Chapter 1

Anatomy

Dallis Clendeninn and Nadia Hernandez

Head and Neck

Vasculature

Internal jugular vein (IJ)

- Drains the blood that comes from the head, face, and brain
- Lies deep to the sternocleidomastoid (SCM) muscle and lateral to the carotid artery within the carotid sheath, coursing inferiorly to join with the subclavian vein (SCV) to become the brachiocephalic (or innominate) vein
- Easily accessed for central venous cannulation

External jugular vein (EJ)

- Carries deoxygenated blood from the face, and is most noticeable on the neck
- Superficial to the SCM muscle as it crosses obliquely from the angle of the mandible and dives posterior to the SCM and clavicle to join the SCV

Subclavian vein

- Posterior to the clavicle but anterior to the insertion of the anterior scalene muscle on the first rib, coursing laterally to become the axillary vein
- Accessed by placing a needle inferior to clavicle, 1–2 cm lateral to the midclavicular line, with the tip directed medially and superiorly toward the sternal notch (Figure 1.1)

Vertebral artery

- Branches from the subclavian artery, traveling cephalad to enter the spinal column deep to Chassaignac's tubercle
- Travels through the transverse foramen of C1–C6 before fusing to form the basilar artery, supplying the posterior Circle of Willis and the spinal cord
- Can be injected directly during an interscalene brachial plexus block

Carotid artery

- Arises from brachiocephalic artery on the right and the aortic arch on the left
- Travels in carotid sheath medial to IJ and anterior to cranial nerve (CN) X
- Bifurcates into internal and external carotid arteries at the level of the C4
  - Carotid sinus:
    - Located at bifurcation of carotid artery

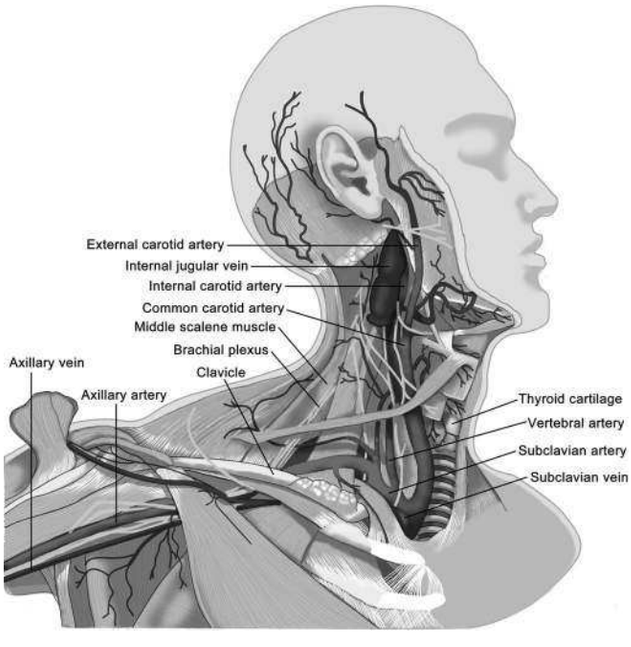

Figure 1.1 Normal anatomical relationships of the major vessels, nerves, bones, and muscles of the neck and axilla

    - Compression during carotid endarterectomy can cause a baroreceptor reflex resulting in bradycardia.

Thoracic duct

- Primary endpoint for the lymphatic drainage of the body before joining the venous system
- Arises at the L2 level, courses through the diaphragm posterior to the esophagus, and ascends the thorax just right of the midline between the aorta and azygos vein
- Crosses to the left at T4–T5 and empties into the SCV just lateral to the IJ
- Can be damaged during attempts for central access to the left SCV or IJ, leading to chylothorax

Surface Landmarks

Thyroid cartilage

- In adults, located approximately at the level of C5. Marks the glottic opening, or the start of the larynx

- 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 external branch of superior laryngeal nerve.

