1

Vertebral Column

I. **THE VERTEBRAL COLUMN** consists of 33 vertebrae [C1–7, T1–12, L1–5, S1–5 (sacrum), and Co1–4 (coccyx)]. The **vertebral canal** contains the spinal cord, dorsal nerve root, ventral nerve root, and meninges. The spinal nerve is located outside the vertebral canal by exiting through the **intervertebral foramen**.

A. **Vertebral levels (Table 1-1)** are used to reference the location of important anatomic structures. Knowledge of these vertebral levels is helpful when answering clinical vignette questions. For example, a clinical vignette question may describe a pulsatile swelling located at vertebral level T2. Knowing that the arch of the aorta is found at T2 suggests the correct answer: **aortic arch aneurysm**.

B. **Curves**

1. **Primary curves** are the thoracic and sacral curvatures that form during the fetal period.
2. **Secondary curves** are the cervical and lumbar curvatures that form after birth as a result of lifting the head and walking, respectively.
3. **Kyphosis** is an exaggeration of the thoracic curvature that may occur in elderly persons as a result of osteoporosis or disk degeneration.
4. **Lordosis** is an exaggeration of the lumbar curvature that may be temporary and occurs as a result of pregnancy, spondylolisthesis, or potbelly.
5. **Scoliosis** is a complex lateral deviation, or torsion, that is caused by poliomyelitis, a leg-length discrepancy, or hip disease.

C. **Joints**

1. **Atlanto-occipital joints.** Nodding the head (e.g., indicating "yes") occurs at the atlanto-occipital joints between C1 (atlas) and the occipital condyles. These are synovial joints and have **no** intervertebral disk. The **anterior and posterior atlanto-occipital membranes** limit excessive movement at this joint.
2. **Atlanto-axial joints.** Turning the head side-to-side (i.e., indicating "no") occurs at the atlanto-axial joints between C1 (atlas) and C2 (axis). These are synovial joints and have **no** intervertebral disk. The **alar ligaments** limit excessive movement at this joint.

D. **Clinical considerations**

1. **Atlanto-axial dislocation**
   a. **Tearing of the transverse (cruciform) ligament** because of trauma (e.g., Jefferson fracture) or rheumatoid arthritis allows the **dens** (part of the axis) to move within the vertebral canal. This mobility contributes to the risk of injury to the

Table 1-1.
Vertebral Levels as Reference Points

Vertebral Level	Anatomic Structure
C4	Hyoid bone Bifurcation of common carotid artery
C5	Thyroid cartilage Carotid pulse palpated
C6	Cricoid cartilage Start of trachea Start of esophagus
T2	Sternal notch Arch of the aorta
T4	Sternal angle Junction of superior and inferior mediastinum Bifurcation of trachea
T5—7	Pulmonary hilum
T8	Inferior vena cava hiatus
T9	Xiphisternal joint
T10	Esophageal hiatus
T12	Aortic hiatus
T12—L1	Duodenum
T12	Celiac artery Upper pole of left kidney
L1	Superior mesenteric artery Upper pole of right kidney End of spinal cord in adult (conus medullaris) and pia mater
L2	Renal artery
L3	End of spinal cord in newborn Inferior mesenteric artery Umbilicus
L4	Iliac crest Bifurcation of aorta
S1	Sacral promontory Start of sigmoid colon
S2	End of dural sac, dura, arachnoid, subarachnoid space, and cerebrospinal fluid
S3	End of sigmoid colon

cervical spinal cord (leading to quadriplegia) and medulla (respiratory paralysis, leading to sudden death).

b. The **dens** is secured in its position by the following structures: transverse ligament, alar ligaments, apical ligament, and tectorial membrane (which is a continuation of the posterior longitudinal ligament).

c. Widening of the atlanto-dental interval (distance from the anterior arch of C1 to the dens) suggests tearing of the transverse ligament.

2. Denervation of zygapophyseal (facet) joints

a. The zygapophyseal (facet) joints are synovial joints between the **inferior and superior articular processes.** These joints are located near the intervertebral foramen.

   b. If these joints are damaged as a result of trauma or disease (e.g., rheumatoid arthritis), a spinal nerve may be impinged and cause severe pain. To relieve the pain, medial branches of the dorsal primary ramus are severed (dorsal rhizotomy).

3. **Dislocations without fracture** occur only in the cervical region because the articular surfaces are inclined horizontally. Cervical dislocations stretch the posterior longitudinal ligament.

4. **Dislocations with fracture** occur in the thoracic and lumbar regions because the articular surfaces are inclined vertically.

5. **Stability of the vertebral column** is determined primarily by four ligaments: anterior longitudinal ligament, posterior longitudinal ligament, ligamentum flavum, and interspinous ligaments.

6. Breast, lung, and prostate cancers metastasize to the brain because the **internal vertebral venous plexus, basivertebral veins,** and **external vertebral venous plexus** that surround the vertebral column communicate with the cranial dural sinuses and veins of the thorax, abdomen, and pelvis.

7. **Spina bifida occulta** is a common congenital malformation in which the **vertebral arch** is absent. The defect is covered by skin and usually is marked by a tuft of hair. This condition is not associated with any neurologic deficit.

8. **Hemivertebrae** occurs when a portion of the **vertebral body** does not develop. This condition can lead to scoliosis.

9. **Sickle cell anemia** is associated with **"fish mouth vertebra"** (seen radiographically), in which central depressions occur in the **vertebral body.**

10. **Spondylolysis** is a chronic stress fracture of the **pars interarticularis** (an area between the pedicle and lamina of a vertebra). It often is seen in adolescent athletes, most commonly at vertebra L5. On an oblique radiograph of the lumbar vertebrae, the fracture appears as a **"collar" around the neck of the Scottie dog.**

11. **Spondylolisthesis** occurs when the **pedicles** of a lumbar vertebra degenerate or do not develop properly. As a result, the body of the lumbar vertebra moves anterior with respect to the vertebrae below it, causing lordosis. **Degenerative spondylolisthesis** usually occurs at vertebral level L4–5. **Congenital spondylolisthesis** usually occurs at vertebral level L5–S1.

12. **Spondylosis** is a degenerative process that is characterized by the formation of osteophytes and bone spurs. It typically occurs in the cervical region of elderly patients.

13. **Ankylosing spondylosis** (rheumatoid spondylitis, or Marie-Stumpel disease) is an inflammatory osteoarthritis that usually affects the lumbar vertebrae and sacroiliac joint. The **annulus fibrosus** of the intervertebral disks may become ossified, producing severe spinal immobility. The ossification bridges the disks at various levels, forming a **"bamboo spine."** Most of these patients are positive for histocompatibility antigen HLA-B27.

14. **Osteomyelitis** is a bacterial infection that may occur within vertebral bodies. *Staphylococcus aureus* and *Pseudomonas aeruginosa* (in immunosuppressed patients and intravenous drug users) are causative agents.

15. **Protrusion of the nucleus pulposus**
   a. An intervertebral disk consists of the **annulus fibrosus** (fibrocartilage) and **nucleus pulposus** (remnant of the embryonic notochord). The nucleus pulposus usually herniates posterolaterally and compresses a nerve root.

b. **Table 1-2** shows important features of a herniated disk at various vertebral levels. From the clinical signs listed in Table 1-2, you should be able to deduce which nerve root is compressed and then identify the appropriate herniated disk on a radiograph or an MRI.

Table 1-2.
Vertebral Levels of Herniated Disk*

Herniated Disk Between	Compressed Nerve Root	Dermatome Affected	Muscles Affected	Movement Weakness	Nerve and Reflex Involved
C4–C5	C5	C5 Shoulder Lateral surface of upper limb	Deltoid	Abduction of arm	Axillary nerve ↓ Biceps jerk
C5–C6	C6	C6 Thumb	Biceps Brachialis, Brachio-radialis	Flexion of forearm Supination or pronation	Musculocutaneous nerve ↓ biceps jerk ↓ brachioradialis jerk
C6–C7	C7	C7 Posterior surface of upper limb Middle and index fingers	Triceps Wrist extensors	Extension of forearm Extension of wrist	Radial nerve ↓ triceps jerk
L3–L4	L4	L4 Medial surface of leg Big toe	Quadriceps	Extension of knee	Femoral nerve ↓ knee jerk
L4–L5	L5	L5 Lateral surface of leg Dorsum of foot	Tibialis anterior Extensor hallucis longus Extensor digitorum longus	Dorsiflexion of ankle (cannot stand on heels) Extension of toes	Common peroneal nerve Absent or ↓ knee jerk
L5–S1 (most common)	S1	S1 Posterior surface of lower limb Little toe	Gastrocnemius Soleus	Plantar flexion of ankle (cannot stand on toes) Flexion of toes	Tibial nerve ↓ ankle jerk

*Note the correspondence between the dermatome affected and the compressed nerve root (*shaded*).

16. **Cervical column trauma**
    a. **Teardrop fracture**
        (1) Teardrop fracture is caused by **hyperflexion of the cervical region** (e.g., diving into shallow water, whiplash).
        (2) It places the spinal cord at risk.
        (3) Teardrop fractures include the following pathology: avulsion fracture of the vertebral body ("teardrop body"), fracture of the spinous process, posterior subluxation of vertebrae, compression of the spinal cord, tear of the anterior longitudinal ligament, and tear or disruption of the posterior longitudinal ligament, ligamentum flavum, interspinous ligament, or supraspinous ligament.
    b. **Jefferson fracture**
        (1) Jefferson fracture is caused by **compression of the cervical region** (e.g., force applied to the top of the head).
        (2) It places the spinal cord at risk.
        (3) It includes the following pathology: fracture of vertebra C1 at multiple sites, lateral displacement or location of vertebra C1 beyond the margins of vertebra C2, and tear of the transverse ligament.
    c. **Hangman fracture**
        (1) Hangman fracture is caused by **hyperextension of the cervical region** (e.g., hanging, car accident in which the chin strikes the dashboard).
        (2) This fracture places the spinal cord at risk.
        (3) It includes the following pathology: bilateral fracture of the pars interarticularis of vertebra C2, anterior subluxation of vertebra C2, tear of the anterior longitudinal ligament, and continued attachment of the fractured portion of vertebra C2 to vertebra C3 (e.g., in a legal drop hanging).

17. **Thoracolumbar column trauma (Chance fracture)**
    a. Thoracolumbar column trauma is caused by **hyperflexion of the thoracic or lumbar region** (e.g., "seat belt injury" that occurs when a car occupant is restrained only by a lap seat belt; associated with intraabdominal injuries).
    b. It usually does not place the spinal cord at risk.
    c. It includes the following pathology: transverse fracture of the vertebral body and spinous process, rupture of the intervertebral disk, and tear of the posterior longitudinal ligament, ligamentum flavum, interspinous ligament, and supraspinous ligament.

II. RADIOLOGY

A. Median sagittal magnetic resonance imaging (MRI) scan of the cervical region (Figure 1-1)

B. Lateral radiograph of the lumbar region (Figure 1-2)

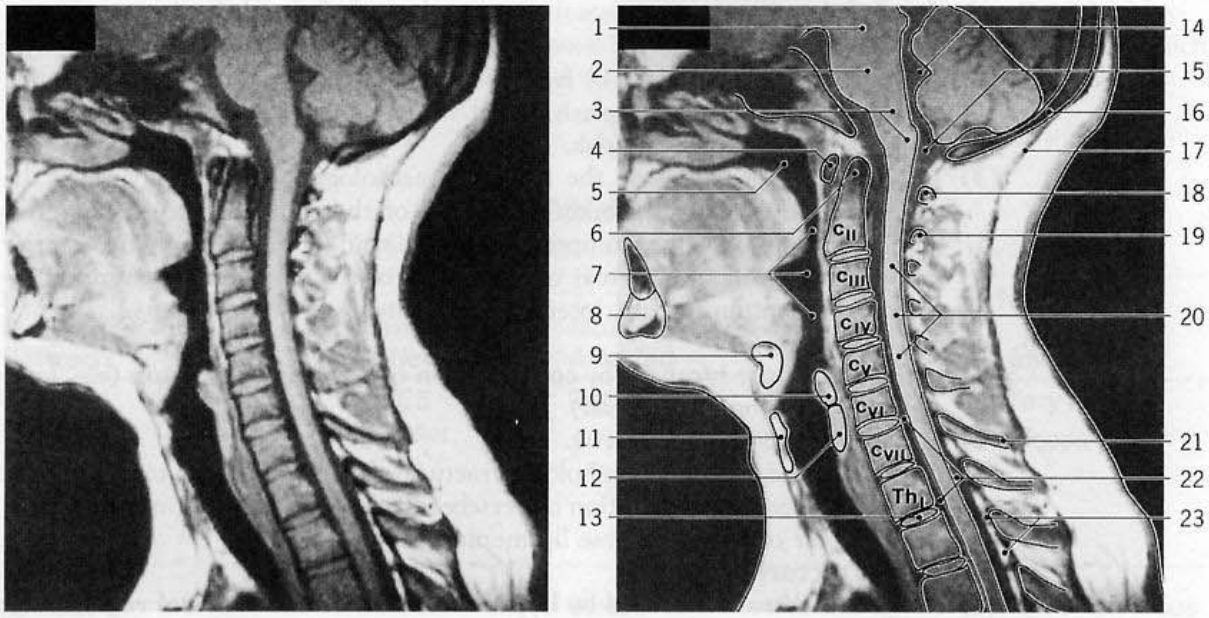
C. Oblique radiograph of the lumbar region ("Scottie dog" projection) [Figure 1-3]

D. Median sagittal MRI scan of the lumbar region (Figure 1-4)

E. Lateral radiograph of a teardrop hyperflexion injury (Figure 1-5)

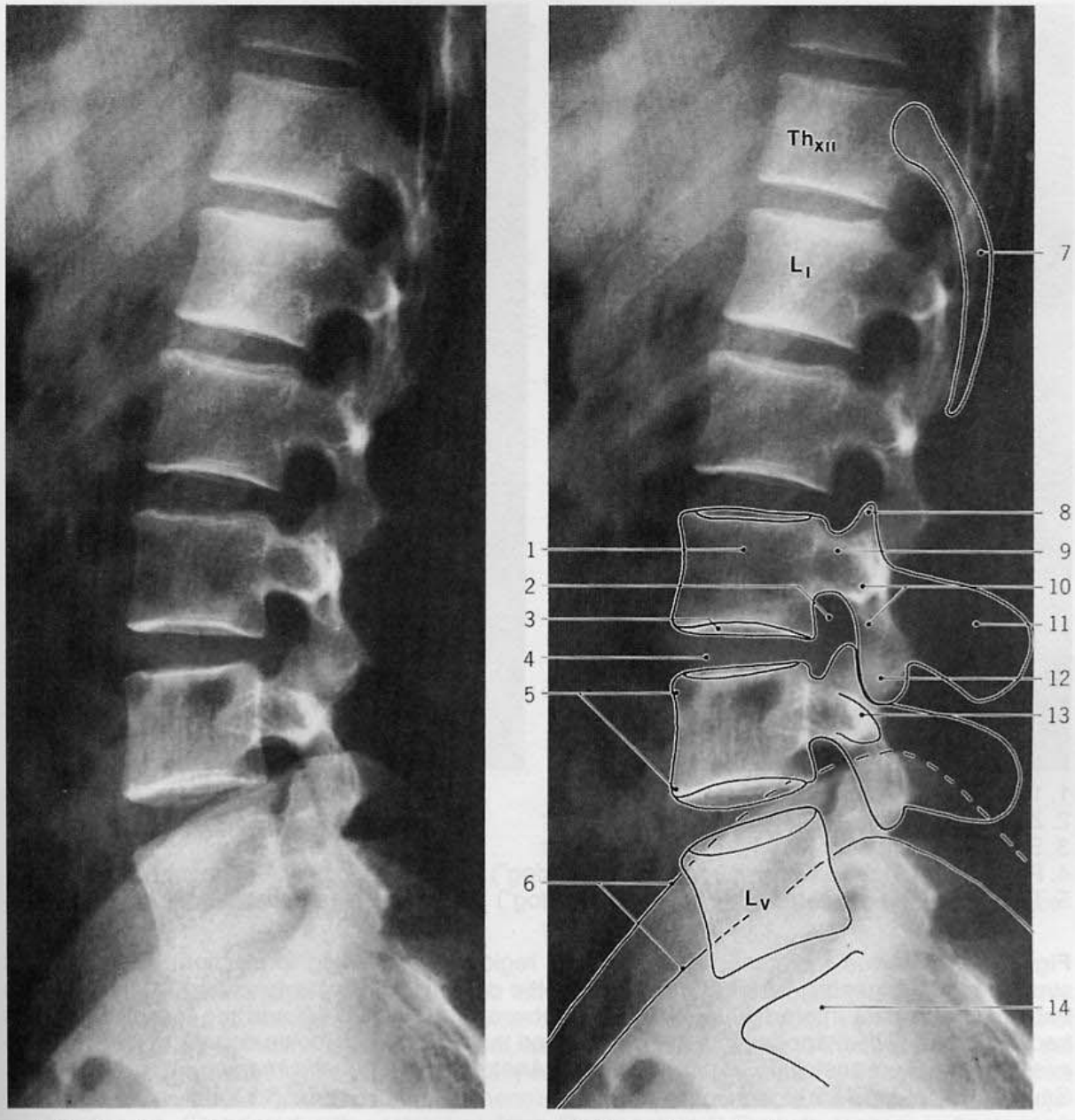
F. CT scan of a Jefferson fracture (Figure 1-6)

G. Lateral radiograph of a hangman fracture (Figure 1-7)



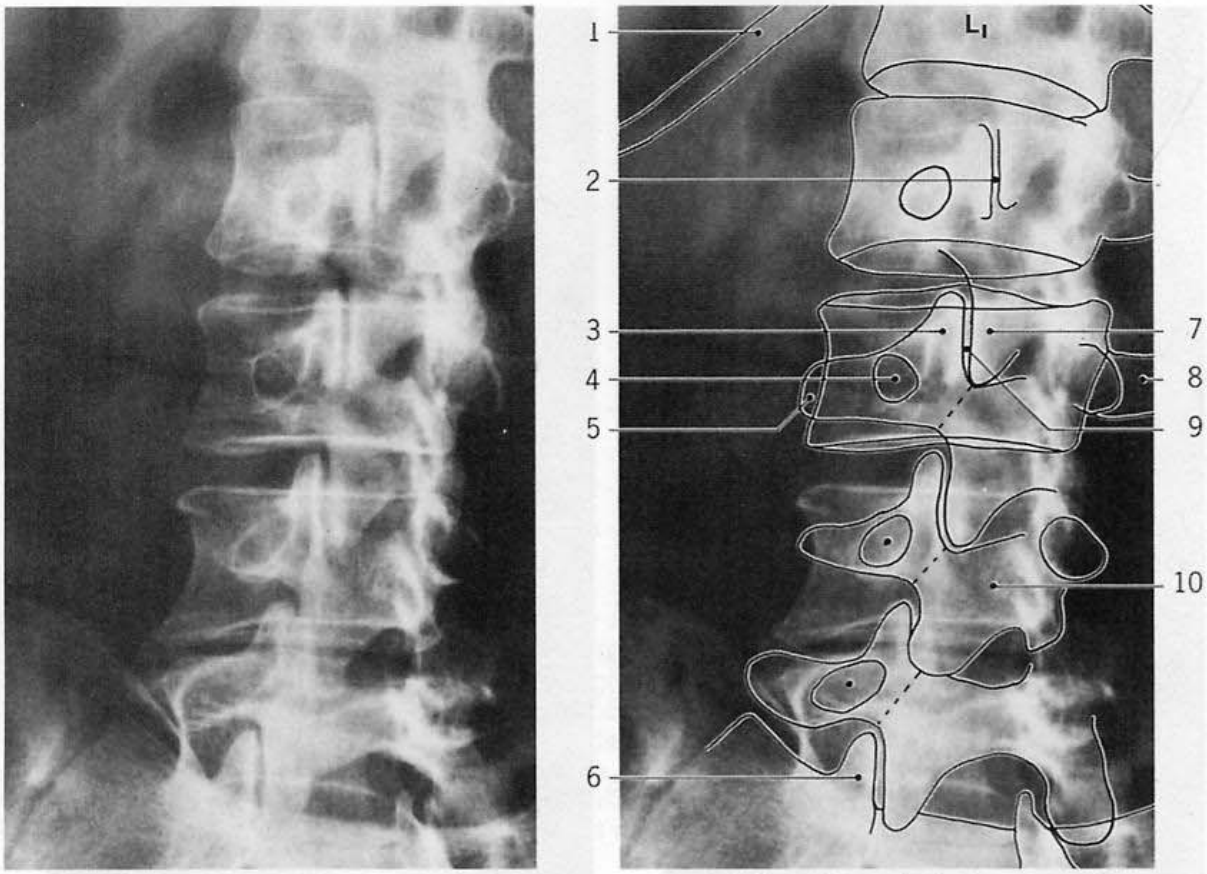
1. Mesencephalon
2. Pons
3. Medulla oblongata
4. Anterior arch of atlas
5. Nasal part of pharynx
6. Dens axis
7. Oral part of pharynx
8. Mandible
9. Body of hyoid bone
10. Arythenoid cartilage
11. Thyroid cartilage
12. Lamina of cricoid cartilage
13. Intervertebral disc Th1—2
14. Fourth ventricle
15. Cerebellomedullary cistern
16. Squamous part of occipital bone
17. Ligamentum nuchae
18. Posterior arch of atlas
19. Lamina of vertebral arch C2
20. Spinal cord
21. Spinous process of C7
22. Subarachnoid space
23. Fat in epidural space

Figure 1-1. Median sagittal MRI scan of the cervical region. Note the location of the anterior arch (*4*) and posterior arch (*18*) of the atlas. Note the superior projection of the dens axis (*6*) and its relation to the atlas, spinal cord (*20*), and medulla (*3*). The dens axis is secured in its position predominantly by the transverse ligament. Rupture of this ligament places the spinal cord and possibly the medulla at risk. (Reprinted with permission from Fleckenstein P, Tranum-Jensen J: *Anatomy in Diagnostic Imaging*. Philadelphia, WB Saunders, 1993, p 119.)



