Ehab Farag · Maged Argalious
John E. Tetzlaff · Deepak Sharma
Editors

Basic Sciences in Anesthesia

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Thanks to my mother, my late father, and my brother and his family for their help, support, and prayers.

Ehab Farag

Thanks to my parents whose passion for research and scientific discovery proved to be contagious.
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Maged Argalious

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John E. Tetzlaff

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Deepak Sharma

Preface

The basic sciences are the essence of anesthesiology. Therefore, the American Board of Anesthesiology (ABA) includes an examination on the basic sciences for the ABA certification. The lack of a specific book dedicated to the basic sciences in anesthesiology has driven us to compose this book. We tried our best to follow the syllabus of the ABA basic sciences examination in order to create an accurate resource for study. The motto of this book is to follow Alexander Pope's advice in 1709: "A little learning is a dangerous thing; drink deep, or taste not the Pierian spring: there shallow droughts intoxicate the brain, and drinking largely sobers us again." This message is still relevant today in the field of anesthesiology.

The content of each chapter of the book is presented in a comprehensive manner and is conducive for successful study. Every chapter highlights key topics and includes questions testing comprehension of the respective subject matter. Moreover, suggested references are included for further research in the basic sciences.

We would like to thank our colleagues for their hard work and dedication in writing the book. In addition, we would like to thank Ms. Maureen K. Pierce and Joanna Renwick from Springer International Publishing for their perseverance during the process.

At the end, we hope this book will be helpful in preparing for the ABA basic science examination as well as serve as a tool for practicing anesthesiologists who would like to refresh their knowledge in basic sciences.

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Applied Anatomy

Contents

Peripheral Nerve Block Anesthesia

Sree Kolli and Loran Mounir Soliman

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1

Key Points

1. Peripheral nerve is composed of axons of multiple neurons bundled together in fascicles.
2. To achieve good block, local anesthetic should be injected in close proximity to the nerve or in the same fascial plane in which the nerve lies.
3. Advances in ultrasound technology allows real-time visualization of needle advancement toward the nerve, potentially avoiding critical structures. It also allows to visualize the spread of local anesthetic around the nerve.
4. Ultrasound and peripheral nerve stimulators facilitate nerve blockade, but their use does not eliminate the risk of nerve injury.
5. Anesthesia of the shoulder and upper extremity can be obtained by blockade of the brachial plexus (C5-T1).
6. Supraclavicular block does not eliminate the risk of phrenic nerve paralysis. The incidence depends on the volume of local anesthetic injected.
7. Interscalene and supraclavicular block can miss the lower trunk, hence axillary approach to brachial plexus is most optimal for procedures on forearm and hand.
8. Infraclavicuar block avoids the risk of phrenic nerve paralysis, making it an excellent choice in patients with respiratory issues.
9. Femoral nerve block is easy to learn, low risk with minimal complications. It is useful for surgery on the anterior thigh and knee, quadriceps tendon repair, and postoperative pain management of femur and knee surgery.
10. Sciatic nerve block is useful for surgical procedures involving hip, knee, and distal lower extremity. It can be blocked at multiple locations by multiple approaches.
11. Popliteal nerve block is useful for surgery on foot and ankle, combined with saphenous nerve block can provide complete anesthesia of the limb distal to the knee.
12. Transversus abdominis plane (TAP) block provides postoperative analgesia for surgeries on anterior abdominal wall. It is relatively easy and safe block to perform under ultrasound guidance.

1.1 Anatomy of the Nerve

A peripheral nerve trunk is composed of axons of multiple neurons bundled together in connective tissue and endoneural fluid (Fig. 1.1). Each axon is surrounded by endoneurium, which is made up of glycocalyx and a mesh of collagen. Axons are bundled together into groups called fascicles and each fascicle is wrapped in a layer of connective tissue called perineurium. All the fascicles are finally ensheathed in a connective tissue layer called epineurium. The blood vessels run between the fascicles and supply oxygen and nutrients to the axons.

1.2 Upper Limb Blocks

The brachial plexus is a neural bundle that provides sensory and motor innervation to the upper extremity. Nerve roots of C5-T1 undergo complex congregation forming components named roots, trunks, divisions, cords, before forming the terminal nerves of the upper extremity (Fig. 1.2). The plexus can be blocked at several locations, depending on the required region of the upper limb to be blocked.

The interscalene space is a potential space between the anterior and middle scalene muscles. The 5 roots of the cervical and the first thoracic spinal nerves give rise to 3 trunks (superior, middle, and inferior) that emerge between the medial and anterior scalene muscles to lie on the floor of the posterior triangle of the neck. The roots of the plexus lie deep to the prevertebral fascia, whereas the trunks are covered by its lateral extension, the axillary sheath. Each trunk divides into an anterior and a posterior division behind the clavicle, at the apex of the axilla. The divisions combine to produce the 3 cords, which are named lateral, median, and posterior according to their relationship to the axillary artery. Individual nerves are formed as these neuronal elements descend distally.

1.2.1 Interscalene Block

This is a technique of anesthetizing the roots or trunks of the brachial plexus in the neck between the anterior and middle scalene muscles. The procedure was first well described and popularized by Alon Winnie in 1970 [1].

Interscalene nerve block is typically performed to provide anesthesia or analgesia for surgery of the shoulder and upper arm. A successful block at this level anesthetizes the shoulder and upper arm, but does not reliably block nerve roots innervating the forearm, as the inferior trunk is often not included into the block.

- **Indications:** Shoulder surgeries such as rotator cuff repair, acromioplasty, hemiarthroplasty, total shoulder arthroplasty, humerus fractures, elbow surgery.
- **Contraindications:** Patient refusal, infection at planned injection site, preexisting neurologic defects, local anesthetic allergy, coagulopathy, contralateral phrenic nerve dysfunction, severe chronic obstructive pulmonary disease
- **Complications:** Diaphragmatic paralysis, pneumothorax, hoarseness, Horner's syndrome, epidural/intrathecal injection, local anesthetic (LA) toxicity, infection, hematoma, and allergic reaction.

