Chapter 1

Anatomy

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Head and Neck

Vasculature

Internal Jugular Vein (IJV)

- Drains blood from the head, face, and brain.
- Lies deep to the sternocleidomastoid (SCM) muscle and lateral to the carotid artery, coursing inferiorly to join the subclavian vein to become the brachiocephalic (also known as innominate) vein.

External Jugular Vein (EJV)

- Carries blood from the face.
- Lies superficial to the SCM as it crosses obliquely from the angle of the mandible and dives posterior to the clavicle to join the subclavian vein.

Subclavian Vein (SCV)

- Posterior to the clavicle but anterior to the insertion of the anterior scalene muscle on the first rib (Figure 1.1).

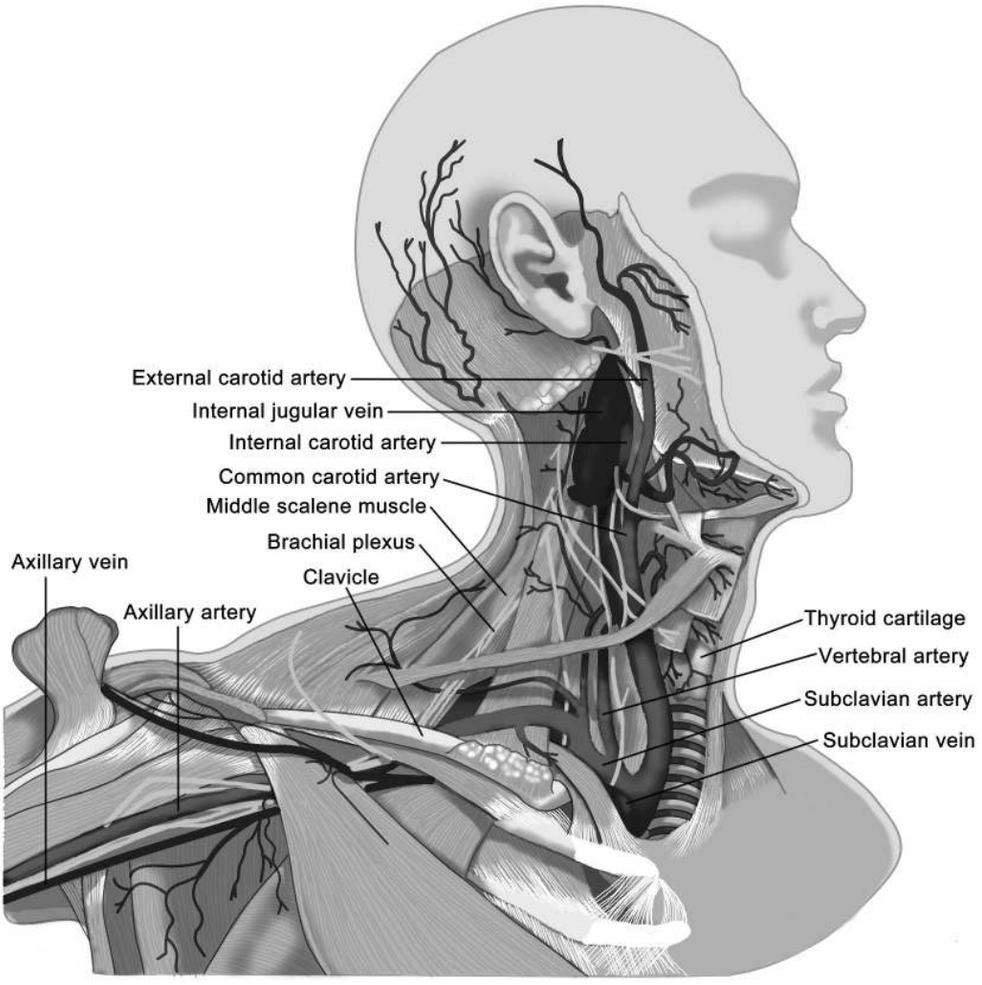

Figure 1.1 Normal anatomical relationships of the major vessels, nerves, bones, and muscles of the neck and axilla. A black and white version of this figure will appear in some formats. For the color version, please refer to the plate section.

Vertebral Artery

- Branches from the subclavian artery, traveling cephalad to enter the spine deep to Chassaignac's tubercle.
- Travels through the transverse foramen of C1–C6 vertebrae before forming the basilar artery, supplying the posterior circle of Willis.
- Can inject into during interscalene block, causing seizures.

Carotid Artery

- Arises from brachiocephalic artery on the right, and aortic arch on the left.
- Bifurcates into internal and external carotid arteries at the level of C4 vertebra.
  - Carotid sinus:
    - Located at bifurcation of carotid artery.
    - Compression during carotid endarterectomy can cause a baroreceptor reflex resulting in bradycardia.

Thoracic Duct

- Lymphatic drainage of the body into the venous system.
- Formed at L2 level, ascends between aorta and azygos vein, crosses diaphragm posterior to esophagus.
- Crosses from right to left at T4–T5 and empties into the SCV just lateral to the IJV.
- Can be damaged during attempts for central access to the left SCV or IJV, leading to chylothorax.

Surface Landmarks

Thyroid Cartilage

- Motor and sensory innervation to the larynx is derived from CN X (vagus nerve) via the superior, inferior, and the recurrent laryngeal nerves bilaterally.
- Musculature of the larynx is innervated entirely by the recurrent laryngeal nerve except for the cricothyroid muscle, which is innervated by the external branch of the superior laryngeal nerve.