Cricothyroid membrane

- Palpable in the anterior neck just inferior to the thyroid cartilage and superior to the cricoid cartilage
- Located approximately at the C6 vertebral level
- Marks the access point for the cricothyroidotomy procedure

Chassaignac's tubercle

- Another name for the anterior tubercle of the transverse process of C6
- Lies just posterior to the carotid artery, which can be compressed upon this structure to increase vagal tone via carotid massage
- Marks the approximate location of the vertebral artery, which enters deep to this structure into the spinal column after rising from the subclavian artery
- Clinically used to identify the appropriate location to perform nerve blocks of the brachial plexus, cervical plexus, and stellate ganglion

Vertebrae prominens

- Another name for the spinous process of the C7 vertebral body
- This spinous process is the most prominent in the majority of patients (can be C6 or T1 in small subset of patients).

Stellate ganglion

- Named for its "star-like" appearance
- Is the fusion of the inferior cervical and first thoracic sympathetic ganglia
- Located lateral to the vertebral body of C7
- Blockade of this structure is clinically useful for the treatment of sympathetically mediated pain syndromes, such as 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 many of the cervical and brachial plexus nerve blocks.

Brachial plexus

- Provides cutaneous and motor innervation to the upper extremity
- Lies between the anterior and middle scalene muscles in the neck before running alongside the subclavian and axillary arteries

Radiological Anatomy

See Figure 1.2.

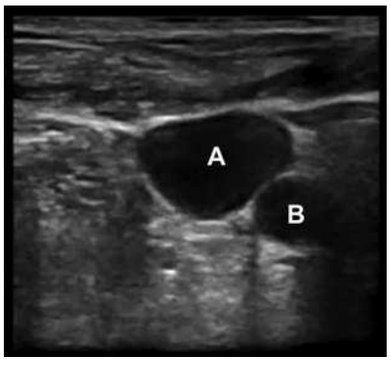

Figure 1.2 Ultrasound image of the lateral neck, displaying (A) the internal jugular vein and (B) the carotid artery

Chest

Surface Landmarks

Trachea

- Begins at C6 and continues inferiorly until it bifurcates at the primary *carina*
- This bifurcation occurs at the level of the *sternal angle*, or *Angle of Louis*, which is the joint between the sternum and manubrium and the connection of the T2 costal cartilages. This structure also marks the approximate level of the T4–T5 intervertebral disk.

Lungs

- Are divided into their lobes by the structures called 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 fissures begin posteriorly at the level of T4, traveling caudally and laterally, and then around the torso to terminate anteriorly approximately at 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 approximately at 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 located at level of the fifth intercostal space (ICS) 6–10 cm lateral to midline
- **Auscultation zones**
    - **Aortic**: Second ICS right upper sternal border
    - **Pulmonary valve:** Second ICS left upper sternal border
    - **Tricuspid valve:** Fourth left ICS on the sternal border
    - **Mitral valve:** Fifth left ICS midclavicular line