Landmark/Nerve Stimulator Technique

The landmarks used for the block are the clavicular head of the sternocleidomastoid muscle, clavicle, and external jugular vein. The patient can be positioned supine or with the back mildly elevated and head rotated away from the side to be blocked. Palpate the sternocleidomastoid that overlies the superior aspects of the scalene muscles. Having the patient lift his or her head off the bed will help define the lateral border of the sternocleidomastoid muscle. The anterior scalene

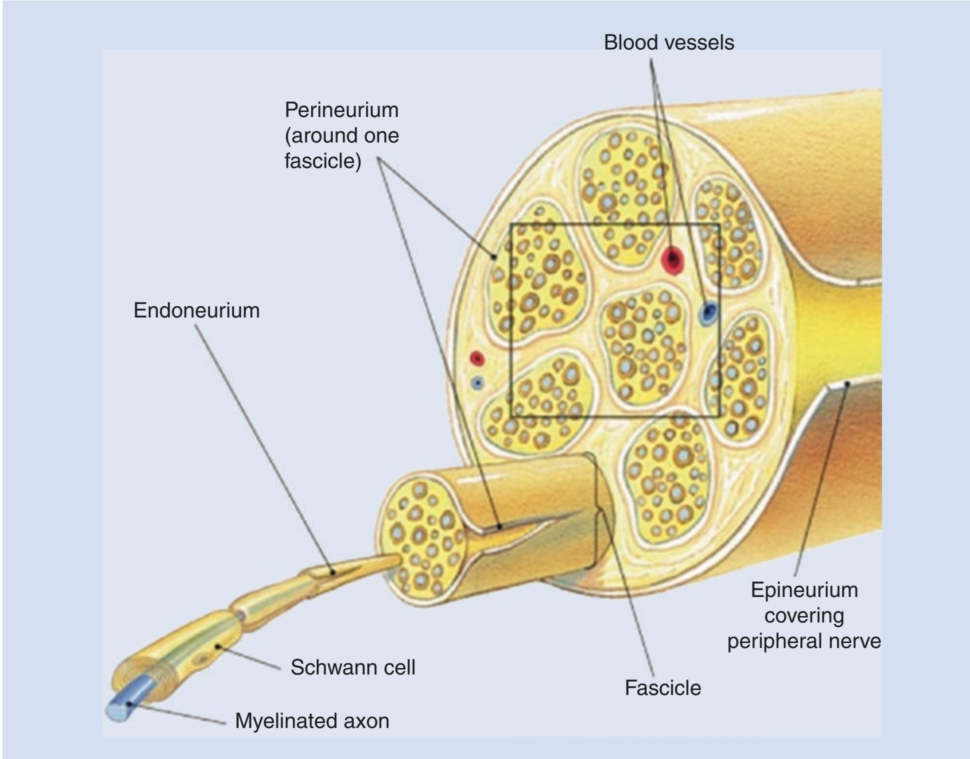

Fig. 1.1 Anatomy of a nerve (Reprinted under Creative Commons Attribution 4.0 International License from OpenStax, Anatomy & Physiology. Houston, TX, OpenStax, Rice University. 2016. Download for free at ▶ http://cnx.org/content/col11496/latest/)

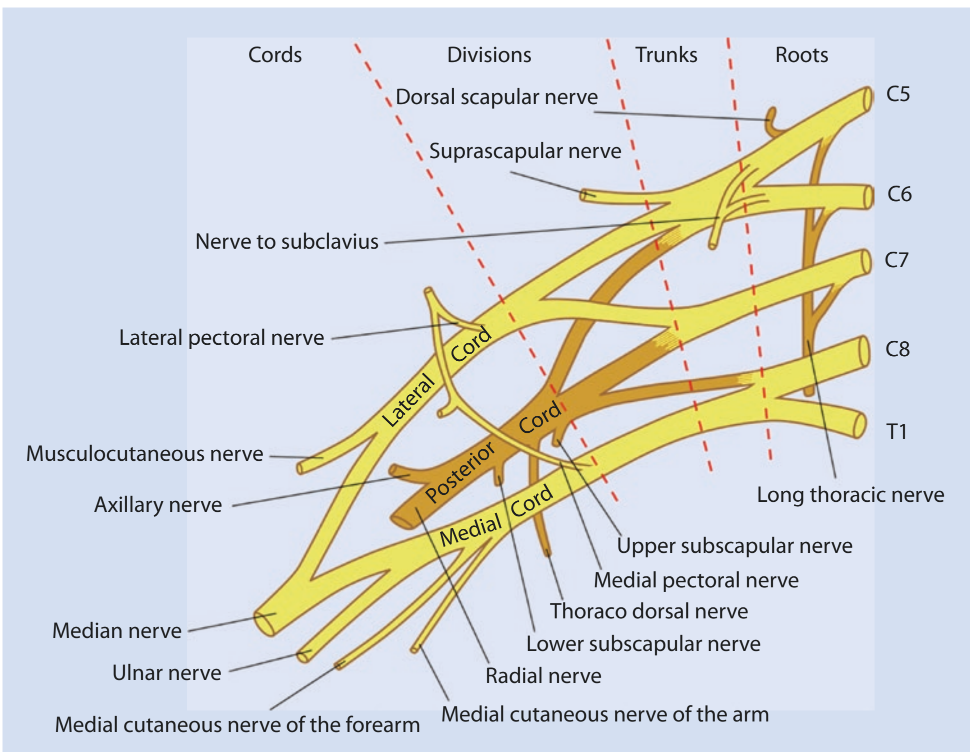

Fig. 1.2 Brachial plexus anatomy

muscle emerges from under the sternocleidomastoid muscle and runs inferiorly and laterally toward the first rib.

By placing the fingers under the sternocleidomastoid muscle and inferior to the external jugular vein, sliding them laterally will identify anterior scalene muscle. The interscalene groove separates the anterior from the middle scalene muscle. This groove sometimes is very obvious during palpation, but frequently is subtle and more like a cleft.

Once the groove is palpated, several maneuvers can be performed to confirm the groove. During deep inspiration, the groove often is accentuated because the scalenes are accessory muscles of respiration, which tense during inspiration. The groove also can be tracked down toward the first rib and palpate for the subclavian artery, which emerges between the scalenes.

Once the interscalene groove is identified the palpating fingers should be gently but firmly pressed between the anterior and middle scalene muscles and should not be moved during the entire block procedure to allow for precise redirection of the needle when necessary. The needle is inserted 3–4 cm above the clavicle and advanced at an angle almost perpendicular to the skin plane. The nerve stimulator should be initially set to deliver 0.8–1.0 mA. The needle is advanced slowly until stimulation of the brachial plexus is obtained—seen as twitch of the pectoralis, deltoid, arm, forearm, or hand muscles at 0.2–0.5 mA. This typically occurs at a depth of 1–2 cm in most of the patients and 25–35 mL of local anesthetic is injected slowly with intermittent aspiration to rule out intravascular injection.

Ultrasound Technique

Apart from precisely locating the brachial plexus, the ultrasound guidance allows to visualize the distribution of the local anesthetic around the plexus. It allows multiple injections around the brachial plexus, therefore eliminating the reliance on a single large injection of LA and may allow for the reduction in the volume of local anesthetic required to accomplish the block. It reduces the risk of injury to the blood vessels and the nerves in the plexus.