Cricothyroid Membrane

- Palpable as a soft, flat membrane in the anterior neck at the level of C6 between the rigid thyroid cartilage superiorly and cricoid cartilage inferiorly.
- Can be punctured with a needle, allowing for transtracheal injection of local anesthetic, insertion of a wire for retrograde intubation, or percutaneous cricothyroidotomy.

Chassaignac's Tubercle

- Name for the anterior tubercle of the transverse process of C6.
- Lies between the carotid artery anteriorly and the vertebral artery posteriorly.
- Used to identify the appropriate location to perform stellate ganglion blockade.

Vertebra Prominens

- Another name for spinous process of the C7.
- This spinous process is the most prominent in the majority of patients.

Stellate Ganglion

- Named for its "star-like" appearance.
- Is formed by the fusion of the inferior cervical and first thoracic sympathetic ganglia.
- Located lateral to the vertebral body of C7.
- Blockade of this structure is useful for the treatment of complex regional pain syndrome (CRPS) or Raynaud's phenomenon.
  - Side effect associated with stellate ganglion blockade is Horner's Syndrome (e.g., ptosis, anhidrosis, miosis), and may frequently occur following brachial plexus nerve blocks.

Brachial Plexus

- Provides sensory and motor innervation to the upper extremity.
- Courses between the anterior and middle scalene muscles in the neck before running down the arm.

Radiological Anatomy

See Figure 1.2.

Chest

Surface Landmarks

Trachea

- Begins at C6 and continues inferiorly until it bifurcates into the right and left main bronchi at the *carina*.
- This bifurcation occurs at the level of the *sternal angle*, or *angle of Louis*, which is the joint between the sternum and manubrium.

Lungs

- Are divided into their lobes by fissures.
- Three lobes on the right and two lobes on the left plus the lingual.
- Fissures
  - Bilaterally, the *oblique fissure* divides the *superior and inferior lobes* on the left and *superior and middle lobes* on the right.
  - The oblique fissures begin posteriorly at the level of T4, traveling caudally and laterally, and then around the

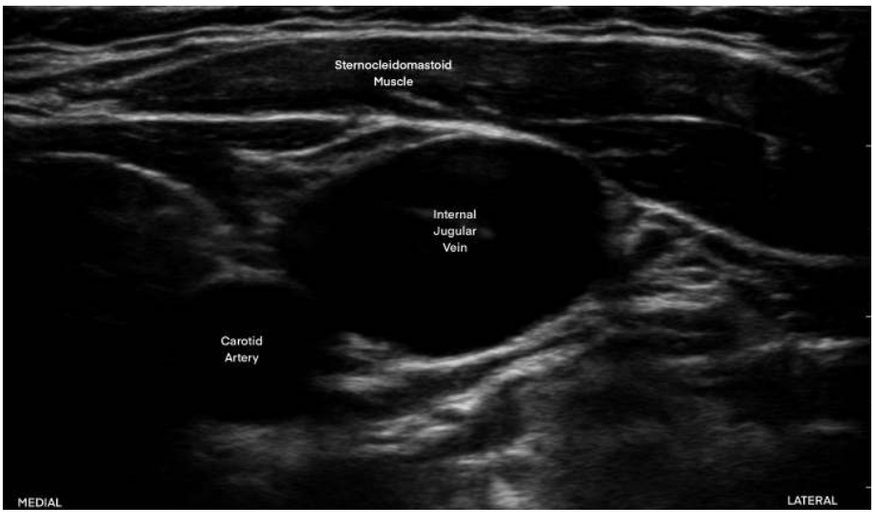

Figure 1.2 Ultrasound image of the lateral neck, displaying the internal jugular vein and the carotid artery.

torso to terminate anteriorly at approximately the level of the seventh rib on the midclavicular line.
- The right lung is divided a second time by the *horizontal fissure*, which begins anteriorly at approximately the fourth costal cartilage and traverses laterally to the anterior axillary line, where it intersects with the oblique fissure at the level of the fifth rib. This fissure demarcates the border between the inferior and middle lobes.

Heart

- **Point of maximal impulse (PMI)**
  - Landmark for the apex of the heart is the fifth intercostal space in the midclavicular line.
- **Coronary arteries**
  - Left and right main arise from the left and right aortic valve leaflets respectively.
  - Left main divides into the left anterior descending (LAD) and the circumflex (LCX).
  - LAD supplies the anterior wall of the left ventricle (LV) and the anterior two-thirds of the interventricular septum (IVS).
  - LCX supplies the lateral wall of the LV and part of the posterior wall.
  - Right coronary artery (RCA)
    - Supplies most of the right ventricle (RV) and usually both sinoatrial (SA) and atrioventricular (AV) nodes.
      - LAD supplies the apex of the RV.
      - Right atrium
      - Upper half of the interatrial septum
      - Posterior third of IVS
      - Inferior wall of LV
  - Posterior descending artery (PDA) arises from RCA in approximately 80% of patients. This is called "right-dominant" circulation.

Radiological Anatomy

See Figure 1.3.

Upper and Lower Extremities

Upper Extremity Vasculature

Basilic Vein

- Travels from the medial posterior forearm at the ulnar head proximally to the anterior elbow, where it lies *medial to the tendon of the biceps brachii muscle.*
- Becomes the axillary vein at the border of the *teres major muscle.*
- Becomes the subclavian vein at the outer border of the first rib.