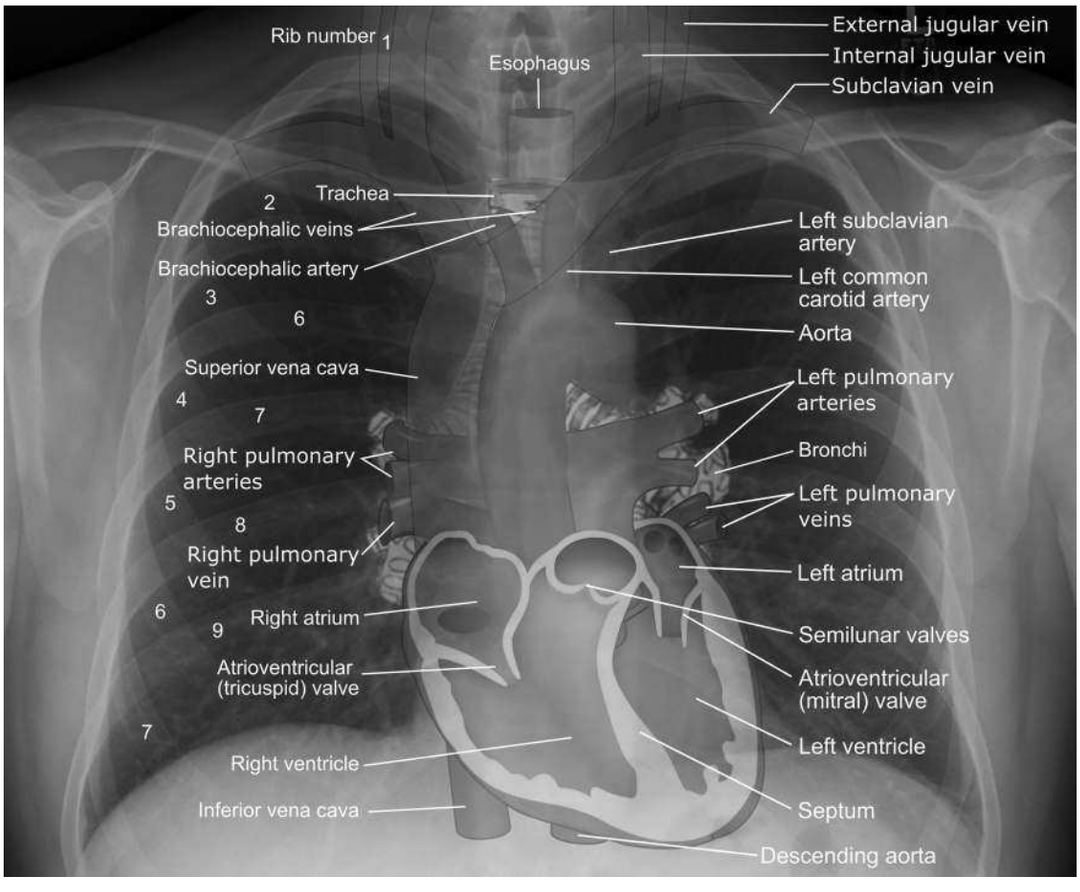

Figure 1.3 Normal radiograph of the chest. Superimposed on this image are outlines of some of the major topographical landmarks of the chest.

- **Coronary arteries**
  - Left and right main arteries arise from the aorta behind the left and right aortic valve leaflets.
  - Left main artery 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-third 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 side and usually both sinoatrial (SA) and atrioventricular (AV) nodes
      - Posterior and anterior walls of the right ventricle (RV) except for the apex (LAD)
      - Right atrium including SA node
      - Upper half of the atrial septum
      - Posterior one-third of IVS
      - Inferior wall of LV
      - AV node
  - Posterior descending artery (PDA) arises from RCA in approximately 80 percent of patients. This is called "right-dominant" circulation.

Radiological Anatomy

See Figures 1.3–1.4.

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 SCV 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 most 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.

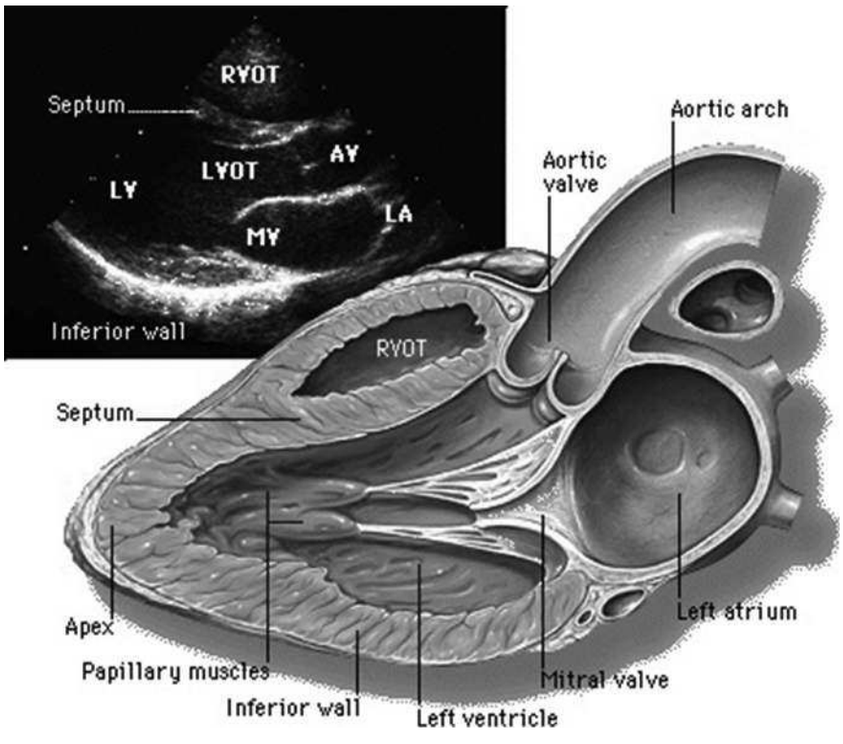

Figure 1.4 Transesophageal echo (TEE) image depicting normal anatomy of the heart