The block can be performed with the patient in supine, semi-sitting, or semi-lateral decubitus position, with the patient's head facing away from the side to be blocked. The latter position is more suitable for in-plane approach from the lateral side, especially when a catheter is placed that needs to be tunneled away from the surgical drapes.

- **Scanning Technique 1 (Transverse Sweep):** The transducer is positioned in the transverse plane just below the level of cricoid. Start by identifying the hyperechoic arc of the trachea and moving the probe posterolaterally until sternocleidomastoid muscle is identified. This muscle is triangular shaped and located anteriorly to the carotid artery and internal jugular vein. Once the great vessels are identified, slide the probe more laterally to identify the scalene muscles and the brachial plexus that lies in between them appearing as hypoechoic trunks.
- **Scanning Technique 2 (Backtracking):** The other scanning technique is to identify the brachial plexus in the supraclavicular fossa and then track cephalad into the interscalene space. The transducer is placed over the sternocleidomastoid, 1–2 cm superior to the head of the clavicle. Move laterally to identify the subclavian artery and immediately superior and posterior to the artery, the brachial plexus is seen as a grouping of small hyperechoic circles with hypoechoic centers, similar to a cluster of grapes. The plexus is then traced cephalad to the preferred block region at the level of C6.

Once the plexus is identified the needle is inserted in-plane—typically in a lateral to medial direction. As the needle passes through the prevertebral fascia, a certain loss of resistance is often felt. Inject 1–2 ml of local anesthetic to confirm correct location before the rest of the dose (15–25 cc in adults) is injected, visualizing the spread around the plexus.

1.2.2 Supraclavicular Block

Often called the "spinal anesthesia of the upper extremity," the supraclavicular block is a technique of anesthetizing the brachial plexus at distal trunks and origin of the divisions, where the brachial plexus is confined to its smallest surface area. The first percutaneous supraclavicular block was performed by Kulenkampff in Germany in 1911, reportedly on himself [2]. The advantages of a supraclavicular technique over other brachial plexus block approaches are its rapid onset and complete and predictable anesthesia for the entire upper extremity and particularly hand surgery. The introduction of ultrasound guidance to regional anesthesia in the last decade has resulted in significant renewed interest in the clinical application of the supraclavicular block, as well as a greater understanding of its mechanics.

- **Indications:** Upper extremity surgery including arm, elbow, forearm, wrist and hand. (It is best for areas below the mid-humerus level. Above the mid humerus, the shoulder area, an interscalene block would provide better coverage). However, if enough volume is used it can diffuse to the shoulder area.
- **Contraindications:** Patient refusal, infection at planned injection site, preexisting neurologic defects, local anesthetic allergy, coagulopathy, contralateral phrenic nerve dysfunction, severe chronic obstructive pulmonary disease.
- **Complications:** Diaphragmatic paralysis, pneumothorax, hoarseness, Horner's syndrome, LA toxicity, infection, hematoma, and allergic reaction.

Landmark/Nerve Stimulator Technique Classic Approach

The most common supraclavicular technique is the subclavian perivascular approach, described by Winnie and Collins [3]. The interscalene groove is palpated and followed distally until the pulsation of the subclavian artery is felt. This should be at the midpoint of the clavicle, about 1 cm posterior to it. It is important to note that the dome of the lung is medial to the insertion point of the needle. Entry to the sheath can be identified by a "click" as the needle pierces the tough fascia, by paresthesia, or by an appropriate motor response when a nerve stimulator is used.

For vertical supraclavicular block, also called the "plumb bob" technique, identify the lateral border of the sternocleidomastoid as it inserts onto the clavicle by asking the patient to raise the head slightly off the bed. The needle entry site is immediately superior to the clavicle, just lateral to the identified lateral border of the sternocleidomastoid. The needle is inserted vertically at 90° to the bed and would result in contact with the brachial plexus in most patients.

Ultrasound Technique

The patient can be positioned anywhere from supine to sitting upright with their head rotated away from the block site. The probe is placed in the supraclavicular fossa and oriented perpendicular to the subclavian artery. The subclavian artery is identified by its thick wall and brisk pulsations. Immediately superior and postero-lateral to the artery, the brachial plexus is seen as a grouping of small hyperechoic circles with hypoechoic centers, similar to a bunch of grapes. Alternatively, the plexus can be found in the interscalene space and followed distally to its association with the subclavian artery. Deep to the artery the structures of note are the dome of the lung (identified by its characteristic movement and scatter) and the first rib (identified by its hyperechoic surface with dense posterior shadowing).

Once the plexus is identified, the needle is inserted in-plane from a lateral to medial direction. The entrance of the needle into the brachial plexus sheath is often associated with a palpable "pop" as the needle passes through the paravertebral fascia/ brachial plexus sheath. After a careful aspiration, 1–2 mL of local anesthetic is injected to confirm the proper needle placement. When the injection displaces the brachial plexus away from the needle, an additional advancement of the needle 1–2 mm deeper may be required to accomplish adequate spread of the local anesthetic. When injection of the local anesthetic does not appear to result in a spread in and around the brachial plexus, additional needle repositioning and injections may be necessary.

1.2.3 Infraclavicuar Block

The infraclavicuar brachial plexus block is another way of blocking the brachial plexus below the level of the clavicle. It is functionally similar to the supraclavicular block and is useful for distal arm, elbow, wrist, and hand surgery. Infraclavicuar block avoids the risk of phrenic nerve block, making it an excellent choice in patients with respiratory issues.

In the infraclavicuar fossa, the brachial plexus separates into individual cords that are named medial, lateral, and posterior based on their locations relative to the axillary artery. These cords bundle around the axillary artery as it travels inferior to the coracoid and into the axilla. The cords lie deep to the pectoralis muscles and superficial to the lung while the axillary vein runs inferior to the artery.

- **Indications:** Surgery on the distal arm, elbow, wrist, and hand.
- **Contraindications:** Patient refusal, infection at planned injection site, presence of pacemaker at the site (U/S technique may not be possible due to limitation of probe placement), preexisting neurologic defects, local anesthetic allergy, coagulopathy.
- **Complications:** LA toxicity, infection, bleeding, hematoma, pneumothorax, and nerve injury.

Landmark Technique

Vertical Infraclavicuar Block The landmarks required for the block are anterior process of the acromion, jugular notch, and the subclavian artery; and coracoid process and the medial clavicular head. The patient is positioned supine with the head tuned to the opposite side and arm abducted and flexed at the elbow. The coracoid process can be identified by palpating the bony prominence just medial to the shoulder by elevating and lowering the arm. The coracoid process meets the fingers of the palpating hand as the arm is lowered. Mark the medial clavicular head and draw a line joining these 2 points. The needle insertion point is 3 cm caudal to the mid point of the line joining the coracoid process and the medial clavicular head. The goal is to achieve a hand twitch using a current of 0.2–0.5 mA.