Cephalic Vein

- Begins laterally at the wrist within the *anatomic snuffbox* – a triangle formed by the *radial head*, the *extensor pollicis longus tendon* and the *extensor pollicis brevis tendon.*
- At the elbow it is commonly found lateral to the biceps tendon. It then continues proximally in the arm lateral to the biceps brachii muscle before crossing anterior to the deltoid and diving deep to join with the axillary vein under the clavicle.

Axillary Artery

- Direct continuation of the subclavian artery, begins at the border of the 1st rib, coursing laterally until the border of the *teres muscle* where it becomes the brachial artery.

Brachial Artery

- The pulsation is typically felt just *medial to the biceps brachii tendon* at the cubital fossa.
- Subsequently bifurcates into the *radial and ulnar arteries* (Figure 1.4).

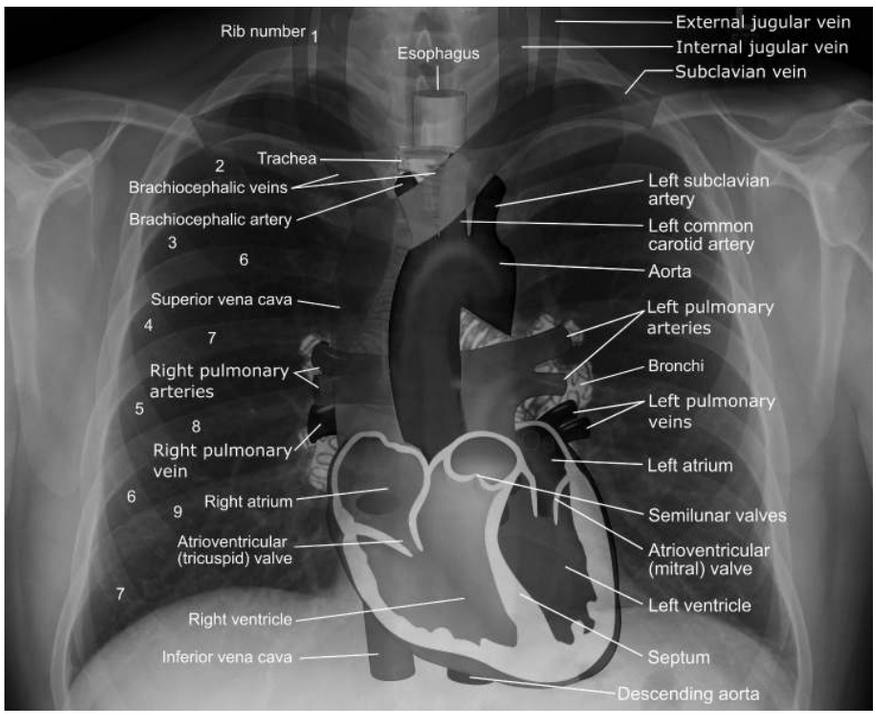

Figure 1.3 Normal radiograph of the chest. Superimposed on this image are outlines of some of the major topographical landmarks of the chest. A black and white version of this figure will appear in some formats. For the color version, please refer to the plate section.

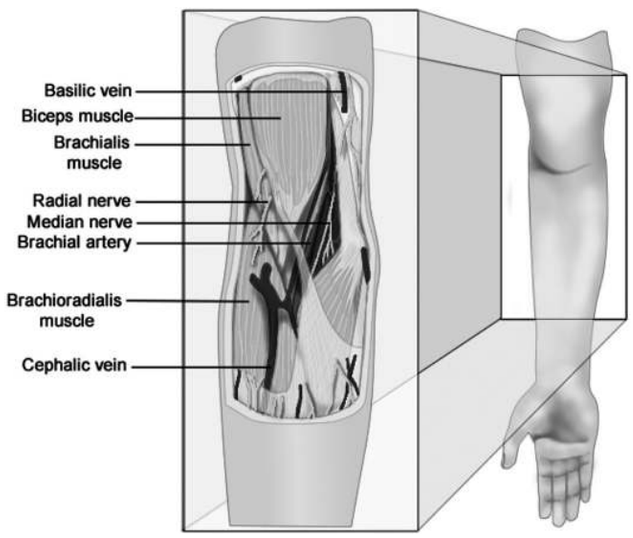

Figure 1.4 Normal anatomical relationships of the major vessels and nerves, bones, and muscles of the antecubital fossa. A black and white version of this figure will appear in some formats. For the color version, please refer to the plate section.

Upper Extremity Innervation

Brachial Plexus

- A complex network of nerves formed by ventral rami of *C5–T1*.
- Provides sensory and motor innervation of the upper extremities. Clinically, the anesthesiologist can provide surgical anesthesia to the upper extremity via blockade of the brachial plexus (see Table 1.1).
- ROOTS: exit the spinal column via the intervertebral foramen.
- TRUNKS: *roots* (C5–T1) combine to form the *trunks*, which lie between the anterior and middle scalene muscles.
  - *Superior trunk (C5–C6)* gives rise to the *suprascapular nerve*, which innervates 70% of the shoulder joint. Of the brachial plexus blocks, the interscalene block (ISB) is the only one that blocks this nerve. It is also the only block that can be used for shoulder surgery without supplementation.
  - *Middle trunk* is formed by the C7 nerve root.
  - *Inferior trunk* is formed by the C8 and T1 nerve roots.
  - *Roots/trunks* are blocked for the interscalene block.