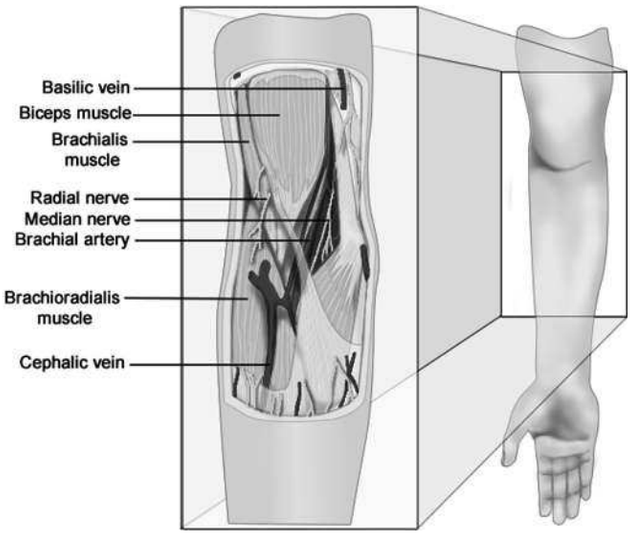

Figure 1.5 Normal anatomical relationships of the major vessels and nerves, bones, and muscles of the antecubital fossa

Box 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 SCM
Infraclavicular (i.e., brachial plexus: cords)	Three centimeters 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

Axillary artery

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

Brachial artery

- The pulsation that is typically felt just *medial to the biceps brachii tendon* at the cubital fossa
- Subsequently bifurcates into the *radial and ulnar arteries* (Figure 1.5)

Upper Extremity Innervation

Brachial plexus

- Originates from 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 Box 1.1)

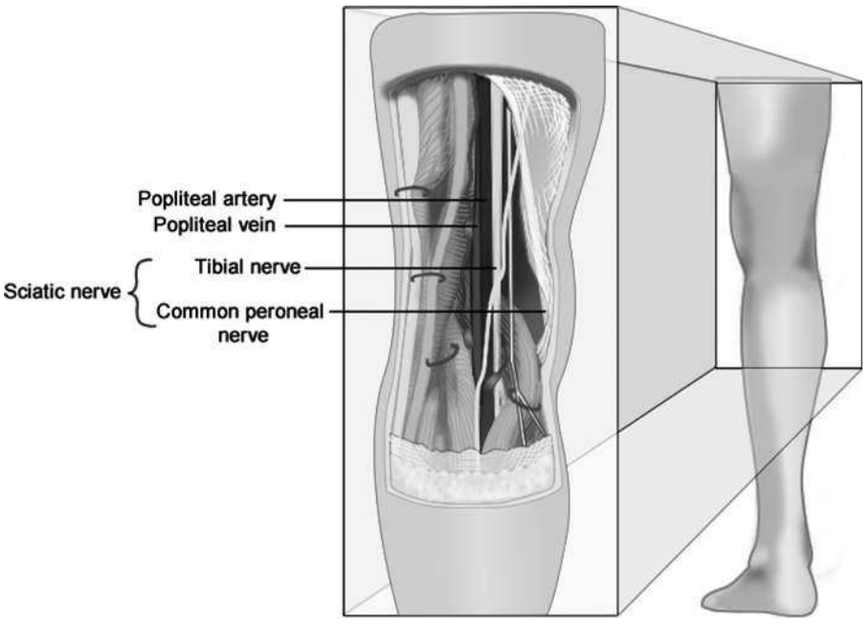

Figure 1.6 Normal anatomical relationships of the major vessels, nerves, bones, and muscles of the popliteal fossa