Ultrasound Technique

The patient can be positioned anywhere from supine to sitting position, and abduction of the arm will bring the artery and plexus closer to the skin. The transducer is placed just medial to the coracoid process with its cranial end below the clavicle. The pectoralis major and minor muscles are identified just above the plexus and vessels. The probe is rotated and moved as needed to obtain a transverse image of the artery. The 3 cords of the brachial plexus appear as hyperechoic circles surrounding the artery. The lateral cord is the closest to the coracoid; the posterior cord is deep to the artery; while the medial cord is the furthest from the coracoid and sometimes lies between the artery and the vein.

Once the structures of interest are identified, the needle is inserted in-plane from the superior or inferior end of the transducer. The aim of the block is to surround each cord with local anesthetic, often achieved by injecting local anesthetic around the artery. Appropriate needle position is confirmed by the spread of the local anesthetic around the artery, dissecting the cords away from the artery. The steep angle of the needle for this deep block severely compromises the needle visualization. This can be improved by applying extra pressure on the probe and often injecting small amount of local anesthetic solution also improves needle visualization.

1.2.4 Axillary Block

The axillary block is one of the most commonly used regional anesthesia techniques. This block aims to block the terminal branches of the brachial plexus, which include the median, radial, ulnar and musculocutaneous nerves. It is achieved by injecting local anesthetic around the axillary artery as median, ulnar, and radial nerves are all located within the neurovascular sheath. A separate injection is needed to block the musculocutaneous nerve.

- **Indications:** Surgeries on hand, elbow, and some forearm operations.
- **Contraindications:** Patient refusal, infection at planned injection site, preexisting neurologic defects, local anesthetic allergy, coagulopathy.
- **Complications:** LA toxicity, infection, bleeding, hematoma, and allergic reaction.

Landmark Technique

Surface landmarks required for the axillary brachial plexus block are the axillary artery pulsation, coracobrachialis muscle, and the pectoralis major muscle. With the patient positioned supine and arm abducted at 90° and the axillary arterial pulsation as a point of reference, the median nerve is positioned superficially and immediately above the pulse; the ulnar nerve is found superficial slightly deeper than the median nerve; the radial nerve is located behind the pulse. The musculocutaneous nerve can be found 1–3 cm deeper and above the pulse, often outside the brachial plexus sheath as it moves distally away from the axillary fossa.

Once the axillary artery pulse is felt, the artery is fixed between the index and middle finger, pressed firmly against the humerus. The needle is advanced directly below the pulse until a radial nerve twitch is obtained, and local anesthetic is injected. The needle is withdrawn and reinserted above the artery and advanced slowly; median nerve twitch should be encountered first and on further advancement ulnar twitch should appear. Inject local anesthetic at both these points. The needle is finally brought back to skin and redirected into the coracobrachialis muscle until the tip is close to the musculocutaneous nerve. This is confirmed by the disappearance of the local coracobrachialis twitch and appearance of biceps twitch. Inject the last portion of the local anesthetic dose here.

Ultrasound-Guided Technique

The patient position is the same as the landmark technique. Palpate the pectoralis major muscle at its insertion into the humerus and place the transducer immediately distal to it and perpendicular to the axis of the arm. Slide the transducer to locate the axillary artery and brachial plexus if not already visualized. Identify the individual nerves and insert the needle in-plane from the cephalad direction toward the posterior aspect of the axillary artery. Local anesthetic should be deposited posterior to the artery first covering the radial nerve. The needle is then withdrawn and redirected superior to the artery and local anesthetic is injected around the median and ulnar nerves. Finally, the musculocutaneous nerve is anesthetized by injecting local anesthetic around it in the coracobrachialis muscle. Frequent aspiration, slow administration of local anesthetic, and avoiding injection at high pressure are critical to decrease the risk of intravascular injection and nerve injury.

1.3 Lower Limb Blocks

1.3.1 Femoral Nerve Block

The femoral nerve block is an essential block that is easy to learn, low risk with minimal complications. It is useful for surgery on the anterior thigh and knee, quadriceps tendon repair, and postoperative pain management of femur and knee surgery. It is frequently combined with other lower extremity blocks, such as sciatic and obturator blocks, to achieve anesthesia of almost the entire lower extremity.

- **Anatomy:** The femoral nerve is the largest branch of the lumbar plexus and travels through the pelvis in the groove between the psoas and iliacus muscle. It emerges beneath the inguinal ligament, posterolateral to the femoral vessels (Fig. 1.3). At the femoral crease, the nerve is on the surface of the iliacus muscle and covered by the fascia iliaca or sandwiched between 2 layers of fascia iliaca. It divides into its branches at or above the level of the inguinal ligament.
- **Indications:** Surgery on anterior thigh, knee, quadriceps tendon, and in combination with sciatic and obturator blocks for distal limb and foot surgery.

Landmark Technique

The patient is positioned supine with both legs extended and the operator should stand on the same side of the patient. Identify the landmarks anterior superior iliac spine and the pubic tubercle, and draw a line joining the 2 points (Fig. 1.4). Palpate the femoral artery on this line and insert the needle perpendicularly, just lateral to the femoral artery pulsations. A visible or palpable

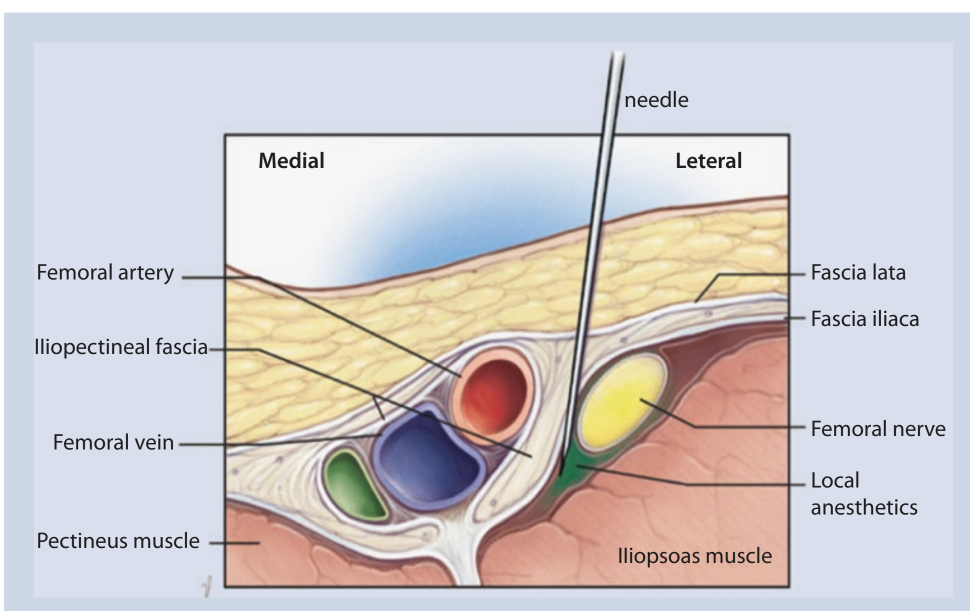

Fig. 1.3 Femoral nerve anatomy (Reprinted with permission from Farag and Brown [5])

Fig. 1.4 Femoral nerve block – landmark technique (Reprinted with permission from Farag and Brown [5])

twitch of the quadriceps muscle or the patella at 0.2–0.4 mA is the most reliable nerve stimulator response. It is very common to get a sartorius muscle twitch as the nerve to the sartorius muscle branch from the anteromedial aspect of the femoral nerve may be lying outside the iliacus fascia. When injecting local anesthetic, accepting the sartorius muscle twitch results in inconsistent block success, hence it should not be accepted in landmark/nerve stimulation technique.