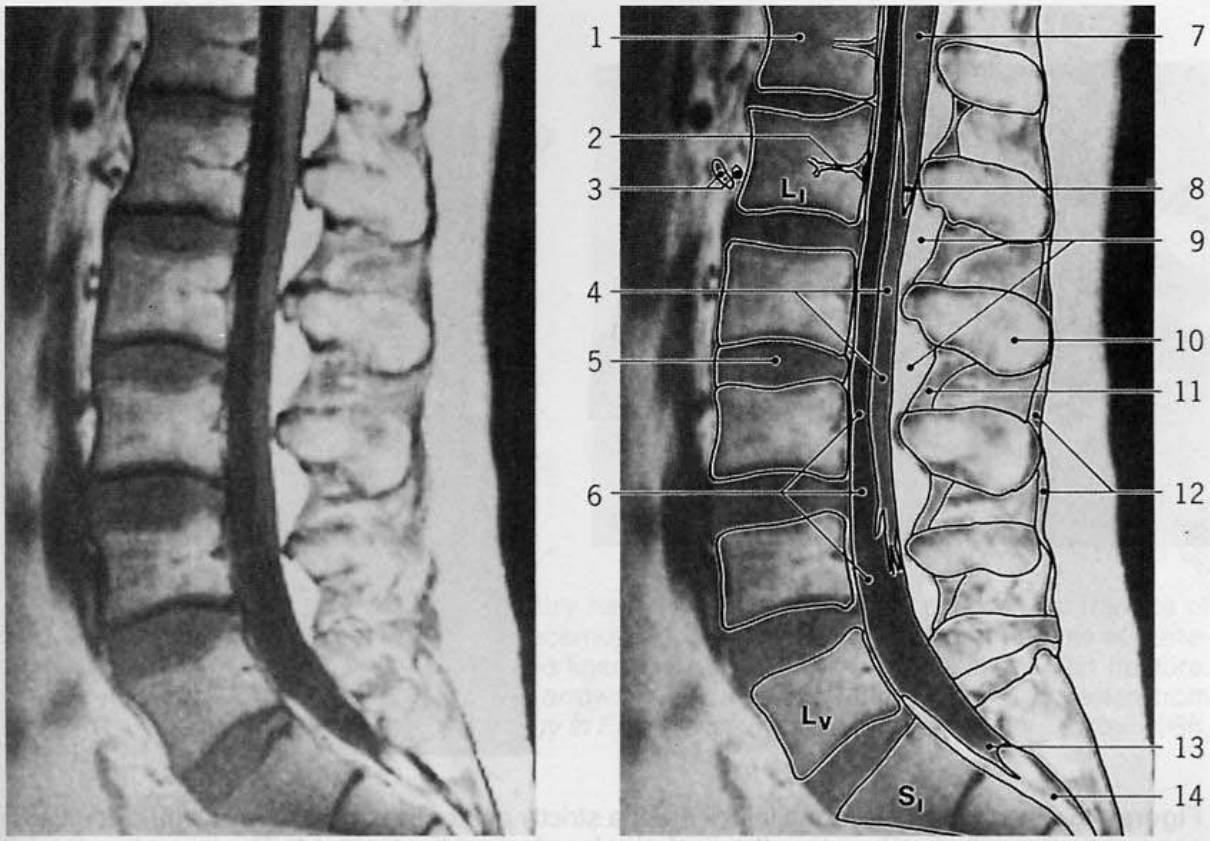
1. Body of vertebra
2. Intervertebral foramen
3. Lower end plate of L3
4. Intervertebral disk L3–4
5. Upper and lower ambitus eminens
6. Iliac crests
7. 12th rib
8. Superior articular process
9. Pedicle of vertebral arch
10. Lamina of vertebral arch
11. Spinous process
12. Inferior articular process
13. Transverse (costal) process
14. Sacrum

Figure 1-2. Lateral radiograph of the lumbar region. Note that the zygapophyseal (facet) joint that is formed between the inferior (*12*) and superior (*8*) articular processes is inclined somewhat vertically. Because of this orientation, dislocations occur only with an accompanying fracture of the thoracic or lumbar vertebrae. Note the close relation between the zygapophyseal (facet) joint and the intervertebral foramen (*2*), which transmits the spinal nerve. Because facet joints are synovial joints, rheumatoid arthritis may impinge on the spinal nerve and cause severe pain. The sacral promontory is the anterior edge of vertebral body S1 (*14*) and is an important obstetric landmark. (Reprinted with permission from Fleckenstein P, Tranum-Jensen J: *Anatomy in Diagnostic Imaging.* Philadelphia, WB Saunders, 1993, p 124.)



1. 12th rib
2. Zygapophyseal (facet) joint L1–2
3. Superior articular process of L3
4. Pedicle of vertebral arch L3 (eye of "Scottie dog")
5. Transverse process of L3 (snout of "Scottie dog")
6. Superior articular process of sacrum
7. Inferior articular process of L2
8. Transverse process of L3
9. Zygapophyseal (facet) joint L2–3
10. Lamina of vertebral arch L4

Figure 1-3. Oblique radiograph of the lumbar region ("Scottie dog" projection). The anatomic structures of the lumbar vertebrae make a Scottie dog shape. Spondylolysis is a chronic stress fracture of the pars interarticularis [an area between the pedicle (*4*) and the lamina (*10*)]. The fracture (*dotted lines*) appears as a "collar" around the neck of the Scottie dog. (Adapted with permission from Fleckenstein P, Tranum-Jensen J: *Anatomy in Diagnostic Imaging*. Philadelphia, WB Saunders, 1993, p 125.)



1. Body of 12th thoracic vertebra
2. Basivertebral vein
3. Lumbar artery and vein
4. Cauda equina
5. Intervertebral disk L2–3
6. Subarachnoid space
7. Spinal cord
8. Conus medullaris
9. Epidural fat
10. Spinous process of L2
11. Ligamentum flavum
12. Supraspinous ligament
13. Caudal termination of subarachnoid space
14. Sacral canal

Figure 1-4. Median sagittal MRI scan of the lumbar region. Note the basivertebral vein (*2*) that connects the internal vertebral venous plexus and the external vertebral venous plexus, all of which are involved in the metastasis of breast, lung, or prostate cancer to the brain. Note that the supraspinous ligament (*12*) continues cranially to the cervical region as the ligamentum nuchae (see Figure 1-1, label *17*), and that the ligamentum flavum (*11*) connects the laminae of two adjacent vertebrae. (Reprinted with permission from Fleckenstein P, Tranum-Jensen J: *Anatomy in Diagnostic Imaging.* Philadelphia, WB Saunders, 1993, p 129.)

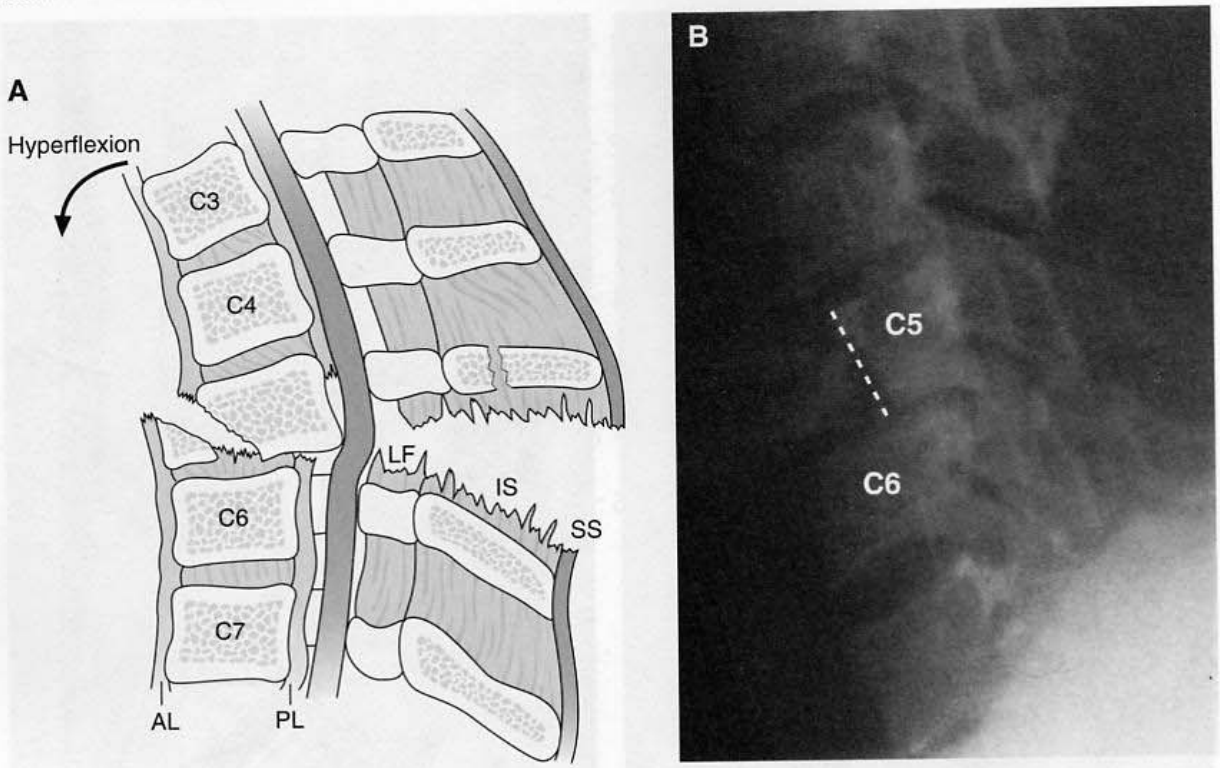


Figure 1-5. Teardrop hyperflexion injury. From a strictly anatomic perspective, hyperflexion of the cervical flexion will stretch or tear the posterior longitudinal ligament. (*A*) The injury has the following classic components (although variations occur, depending on the severity of the injury): avulsion fracture of a cervical (C5 shown) vertebral body ("teardrop body"), fracture of the spinous process, posterior subluxation of vertebrae, compression of the spinal cord, tear of the anterior longitudinal ligament (*AL*), and tear or disruption of the posterior longitudinal ligament (*PL*), ligamentum flavum (*LF*), interspinous ligament (*IS*), and supraspinous ligament (*SS*). (*B*) Lateral radiograph of a teardrop hyperflexion injury. Note the avulsion fracture of vertebral body C5 ("teardrop body"; *dotted line*) and the posterior subluxation of vertebra C5. (Adapted with permission from Levy RC, Hawkins H, Barsan WG: *Radiology in Emergency Medicine.* St. Louis, CV Mosby, 1986, p 78.)

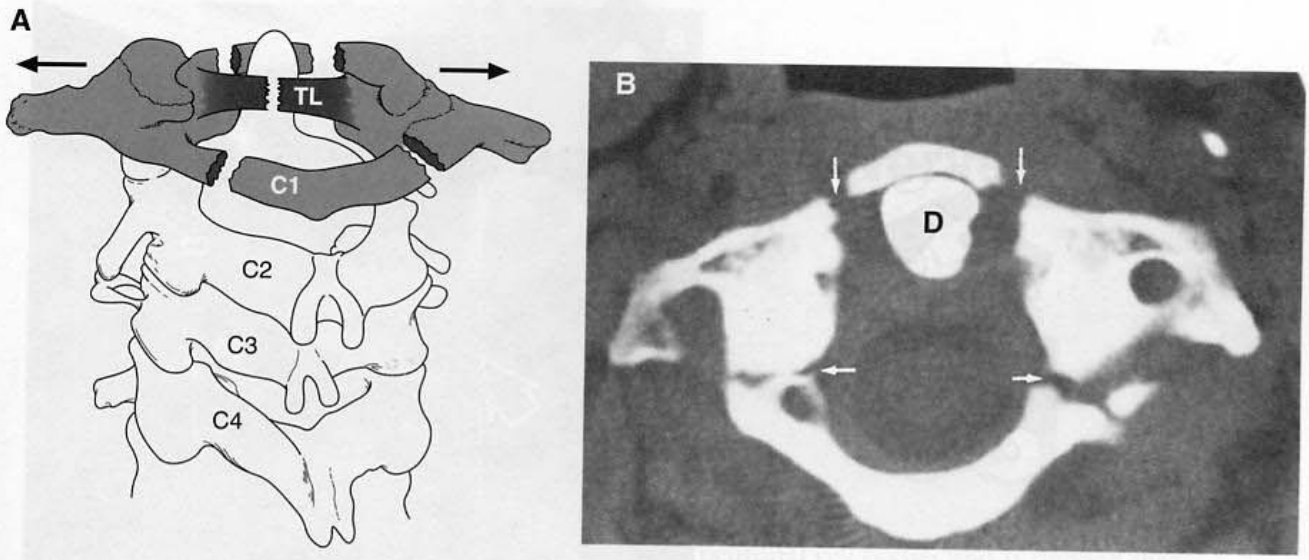


Figure 1-6. Jefferson fracture. (*A*) The injury has the following classic components: fracture of vertebra C1 at multiple sites, lateral displacement of vertebra C1 beyond the margins of vertebra C2 (*arrows*), and tear of the transverse ligament (*TL*). (*B*) CT scan of a Jefferson fracture. Fracture of vertebra C1 at multiple sites (*arrows*). *D* = dens. (*B* adapted with permission from Levy RC, Hawkins H, Barsan WG: *Radiology in Emergency Medicine*, St. Louis, CV Mosby, 1986, p 70.)

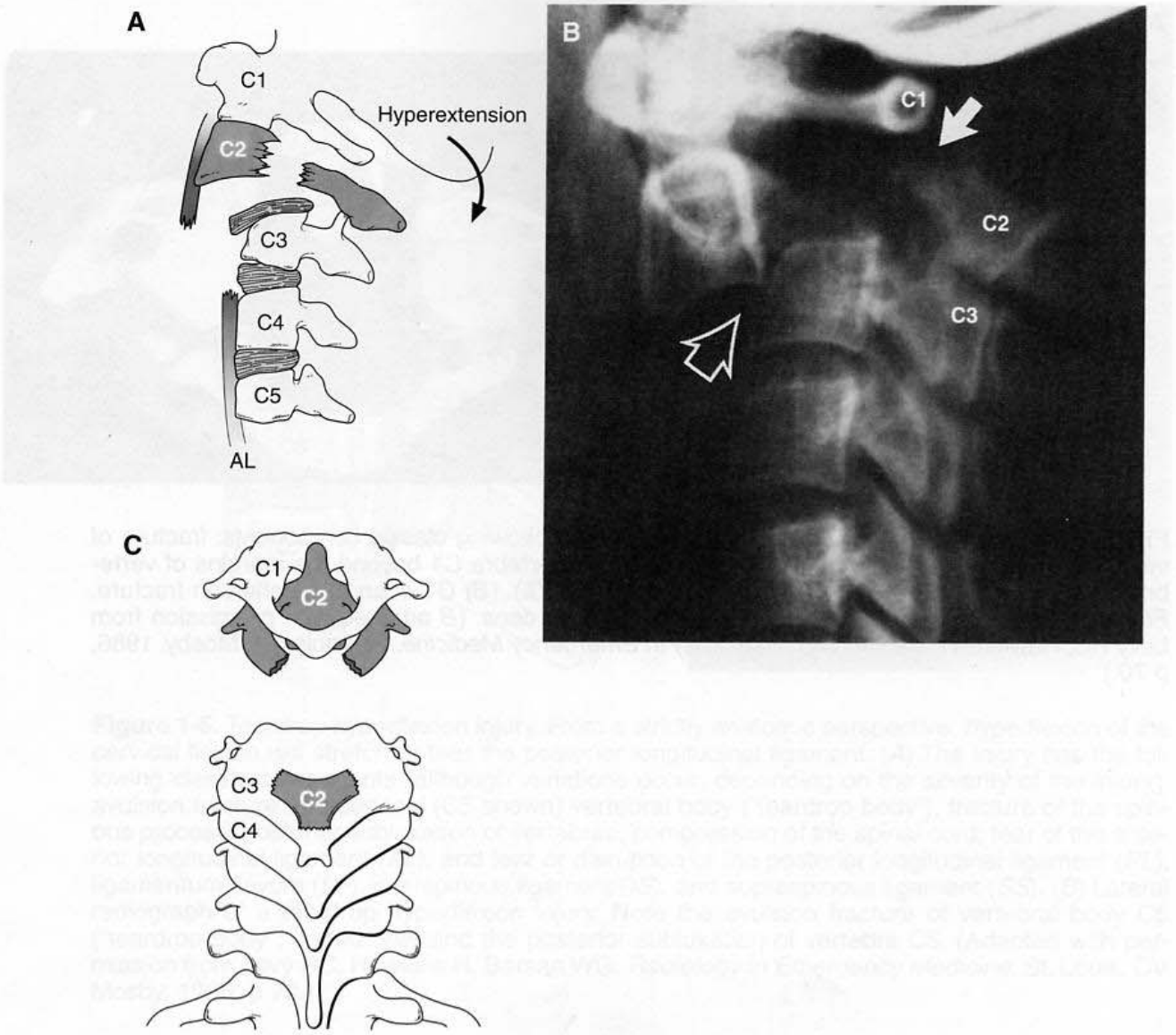


Figure 1-7. Hangman fracture. From a strictly anatomic perspective, hyperextension of the cervical column will stretch or tear the anterior longitudinal ligament. (*A*) The injury has the following classic components: bilateral fracture of the pars interarticularis of vertebra C2, anterior subluxation of vertebra C2, and tear of the anterior longitudinal ligament (*AL*). (*B*) Lateral radiograph of a hangman fracture. Note the fracture of the pars interarticularis of vertebra C2 (*solid arrow*) and the anterior subluxation of vertebra C2 (*open arrow*). (*C*) In a legal drop hanging, the posterior fractured portion of C2 remains attached to C3, and the distance between C2 and C3 is increased so that the spinal cord is stretched, causing death. [*B* adapted with permission from Osborn AG: Head trauma. In Eisenberg RL, Amberg JR (eds): *Critical Pathways in Radiology.* Philadelphia, JB Lippincott, 1981.]

