle, and superiorly by the hyperechoic:
   (a) Iliopectineal ligament
   (b) Fascia lata
   (c) Femoral nerve
   (d) Psoas muscle
6. After performing a popliteal fossa sciatic nerve block for an ankle procedure, the patient is experiencing pain on the dorsum of the foot. A likely scenario of failure is:
   (a) The femoral nerve has been mistakenly blocked.
   (b) The saphenous nerve was not adequately anesthetized.
   (c) There is typically sparing of anesthesia in this location.
   (d) The block occurred distal to the bifurcation of the sciatic, only including the tibial nerve.
7. The "trackback" technique involves locating the saphenous nerve related to its branching from the:
   (a) Femoral nerve
   (b) Sural nerve
   (c) Sciatic nerve
   (d) Obturator nerve
8. The ilioinguinal and iliohypogastric nerves are blocked as they course between the:
   (a) Transverse abdominis muscle and the parietal peritoneum
   (b) External and internal oblique muscles
   (c) Internal oblique and transverse abdominis muscles
   (d) Iliacus and transverse abdominis muscles
9. When utilizing a TAP block for a laparoscopic appendectomy, the following is false:
   (a) Parenteral opiates or NSAIDs are useful for the treatment of uncovered visceral pain.
   (b) The anterior abdominal wall is anesthetized by the TAP block.
   (c) The anterior parietal peritoneum is blocked by the TAP block.
   (d) The TAP block should cover components of visceral pain.

10. When injecting a local anesthetic solution during ultrasound-guided peripheral nerve block placement, you notice large hyperechoic artifacts filling the target area. The likely problem is:
    (a) Vascular perforation
    (b) Air has been injected through the needle
    (c) Intraneural injection
    (d) Vasospasm
11. While performing a TAP block, injection reveals a round, circular spread of injectate in an area presumed to lie between the transverse abdominis and internal oblique muscles. The block fails. The likely problem is:
    (a) This was an intramuscular injection.
    (b) This was an intravascular injection.
    (c) The nerve was missed.
    (d) The volume of local anesthetic was insufficient.
12. While performing an interscalene nerve block, the image appears as bright, causing difficulty in identifying neural structures. An appropriate control to manipulate would be:
    (a) The depth
    (b) The frequency
    (c) The gain
    (d) The focus position
13. While placing a femoral nerve block, difficulty is encountered in identifying the needle placement. Injection of a small amount of local anesthetic results in a widening of the femoral nerve image. A likely scenario is:
    (a) Intraneural injection
    (b) Correct placement
    (c) Intravascular injection
    (d) Air injection
14. While placing a femoral nerve block, you notice an asymmetric, expanding hypoechoic element next to the nerve and artery. This is likely:
    (a) Extravasation of a small amount of local anesthetic from the needle
    (b) Separation of the fascial plains
    (c) Mild damage to and extravasation of the lymphatic system
    (d) Formation of a hematoma from the femoral artery
15. While performing an interscalene block, it is difficult to obtain an acceptable image of the axillary artery and brachial plexus due to the depth of the structures. The following would be appropriate manipulations of the ultrasound machines *EXCEPT*:
    (a) Decreasing frequency
    (b) Increasing frequency
    (c) Manipulating the TGC
    (d) Increasing depth

Answers:

1. b—Axial resolution refers to the ability to distinguish two points in the same line of axis. Higher-frequency beams improve axial resolution at the cost of poorer depth penetration and visualization.
2. d—The interscalene block aims to inject the brachial plexus at the level of the trunks, which usually exists at C6. Here, the trunks lie between the anterior and middle scalene, though the anterior scalene may appear small.
3. a—The brachial plexus follows a similar course to the subclavian artery, which becomes the axillary artery. As such, this is a useful landmark in locating the brachial plexus.
4. d—The musculocutaneous nerve is frequently missed in the axillary nerve block. It can be visualized with an ultrasound and injected separately or accessed by directly injecting into the body of the coracobrachialis muscle.
5. b—The fascia lata is the superior border of the femoral nerve sheath. It separates from the fascia iliaca at the femoral nerve and rejoins laterally.
6. d—Blocking the sciatic nerve in the popliteal fossa must be performed proximal to the bifurcation of the sciatic nerve into the tibial and peroneal nerves.
7. a—The saphenous nerve is a branch of the femoral nerve. As such, it is often responsible for medial foot pain when only a sciatic block is performed.

8. c—Much like the TAP block, the ilioinguinal and iliohypogastric nerves course between the internal oblique muscle and the transverse abdominis muscle.
9. d—While the TAP block anesthetized the terminal branches of T8–T11, it does not typically block visceral pain. As such, the anterior abdominal wall and the parietal peritoneum will likely be covered, but visceral pain must be addressed with either parenteral medicines or additional neuraxial anesthetics.
10. b—As air is hyperechoic, even small amounts can significantly worsen imaging when injected. Therefore, it is essential to always flush needles before ultrasound-guided peripheral nerve blockade.
11. a—The TAP block relies on anesthetic deposition between two fascial layers. As such, the injectate should appear as an elliptical spread of hypoechoic fluid. Round-appearing injectate is frequently indicative of intramuscular injection.
12. c—Gain refers to the amplification of received signals. As such, too much gain leads to an amplification of background noise and, in this case, should be lowered.
13. a—Widening of the nerve image is often indicative of intraneural injection, which has been associated with nerve injury.
14. d—Inadvertent vascular puncture is often seen as a hypoechoic expansion of the perivascular space.
15. b—By decreasing frequency and depth, deeper structures are better imaged. TGC may help optimize the gain on attenuated deeper structures.

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