Table 1.1 Upper extremity nerve block landmarks

Interscalene (i.e., brachial plexus: roots)	Between anterior and middle scalene muscles at level of C6
Supraclavicular (i.e., brachial plexus: trunks/divisions)	Lateral to the clavicular attachment of the sternocleidomastoid
Infraclavicular (i.e., brachial plexus: cords)	3 cm caudal to the midpoint of a line between the coracoid process and the medial clavicle
Axillary (i.e., brachial plexus: branches)	At the point of palpation of the axillary artery
Radial nerve	Between the brachioradialis and the biceps tendon
Ulnar nerve	Between the medial epicondyle and olecranon
Median nerve	Medial to the brachial artery at the antecubital fossa

- Due to proximity, *the phrenic nerve, stellate ganglion, superficial cervical plexus, recurrent laryngeal nerve and CN XI* are frequently blocked with ISB.
- DIVISIONS: *trunks* split into *anterior and posterior divisions*.
- CORDS: *divisions* recombine into the *lateral, medial and posterior cords*, which are named for their relationship to the *subclavian artery*.
- BRANCHES: *cords* split further to form the terminal *branches*.
  - There are five terminal branches of the brachial plexus, including:
    - axillary nerve (C5–C6)
    - musculocutaneous nerve (C5–C7)
    - radial nerve (C5–T1)
    - median nerve (C5–T1)
    - ulnar nerve (C8–T1)

Intercostobrachial Nerve

- Derived from the T2 intercostal nerve to innervate the skin of the axilla and medial upper arm.
- If not blocked, patient may experience tourniquet pain (Figure 1.5).

Lower Extremity Vasculature

Small Saphenous Vein

- Begins posterior to the lateral malleolus and extends proximally on the posterior lower leg until the popliteal fossa, where it drains into the popliteal vein.

Popliteal Vein

- Lies between the popliteal artery and the tibial nerve at the popliteal fossa (see Figure 1.5).
- The popliteal vein continues proximally through the adductor magnus muscle, where it becomes the femoral vein.

Great Saphenous Vein

- Longest vein the body. Typically found superficially anterior to the medial malleolus.
- Commonly cannulated in pediatrics for peripheral venous access.
- Courses proximally on the medial surface of the leg before entering the fossa ovalis to empty into the femoral vein on the anterior thigh near the inguinal crease.

Femoral Artery

- Arises as the direct continuation of the *external iliac artery*.
- Lies just lateral to the femoral vein at the inguinal ligament.
- Divides into superficial femoral artery and profunda femoris (also known as the deep artery of the thigh).
  - The profunda femoris provides vascular supply to the structures of the thigh.
  - The superficial femoral artery courses posteriorly and distally resurfacing at the popliteal fossa as the popliteal artery.

Popliteal Artery

- Divides into two branches: anterior and posterior tibial arteries.
- Anterior tibial artery:

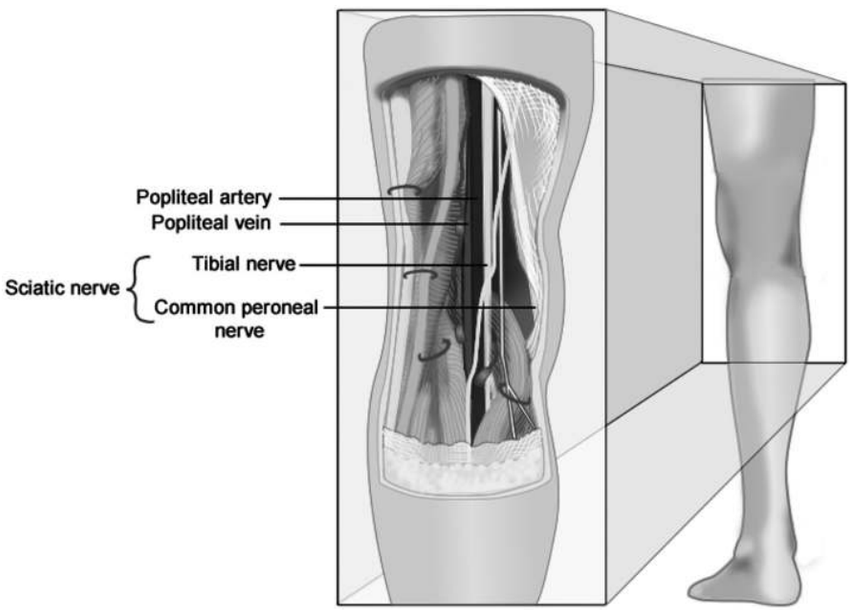

Figure 1.5 Normal anatomical relationships of the major vessels, nerves, bones, and muscles of the popliteal fossa (medial to lateral). A black and white version of this figure will appear in some formats. For the color version, please refer to the plate section.