- ROOTS: After exiting the spinal column, the C5–T1 *roots* split and recombine to form the *superior* (*C5–C6*), *middle* (*C7*), *and inferior* (*C8–T1*) *trunks*, which lie between the anterior and middle scalene muscles.
- TRUNKS: Further split into anterior and posterior divisions
  - *Superior trunk* gives rise to the *suprascapular nerve* which innervates 70 percent 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.
  - *Roots/trunks* are blocked for the ISB.
  - Due to proximity, the phrenic nerve, stellate ganglion, superficial cervical plexus, recurrent laryngeal nerve, and CN XI are frequently blocked with ISB.
- DIVISIONS: Recombine into the *lateral, medial, and posterior cords*, which are named for their relationship with the *subclavian artery*
  - Level of blockade for supraclavicular block
- CORDS: Split further and recombine to form the terminal *branches*
  - Level of blockade for *infraclavicular block*
- BRANCHES:
  - There are five major 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

- Skin over axilla and medial arm is the only part of the arm not innervated by the brachial plexus.
- Intercostobrachial nerve which is derived from T2–T3
- If not blocked separately, can contribute to tourniquet pain (Figure 1.7)

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 (Figure 1.6)
- Continues proximally through the adductor magnus muscle, where it becomes the femoral vein

Great saphenous vein

- Longest vein in the body. Typically found superficially at the dorsum of the foot medial to the medial malleolus
- Commonly cannulated in pediatrics for peripheral venous access
- Used as a landmark to block the saphenous nerve at the ankle. It innervates the medial aspect of the foot
- 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
  - The profunda femoris (deep artery of the thigh) provides vascular supply to the structures of the thigh.
  - The superficial femoral artery courses posteriorly and distally until resurfacing at the popliteal fossa as the popliteal artery.

Popliteal artery

- Divides into two major branches: anterior and posterior tibial arteries
- Anterior tibial artery
  - Terminates as the dorsalis pedis (DP) artery
  - DP pulse 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 space between the first and second toes.
- Posterior tibial artery (PT)
  - Pulsation can be felt posterior to the medial malleolus at the ankle.
  - PT pulse is a landmark for blockade of the posterior tibial nerve which innervates the plantar aspect of the foot (Figure 1.7).

Lower Extremity Innervation

Lumbar plexus

- Originates from a complex network of nerves 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 into 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 percent reduction in quadriceps strength
  - Sensory innervation anterior and medial thigh via two anterior cutaneous branches
- **Lateral femoral cutaneous nerve (LFCN)** (L2–L3):
  - Provides only cutaneous innervation of the lateral thigh
- **Obturator nerve** (L2–L4):
  - Innervates the adductor muscles
  - Sensory innervation varies within the population:
    - One-third posterior knee, one-third medial thigh, one-third no innervation

Sacral plexus (L4–S4)

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

Cutaneous innervation of the distal lower extremity, 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 1.8).

- Sciatic branches (all of these can be blocked at once with a popliteal block)
  - **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 the first and second toes
    - Blocked at the intermalleolar axis by injection posterior to the extensor hallicus longus tendon
    - 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
    - Blocked by injection of local anesthetic between lateral malleolus and Achilles tendon
- Femoral branch
  - **Saphenous nerve** provides sensory innervation at the medial lower leg and medial ankle and foot.
    - Blocked by injection medial to medial malleolus next to great saphenous vein

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

Radiological Anatomy

See Figures 1.9–1.11.

Spinal Anatomy, Landmarks, and Dermatomes

Surface Landmarks

Box 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-third of spinal cord receives its blood supply from a single *anterior spinal artery,* which arises from the vertebral arteries.
  - Receives branches from 6–8 radicular arteries, most important of which is the *artery of Adamkiewicz*, arising most commonly from T9–T12