Ultrasound Technique

The patient is positioned supine and the ultrasound probe is placed parallel to the inguinal crease. Sliding the transducer medially and laterally, identify the femoral artery and trace upward to the common femoral artery if profunda femoris branch is seen on the initial scan. Immediately lateral to the vessel, and deep to the fascia iliaca is the femoral nerve, which is typically hyperechoic and roughly triangular or oval in shape. Once the femoral nerve is identified the needle is inserted in-plane from a lateral to medial orientation. The goal is to place the needle tip below the fascia iliaca, immediately adjacent to the lateral aspect of the femoral nerve. The correct placement is confirmed by the spread of the local anesthetic in the wedge-shaped tissue space lateral to the femoral artery, either lifting the femoral nerve off the iliopsoas or the spread above the nerve lateral to the artery.

1.3.2 Sciatic Nerve Block

The sciatic nerve is the largest nerve trunk in the body and arises from the sacral plexus. It exits the pelvis posteriorly via the greater sciatic notch and descends into the thigh between the greater trochanter and the ischial tuberosity. The sciatic nerve provides sensory and motor supply to most of the lower leg via its terminal branches (tibial and common peroneal).

Landmark/Nerve Stimulator Techniques

Posterior Approach (Labat) [4] The patient is placed in Sim's position (lateral decubitus position with the upper operative leg flexed to 90° at hip and knee. The landmarks are the greater trochanter (GT), posterior superior iliac spine (PSIS), and the sacral hiatus. Draw the first line joining the greater trochanter and the PSIS and mark a midpoint on the line. Draw a second line joining the greater trochanter and the sacral hiatus. Now drop a line perpendicularly from the midpoint of the first line, and the point of needle insertion is where it crosses the second line. The needle is inserted perpendicular to the skin surface and any motor stimulation of the sciatic nerve (hamstring, calf foot, or toe twitches) is acceptable and inject local anesthetic.

Inferior Approach (Raj) The patient is positioned supine and the hip and knee are flexed to 90°. Identify and draw a line joining the greater trochanter and the ischial tuberosity. Mark a point half way in the groove between the hamstrings and the adductor muscles. Insert the needle perpendicular to the skin with a slight medial intent to get the sciatic motor response.

Anterior Approach (Beck) The anterior sciatic nerve block can be performed when the patient cannot be positioned laterally due to postoperative pain, trauma, or the presence of external fixation devices. The patient is positioned supine. Identify and draw a line joining the anterior superior iliac spine and the pubic tubercle. Draw another line parallel to the first one from the greater trochanter (Fig. 1.5). The point of needle insertion

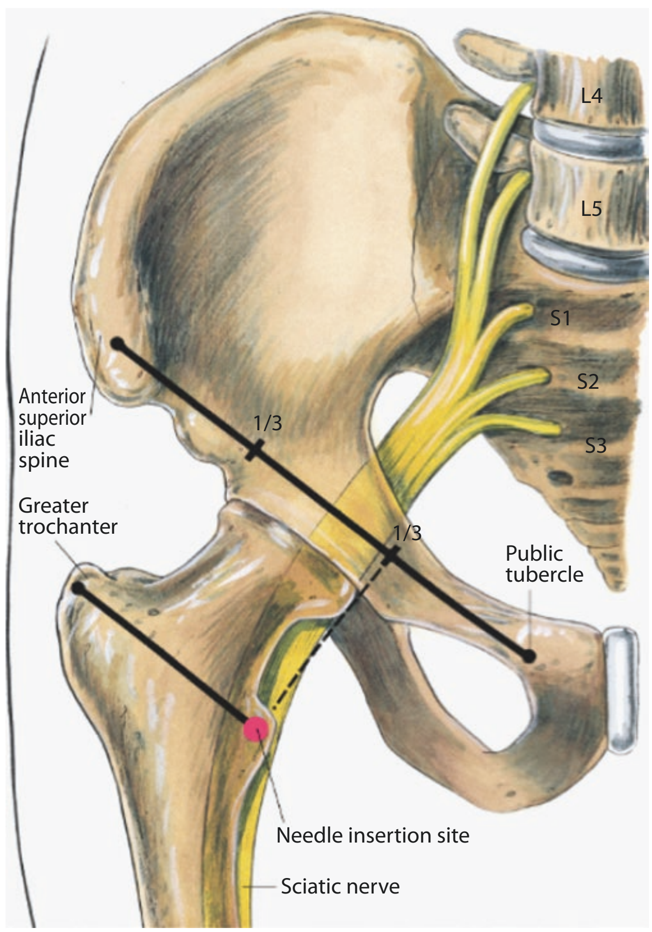

Fig. 1.5 Anterior sciatic nerve block (Reprinted with permission from Farag and Brown [6])

is where a perpendicular line from the junction of the medial and middle third of the first line meets the second line. Insert the needle perpendicularly until it contacts the femur. Now redirect slightly medially to slide off the femur and advance a few centimeters to get a motor response. In a few patients the sciatic nerve lies immediately posterior to the femur and may be inaccessible. A slight external rotation of the limb can overcome this problem.

Ultrasound Technique

The use of ultrasound guidance facilitated multiple approaches at several convenient levels to block the sciatic nerve. The common sites are the transgluteal/subgluteal and the anterior approaches.