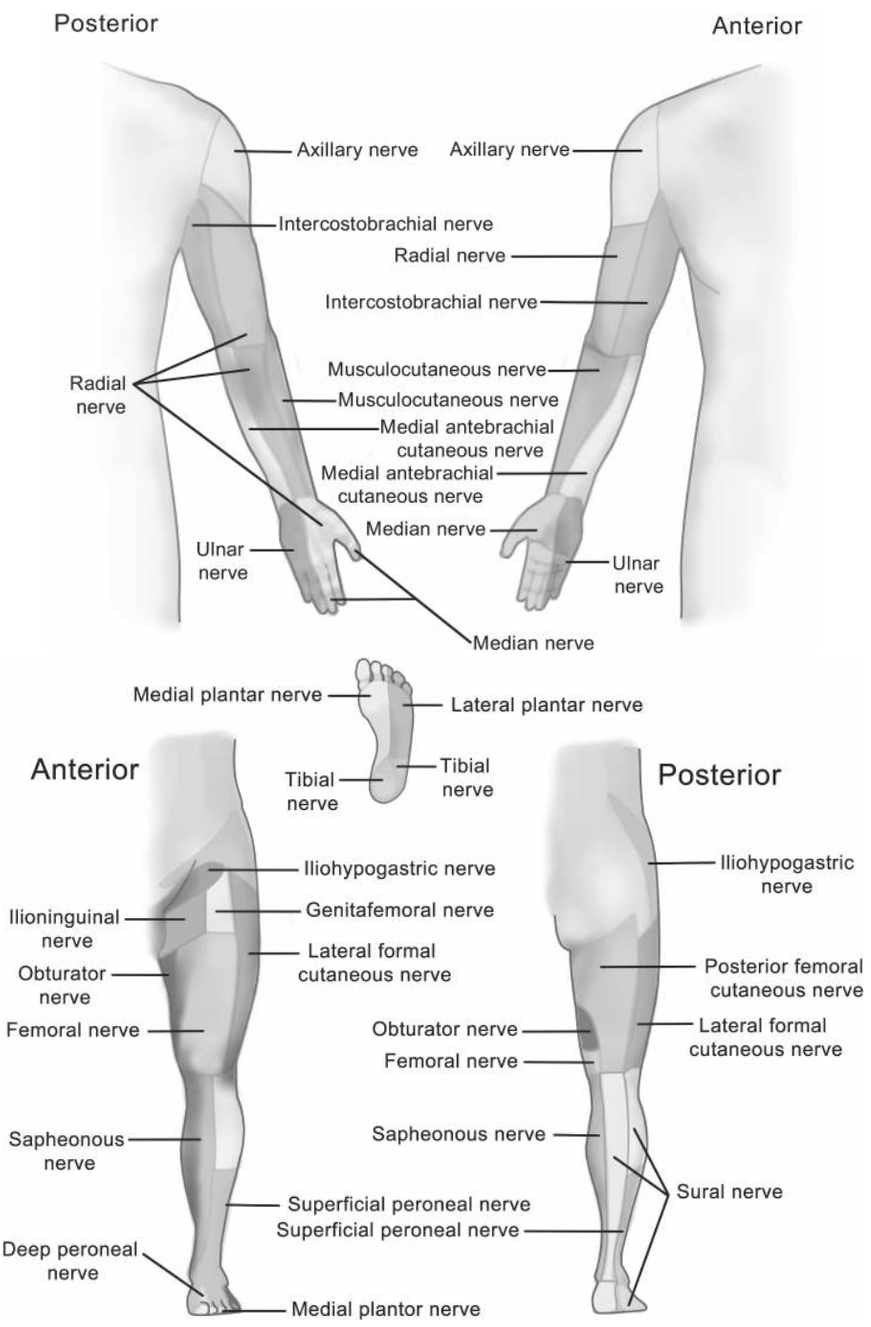

Figure 1.6 Distribution of the major cutaneous nerve branches of the upper and lower extremities. A black and white version of this figure will appear in some formats. For the color version, please refer to the plate section.

- Terminates as the dorsalis pedis artery (DP).
- Can be palpated on the dorsal surface of the foot between the extensor hallicus longus and extensor digitorum longus tendons.
- DP pulse is a landmark for deep peroneal nerve blockade, which innervates the first dorsal webspace.

- Posterior tibial artery (PT):
  - Pulsation can be felt posterior to the medial malleolus (Figure 1.6).

Lower Extremity Innervation

Lumbar Plexus

- Formed by ventral rami of T12–L4.
- Gives rise to femoral, obturator, lateral femoral cutaneous, ilioinguinal, genitofemoral, and iliohypogastric nerves.
- **Femoral nerve** (L2–L4):
  - Found deep to the inguinal ligament lateral to the femoral artery.

- Provides motor innervation to the muscles for knee extension. Blockade of the femoral nerve results in 80% reduction in quadriceps strength.
- Sensory innervation anterior and medial thigh via two anterior cutaneous branches.

- **Lateral femoral cutaneous nerve (LFCN)** (L2–L3):
  - Provides cutaneous innervation of the lateral thigh.
- **Obturator Nerve** (L2–L4):
  - Innervates the adductor muscles.
  - Sensory innervation varies:
    - One-third posterior knee, one-third medial thigh, one-third no innervation.

Sacral Plexus (L4–S4)

- **Sciatic nerve** (L4–S3)
  - Deep to piriformis muscle, travels distally toward the popliteal fossa.
  - Two branches:
    - **Tibial nerve**
      - Motor function of all muscles in the posterior compartment.
    - **Common peroneal nerve**
    - Supplies the muscles of the anterior compartment.
      - Blockade or damage results in foot drop.

Cutaneous innervation of the ankle and foot is supplied by a combination of five nerves: four derived from the **sciatic nerve** and one derived from the **femoral nerve (Figure 1.7)**.

- Sciatic branches
  - **Tibial nerve**: provides sensory innervation to the heel and plantar surface of the foot.
    - Blocked by injection next to PT pulsation posterior to medial malleolus.
  - **Superficial peroneal nerve:** sensory to the dorsum of the foot.
    - Blocked by superficial infiltration of local anesthetic between medial and lateral malleoli.
  - **Deep peroneal nerve**: sensory to the web space between first and second toes.
    - Blocked at the dorsum of the foot by injecting next to DP pulsation.
  - **Sural nerve**: derived from both the tibial and common peroneal nerves. Provides sensory innervation to the posterior lower leg and lateral ankle.