2

Spinal Cord and Spinal Nerves

I. STRUCTURE OF THE SPINAL CORD

A. Components (Figure 2-1)

1. **Gray matter** of the spinal cord consists of neuronal cell bodies and is divided into the **dorsal horn, ventral horn**, and **lateral horn**.
2. **White matter** of the spinal cord consists of neuronal fibers and is divided into the **dorsal funiculus, ventral funiculus,** and **lateral funiculus**.
3. The **ventral median fissure** is a distinct surface indentation that is present at all levels of the spinal cord. It is related to the anterior spinal artery.
4. The **dorsal median fissure** is a surface indentation that is less distinct than the ventral median fissure. It is present at all levels of the spinal cord.
5. The **dorsal intermediate septum** is a surface indentation that is present only **at and above vertebra T6.** It distinguishes ascending fibers within the **gracile fasciculus** (from the lower extremity) from ascending fibers within the **cuneate fasciculus** (from the upper extremity).
6. The **conus medullaris** is the end of the spinal cord. It is located at vertebral level **L1 in the adult** and at vertebral level **L3 in the newborn**.
7. The **cauda equina** consists of the dorsal and ventral nerve roots of spinal nerves L2 through coccygeal 1. These nerve roots travel in the subarachnoid space below the conus medullaris.
8. The **filum terminale** is an extension of the **pia mater** that reaches from the conus medullaris to the end of the dural sac at vertebral level S2, where it joins the dura. The dura continues caudally as the **filum of the dura mater** (or coccygeal ligament), which attaches to the dorsum of the coccyx bone.

B. Meninges and spaces (see Figure 2-1)

1. The **epidural space** is located between the vertebra and the dura mater. This space contains fat and the **internal vertebral venous plexus**.
2. The **dura mater** is the tough, outermost layer of the meninges.
3. The **subdural space** is located between the dura mater and the arachnoid.
4. The **arachnoid** is a filmlike, transparent layer that is connected to the pia mater by **trabeculations**.
5. The **subarachnoid space** is located between the arachnoid and the pia mater. This space is filled with **cerebrospinal fluid**.

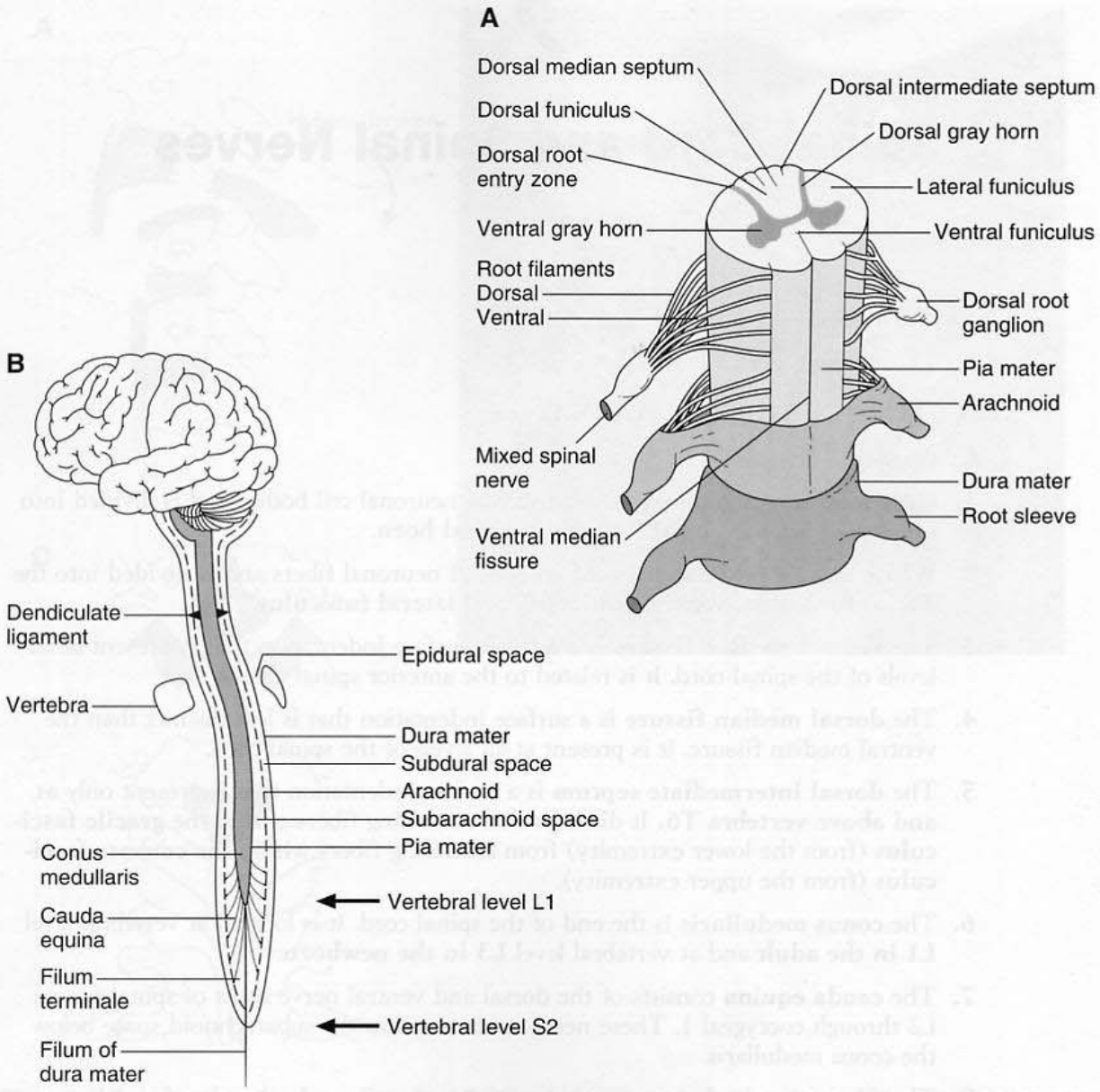


Figure 2-1. (*A*) Spinal cord and meninges. (*B*) Craniocaudal extent of the spinal cord and meninges. (*A* adapted with permission from Carpenter MB: *Core Text of Neuroanatomy*, 4th ed. Baltimore, Williams & Wilkins, 1991; *B* adapted with permission from Chung KW: *BRS Gross Anatomy*, 4th ed. Philadelphia, Lippincott Williams & Wilkins, 2000, p 289.)

6. The **pia mater** is a thin layer that adheres closely to the spinal cord. It has lateral extensions **(denticulate ligaments)** that attach to the dura mater, thereby suspending the spinal cord within the dural sac.

II. VASCULAR SUPPLY OF THE SPINAL CORD

A. Anterior spinal artery. There is only one anterior spinal artery, which arises from the vertebral arteries. It supplies the **ventral two-thirds** of the spinal cord.

B. Posterior spinal arteries. There are two posterior spinal arteries that arise from the vertebral arteries or the posterior inferior cerebellar arteries. They supply the **dorsal one-third** of the spinal cord.

C. Radicular arteries. The radicular arteries arise from the vertebral, deep cervical, ascending cervical, posterior intercostal, lumbar, and lateral sacral arteries. They enter the vertebral canal through the intervertebral foramina and branch into the anterior and posterior radicular arteries.

D. Great radicular artery (artery of Adamkiewicz)

1. The great radicular artery usually arises on the left side, from a posterior intercostal artery or a lumbar artery.
2. This artery is clinically important because it makes a major contribution to the anterior spinal artery. It also provides the main blood supply to the lower part of the spinal cord.
3. Ligation of the great radicular artery during resection of an **abdominal aortic aneurysm** may result in **anterior spinal artery syndrome**. Clinical findings include: paraplegia, impotence, loss of voluntary control of the bladder and bowel (incontinence), and loss of pain and temperature sensation (although vibration and proprioception sensation are retained).

III. THE SPINAL NERVE (Figures 2-1A and 2-2). There are 31 pairs of spinal nerves: 8 cervical, 12 thoracic, 5 lumbar, 5 sacral, and 1 coccygeal. Each spinal nerve has several components, as indicated below.

A. Small bundles of nerve fibers called **root filaments,** or **rootlets** (see Figure 2-1), arise from the dorsal and ventral surfaces of the spinal cord.

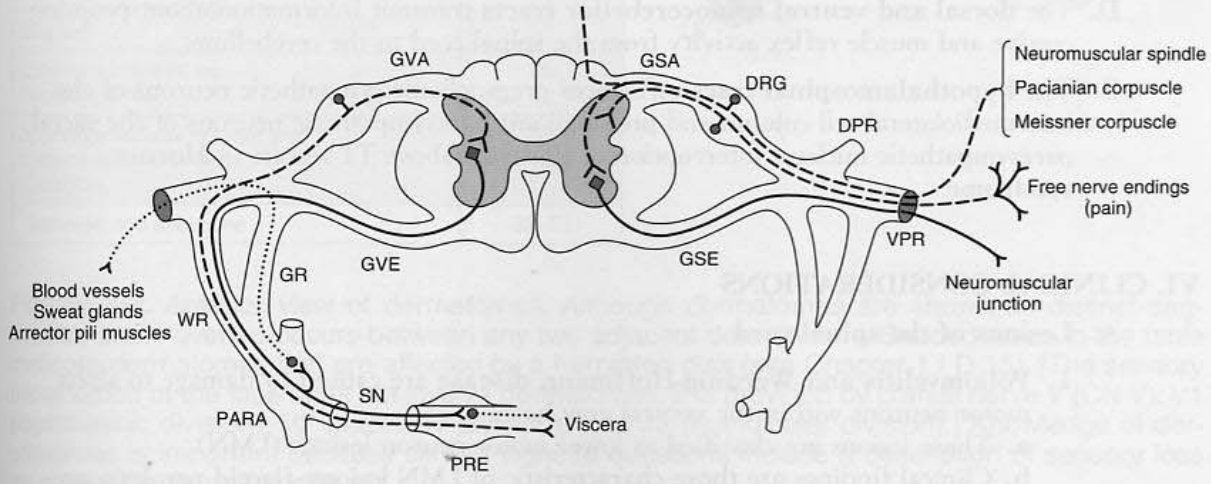


Figure 2-2. Components of a typical thoracic spinal nerve. The four functional components are the general somatic afferent (*GSA*), general somatic efferent (*GSE*), general visceral afferent (*GVA*), and general visceral efferent (*GVE*). The muscle stretch (myotactic) reflex includes the neuromuscular spindle, GSA dorsal root ganglion cell, GSE ventral horn motor neuron, and neuromuscular junction. *DRG* = dorsal root ganglion; *DPR* = dorsal primary ramus; *GR* = gray communicating ramus; *PARA* = paravertebral (sympathetic chain) ganglion; *PRE* = prevertebral ganglion; *SN* = splanchnic nerve; *VPR* = ventral primary ramus; *WR* = white communicating ramus.

B. Root filaments converge to form the **dorsal root**, which contains afferent (sensory) fibers, and the **ventral root**, which contains efferent (motor) fibers.

C. The dorsal and ventral roots join to form the **mixed spinal nerve** near the intervertebral foramen.

D. Each spinal nerve divides into a **dorsal primary ramus**, which innervates the skin and deep muscles of the back, and a **ventral primary ramus**, which innervates the remainder of the body.

E. Spinal nerves are connected to the paravertebral ganglia (sympathetic chain ganglia) and prevertebral ganglia by two types of rami.

1. The **white communicating rami** contain myelinated preganglionic sympathetic nerve fibers and are present only in spinal nerves T1–L3.
2. The **gray communicating rami** contain unmyelinated postganglionic sympathetic nerve fibers and are present in all spinal nerves.

IV. DERMATOMES (Figure 2-3)

are strips of skin that extend from the posterior midline to the anterior midline. Dermatomes are supplied by sensory branches of the dorsal and ventral rami of a single spinal nerve. A clinical finding of sensory deficit in a dermatome helps to assess which spinal nerve, nerve root, or spinal cord segment is damaged.

V. MAJOR TRACTS OF THE SPINAL CORD

A. The **dorsal column–medial lemniscus pathway** mediates tactile discrimination, vibration sensation, form recognition, and joint and muscle sensation (proprioception).

B. The **lateral spinothalamic pathway** mediates pain and temperature sensation.

C. The **lateral corticospinal tract** mediates voluntary skilled motor activity.

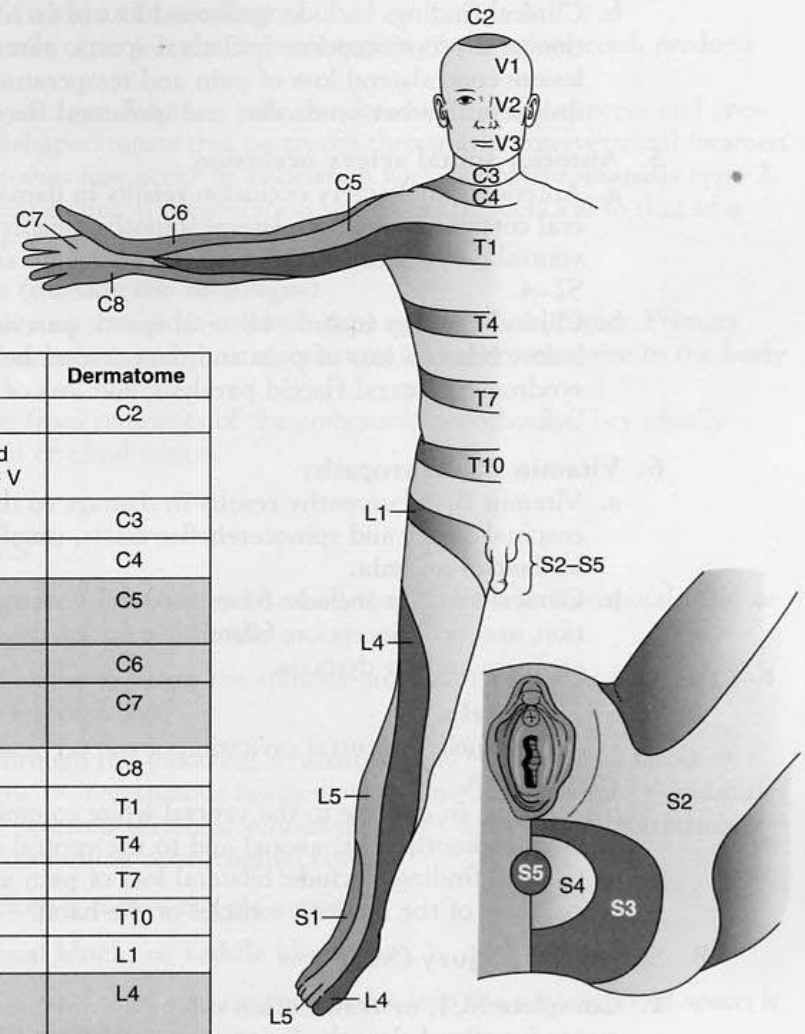
D. The **dorsal and ventral spinocerebellar tracts** transmit information about proprioceptive and muscle reflex activity from the spinal cord to the cerebellum.

E. The **hypothalamospinal tract** influences preganglionic sympathetic neurons of the intermediolateral cell column and preganglionic parasympathetic neurons of the sacral parasympathetic nucleus. Interruption of this tract above T1 results in **Horner syndrome**.

VI. CLINICAL CONSIDERATIONS

A. Lesions of the spinal cord

1. **Poliomyelitis and Werdnig-Hoffmann disease** are caused by damage to alpha motor neurons within the ventral gray horn.
   a. These lesions are classified as lower motor neuron lesions (LMN).
   b. Clinical findings are those characteristic of LMN lesions: flaccid paralysis, areflexia, atrophy, fasciculations and fibrillations, and an absent Babinski sign.
2. **Amyotrophic lateral sclerosis (Lou Gehrig disease)** is caused by damage to alpha motor neurons within the ventral gray horn and the lateral corticospinal tract.
   a. This lesion is classified as an LMN and upper motor neuron (UMN) lesion.
   b. Clinical findings are those characteristic of LMN (see VI A 1 b) and UMN lesions: spastic paralysis or paresis, no atrophy, hyperreflexia, no fasciculations or fibrillations, and a positive Babinski sign.



Structure	Dermatome
Top and posterior part of skull	C2
Face; V1 (ophthalmic), V2 (maxillary), and V3 (mandibular) divisions of cranial nerve V	
Upper neck (turtleneck shirt)	C3
Lower neck (low-collar shirt)	C4
Shoulder Lateral surface of upper limb	C5
Thumb	C6
Posterior surface of upper limb Index and middle fingers	C7
Ring and little fingers	C8
Medial surface of upper limb	T1
Nipples	T4
Xiphoid process	T7
Umbilicus (appendicitis pain)	T10
Inguinal ligament	L1
Medial surface of leg Big toe	L4
Lateral surface of leg Dorsum of foot	L5
Posterior surface of lower limb Lateral surface of foot Little toe	S1
Genitalia and anal zone	S2–S5

Figure 2-3. Anterior view of dermatomes. Although dermatomes are shown as distinct segments, some overlap occurs between any two adjacent dermatomes. Shaded areas in the table indicate dermatomes that are affected by a herniated disk (see Chapter 1 I D 15). [The sensory innervation of the face does not involve dermatomes. It is provided by cranial nerve V (CN V): V1 (ophthalmic division), V2 (maxillary division), and V3 (mandibular division).] Knowledge of dermatomes is important because clinical vignette questions include a description of sensory loss at a specific dermatome level.

3. **Tabes dorsalis (dorsal column disease)** is caused by damage to the sensory pathways of the dorsal column. Clinical findings include: loss of tactile discrimination, vibration sensation, and proprioception.

4. **Brown-Séquard syndrome (incomplete spinal cord injury, or hemisection)**
   a. Brown-Séquard syndrome may be caused by a penetrating blow to the dorsal columns, lateral corticospinal tract, lateral spinothalamic tract, hypothalamospinal tract, or ventral gray horn.

b. Clinical findings include: ipsilateral loss of tactile discrimination, vibration sensation, and proprioception; ipsilateral spastic paresis with pyramidal signs below the lesion; contralateral loss of pain and temperature one segment below the lesion; ipsilateral Horner syndrome; and ipsilateral flaccid paralysis.

5. **Anterior spinal artery occlusion**
   a. Anterior spinal artery occlusion results in damage to the following systems: lateral corticospinal tracts, lateral spinothalamic tracts, hypothalamospinal tracts, ventral gray horns, and corticospinal tracts to sacral parasympathetic centers at S2–4.
   b. Clinical findings include: bilateral spastic paresis, with pyramidal signs below the lesion; bilateral loss of pain and temperature below the lesion; bilateral Horner syndrome; bilateral flaccid paralysis; and loss of voluntary bladder and bowel control.

6. **Vitamin B_{12} neuropathy**
   a. Vitamin B_{12} neuropathy results in damage to the dorsal columns, lateral corticospinal tracts, and spinocerebellar tracts, usually due to **pernicious (megaloblastic) anemia.**
   b. Clinical findings include: bilateral loss of tactile discrimination, vibration sensation, and proprioception; bilateral spastic paresis with pyramidal signs; and bilateral arm and leg dystaxia.

7. **Syringomyelia**
   a. Syringomelia is central cavitation of the cervical spinal cord whose etiology is unknown.
   b. It results in damage to the ventral white commissure (involving the decussating lateral spinothalamic axons) and to the ventral gray horns.
   c. Clinical findings include: bilateral loss of pain and temperature, and flaccid paralysis of the intrinsic muscles of the hand.