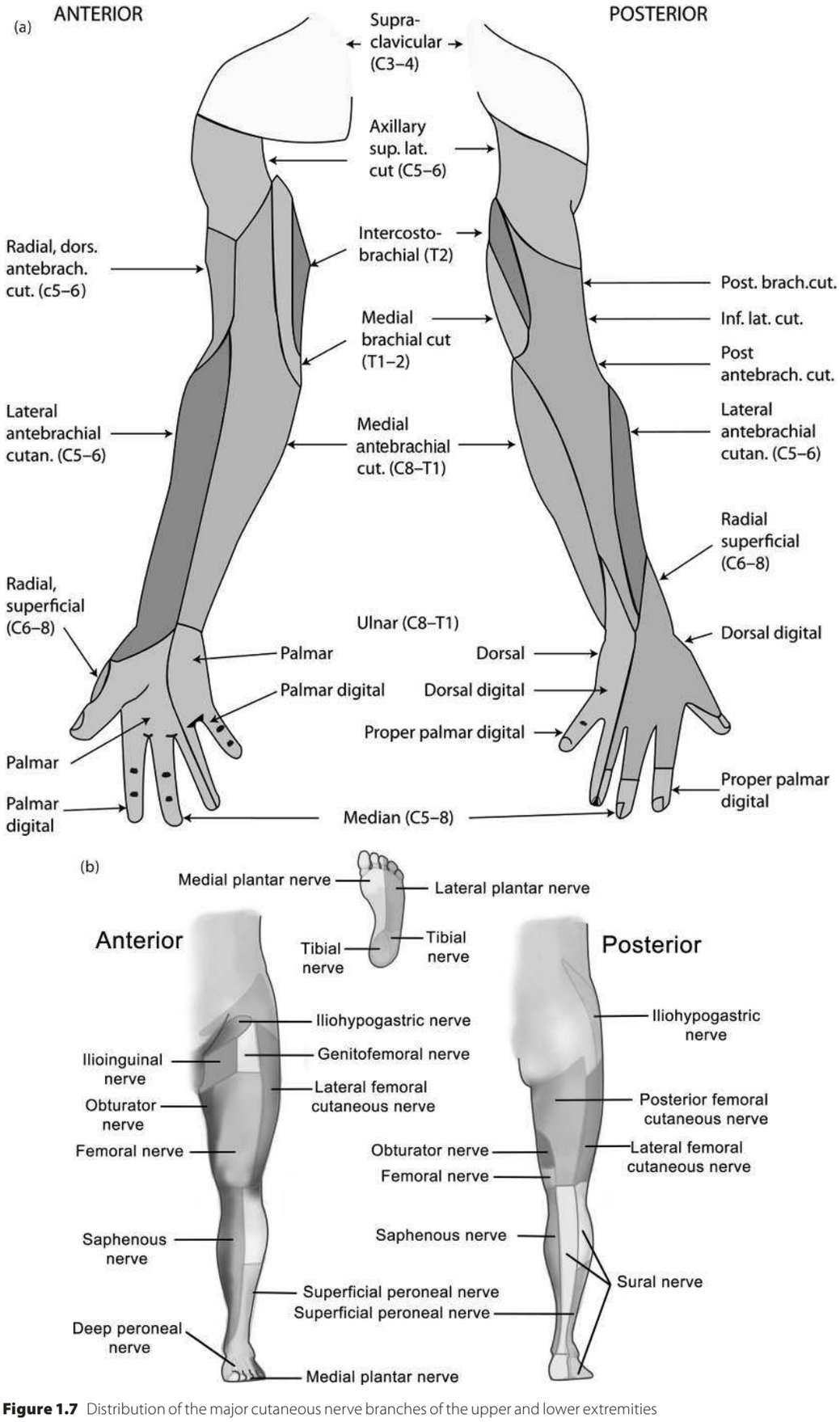

Figure 1.7 Distribution of the major cutaneous nerve branches of the upper and lower extremities