Anterior Approach The anterior sciatic nerve block is ideally suited for postoperative patients requiring additional block as positioning them laterally is not easy. The ultrasound guidance not only reduces the risk of vascular injury, it eliminates the need for use of precise geometry to identify the needle entry point. The patient is positioned supine with slight abduction and external rotation of the thigh. The sciatic nerve is imaged approximately at the level of the minor trochanter. At this location, a curved transducer placed over the anteromedial aspect of the thigh will reveal the musculature of all 3 fascial compartments of the thigh: anterior, medial, and posterior. Beneath the superficial sartorius muscle is the femoral artery, and deep and medial to this vessel is the profunda femoris artery. Both of these can be identified with color Doppler ultrasound for orientation. The femur is easily seen as a hyperechoic rim with the corresponding shadow beneath the vastus intermedius. Medial to the femur is the body of the adductor magnus muscle, separated by the fascial plane(s) of the hamstrings muscles. The sciatic nerve is visualized as a hyperechoic, slightly flattened oval structure sandwiched between these 2 muscle planes and is typically visualized at a depth of 6–8 cm. The needle is inserted in-plane or out of plane from the medial aspect of the thigh and advanced toward the sciatic nerve avoiding the femoral vessels. Once the needle tip is close to the nerve or in the fascial plane between the adductors and the hamstrings when the nerve is not clearly visualized, 1–2 mL of local anesthetic is injected to confirm the adequate distribution of the local anesthetic and the rest of the dose in injected in divided doses after negative aspiration.

Posterior Approach (Transgluteal/Subgluteal) The sciatic nerve can be easily identified between the greater trochanter and ischial tuberosity, beneath a well-defined muscle plane. The nerve also can be traced backward from the popliteal region in difficult cases. The approach and the actual site of the block is based on the patient's anatomic characteristics and personal preference.

A low frequency curvilinear probe is used to identify the bony landmarks at the transgluteal level. The sciatic nerve is located deep to the gluteus muscle, slightly closer to the ischial tuberosity, and appears as an oval or triangular hyperechoic structure. At the subgluteal level the nerve is located deep to the long head of the biceps muscle and the posterior surface of the adductor magnus. The needle is inserted in-plane typically from the lateral side and advancer toward the nerve. Once in the desired location 1–2 cc of local anesthetic is injected after negative aspiration. Often the nerve is better visualized after the initial injection of local anesthetic and moves away from the needle. The rest of the local anesthetic is injected in divided doses after negative aspiration and absence of high resistance to injection.

1.3.3 Popliteal Sciatic Nerve Block

The popliteal block is essentially a block of the sciatic nerve in the popliteal fossa. Sciatic nerve is a nerve bundle that consists of 2 separate nerve trunks: the tibial and the common peroneal nerves. They diverge in the popliteal fossa about 4–10 cm above the popliteal crease (Fig. 1.6). It is a commonly performed block for surgery on the ankle and foot. The addition of saphenous nerve block to cover the medial lower leg and ankle gives complete analgesia for ankle and foot surgery.

- **Indications**: Ankle and foot surgery, Achilles tendon repair.

Landmark Techniques

Lateral Popliteal Approach The landmarks are popliteal fossa crease, vastus lateralis, and biceps femoris muscles. This block is performed with the patient supine and thus has the advantage of not requiring to place the position prone. The foot on the side to be blocked is positioned elevated to facilitate easy visualization of muscle twitch.

The groove between the vastus lateralis and the biceps femoris muscles is palpated and a point in the groove, approximately 7 cm above the popliteal crease or at the level of superior border of patella, is marked for needle point. The needle is inserted perpendicular to the leg into the groove and advanced to contact the femur. The needle is withdrawn to skin and redirected 30° posteriorly to locate the nerve with nerve stimulator. Once the desired muscle twitch is obtained the calculated dose of local anesthetic is injected after negative aspiration.

Posterior Approach The landmarks used are the popliteal crease, semimembranosus, and the biceps femoris. The patient is positioned prone for this approach with the leg resting on a pillow. The knee is flexed to mark the popliteal crease. Trace the biceps femoris laterally and semimembranosus medially and find the apex of the popliteal fossa. Drop a line from the apex of the fossa to the middle of the popliteal crease and mark a point 5–7 cm proximal and 1 cm lateral to popliteal crease for needle entry (Fig. 1.7).

Ultrasound-Guided Technique

The level at which the sciatic nerve divides into tibial and common peroneal nerve is so variable in individuals that one of the components can be easily missed in the isolated nerve stimulation/landmark technique. The ultrasound guidance correctly identifies the level of division and the local anesthetic can be

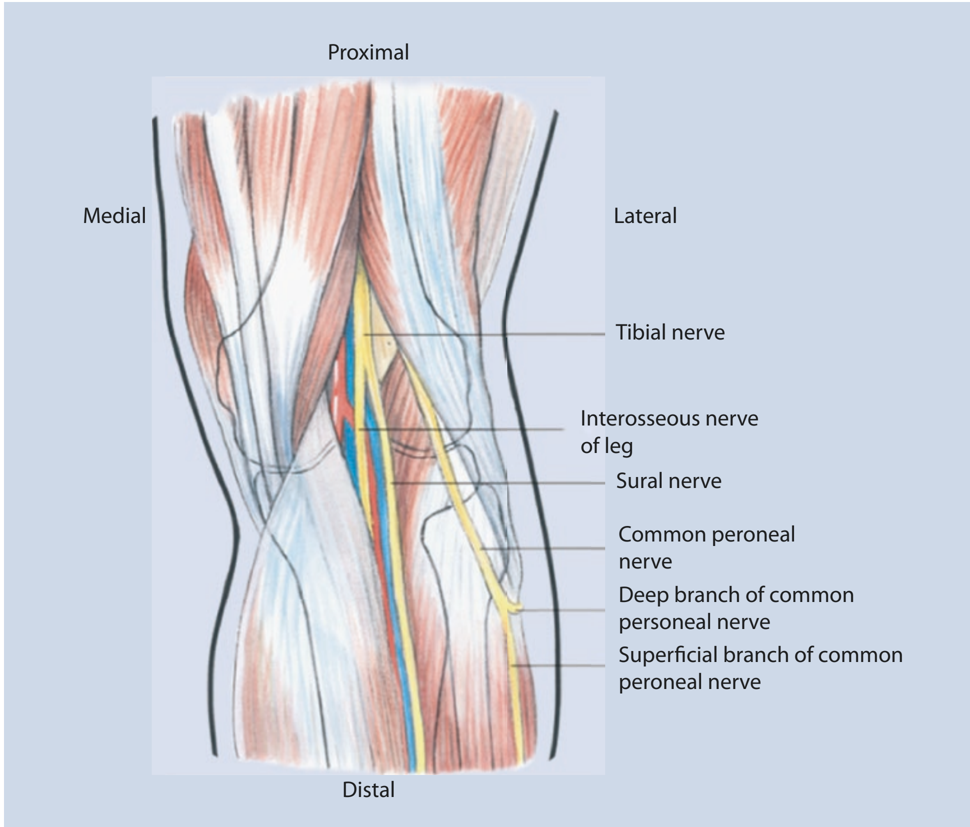

Fig. 1.6 Popliteal sciatic nerve block (Reprinted with permission from Yared and Brown [7])