B. Spinal cord injury (SCI)

1. **Complete SCI, or transection of the spinal cord,** results in loss of sensation and motor function below the lesion. There are two types.
   a. **Paraplegia,** or paralysis of the lower limbs, results if the transection occurs anywhere between the cervical and lumbar enlargements of the spinal cord.
   b. **Quadriplegia**, or paralysis of all four limbs, occurs if the transection occurs above C3. If the phrenic nerve is compromised, death may occur rapidly as a result of respiratory failure.

2. **Incomplete SCI** can be ameliorated somewhat by rapid surgical intervention. Three situations may lead to incomplete SCI: concussive blow, anterior spinal artery occlusion, or penetrating blow (e.g., Brown-Séquard syndrome).

3. **Complications of SCI** include: hypotension in the acute setting, ileus (bowel obstruction because of lack of motility), renal stones, pyelonephritis, renal failure, and deep venous thrombosis. **Methylprednisolone** may be beneficial if administered within 8 hours of injury.

C. Tumors of the spinal cord

1. **Intramedullary tumors (within the spinal cord)**
   a. **Ependymoma** is the most common intramedullary tumor (60%). These tumors may occur in the cervical region, near the obliterated central canal where tumor cells align around pathologic tubular cavities **(syrinx).** They also may occur in the lumbosacral region associated with the conus medullaris.
   b. **Astrocytoma** usually occurs in the cervical and thoracic regions of the spinal cord.

2. **Intradural tumors (within the meninges)**
   a. **Meningioma** usually occurs in the thoracic region of the spinal cord, predominantly in women.
   b. **Schwannomas** arise from Schwann cells associated with a spinal nerve and present as a dumbbell-shaped tumor that protrudes through the intervertebral foramen. Multiple schwannomas may occur in association with **neurofibromatosis type 2.**
   c. **Neurofibroma** has a clinical presentation that is nearly identical to that of a schwannoma (see VI C 2 b).
3. **Extradural tumors (outside the meninges)**
   a. **Metastatic tumors** are the most common type of extradural tumor. Primary cancers of the lung, breast, and prostate most commonly metastasize to the **body of vertebrae.**
   b. **Chordomas** arise from remnants of the embryonic notochord. They usually occur in the sacral or clival region.

VII. CLINICAL PROCEDURES

A. Lumbar puncture (Figure 2-4) can be performed to withdraw cerebrospinal fluid or to inject an anesthetic (e.g., spinal anesthesia).

1. A needle is inserted above or below the spinous process of **vertebra L4** (i.e., L3–4 or L4–5 interspace, respectively)
2. The needle passes through the following structures: skin → superficial fascia → supraspinous ligament → interspinous ligament → ligamentum flavum → epidural space containing the internal vertebral venous plexus → dura mater → arachnoid → subarachnoid space containing cerebrospinal fluid.
3. The needle stops before it pierces the pia mater.

B. Spinal anesthesia (spinal block, or saddle block)

1. Spinal anesthesia is produced by injecting anesthetic into the subarachnoid space; it may be used during childbirth.
2. Sensory nerve fibers for pain from the uterus travel with the pelvic splanchnic nerves (parasympathetic) to spinal levels S2–4 from the cervix, and may be responsible for referred pain to the gluteal region and legs. Sensory nerve fibers for pain also travel with the hypogastric plexus and lumbar splanchnic nerves (sympathetic) to spinal levels L1–3 from the fundus and body of the uterus and oviducts, and may be responsible for referred pain to the back.
3. Spinal anesthesia up to **spinal nerve T10** is necessary to block pain from vaginal childbirth. Anesthesia must reach **spinal nerve T4** for cesarean delivery, which is accomplished by increasing the amount of anesthetic injected.
4. Pregnant women require less anesthetic than nonpregnant patients because the subarachnoid space is compressed by the **internal vertebral venous plexus,** which is engorged with blood because the pregnant uterus compresses the inferior vena cava.
5. Complications may include: **hypotension** as a result of sympathetic blockade and vasodilation; **respiratory paralysis** involving the phrenic nerve as a result of high spinal blockade and **spinal headache** as a result of leakage of cerebrospinal fluid.

C. Lumbar epidural anesthesia

1. Lumbar epidural anesthesia is produced by injecting anesthetic into the **epidural space,** most commonly at the L2–3 or L3–4 interspace; it may be used during childbirth.

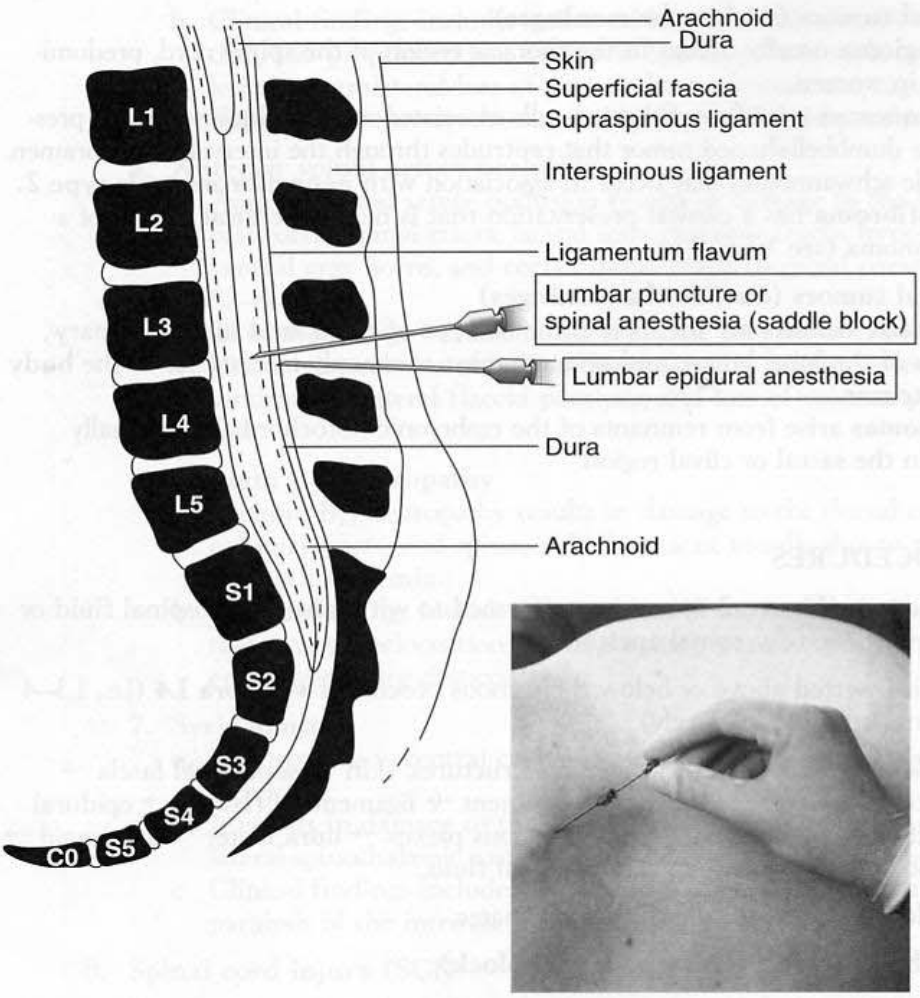


Figure 2-4. Lumbar vertebral column and spinal cord. A needle is shown inserted into the subarachnoid space above the spinous process of L4 (L3—4 interspace) to withdraw cerebrospinal fluid or administer spinal anesthesia. A second needle is shown inserted into the epidural space to administer lumbar epidural anesthesia. Note the sequence of layers (superficial to deep) that the needle must penetrate. (*Inset* reprinted with permission from Scott DB: *Techniques of Regional Anaesthesia*, East Norwalk, CT, Appleton & Lange, 1989, p 169.)

Figure 2-5. (*A*) MRI scan of an astrocytoma. An astrocytoma is an intramedullary (within the spinal cord) tumor. Note the astrocytoma (*arrows*) within the substance of the spinal cord; it has a cystic appearance. (*B*) MRI scan of a meningioma. A meningioma is an intradural (within the meninges) tumor. Note the meningioma (*arrow*) outside the spinal cord, causing some compression of the spinal cord. (*C, D*) MRI scan of a schwannoma. A schwannoma is another type of intradural (within the meninges) tumor. (*C*) Note the schwannoma (*arrow*) within the dural sac, at approximately vertebral level L3, involving the cauda equina. The key to interpreting this image is to remember that in adults, the spinal cord ends at vertebral level L1. Therefore, the spinal cord is not present at L3, so this tumor *cannot* be intramedullary. (*D*) MRI scan of the intervertebral foramen showing the schwannoma protruding through the intervertebral foramen (*arrow*), a clear characteristic of a schwannoma (or neurofibroma). (*A* reprinted with permission from Reimer P, Parizel PM, Stichnoth F-A: *Clinical MR Imaging: A Practical Approach.* Berlin, Springer-Verlag, 1999, p 147; *B—D* adapted with permission from Runge VM: *Contrast Media in Magnetic Resonance Imaging: A Clinical Approach.* Philadelphia, JB Lippincott, 1992, pp 97–99.)

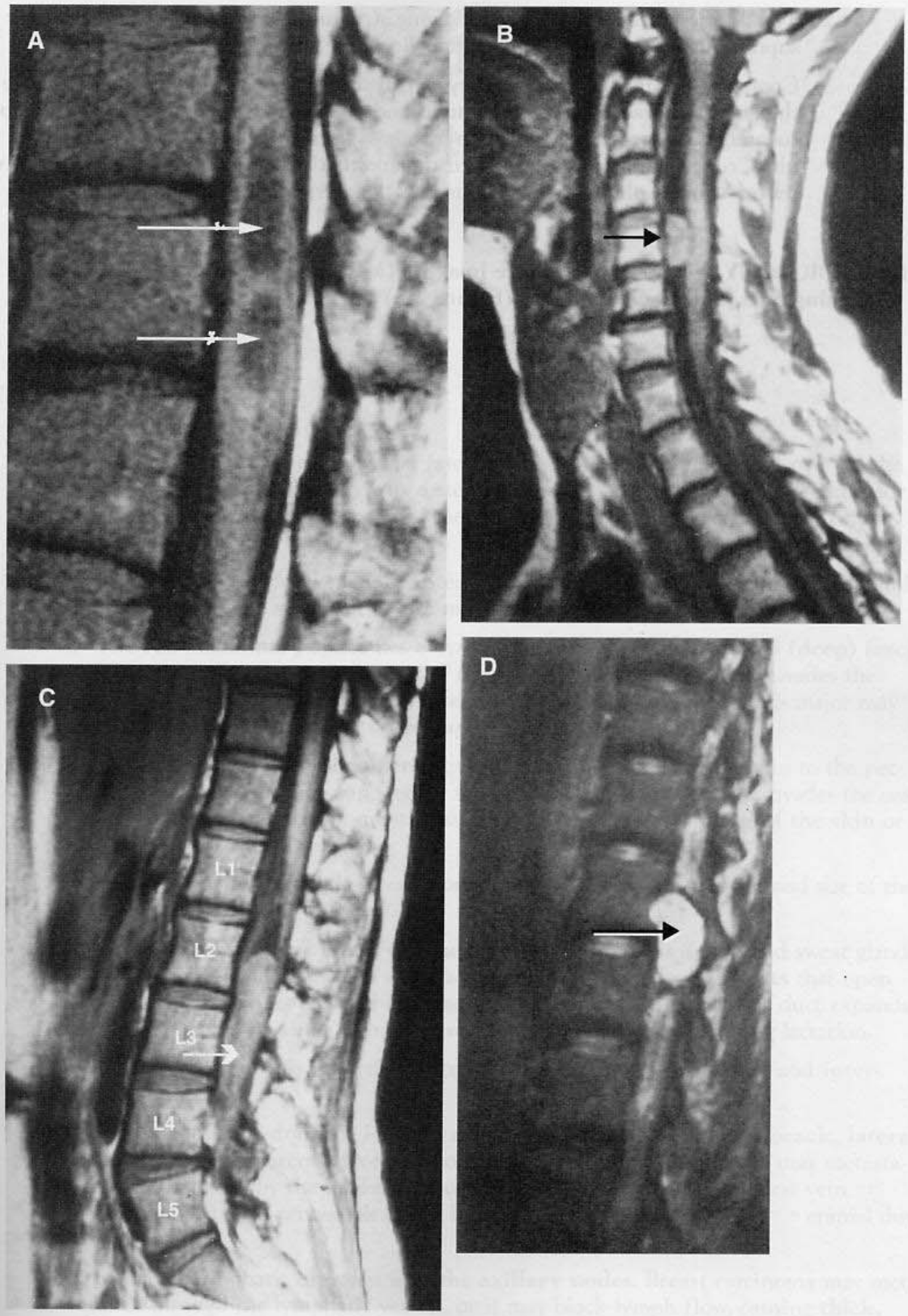


Figure 2-5.

2. The needle passes through the following structures: skin → superficial fascia → supraspinous ligament → interspinous ligament → ligamentum flavum.
3. Complications include: **respiratory paralysis** as a result of high spinal blockage if the dura and arachnoid are punctured and anesthetic is mistakenly injected into the subarachnoid space, and **central nervous system toxicity** (e.g., slurred speech, tinnitus, convulsions, cardiac arrest) if the anesthetic is injected into the **internal vertebral venous plexus** (intravenous injection versus epidural application).

VIII. RADIOLOGY. Magnetic resonance imaging (MRI) scans of an astrocytoma, a meningioma, and a schwannoma (Figure 2-5)

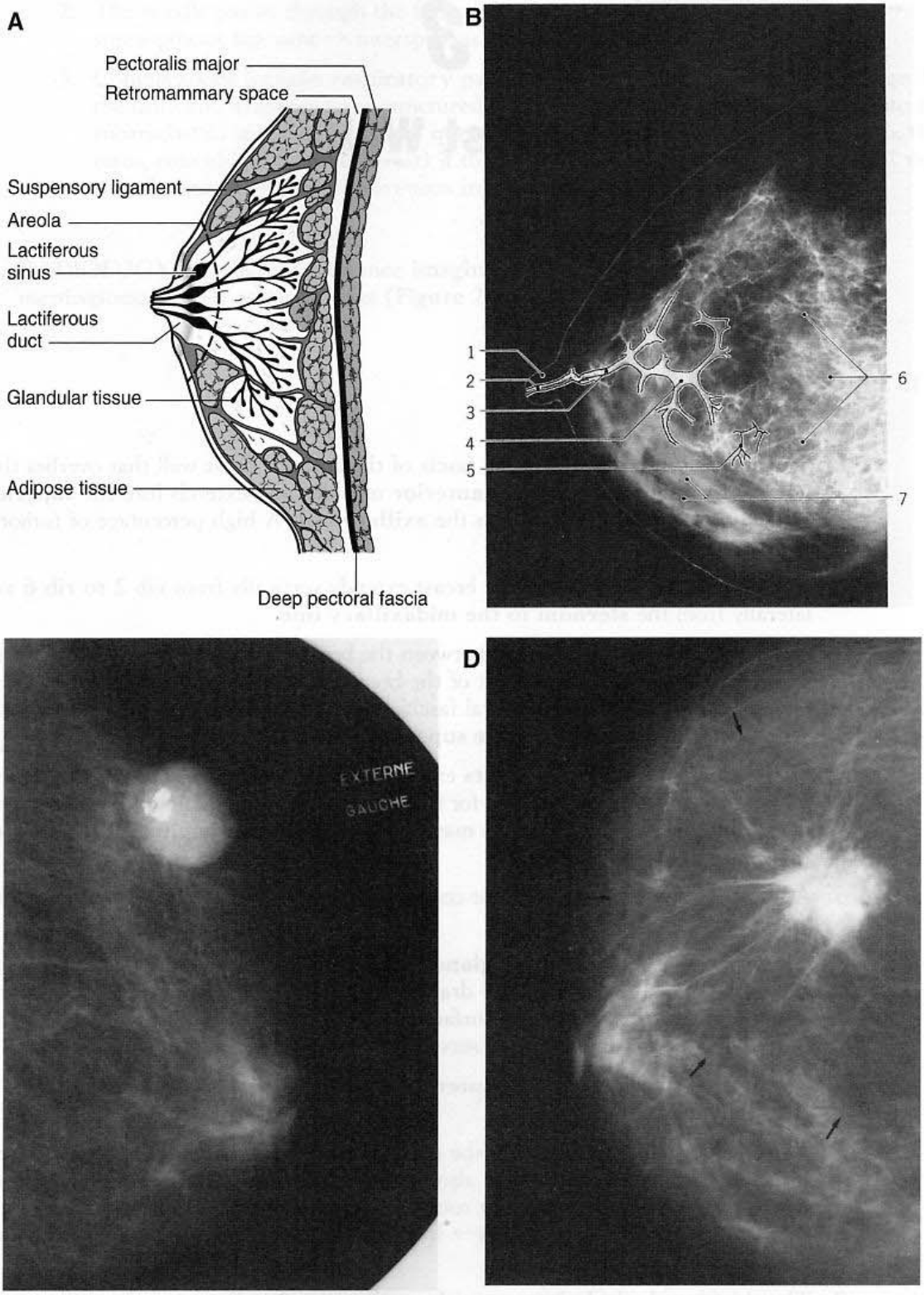
3

Chest Wall

I. BREAST (Figure 3-1)

A. Components

1. The breast lies in the superficial fascia of the anterior chest wall that overlies the **pectoralis major** and **serratus anterior muscles** and extends into the **superior lateral quadrant** of the axilla as the **axillary tail.** A high percentage of tumors occur in the axillary tail.
2. In a fully developed woman, the breast extends vertically from **rib 2 to rib 6** and laterally from the **sternum to the midaxillary line.**
3. The **retromammary space** lies between the breast and the **pectoral (deep) fascia.** This space allows free movement of the breast. If breast carcinoma invades the retromammary space and pectoral fascia, contraction of the pectoralis major may cause the **whole breast to move superiorly.**
4. **Suspensory (Cooper) ligaments** extend from the dermis of the skin to the pectoral fascia and provide support for the breast. If breast carcinoma invades the suspensory ligaments, the ligaments may shorten and cause **dimpling of the skin** or **inversion of the nipple.**
5. **Adipose tissue** within the breast contributes largely to the contour and size of the breast.
6. **Glandular tissue (mammary gland)** within the breast is a modified sweat gland consisting of acini. The acini are drained by 15–20 **lactiferous ducts** that open onto the nipple. Just below the surface of the nipple, each lactiferous duct expands into a **lactiferous sinus,** which serves as a reservoir for milk during lactation.
7. The arterial supply is from the **internal thoracic, lateral thoracic,** and **intercostal arteries.**
8. The chief venous drainage is to the **axillary vein.** The **internal thoracic, lateral thoracic,** and **intercostal veins** also participate. **Breast carcinoma** may metastasize to the brain by the following route: cancer cells enter an intercostal vein → external vertebral venous plexus → internal vertebral venous plexus → cranial dural sinuses.
9. The chief lymphatic drainage is to the **axillary nodes.** Breast carcinoma may metastasize through the lymphatic vessels, or it may block lymph flow, causing **thick, leathery skin.**
10. Sensory innervation is via **intercostal nerves 2–6.**


A
Pectoralis major
Retromammary space
Suspensory ligament
Areola
Lactiferous sinus
Lactiferous duct
Glandular tissue
Adipose tissue
Deep pectoral fascia
B
1
2
3
4
5
6
7
C
EXTERNE
GAUCHE
D

B. Nipple secretion or discharge

1. **Nipple secretion** typically contains exfoliated duct cells, α-lactalbumin, immunoglobulins, lactose, cholesterol, steroids, and fatty acids, along with ethanol, caffeine, nicotine, barbiturates, pesticides, and technetium.
2. **Nipple discharge**
   a. Nipple discharge from a **benign** cause typically is green, milky, yellow, or brown; is bilateral; is not spontaneous; and affects multiple ducts.
   b. Milky discharge (galactorrhea) that is accompanied by headache and loss of peripheral vision may indicate a **pituitary adenoma (prolactinoma).**
   c. Nipple discharge from a **malignant** cause typically is bloody or clear (serous), is unilateral, is spontaneous, and affects a single duct.