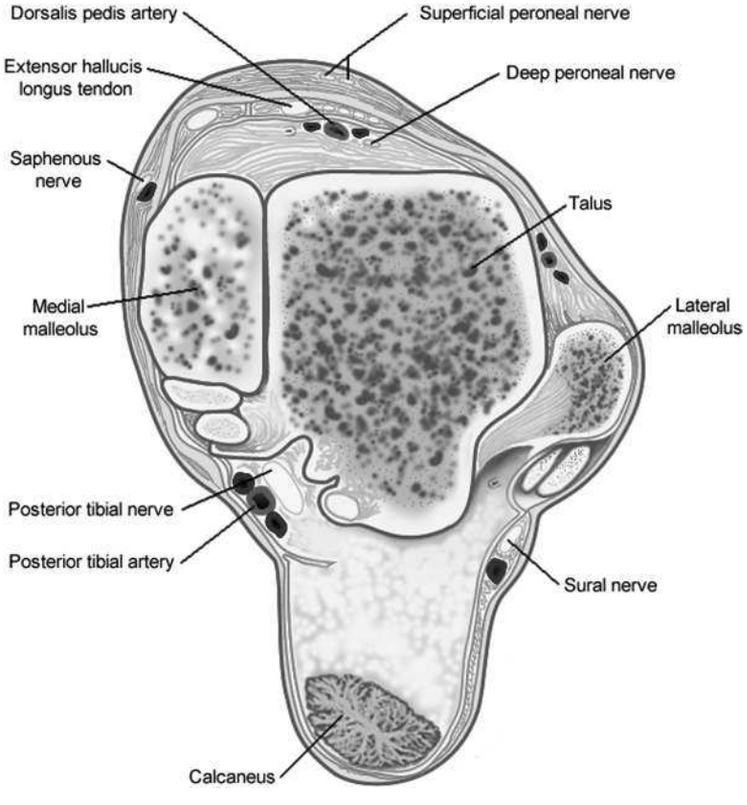

Figure 1.8 Normal anatomical relationship of the major vessels, nerves, bones, and the ankle

Box 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	Four centimeters 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

- Damage to artery of Adamkiewicz causes *anterior spinal cord syndrome*
  - Flaccid paralysis of the lower extremities
  - Bowel and bladder dysfunction
  - Proprioception and sensation typically spared
    - Occurs most commonly in emergent repair of dissecting or ruptured thoracic aortic aneurysm (40 percent)

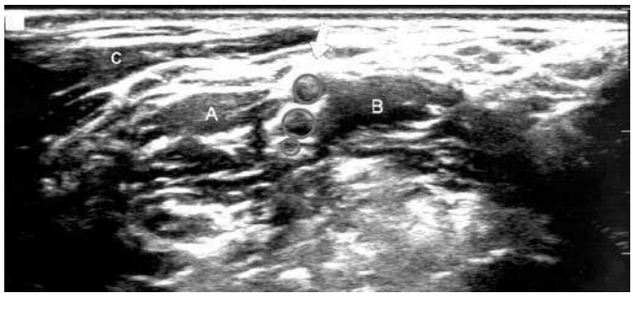

Figure 1.9 Ultrasound image of the brachial plexus at the location for the ISB. At this level, the roots of C5, C6, and C7 appear as hypoechoic circles between (A) the anterior and (B) middle scalene muscles, deep to the (C) SCM muscle.

Figure 1.10 Ultrasound image of the brachial plexus at the location for the axillary block. (A) The axillary artery is surrounded by the (B) median, (C) ulnar, and (D) radial nerves. (E) The musculocutaneous nerve is seen laterally within the coracobrachialis muscle.

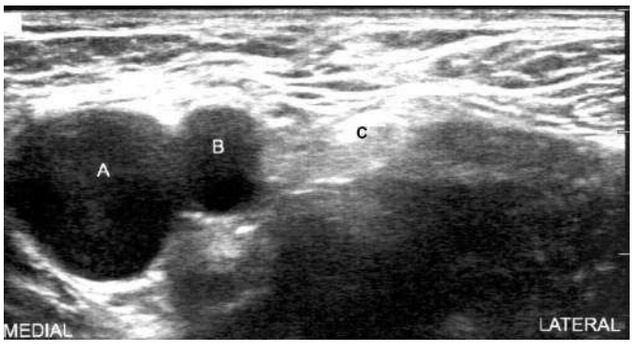

Figure 1.11 Ultrasound image of the inguinal area, depicting the normal relationship between the (A) femoral vein, (B) femoral artery, and (C) femoral nerve. The mnemonic "VAN" can be used to remember the orientation of these structures in the medial to lateral direction.