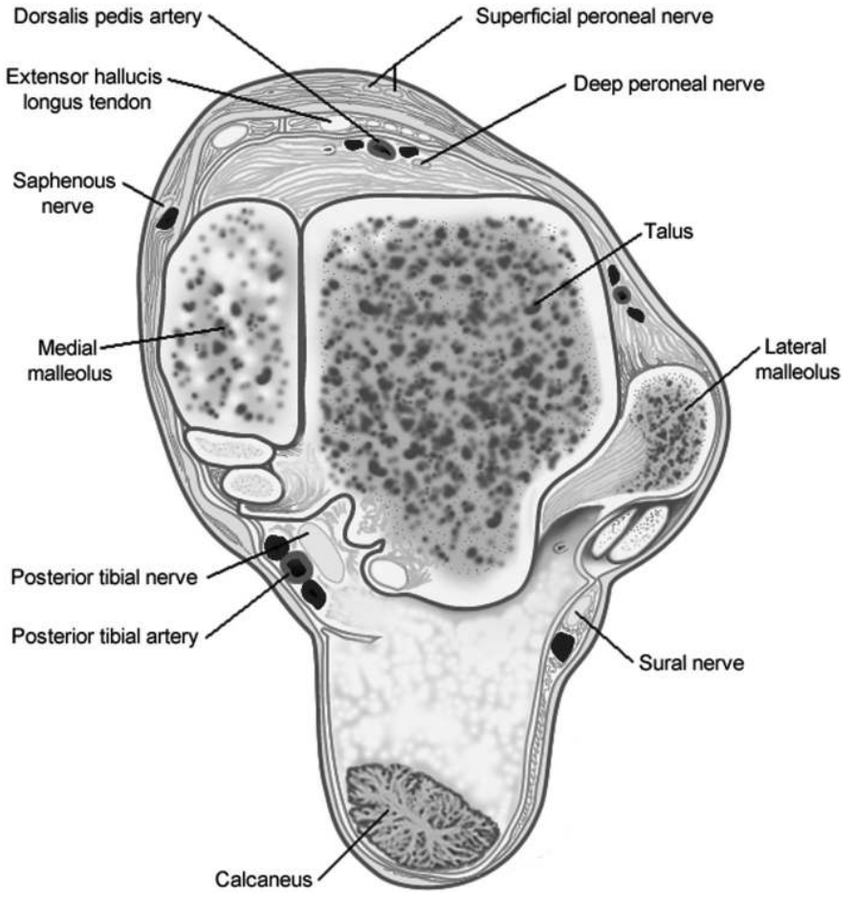

Figure 1.7 Normal anatomical relationship of the major vessels, nerves, bones, and the ankle. A black and white version of this figure will appear in some formats. For the color version, please refer to the plate section.

Table 1.2 Lower extremity nerve block landmarks

Femoral nerve	Lateral to the pulsation of femoral artery at the inguinal ligament
Lateral femoral cutaneous nerve	Medial to anterior superior iliac spine
Sciatic nerve	4 cm distal to the midpoint of a line between the greater trochanter and posterior superior iliac spine
Saphenous nerve	Anterior to the medial malleolus near the saphenous vein
Superficial peroneal nerve	Anterior to the lateral malleolus
Deep peroneal nerve	Near the pulsation of the dorsalis pedis artery at the ankle
Posterior tibial nerve	Posterior to the pulsation of the posterior tibial artery
Sural nerve	Posterior to the lateral malleolus

        - Blocked by injection of local anesthetic between lateral malleolus and Achilles tendon.
- Femoral branch
    - **Saphenous nerve** provides sensory innervation at the medial lower extremity.
        - Blocked by injection anterior to medial malleolus next to saphenous vein.

Table 1.2 lists some of the normal anatomical relationships and topographic landmarks associated with nerve blocks of the lower extremities.

Radiological Anatomy

See Figures 1.8–1.12.

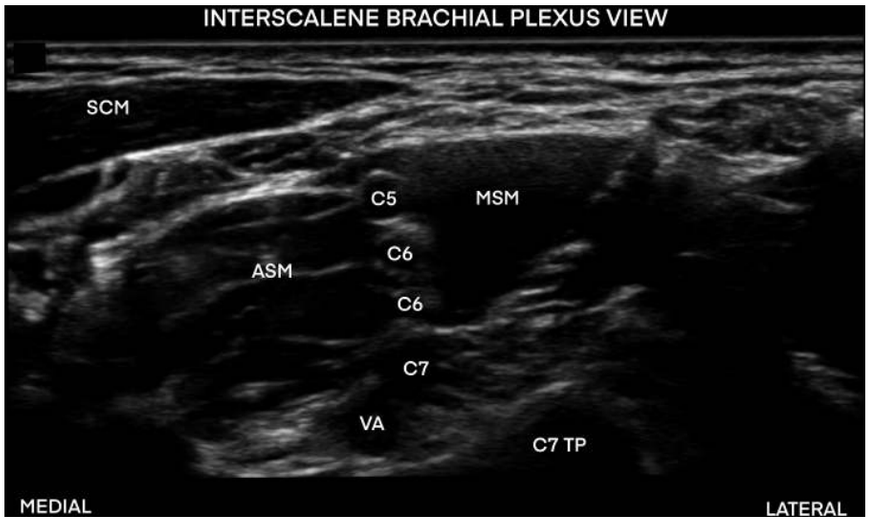

Figure 1.8 Ultrasound image of the brachial plexus at the location for the interscalene block. At this level, the roots of C5, C6, and C7 appear as hypoechoic circles between the anterior (ASM) and middle (MSM) scalene muscles, deep to the sternocleidomastoid muscle (SCM). Also seen is the vertebral artery (VA) and C7 transverse process (TP).