C. Clinical considerations

1. **Fibroadenoma** is a benign proliferation of connective tissue in which the mammary glands are compressed into cords of epithelium. It presents clinically as a sharply circumscribed, spherical nodule that moves freely.
2. **Infiltrating ductal carcinoma**
   a. Infiltrating ductal carcinoma is a malignant proliferation of duct epithelium in which the tumor cells are arranged in cell nests, cords, anastomosing masses, or a mixture of all of these.
   b. It is the most common type of breast cancer, accounting for 65%–80% of all cases.
   c. It presents clinically as a jagged-edged mass that is fixed in position, with dimpled skin in the area of the lesion, an inverted nipple, and thick, leathery skin.
   d. The presence of **estrogen receptors** or **progesterone receptors** within the carcinoma cells indicates a good prognosis for treatment. **Tamoxifen** is an estrogen-receptor blocker and is one of the preferred drugs for treatment.
   e. The presence of the **c-erb B2 oncoprotein** (a protein similar to the epidermal growth factor receptor) on the surface of the carcinoma cells indicates a poor prognosis for treatment.
   f. **BRCA 1** (the breast cancer susceptibility gene) is an antioncogene (tumor suppressor gene) located on chromosome 17 (17q21). This gene encodes for **BRCA protein** (a zinc finger gene regulatory protein) that contains phosphotyrosine and suppresses the cell cycle. A mutation of the BRCA 1 gene is present in 5%–10% of women with breast cancer. This mutation confers a very high lifetime risk of breast and ovarian cancer.

◀ **Figure 3-1.** (*A*) Anatomy of the breast. (*B*) Ductogram. *1* = nipple; *2* = lactiferous duct; *3* = lactiferous sinus; *4* = major excretory duct; *5* = minor excretory duct; *6* = glandular tissue with contrast filling; *7* = glandular tissue without contrast filling. (*C*) Mediolateral oblique mammogram showing a benign mass. A benign mass has the following characteristics: the shape is round or oval; the margins are well circumscribed; the density is low to medium contrast; it becomes smaller over time; and calcifications are large, smooth, and uniform. (*D*) Craniocaudal mammogram showing a malignant mass. A malignant mass has the following characteristics: the shape is irregular, with many lobulations; the margins are irregular or spiculated; the density is medium to high; the breast architecture may be distorted; it becomes larger over time; and calcifications (not shown) are small, irregular, variable, and found within the ducts (ductal casts). *Arrows* indicate a clear zone around the tumor, with spicules. (*B* reprinted with permission from Fleckenstein P, Tranum-Jensen J: *Anatomy in Diagnostic Imaging.* Philadelphia, WB Saunders, 1993, p 239; *C* reprinted and *D* adapted with permission from Le Treut A, Dilhuydy MH: *Mammography: A Guide to Interpretation.* St. Louis, Mosby-Year Book, 1991, pp 36, 103.)

3. **Surgical procedures for breast cancer**
   a. **Lumpectomy** is the removal of the primary lesion with clear gross margins around the tumor.
   b. **Axillary lymphadenectomy** is the removal of level I lymph nodes (at the lateral border of the pectoralis minor muscle) and level II nodes (behind the pectoralis minor muscle). Level III nodes (at the medial border of the pectoralis minor muscle) usually are not removed.
   c. **Simple mastectomy** is the removal of all breast tissue, including the nipple–areolar complex. Care is taken to preserve the **long thoracic nerve.** Damage to this nerve paralyzes the serratus anterior muscle, causing a **"winged scapula."**
   d. **Modified radical mastectomy (Patey operation)** is the removal of the skin, entire breast, pectoralis minor muscle, and axillary contents.
   e. **Halsted radical mastectomy** is the removal of the skin, entire breast, pectoralis minor muscle, pectoralis major muscle, and axillary contents.

II. ANTERIOR CHEST WALL

A. Insertion of a central venous catheter (Figure 3-2A). Access to the superior vena cava (SVC) and the right side of the heart is required to monitor blood pressure, maintain long-term parenteral feeding, or administer drugs. The internal jugular vein (IJV) and subclavian vein (SCV) usually are used.

1. **IJV (central or anterior approach).** The needle is inserted at the apex of a triangle formed by two heads of the sternocleidomastoid muscle and the clavicle on the right side.
2. **SCV (infraclavicular approach).** The index finger is placed at the sternal notch, and the thumb is placed at the intersection of the clavicle and first rib as anatomic landmarks. The needle is inserted below the clavicle and lateral to the thumb on the right side.
3. Complications of a central venous catheter include: puncture of the subclavian artery or SCV, pneumothorax, hemothorax, trauma to the trunks of the brachial plexus, arrhythmia, venous thrombosis, erosion of the catheter through the SVC, damage to the tricuspid valve, and infection.

B. Postductal coarctation of the aorta (see Figure 3-2B)

1. Postductal coarctation of the aorta is a congenital malformation that may be associated with increased blood pressure to the upper extremities, diminished and delayed femoral artery pulse, and increased risk of cerebral hemorrhage and bacterial endocarditis.
2. Postductal coarctation of the aorta usually is located distal to the left subclavian artery and the ligamentum arteriosum.
3. Collateral circulation involves the internal thoracic artery → intercostal arteries → superior epigastric artery → inferior epigastric artery → external iliac arteries. These arteries bypass the constriction and become dilated. Dilation of the intercostal arteries causes erosion of the lower border of the ribs, or **rib notching.**
4. **Preductal coarctation** is less common. It occurs proximal to the ductus arteriosus. When preductal coarctation occurs, blood reaches the lower part of the body through a patent ductus arteriosus.

C. Aneurysm of the aorta. Aneurysm of the aorta may compress and tug on the trachea with each cardiac systole so that the aneurysm can be felt by palpating the trachea at the sternal notch (T2).

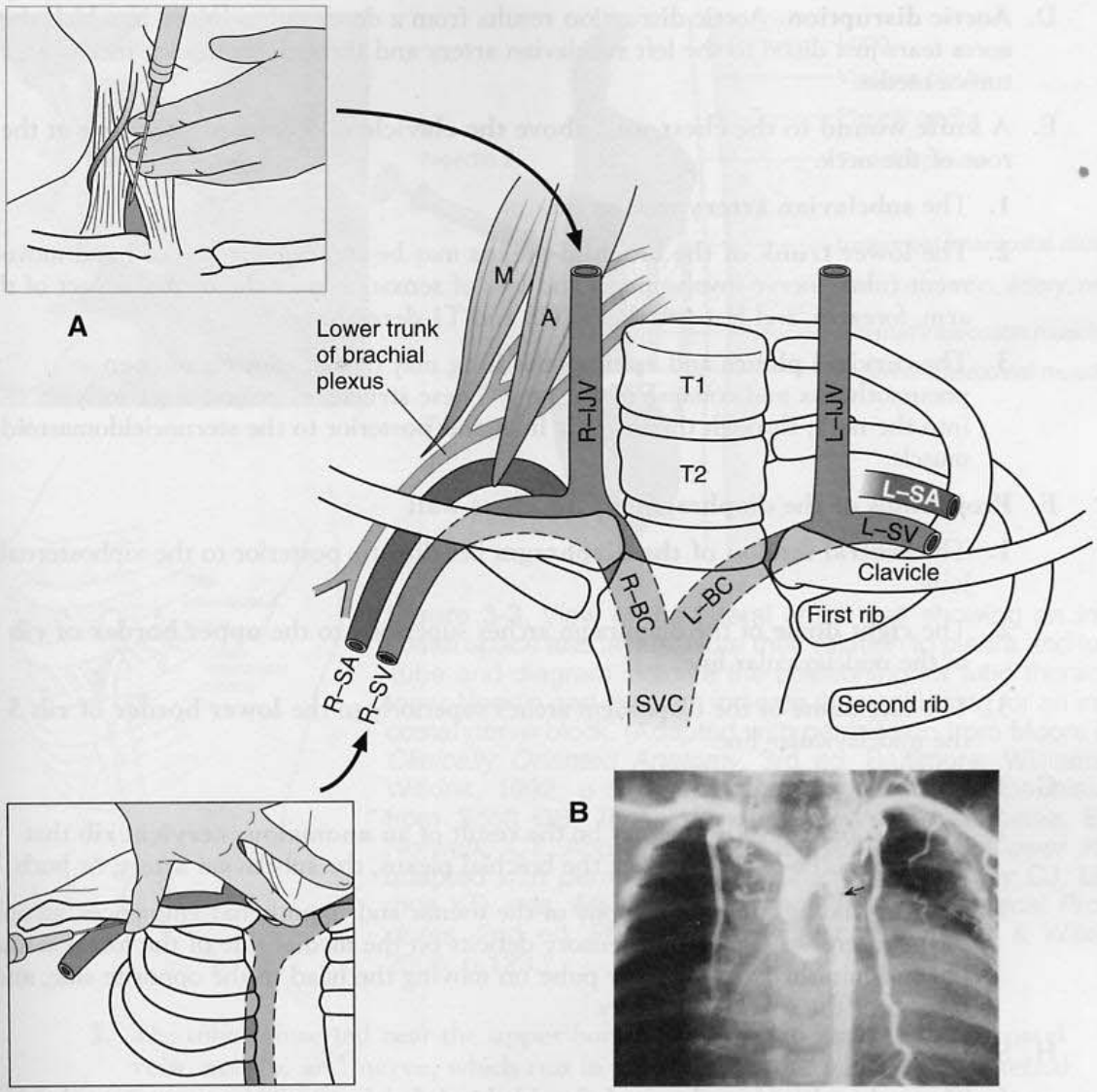


Figure 3-2. (*A*) Anterior chest wall. The first pair of ribs is shown with their articulation with vertebra T1 and the manubrium of the sternum. Structures that cross rib 1 (subclavian vein, subclavian artery, and brachial plexus) are shown on the right. Note the relation of these structures to the clavicle. Note also the arrangement of the large veins in this area and how they may be used in placing a central venous catheter (central or infraclavicular approach). *A* = anterior scalene muscle; *L-BC* = left brachiocephalic vein; *L-IJV* = left internal jugular vein; *L-SA* = left subclavian artery; *L-SV* = left subclavian vein; *M* = middle scalene muscle; *R-BC* = right brachiocephalic vein; *R-IJV* = right internal jugular vein; *R-SA* = right subclavian artery; *R-SV* = right subclavian vein; *SVC* = superior vena cava. (*B*) Anteroposterior aortogram showing postductal coarctation of the aorta (*arrow*). (*A* adapted with permission from Moore KL: *Clinically Oriented Anatomy,* 3rd ed. Baltimore, Williams & Wilkins, 1992, p 38; *B* reprinted with permission from Moller JH, Amplatz K, Edwards JE: *Congenital Heart Disease*, Kalamazoo, MI, Upjohn Company, 1971, p 21; *insets* adapted with permission from Chen H, Sonneday CJ, Lillemoe KD, eds: *Manual of Common Bedside Surgical Procedures,* 2nd ed. Philadelphia, Lippincott Williams & Wilkins, 2000, pp 39, 47.)

D. Aortic disruption. Aortic disruption results from a deceleration injury in which the aorta tears just distal to the left subclavian artery and through the tunica intima and tunica media.

E. A **knife wound to the chest wall above the clavicle** may damage structures at the root of the neck.

1. The **subclavian artery** may be cut.
2. The **lower trunk of the brachial plexus** may be cut, causing loss of hand movement (ulnar nerve involvement) and loss of sensation over the medial aspect of the arm, forearm, and last two digits (C8 and T1 dermatomes).
3. The **cervical pleura** and **apex of the lung** may be cut, causing an open pneumothorax and collapse of the lung. These structures project superiorly into the neck, through the thoracic inlet and posterior to the sternocleidomastoid muscle.

F. Projections of the diaphragm on the chest wall

1. The **central tendon of the diaphragm** lies directly posterior to the xiphosternal joint.
2. The **right dome** of the diaphragm arches superiorly to the **upper border of rib 5** in the midclavicular line.
3. The **left dome** of the diaphragm arches superiorly to the **lower border of rib 5** in the midclavicular line.

G. Thoracic outlet syndrome

1. Thoracic outlet syndrome may be the result of an **anomalous cervical rib** that compresses the lower trunk of the brachial plexus, the subclavian artery, or both.
2. Clinical findings include: atrophy of the thenar and hypothenar eminences, atrophy of the interosseous muscles, sensory deficits on the medial side of the forearm and hand, diminished radial artery pulse on moving the head to the opposite side, and a bruit over the subclavian artery.

H. Scalene lymph node biopsy

1. The scalene lymph nodes are located behind the clavicle. They are surrounded by pleura, lymph ducts, and the phrenic nerve.
2. Inadvertent damage to these structures causes the following clinical findings: pneumothorax (pleura), lymph leakage (lymph ducts), and diaphragm paralysis (phrenic nerve).

III. LATERAL CHEST WALL

A. Tube thoracostomy (Figure 3-3)

1. Tube thoracostomy is performed to evacuate ongoing production of air and fluid into the pleural cavity. A tube is inserted through intercostal space 5 in the anterior axillary line (posterior approach). An incision is made at intercostal space 6, lateral to the nipple, but medial to the latissimus dorsi muscle.
2. The tube penetrates the following structures: skin → superficial fascia → serratus anterior muscle → external intercostal muscle → internal intercostal muscle → innermost intercostal muscle → parietal pleura.

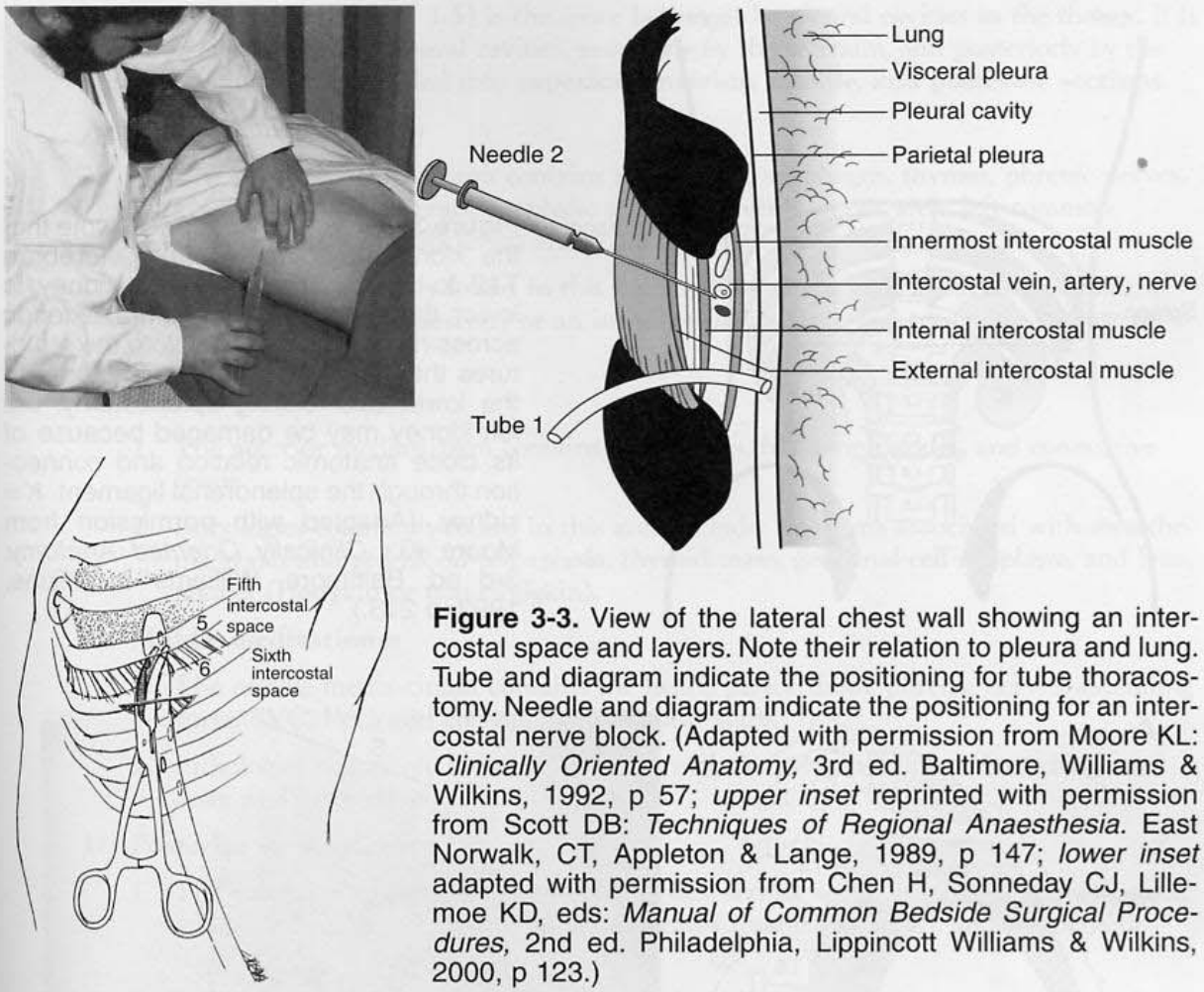


Figure 3-3. View of the lateral chest wall showing an intercostal space and layers. Note their relation to pleura and lung. Tube and diagram indicate the positioning for tube thoracostomy. Needle and diagram indicate the positioning for an intercostal nerve block. (Adapted with permission from Moore KL: *Clinically Oriented Anatomy,* 3rd ed. Baltimore, Williams & Wilkins, 1992, p 57; *upper inset* reprinted with permission from Scott DB: *Techniques of Regional Anaesthesia.* East Norwalk, CT, Appleton & Lange, 1989, p 147; *lower inset* adapted with permission from Chen H, Sonneday CJ, Lillemoe KD, eds: *Manual of Common Bedside Surgical Procedures,* 2nd ed. Philadelphia, Lippincott Williams & Wilkins, 2000, p 123.)

3. The tube is inserted near the **upper** border of the rib to avoid the **intercostal vein, artery, and nerve,** which run in the costal groove between the internal intercostal muscle and the innermost intercostal muscle.

B. Intercostal nerve block (see Figure 3-3)

1. **Intercostal nerve block** may be necessary to relieve pain associated with a rib fracture or herpes zoster (shingles). A needle is inserted at the posterior angle of the rib, along the **lower** border of the rib, to bathe the nerve in anesthetic.
2. The needle penetrates the following structures: skin → superficial fascia → serratus anterior muscle → external intercostal muscle → internal intercostal muscle.
3. Several intercostal nerves must be blocked to achieve pain relief because of the presence of nerve collaterals (i.e., overlapping of contiguous dermatomes; see Figure 2-3).