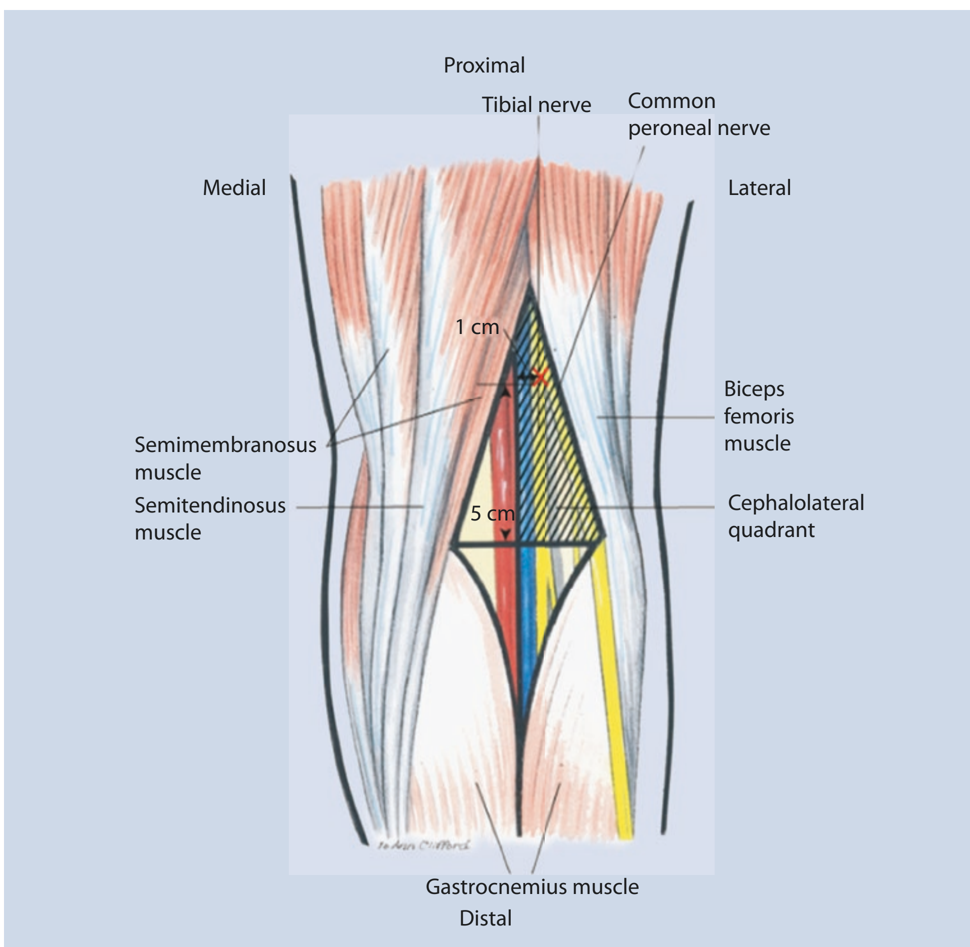

Fig. 1.7 Popliteal sciatic nerve block – posterior approach (Reprinted with permission from Yared and Brown [7])

deposited to cover both the divisions. A linear transducer is placed in the popliteal crease to identify the popliteal artery. The tibial nerve can be identified superficial and lateral to the artery as a hyperechoic oval or round structure with honeycomb pattern. Sliding the transducer proximally will identify the common peroneal nerve laterally and can be visualized coming together to form the sciatic nerve before the division.

Ultrasound-guided block can be performed in prone, lateral, or supine (with elevation of the leg/flexing the knee and hip to create enough space to place the transducer beneath the knee). Once the nerve is identified, the needle is inserted in-plane avoiding the vascular structures. Local anesthetic is injected close to the nerve, repositioning the needle as needed, and injecting in divided doses to ensure adequate circumferential spread around the nerve.

1.3.4 Ankle Block

Ankle block is a simple, easy-to-perform procedure that is highly effective for surgeries involving the foot and toes. It involves blocking the 4 terminal branches of the sciatic nerve (deep and superficial peroneal, tibial, and sural) and the terminal branch of the femoral nerve (saphenous). The ankle block will not provide analgesia/anesthesia for the ankle itself; a popliteal nerve block supplemented by saphenous nerve block is required for surgery on the ankle.

The posterior tibial and the deep peroneal are the 2 deep nerves that need injection underneath the fascia, while the 3 superficial nerves (saphenous, sural, and the superficial peroneal) are anesthetized by subcutaneous infiltration.

- **Indications**: Surgery on the foot and toes including podiatry surgery, foot/toe debridement/amputation.
- **Complications**: Bleeding/hematoma, nerve injury, vascular injury.

Landmark Technique

The deep peroneal nerve is located immediately lateral to the tendon of the extensor hallucis longus muscle (between the extensor hallucis longus and the extensor digitorum longus). The pulsations of the dorsalis pedis artery are felt here; the nerve is positioned immediately lateral to the artery. With the finger positioned in the groove just lateral to the extensor hallucis longus, the needle is inserted under the skin and advanced until the bone is contacted. From the bone, the needle is withdrawn 1–2 mm, and 2–3 mL of local anesthetic is injected (Fig. 1.8).

From the same needle entry point, advance the needle subcutaneously laterally and medially to the malleoli, injecting 3–5 ml in each direction. These lateral and medial infiltrations block the superficial peroneal and the saphenous nerves respectively. The sural nerve is blocked by infiltrating local anesthetic between the lateral malleolus and the Achilles tendon.

The posterior tibial nerve is located just behind and distal to the medial malleolus. The pulse of the posterior tibial artery can be felt at this location; the nerve is just posterior to the artery. The needle is inserted in the groove behind the medial malleolus below the pulse of the tibial artery and advanced to contact the bone. Once bone is contacted, the needle is withdrawn 1–2 mm and local anesthetic is injected after negative aspiration.