Box 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

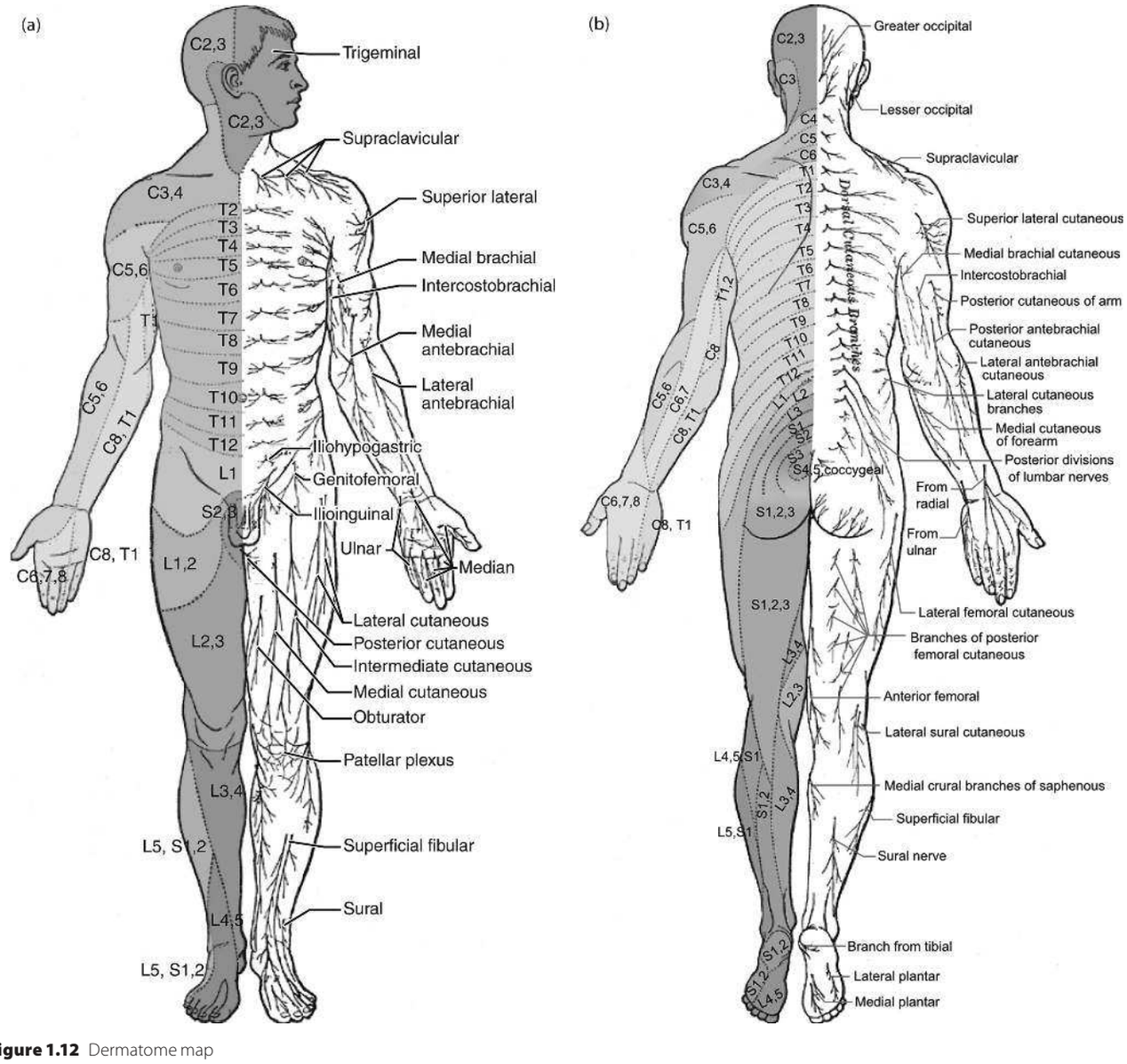

Figure 1.12 Dermatome map

- Posterior one-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 lumbar and sacral 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*, which is characterized by pain, and 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.
- Roofed by the *sacrococcygeal ligament*, an extension of ligamentum flavum

Dermatome

- Describes the cutaneous sensory innervation of a single nerve root

Myotome

- Describes the muscular innervation of a single nerve root

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See Figure 1.12.

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