IV. POSTERIOR CHEST WALL. Fractures of the lower ribs (Figure 3-4)

A. A rib fracture on the right side may damage the **right kidney** and **liver.**

B. A rib fracture on the left side may damage the **left kidney** and **spleen.**

C. A rib fracture on either side may damage the **pleura** as it crosses rib 12.

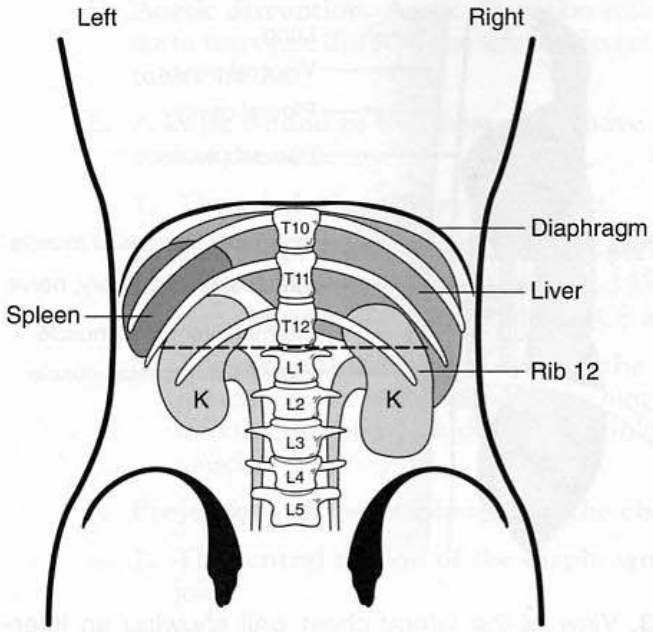


Figure 3-4. Posterior chest wall. Note that the kidneys are located from vertebrae T12 to L3 and that the right kidney is lower than the left. The pleura extends across rib 12 (*dotted line*). Note the structures that may be injured by fractures to the lower ribs. During splenectomy, the left kidney may be damaged because of its close anatomic relation and connection through the splenorenal ligament. *K* = kidney. (Adapted with permission from Moore KL: *Clinically Oriented Anatomy,* 3rd ed. Baltimore, Williams & Wilkins, 1992, p 213.)

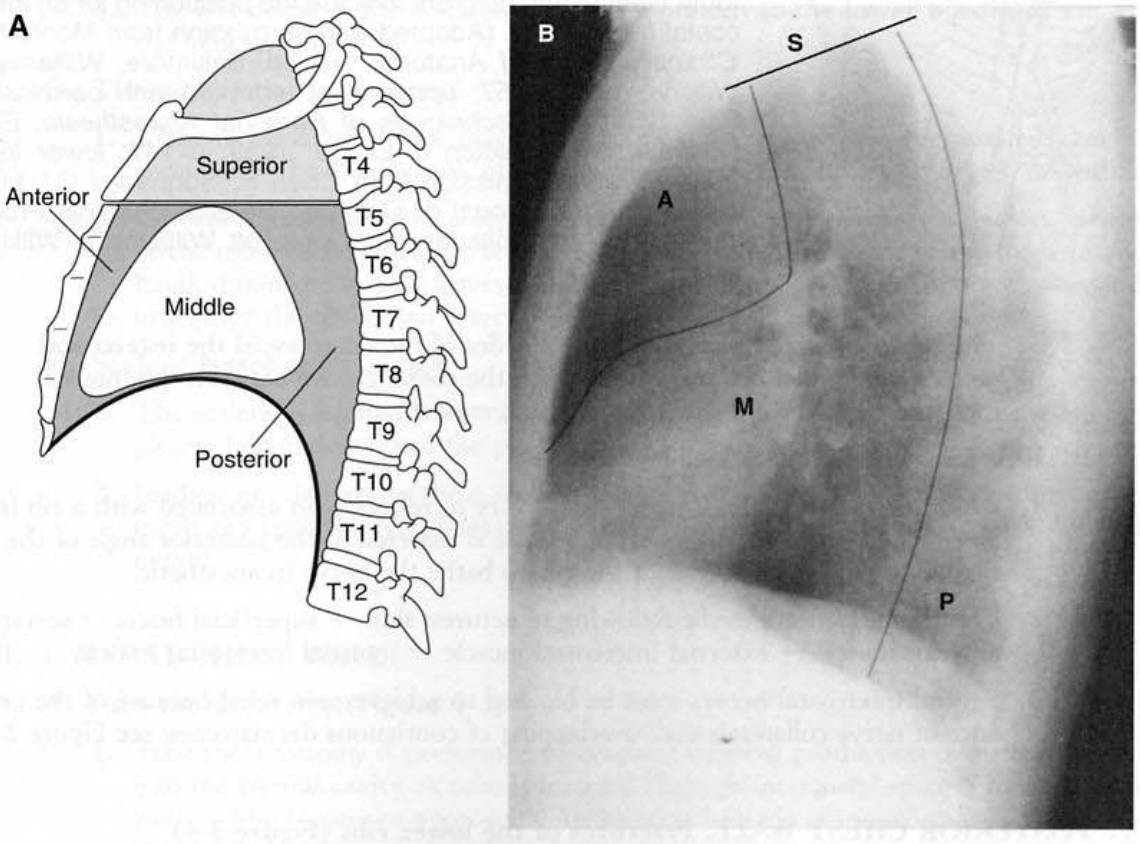


Figure 3-5. Mediastinum. (*A*) Superior, anterior, middle, and posterior divisions of the mediastinum. (*B*) Lateral radiograph demarcating the superior (*S*), anterior (*A*), middle (*M*), and posterior (*P*) divisions of the mediastinum. (*B* adapted with permission from Freundlich IM, Bragg DG: *A Radiologic Approach to Diseases of the Chest,* 2nd ed. Baltimore, Williams & Wilkins, 1997, p 610.)

V. MEDIASTINUM (Figure 3-5) is the space between the pleural cavities in the thorax. It is bounded laterally by the pleural cavities, anteriorly by the sternum, and posteriorly by the vertebral column. It is divided into **superior, anterior, middle, and posterior sections.**

A. Superior mediastinum

1. The superior mediastinum contains the trachea, esophagus, thymus, phrenic nerves, azygous vein, SVC, brachiocephalic artery and veins, aortic arch, left common carotid artery, left subclavian artery, and thoracic duct.
2. Pathologies commonly found in this area include: aortic arch aneurysm, esophageal perforation from endoscopy or an invading malignancy, and traumatic rupture of the trachea.

B. Anterior mediastinum

1. The anterior mediastinum contains the thymus, fat, lymph nodes, and connective tissue.
2. Pathologies commonly found in this area include: thymoma associated with myasthenia gravis and red blood cell aplasia, thyroid mass, germinal cell neoplasm, and lymphoma (Hodgkin or non-Hodgkin).

C. Middle mediastinum

1. The middle mediastinum contains the heart, pericardium, phrenic nerves, ascending aorta, SVC, IVC, and coronary arteries and veins.
2. Pathologies commonly found in this area include: pericardial cysts, bronchiogenic cysts, and sarcoidosis.

D. Posterior mediastinum

1. The posterior mediastinum contains the descending aorta, esophagus, thoracic duct, azygous vein, splanchnic nerves, vagus nerves (cranial nerve X), and sympathetic trunk.
2. Pathologies commonly found in this area include: ganglioneuromas, neuroblastomas, and esophageal diverticula or neoplasms.

VI. RADIOLOGY

A. Anteroposterior radiograph of the thoracic cage (Figure 3-6)

B. Anteroposterior aortogram of the thorax (Figure 3-7)

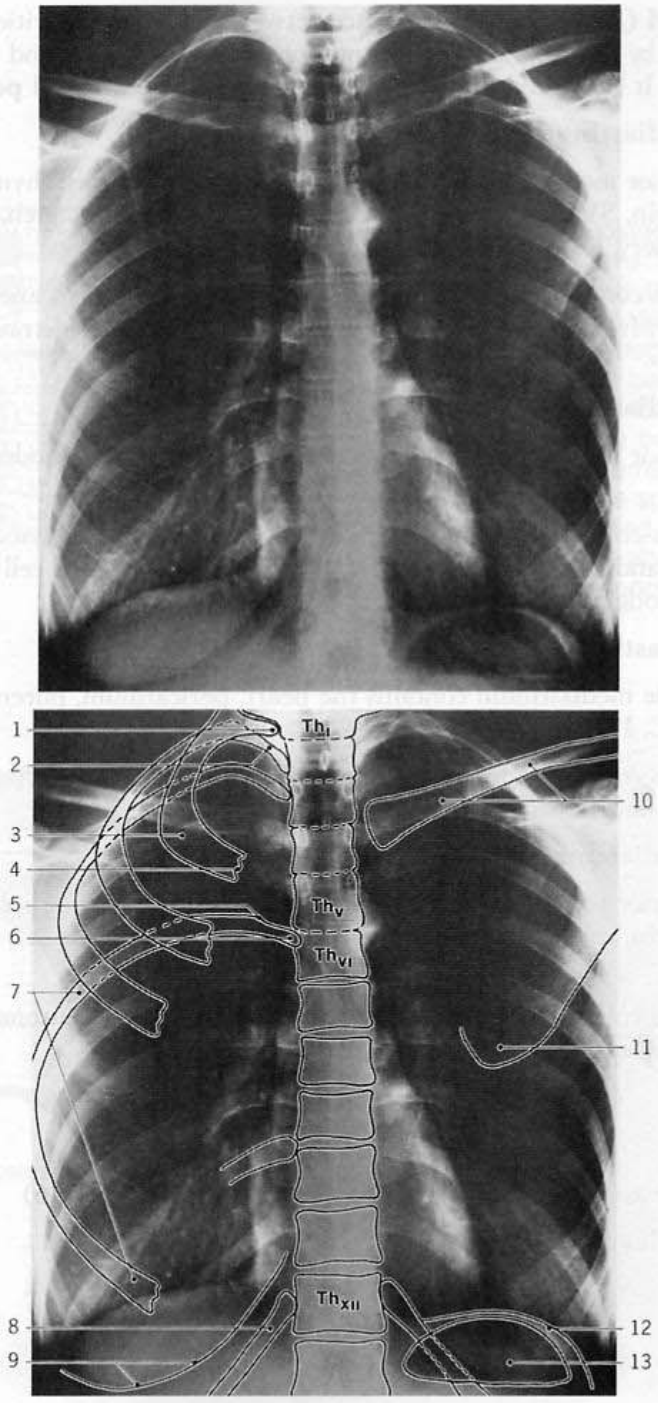


Figure 3-6. Anteroposterior radiograph of the thoracic cage. 1. Head of first rib. 2. Neck of second rib. 3. Shaft of first rib. 4. Osteochondral junction. 5. Tuberculum of costa 6. 6. Head of sixth rib. 7. Shaft of sixth rib. 8. 12th rib. 9. Breast. 10. Clavicle. 11. Inferior angle of scapula. 12. Diaphragm. 13. Gastric air. (Reprinted with permission from Fleckenstein P, Tranum-Jensen J: *Anatomy in Diagnostic Imaging*. Philadelphia, WB Saunders, 1993, p 200.)

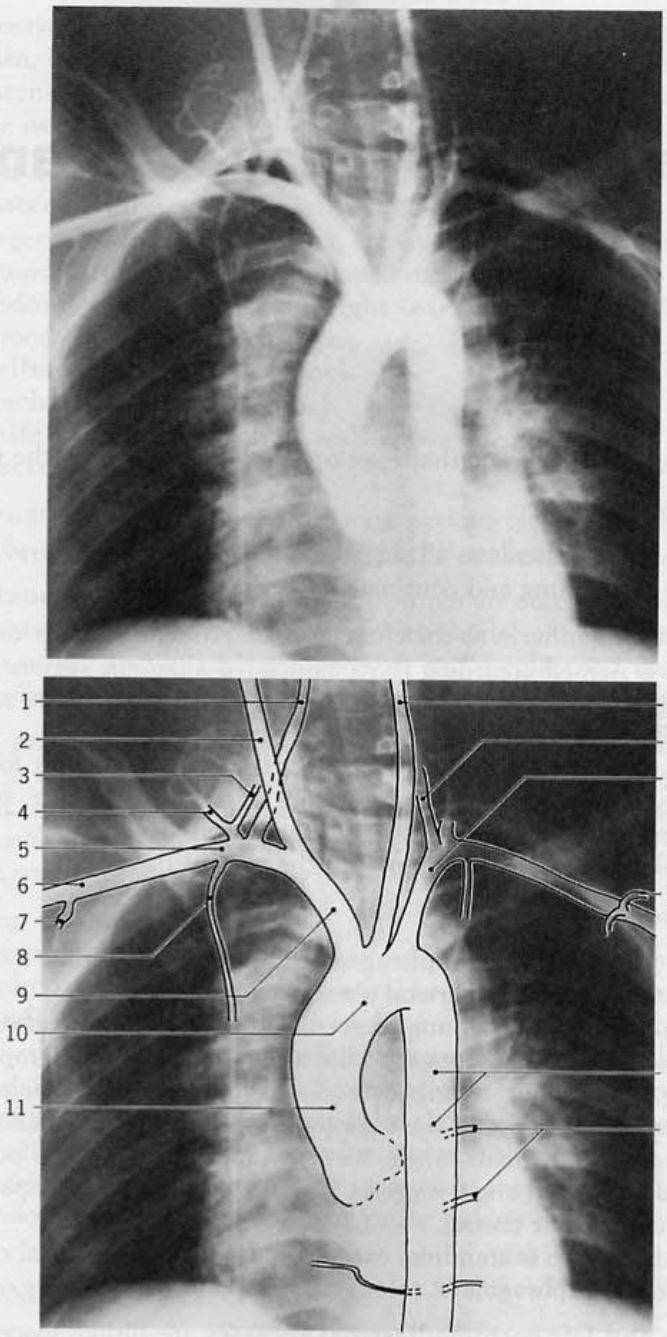


Figure 3-7. Anteroposterior aortogram of the thorax. Injection of contrast dye into the right subclavian artery shows the entire circle of Willis because the dye enters both the right common carotid and right vertebral arteries. However, injection of contrast dye into the left subclavian artery shows only the posterior part of the circle of Willis because the dye enters only the left vertebral artery. 1. Right vertebral artery. 2. Right common carotid artery. 3. Inferior thyroid artery. 4. Transverse cervical artery. 5. Right subclavian artery. 6. Axillary artery. 7. Subscapular artery. 8. Internal thoracic artery. 9. Brachiocephalic trunk. 10. Aortic arch. 11. Ascending aorta. 12. Left common carotid artery. 13. Left vertebral artery. 14. Left subclavian artery. 15. Thoracoacromial artery. 16. Thoracic aorta. 17. Intercostal arteries. (Reprinted with permission from Fleckenstein P, Tranum-Jensen J: *Anatomy in Diagnostic Imaging*. Philadelphia, WB Saunders, 1993, p 227.)

4

Pleura, Tracheobronchial Tree, and Lungs

I. **PLEURA** is the serous membrane that envelops the lungs and lines the thoracic cavity.

A. **Types of pleura**

1. **Visceral pleura** adheres to all surfaces of the lung. The visceral pleura is reflected at the root of the lung and continues as parietal pleura.
2. **Parietal pleura** adheres to the chest wall, diaphragm, and pericardial sac. The parietal pleura is named according to its associated anatomic region.
   a. **Costal pleura** is associated with the internal surface of the sternum, costal cartilages, ribs, and sides of the thoracic vertebrae.
   b. **Mediastinal pleura** is associated with the mediastinum. It forms the **pulmonary ligament** (inferior to the root of the lung), which supports the lung.
   c. **Diaphragmatic pleura** is associated with the diaphragm.
   d. **Cervical pleura** is associated with the root of the neck.

B. **Pleural recesses**

1. The **right and left costodiaphragmatic recesses** are slitlike spaces between the costal and diaphragmatic parietal pleura.
   a. During inspiration, the lungs descend into the right and left costodiaphragmatic recesses. The recesses appear radiolucent (dark) on radiographs.
   b. During expiration, the lungs ascend and the costal and diaphragmatic parietal pleura meet. As a result, the radiolucency disappears on radiographs.
   c. The costodiaphragmatic angle normally appears sharp in a posteroanterior radiograph. A blunted angle suggests pathology of the pleural space (e.g., excess fluid, blood, tumor, scar tissue).
   d. In a patient who is standing, excess fluid within the pleural cavity accumulates in the costodiaphragmatic recesses.
2. The **right and left costomediastinal recesses** are slitlike spaces between the costal and mediastinal parietal pleura.
   a. During inspiration, the anterior borders of both lungs expand and enter the right and left costomediastinal recesses. In addition, the **lingula of the left lung** expands and enters a portion of the left costomediastinal recess. That portion of the recess appears radiolucent (dark) on radiographs.
   b. During expiration, the anterior borders of both lungs recede and exit the right and left costomediastinal recesses.

C. **Clinical considerations**

1. **Pleuritis** is inflammation of the pleura.
   a. Pleuritis that involves only the visceral pleura causes **no pain** because the visceral pleura receives no nerve fibers of general sensation.

b. Pleuritis that involves the parietal pleura causes **sharp local pain** and **referred pain**. Because the parietal pleura is innervated by intercostal nerves and the phrenic nerve (C3–5), pain may be referred to the **thoracic wall** and **root of the neck,** respectively.

2. **Pleura may be damaged inadvertently** in the following situations:
   a. **Posterior surgical approach to the kidney.** Rib 12 is used as a landmark for surgery. If rib 12 is very short, it may be mistaken for rib 11. An incision that is extended to the level of rib 11 will damage the pleura.
   b. **Abdominal incision at the right infrasternal angle.** The pleura extends beyond the rib cage in this area.
   c. **Stellate ganglion nerve block**
   d. **Brachial plexus nerve block**
   e. **Knife wound to the chest wall above the clavicle**
   f. **Fracture of the lower ribs**
3. **Malignant mesothelioma** is the most serious pleural neoplasm. A history of asbestos exposure increases the risk of this malignancy.
4. **Spontaneous pneumothorax** occurs when air enters the pleural cavity.
   a. It usually is caused by a ruptured bleb (bulla) of a diseased lung that results in a loss of negative intrapleural pressure and a **collapsed lung**.
   b. Clinical findings include: chest pain, cough, and mild to severe dyspnea.
5. **Open pneumothorax** occurs when the parietal pleura is pierced and the pleural cavity is opened to the outside atmosphere. On inspiration, air is sucked into the pleural cavity. As a result, the lung collapses. Common causes include: chest trauma (e.g., knife wound) and iatrogenic factors (e.g., thoracentesis, transthoracic lung biopsy, mechanical ventilation, central line insertion).
6. **Tension pneumothorax (Figure 4-1)**
   a. Tension pneumothorax may occur as a sequela to open pneumothorax if the inspired air cannot leave the pleural cavity through the wound on expiration (check valve mechanism).
   b. This situation results in a collapsed lung on the wounded side and a compressed lung on the opposite side due to a deflected mediastinum.
   c. Clinical findings include: chest pain, shortness of breath, absent breath sounds on the affected side, and hypotension, because the mediastinal shift compresses the superior vena cava and inferior vena cava, thereby obstructing venous return. Tension pneumothorax also may cause sudden death.

II. TRACHEOBRONCHIAL TREE (Figure 4-2)

A. General characteristics

1. The trachea is a tube composed of **16–20 U-shaped hyaline cartilages** and the **trachealis** muscle.
2. The trachea begins just inferior to the cricoid cartilage (vertebral level C6) and ends at the sternal angle (vertebral level T4), where it bifurcates into the **right and left main bronchi.**
3. At the bifurcation, the last tracheal cartilage forms the **carina.** The carina is seen on bronchoscopy as a raised ridge of tissue in the sagittal plane.
4. The right main bronchus is shorter, wider, and turns to the right at a shallower angle than the left main bronchus. The right main bronchus branches into **three lobar bronchi** (upper, middle, and lower) and finally into **ten segmental bronchi**.