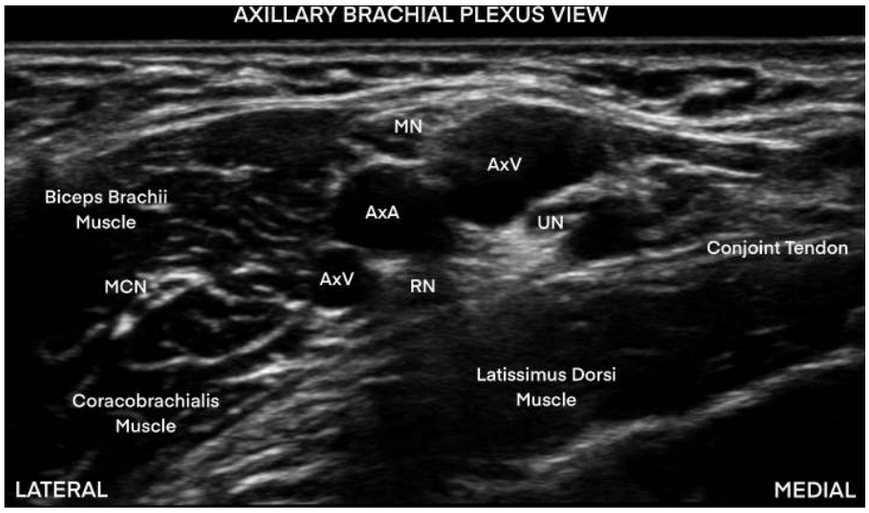

Figure 1.9 Ultrasound image of the brachial plexus at the location for the axillary block. The axillary artery (AxA) is surrounded by the ulnar (UN), median (MN), and radial (RN) nerves. The musculocutaneous nerve (MCN) is seen laterally within the coracobrachialis muscle. Also seen is the axillary vein (AxV).

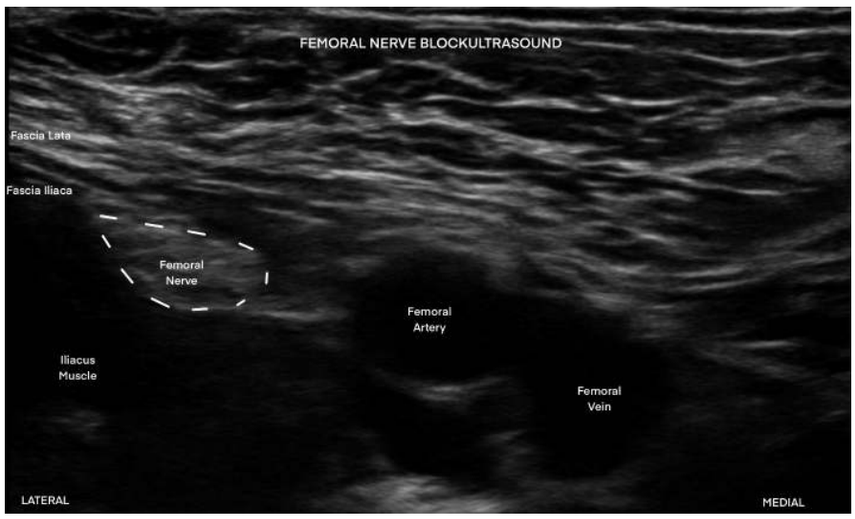

Figure 1.10 Ultrasound image of the inguinal area, depicting the normal relationship between the femoral vein, femoral artery, and femoral nerve. The mnemonic "VAN" can be used to remember the orientation of these structures in the medial to lateral direction.

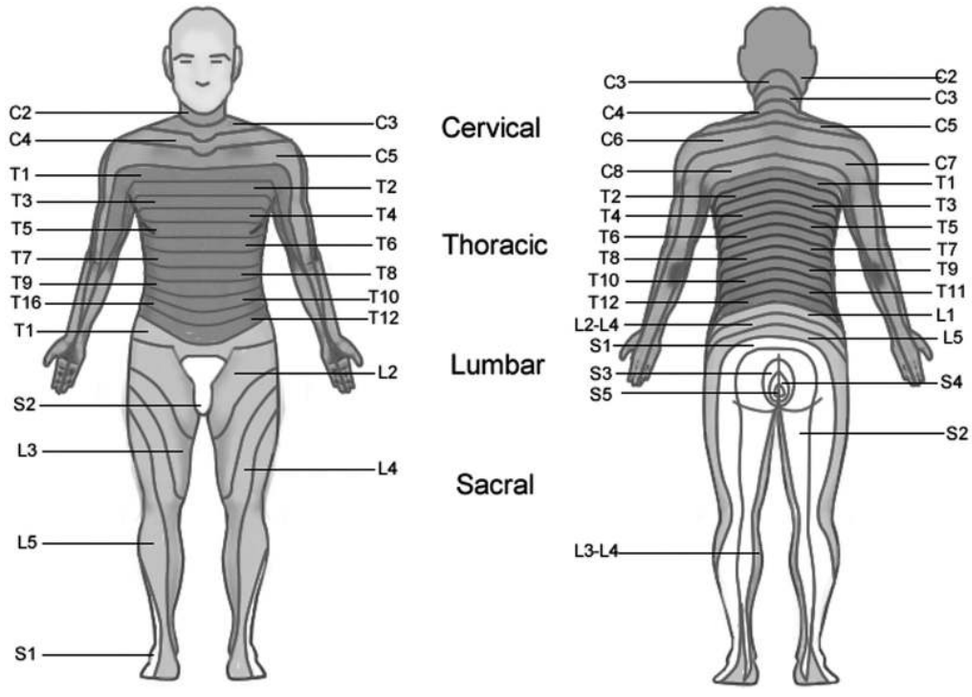

Figure 1.11 Dermatome map. A black and white version of this figure will appear in some formats. For the color version, please refer to the plate section.