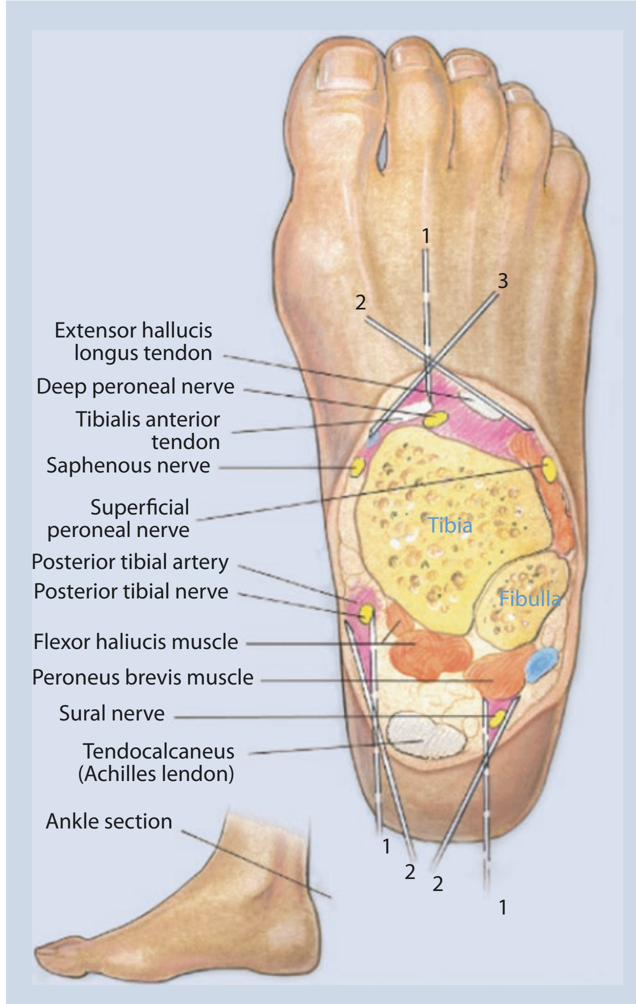

Fig. 1.8 Ankle block (Reprinted with permission from Brown [8])

Ultrasound-Guided Technique

The tibial nerve is the largest of the 5 nerves to be blocked and can be easily identified using ultrasound. A linear transducer placed just proximal to the medial malleolus will identify the tibial nerve immediately posterior to the tibial artery. In difficult cases color Doppler can identify the artery and injecting local anesthetic just behind the artery will block the tibial nerve.

The deep peroneal nerve can be identified with a transducer placed transversely at the level of the ankle and appears as a small hyperechoic structure. It is small and often not easily identified, but the dorsalis pedis artery can be identified and local anesthetic injected next to it to achieve the block. Sural nerve and saphenous nerve are small hyperechoic structures that may be seen next to the saphenous veins.

1.3.5 Transversus Abdominis Plane (TAP) Block

The transversus abdominis plane (TAP) block was first described as a landmark-guided technique involving needle insertion at the triangle of Petit. It has been shown to provide good postoperative analgesia for a variety of procedures.

- **Indications**: Postoperative analgesia for laparotomy, appendectomy, laparoscopic surgery, ileostomy closure, abdominoplasty, and cesarean delivery; as an alternative to epidural anesthesia for operations on the abdominal wall.
- **Complications**: Bowel perforation/hematoma, infection, intravascular injection, liver laceration. The complications are very rare and the use of ultrasound has further minimized the complications.

The anterior abdominal wall (skin, muscles, and parietal peritoneum) is innervated by the anterior rami of the lower 6 thoracic nerves (T7-T12) and the first lumbar nerve (L1). Terminal branches of these somatic nerves course through the lateral abdominal wall within a plane between the internal oblique muscle (IOM) and transversus abdominis muscle. This intermuscular plane is called the transversus abdominis plane. Injection of local anesthetic within the TAP can result in unilateral analgesia to the skin, muscles, and parietal peritoneum of the anterior abdominal wall.

Landmark Technique

The triangle of Petit is an area bounded by the latissimus dorsi muscle posteriorly, the external oblique muscle (EOM) anteriorly, and the iliac crest inferiorly. A needle is inserted perpendicular to all planes, looking for a tactile endpoint of 2 pops. The first pop indicates penetration of the external oblique fascia and entry into the plane between external and internal oblique muscles; the second pop signifies entry into the TAP plane between the internal oblique and transversus abdominis muscles.

Ultrasound Technique

The probe is placed transversely on the abdomen, at the anterior axillary line, between the costal margin and the iliac crest. The 3 muscle layers should be identified and TAP plane located (Fig. 1.9). Once the transverse abdominal plane is identified, a skin wheal is made 2–3 cm medial to the medial aspect of the transducer, and the needle is inserted in-plane in a medial to lateral orientation. The needle penetrates through the subcutaneous tissue, EOM, and IOM. As the needle enters the TAP plane a "pop" may be felt. After gentle aspiration, 1–2 mL of local anesthetic is injected to verify the location of the needle tip. When injection of the local anesthetic appears to be intramuscular, the needle is advanced or withdrawn carefully 1–2 mm and another bolus is administered. This gesture is repeated until the correct plane is achieved. At least 20 cc of LA is required to achieve a satisfactory block.

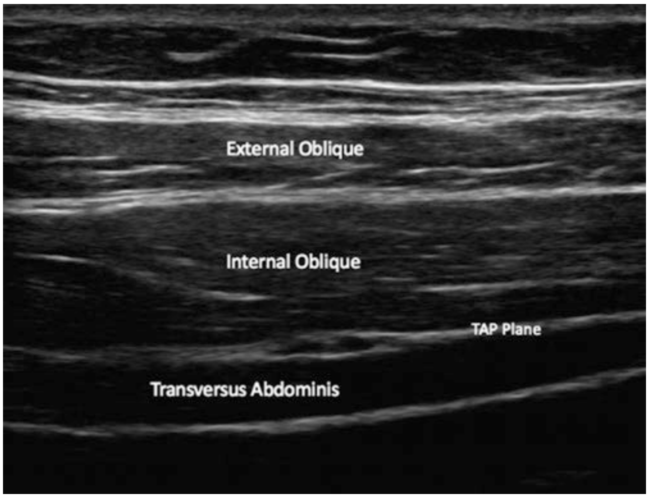

Fig. 1.9 Transversus abdominis plane (TAP) block – ultrasound technique

1.4 Questions and Answers

Questions (Choose the Most Appropriate Answer)

1. A 36-year-old female complains of pain along her medial forearm and hand postoperatively after open reduction internal fixation (ORIF) of a humerus fracture. She received a preoperative interscalene block. Which nerve would have possibly been missed in the block?
   A. Radial nerve
   B. Ulnar nerve
   C. Intecostobrachial nerve
   D. Median nerve
   E. Musculocutaneous nerve
2. A 46-year-old male received an interscalene block for a left shoulder arthroplasty resulting in a dense block along his arm, hand, and the majority of his shoulder except the upper portion. What can be done to supplement the block?
   A. Injecting LA around the C3 to C4 nerve roots
   B. Injecting LA around C8 to T1 nerve roots
   C. Perform an intecostobrachial block
   D. Repeating the interscalene block
   E. None of the above
3. What patient population is most susceptible to the adverse events from an interscalene nerve block?
   A. 62-year-old male smoker with severe chronic obstructive pulmonary disease (COPD)
   B. 37-year-old male with sickle cell trait
   C. 21-year-old female with exercise-induced asthma
   D. 75-year-old male with mild coronary artery disease
   E. 25-year-old female in her first trimester of pregnancy