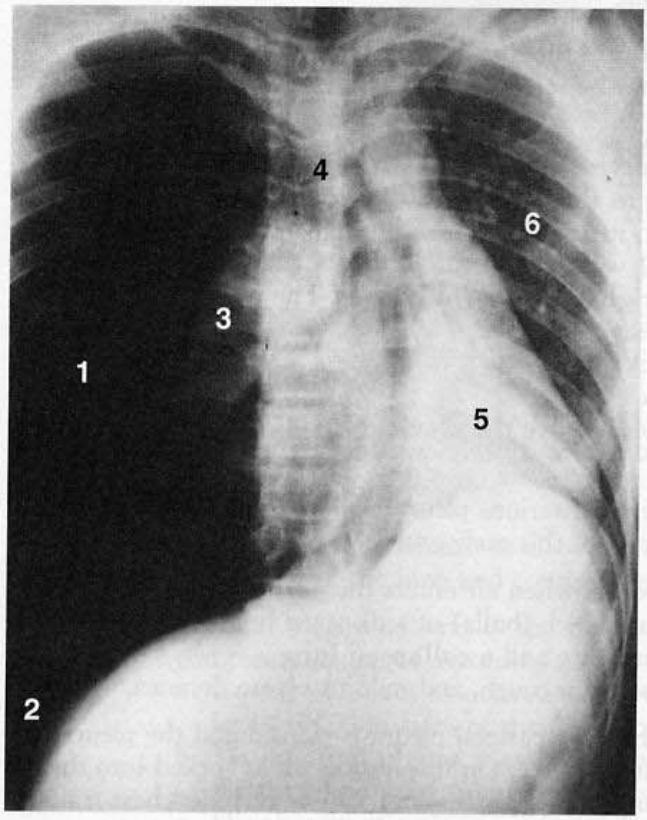


Figure 4-1. Anteroposterior radiograph showing tension pneumothorax as a result of penetrating chest trauma to the right side. *1* = hyperlucent lung field; *2* = hyperexpansion lowering the right diaphragm; *3* = collapsed right lung; *4* = deviation of the trachea; *5* = mediastinal shift; 6 = compressed left lung. (Adapted with permission from Freundlich IM, Bragg DG: *A Radiologic Approach to Diseases of the Chest,* 2nd ed. Baltimore, Williams & Wilkins, 1997, p 270.)

5. The left main bronchus branches into **two lobar bronchi** (upper and lower) and finally into **eight to ten segmental bronchi.**
6. Branching of the segmental bronchi corresponds to the **bronchopulmonary segments** of the lung.

B. Clinical considerations

1. **Compression of the trachea.** The trachea may be compressed by either an **enlarged thyroid gland** or an **aortic arch aneurysm.** The aneurysm may tug on the trachea with each cardiac systole, and can be felt by palpating the trachea at the sternal notch (Vertebral level T2).
2. **Distortions in the position of the carina** may indicate **metastasis of bronchogenic carcinoma** into the tracheobronchial lymph nodes that surround the tracheal bifurcation or **enlargement of the left atrium.**
3. **Aspiration of foreign objects.** Aspirated material enters different parts of the lung, depending on the person's position at the time of aspiration (see Figure 4-2B).
   a. **Sitting or standing.** Aspirated material usually enters the **right lower lobar bronchus** and lodges within the **lower portion of the right lower lobe.**
   b. **Supine.** Aspirated material usually enters the **right lower lobar bronchus** and lodges within the **upper portion of the right lower lobe.**
   c. **Lying on the right side.** Aspirated material usually enters the **right upper lobar bronchus** and lodges within the **posterior portion of the right upper lobe.**
   d. **Lying on the left side.** Aspirated material usually enters the **left upper lobar bronchus** and lodges within the **lingula of the left upper lobe.**

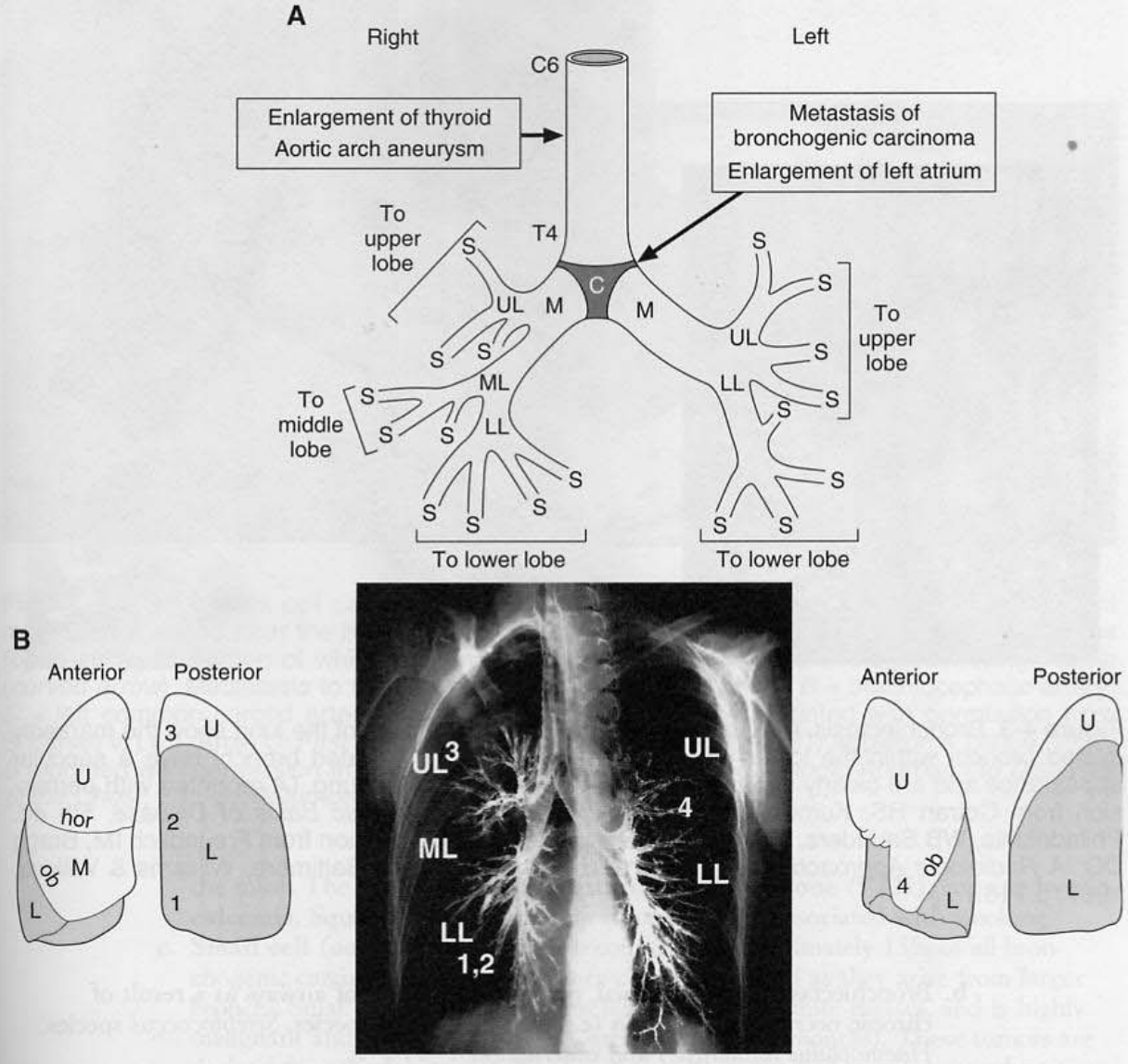


Figure 4-2. (*A*) Tracheobronchial tree. (*B*) Bronchogram of the tracheobronchial tree showing the sites of aspirated foreign material within the bronchi and lobes of the lung. *1* = a person who is sitting or standing; *2* = a person who is supine; *3* = a person who is lying on the right side; *4* = a person who is lying on the left side. Asymmetric lung volumes may be apparent if air can get past the obstruction during inspiration, but cannot get out during expiration. *C* = carina; *LL* = lower lobar bronchus; *M* = main bronchi; *ML* = middle lobar bronchus; *S* = segmental bronchi; *UL* = upper lobar bronchus. Areas of the lung: *U* = upper lobe; *M* = middle lobe; *L* = lower lobe; *ob* = oblique fissure; *hor* = horizontal fissure. (*B* photograph adapted with permission from Moore KL: *Clinically Oriented Anatomy,* 3rd ed. Baltimore, Williams & Wilkins, 1992, p 74; Courtesy of Dr. D. E. Sanders and Dr. E. L. Lansdown, Department of Radiology, University of Toronto, Ontario, Canada.)

4. Bronchiectasis (Figure 4-3)

a. Bronchiectasis belongs to a group of disorders known as **chronic obstructive pulmonary disease (COPD).** COPD is characterized by increased resistance to airflow during both inspiration and expiration. This resistance is caused by airway obstruction. Other forms of COPD are emphysema, chronic bronchitis, and asthma.

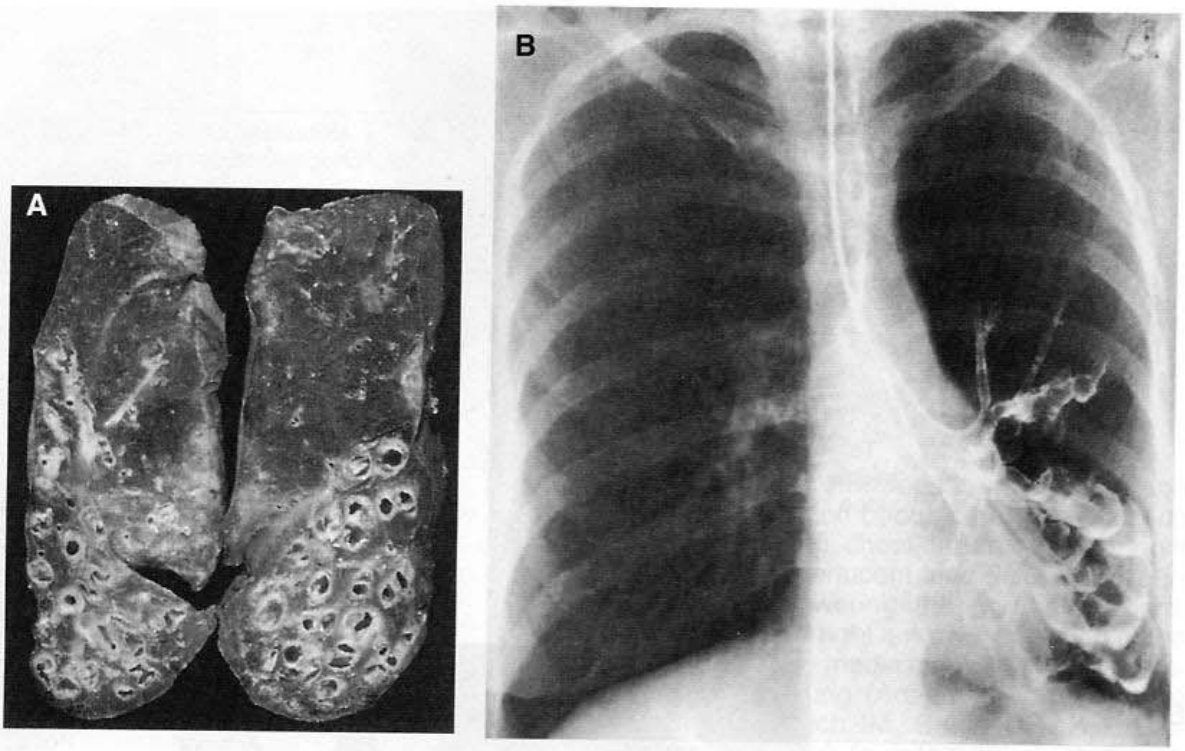


Figure 4-3. Bronchiectasis. (*A*) Gross specimen. The cut surfaces of the lung show the markedly dilated bronchi within the lower lobe. (*B*) Bronchogram. The dilated bronchi have a saccular appearance and are clearly seen within the lower lobe of the left lung. (*A* reprinted with permission from Cotran RS, Kumor V, Robbins SL: Robbins' *Pathologic Basis of Disease,* 5th ed. Philadelphia, WB Saunders, 1994, p 694; *B* reprinted with permission from Freundlich IM, Bragg DG: *A Radiologic Approach to Diseases of the Chest,* 2nd ed. Baltimore, Williams & Wilkins, 1997, p 716.)

   b. Bronchiectasis is an abnormal, permanent dilation of airways as a result of chronic necrotizing infection (e.g., *Staphylococcus* species, *Streptococcus* species, *Haemophilus influenzae*) and obstruction.
   c. The **lower lobes** are predominantly affected, and the affected airways have a **saccular** appearance.
   d. Bronchiectasis occurs secondary to **Kartagener syndrome,** in which the absence of pulmonary cilia prevents clearance of bacteria, or **cystic fibrosis**, in which viscous mucus obstructs the airways.

5. **Bronchogenic carcinoma (Figure 4-4)** begins as hyperplasia of the bronchial epithelium. It progresses through intraluminal growth, infiltrative peribronchial growth, and intraparenchymal growth. Types of bronchogenic carcinoma include: adenocarcinoma, squamous cell carcinoma, and small cell (oat cell) carcinoma.
   a. **Adenocarcinoma** is the most common type (35%). The lesions are peripherally located within the lung as they arise from the distal airways and alveoli. Adenocarcinoma forms well-circumscribed gray-white masses. It is less closely associated with smoking than squamous cell carcinoma.
   b. **Squamous cell carcinoma** is the second most common type of bronchogenic carcinoma (25%). These lesions are centrally located as they arise from larger bronchi. Squamous cell carcinoma begins as a small, red, granular plaque and progresses to a large intrabronchial mass. Cavitation of the lung may occur distal to

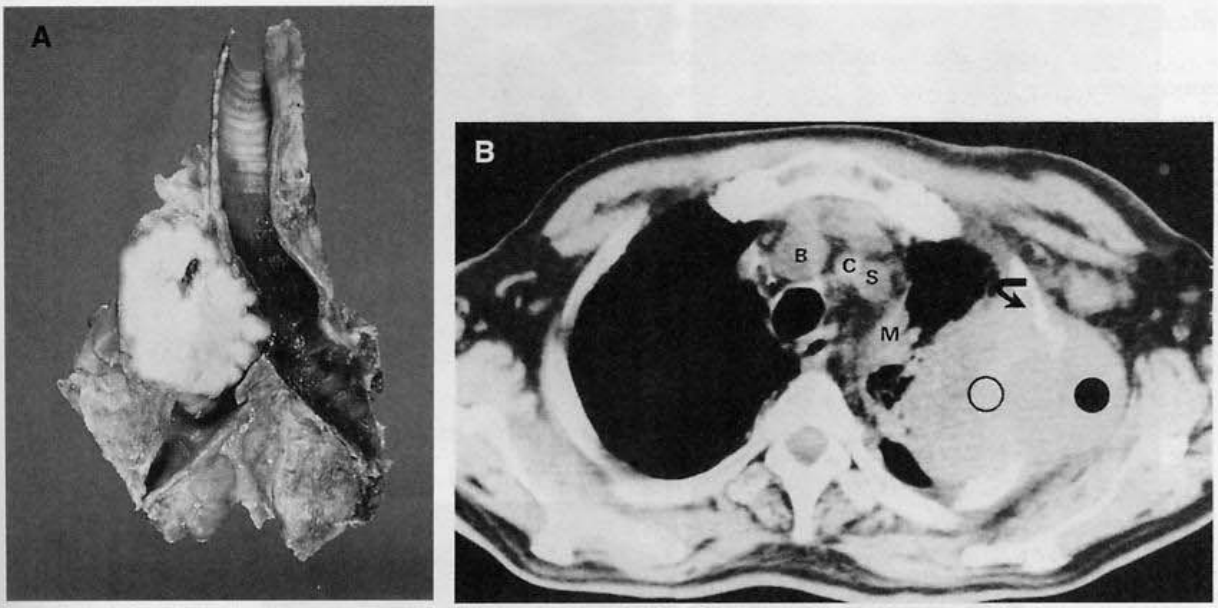


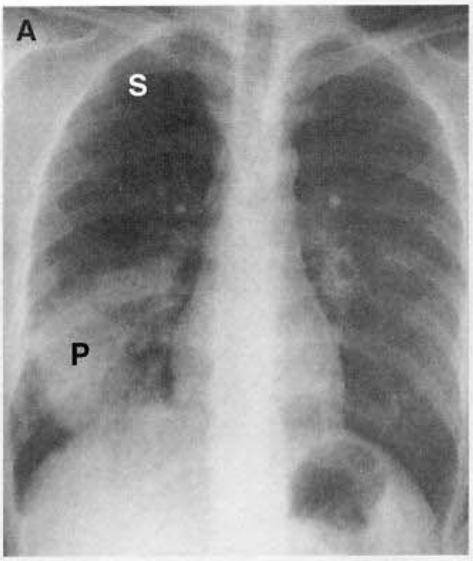
Figure 4-4. Squamous cell carcinoma. (*A*) Gross specimen. Note the large tumor in the right main bronchus and near the bifurcation of the trachea. (*B*) CT scan. Note the upper-lobe mass (*open circle*), a portion of which has invaded the chest wall (*closed circle*), destroying the rib (*curved arrow*). Metastasis to mediastinal nodes (*M*) also is shown. *B* = brachiocephalic artery; *C* = left common carotid artery; *S* = left subclavian artery. (*A* reprinted with permission from Bhushan V, Le T, Amin C: *First Aid for the USMLE Step 1*. Stamford, CT, Appleton & Lange, 1999; *B* reprinted with permission from Freundlich IM, Bragg DG: *A Radiologic Approach to Diseases of the Chest,* 2nd ed. Baltimore, Williams & Wilkins, 1997, p 553.)

the mass. The tumor may secrete **parathyroid hormone (PTH),** causing **hypercalcemia**. Squamous cell carcinoma is most closely associated with smoking.

c. **Small cell (oat cell) carcinoma** accounts for approximately 15% of all bronchogenic carcinomas. The lesions are centrally located as they arise from larger bronchi. Small cell carcinoma forms large, soft, gray-white masses, and is highly malignant and aggressive (median survival time <3 months). These tumors are derived from **Kulchitsky cells** of neural crest origin and may secrete **adrenocorticotropic hormone (ACTH)** or **antidiuretic hormone (ADH),** causing **Cushing syndrome** or **syndrome of inappropriate secretion of antidiuretic hormone (SIADH),** respectively.

d. **Intrathoracic spread** of bronchogenic carcinoma may lead to:
   (1) **Horner syndrome,** which causes **miosis** (constriction of the pupil due to paralysis of the dilator pupillae muscle), **ptosis** (drooping of the eyelid due to paralysis of the superior tarsal muscle), and **hemianhydrosis** (loss of sweating on one side)
   (2) **Superior vena cava syndrome,** which causes dilation of the head and neck veins, facial swelling, and cyanosis
   (3) **Dysphagia** as a result of esophageal obstruction
   (4) **Hoarseness** as a result of recurrent laryngeal nerve involvement
   (5) **Paralysis of the diaphragm** as a result of phrenic nerve involvement
   (6) **Pancoast syndrome,** which causes ulnar nerve pain and Horner syndrome

e. **Metastasis**
   (1) Tracheobronchial (mediastinal), parasternal, and supraclavicular lymph nodes are involved in the lymphatic metastasis of bronchogenic carcinoma. Enlarge-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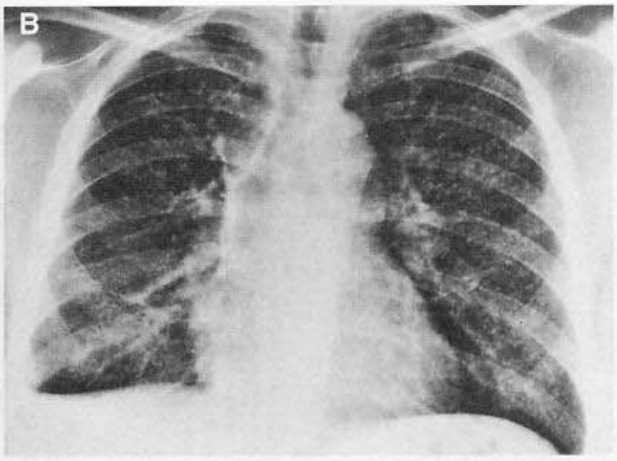
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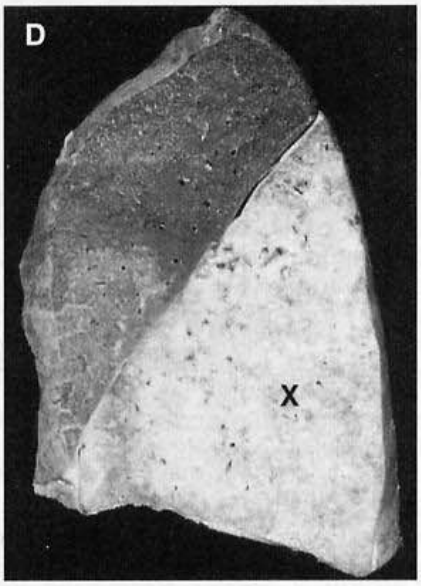
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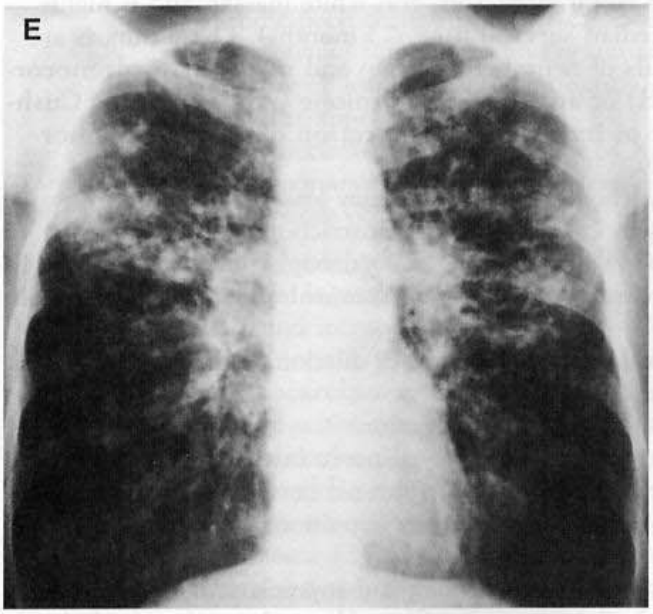
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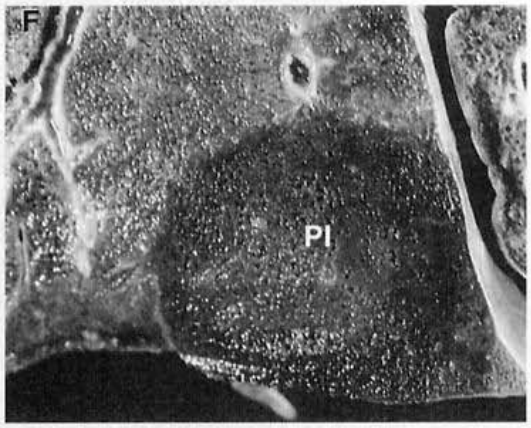
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ment of the mediastinal nodes may **indent the esophagus** (seen radiologically during a barium swallow) or **distort the position of the carina.**

(2) Metastasis to the brain through arterial blood occurs by the following route: cancer cells enter a lung capillary → pulmonary vein → left atrium and ventricle → aorta → internal carotid and vertebral arteries.