Spinal Anatomy, Landmarks, and Dermatomes

Surface Landmarks

Table 1.3 describes some of the clinically relevant surface landmarks, and important key sensory and motor areas of innervation.

Spinal Anatomy

Vascular Supply

- Anterior two-thirds of the spinal cord receives its blood supply from a single *anterior spinal artery*, which arises from the vertebral arteries.
  - Receives branches from six to eight radicular arteries, most important of which is the *artery of Adamkiewicz*, arising most commonly at T9–T12.
  - Damage to artery of Adamkiewicz causes *anterior spinal cord syndrome*.
    - Flaccid paralysis of the lower extremities.
    - Bowel and bladder dysfunction.
    - Proprioception and sensation spared.
      - Occurs most commonly in emergent repair of dissecting or ruptured thoracic aortic aneurysm (40%).

Table 1.3 Clinically relevant topographic landmarks

Mastoid process	Cervical 1
Thyroid cartilage	Cervical 5
Vertebral prominens	Cervical 7
Suprasternal notch	Thoracic 2–3
Sternal angle	Thoracic 4–5
Inferior angle of the scapula	Thoracic 7
Xyphoid process	Thoracic 9–10
Inferior costal margin	Lumbar 2–3
Iliac crest	Lumbar 4–5
Anterior superior iliac spine	Sacral 1–2
Greater trochanter	Distal coccyx
Symphysis pubic	2.5 cm inferior to distal coccyx

- Posterior third of the spinal cord receives its blood supply from two *posterior spinal arteries.*
  - Conversely, *posterior spinal cord syndrome* (very rare) is characterized by loss of sensation and proprioception and spares motor innervation.

Cauda Equina

- Nerve roots of the lumbosacral plexus that arise following the termination of the spinal cord at the *conus medullaris.*
- Conus medullaris terminates at L1–L2 in adults and L3–L4 in infants.
- Damage to this structure can result in *cauda equina syndrome*, characterized by pain, paralysis of the lower extremities, and loss of bowel and bladder function.

Caudal Space

- Lowest part of the epidural space.
- Dural sac ends at S2 (S3–S4 at birth) where it fuses to filum terminale.
- Sacral hiatus is a defect in the lower part of the posterior wall of the sacrum due to failure of S4–S5 laminae to fuse at midline.

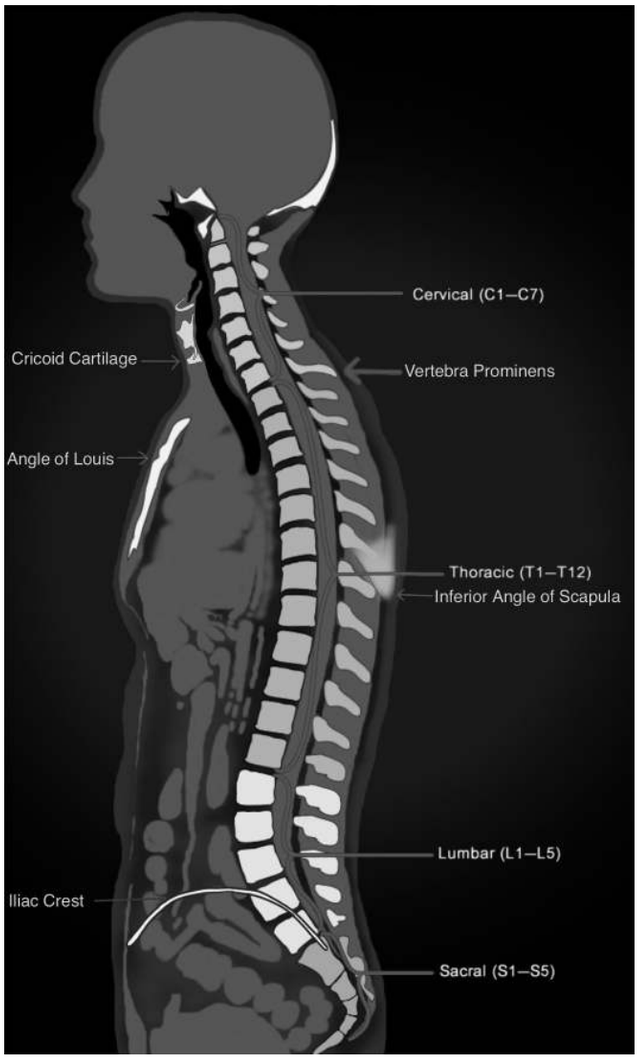

Figure 1.12 Spinal anatomy and relevant surface anatomy. A black and white version of this figure will appear in some formats. For the color version, please refer to the plate section.

- Roofed by the *sacrococcygeal ligament*, an extension of ligamentum flavum.

Further Reading

Gray H. *Anatomy of the Human Body*, 20th ed. 1918. Online edition from Bartleby.com. Published May 2000. Available at: www.bartleby.com/br/107/ (accessed March 2017).

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