(3) Metastasis to the brain through venous blood occurs by the following route: cancer cells enter a bronchial vein → azygous vein → external vertebral venous plexus and internal vertebral venous plexus → cranial dural sinus.

III. LUNGS

A. The **right lung** consists of **three lobes (upper, middle,** and **lower)** separated by a **horizontal fissure** and an **oblique fissure.**

1. The right upper lobe lies in a superior and anterior position.
2. The right middle lobe lies in an anterior position between costal cartilages 4 and 6.
3. The right lower lobe lies in an inferior and posterior position.
4. The horizontal fissure runs at the level of costal cartilage 4 and meets the oblique fissure at the midaxillary line.
5. The **diaphragmatic surface** consists of the middle and lower lobes.

B. The **left lung** consists of **two lobes (upper and lower)** separated by an **oblique fissure.**

1. The left upper lobe lies in a superior and anterior position and contains the **cardiac notch,** where the left ventricle and pericardial sac abut the lung. The **lingula,** which is the embryologic counterpart to the right middle lobe, lies just beneath the cardiac notch.
2. The left lower lobe lies in an inferior and posterior position.
3. The **diaphragmatic surface** consists of the lower lobe.

◀ **Figure 4-5.** (*A*) Posteroanterior radiograph showing primary tuberculosis. Note the consolidation (*P*) in the right lower lobe of the lung. Secondary, or reactivation, tuberculosis usually is located in the apex (*S*). (*B*) Posteroanterior radiograph of miliary tuberculosis. Note the many small consolidations scattered throughout both lungs. (*C*) Gross specimen of the cut surface of the lung showing bronchopneumonia. Note the patchy consolidations throughout the lung (multilobar), surrounding the bronchi. A large area of consolidation also is seen in the basal portion of the lower lobe because of gravitational pooling of bacteria. (*D*) Gross specimen of the lung showing lobar pneumonia. Note that the entire lower lobe (*X*) is uniformly consolidated. The upper and lower lobes appear different because the lower lobe is in the late consolidation, or "gray hepatization," stage, in which the lung has a typical gray-brown, dry surface. (*E*) Posteroanterior radiograph showing cystic fibrosis. Note the hyperinflation of both lungs and the reduced size of the heart as a result of pulmonary compression. Both lungs show cyst formation and atelectasis (collapse of alveoli). (*F*) Gross specimen of the cut surface of the lung showing a pulmonary infarction. Note the hemorrhagic pulmonary infarct (*PI*) within the lower lobe. A pulmonary infarct typically appears wedge-shaped. (*A* adapted and *B* and *E* reprinted with permission from Freundlich IM, Bragg DG: *A Radiologic Approach to Diseases of the Chest,* 2nd ed. Baltimore, Williams & Wilkins, 1997, pp 309, 470, 471; *C* reprinted with permission from Bhushan V, Le T, Amin C: *First Aid for the USMLE Step 1.* Stamford, CT, Appleton & Lange, 1999; *D* and *F* adapted with permission from Cotran RS, Kumor V, Robbins SL: *Robbins' Pathologic Basis of Disease,* 5th ed. Philadelphia, WB Saunders, 1994, pp 686, 697.)

C. Bronchopulmonary segment

1. The bronchopulmonary segment contains a **segmental bronchus**, a **branch of the pulmonary artery**, and a **branch of the bronchial artery.** These structures run together through the central part of the segment.
2. The bronchopulmonary segment contains **tributaries of the pulmonary vein** that are found at the periphery between two adjacent bronchopulmonary segments. These veins form **surgical landmarks** during segmental resection of the lung.

D. Clinical considerations (Figure 4-5)

1. **Primary tuberculosis**
   a. **Primary tuberculosis** is caused by ***Mycobacterium tuberculosis*** (acid fast).
   b. The lung is the usual location of the initial infection.
   c. The initial focus is the **Ghon complex,** which consists of parenchymal or subpleural lesions near a fissure and enlarged caseous lymph nodes.
   d. Most patients remain asymptomatic with the initial infection. The infection may be reactivated years later if the immune system is compromised (e.g., advanced age, poor nutrition, AIDS).
2. **Secondary tuberculosis.** Most cases represent **reactivation** (versus reinfection) of a primary tuberculosis infection. Because *M. tuberculosis* is a strict aerobe, reactivation usually occurs within the **apex of the lung**. Secondary tuberculosis begins as a **small focus of consolidation,** usually less than 3 cm in diameter.
3. **Miliary tuberculosis** is caused by dissemination by lymphatics or blood. The dissemination sometimes is confined to the lungs, with multiple nodules (areas of consolidation) scattered throughout both lungs. However, the dissemination usually spreads widely to other organs.
4. **Bronchopneumonia** is caused by infection with *Streptococcus pneumoniae, Staphylococcus* species, *H. influenzae, Pseudomonas* species, *and* coliform bacilli. It is characterized by patchy consolidation of the lung, which often is multilobar, bilateral, and basal because of gravitational pooling of bacteria.
5. **Lobar pneumonia** usually is caused by acute infection with *S. pneumoniae. Klebsiella* and type II pneumococcus infections may occur in elderly persons, alcoholics, and diabetics. It is characterized by consolidation of an entire lobe or a large part of an entire lobe. The inflammatory response has four stages:
   a. The **initial stage** is characterized by acute congestion, intraalveolar fluid, few neutrophils, and many bacteria.
   b. **Early consolidation,** or **"red hepatization,"** lasts 2–4 days and is characterized by consolidation with infiltration of neutrophils and fibrin within the alveoli. The lung is red as a result of extravasated red blood cells. In addition, it is firm and airless, with a liver-like consistency.
   c. **Late consolidation,** or **"gray hepatization,"** lasts 4–8 days and is characterized by large amounts of fibrin with decreasing numbers of red and white blood cells. The lung has a gray-brown, dry surface.
   d. **Resolution** begins after 8 days.
6. **Cystic fibrosis**
   a. **Cystic fibrosis** is characterized by the production of abnormally thick mucus by epithelial cells that line the respiratory and gastrointestinal tracts. Clinically, this mucus causes obstruction of airways and recurrent bacterial infections (e.g., *Staphylococcus aureus, Pseudomonas aeruginosa*).

b. Cystic fibrosis is caused by autosomal recessive mutations of the CF gene, which is located on the long arm of chromosome 7 (q7). The CF gene encodes for a protein called **CFTR** (**c**ystic **f**ibrosis **tr**ansporter). This protein functions as a **Cl^- ion channel.**

c. In the neonate, cystic fibrosis causes meconium ileus (i.e., obstruction of the bowel). In childhood, cystic fibrosis causes steatorrhea (fatty stool) or obstruction of the bowel. **Cor pulmonale** (right-sided heart failure) usually develops as a result of pulmonary hypertension.

7. Pulmonary embolism is the occlusion of a pulmonary artery by an embolic blood clot that originates from a deep vein thrombosis in the leg or pelvic area.

a. A large embolus may occlude the main pulmonary artery or lodge at the bifurcation as a "saddle embolus." It may cause sudden death, with symptoms easily confused with those of myocardial infarction (e.g., chest pain, severe dyspnea, shock, increased serum lactate dehydrogenase levels). A small embolus may occlude smaller peripheral branches of the pulmonary artery. A pulmonary embolism may cause a **pulmonary infarction.** This wedge-shaped infarction usually occurs in the lower lobes of the lungs.

b. Risk factors for pulmonary embolism include: obesity, cancer, pregnancy, use of oral contraceptives, hypercoagulability, multiple bone fractures, burns, and a history of deep vein thrombosis (a typical clinical scenario involves a postsurgical, bedridden patient who has sudden shortness of breath).

5
Heart

I. THE PERICARDIUM

A. General features. The pericardium consists of three layers: a **visceral layer of serous pericardium** (known histologically as the **epicardium**); a **parietal layer of serous pericardium;** and a thick connective tissue layer called the **fibrous pericardium.** The **pericardial cavity,** which normally contains a small amount of fluid, lies between the visceral and parietal layers of serous pericardium. The fibrous pericardium fuses superiorly to the adventitia of the great vessels, inferiorly to the central tendon of the diaphragm, and anteriorly to the sternum. The **phrenic nerve** and **pericardiophrenic artery** descend through the mediastinum lateral to the fibrous pericardium. They may be injured during surgery to the heart. The **transverse sinus** is a recess of the pericardial cavity. After the pericardial sac is opened, the surgeon can pass a finger or ligature from one side of the heart to the other through the transverse sinus between the great arteries and pulmonary veins. The **oblique sinus** is a recess of the pericardial cavity. It ends in a cul-de-sac surrounded by the pulmonary veins. The **thoracic portion of the inferior vena cava (IVC)** lies within the pericardium. To expose this portion of the IVC, the pericardium must be opened.

B. Clinical considerations

1. **Cardiac tamponade** is the accumulation of fluid within the pericardial cavity. It causes compression of the heart because the fibrous pericardium is inelastic. Clinical findings include: hypotension (blood pressure of 90/40) that does not respond to rehydration; compression of the superior vena cava (SVC), which may cause the veins of the face and neck to engorge with blood; paradoxical pulse (inspiratory lowering of blood pressure by more than 10 mm Hg); spontaneous filling of the syringe when blood is drawn, due to increased venous pressure; and distant heart sounds.

2. **Pericardiocentesis** is the removal of fluid from the pericardial cavity. It can be approached in two ways.
   a. **Sternal approach.** A needle is inserted at intercostal space 5 or 6 on the left side near the sternum, because the cardiac notch of the left lung leaves the fibrous pericardium exposed at this site. The needle penetrates the following structures: skin → superficial fascia → pectoralis major muscle → external intercostal membrane → internal intercostal muscle → transverse thoracic muscle → fibrous pericardium → parietal layer of serous pericardium. The internal thoracic artery, coronary arteries, and pleura may be damaged during this approach.
   b. **Subxiphoid approach.** A needle is inserted at the left infrasternal angle, angled superiorly and posteriorly. The needle penetrates the following structures: skin → superficial fascia → anterior rectus sheath → rectus abdominis muscle → transverse abdominis muscle → fibrous pericardium → parietal layer of serous pericardium. The diaphragm and liver may be damaged during this approach.

II. SURFACES OF THE HEART

A. Posterior surface (base) consists of the **left atrium**.

B. Apex consists of the **left ventricle** at intercostal space 5, along the midclavicular line.

C. Sternal surface consists of the **right ventricle**.

D. Diaphragmatic surface consists of the **left ventricle**.

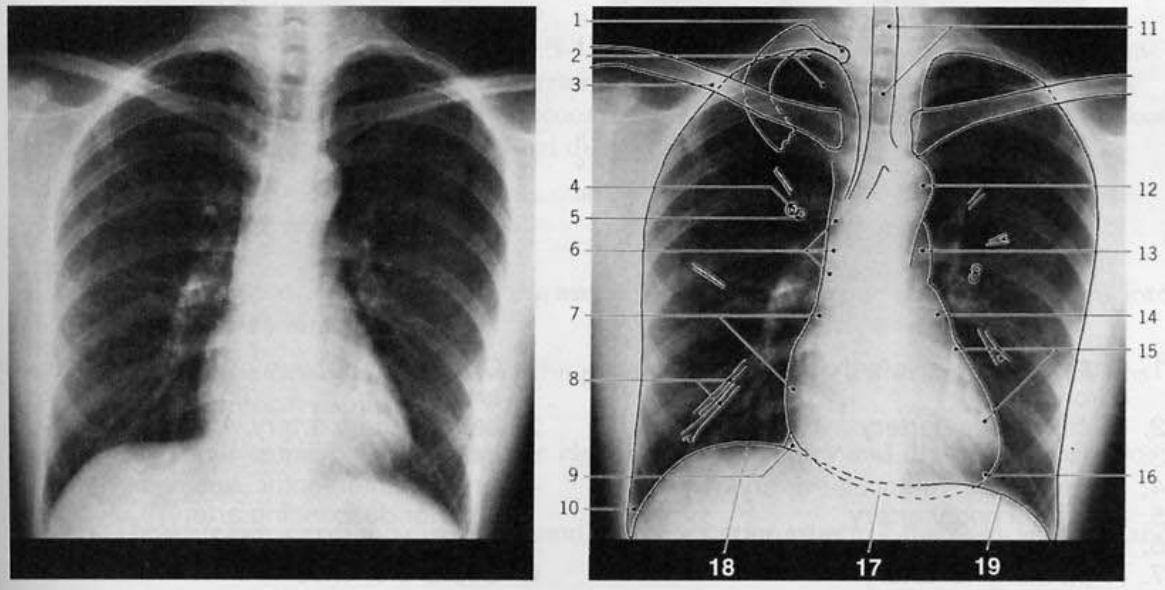
III. BORDERS OF THE HEART (Figure 5-1)

A. Right border consists of the **right atrium** and **superior vena cava (SVC).**

B. Left border consists of the **left ventricle, left atrium, pulmonary trunk**, and **aortic arch.**

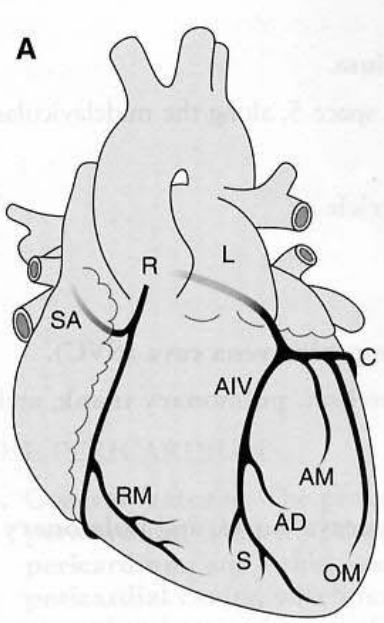
C. Inferior border consists of the **right ventricle.**

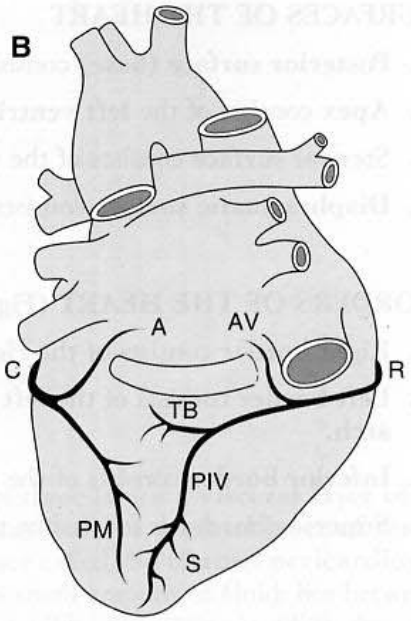
D. Superior border is formed by the **superior vena cava, aorta**, and **pulmonary trunk.**

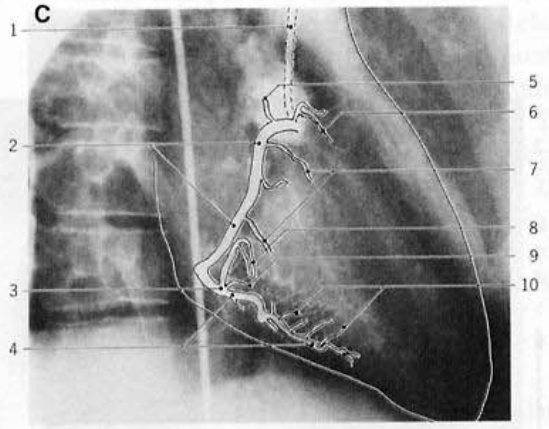


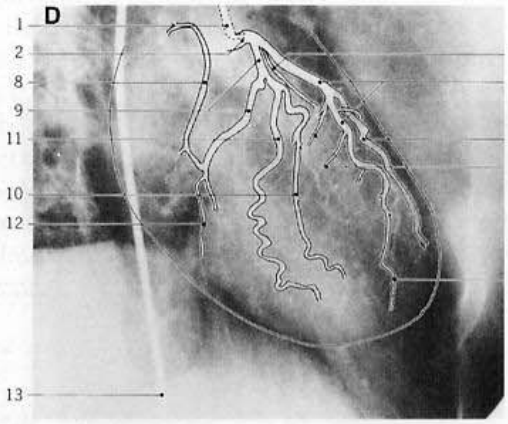
1. Head of first rib
2. Apex of lung
3. Clavicle
4. Bronchus (longitudinal view)
5. Lung vessel (longitudinal view)
6. Superior caval vein
7. Right atrium
8. Lung vessels
9. Inferior caval vein
10. Costodiaphragmatic sulcus
11. Trachea
12. Aortic arch
13. Pulmonary trunk
14. Left auricle
15. Left ventricle
16. Apex of heart
17. Right ventricle
18. Right dome of diaphragm
19. Left dome of diaphragm

Figure 5-1. Posteroanterior radiograph of the thorax. Note the various components of the borders of the heart. The costodiaphragmatic recess and the right and left domes of the diaphragm are apparent. (Adapted with permission from Fleckenstein P, Tranum-Jensen J: *Anatomy in Diagnostic Imaging*. Philadelphia, WB Saunders, 1993, p 202.)









1. Catheter with tip in orifice of right coronary artery
2. Right coronary artery
3. Crux of heart
4. Posterior interventricular artery
5. Sinoatrial nodal artery
6. Conus artery
7. Right marginal artery
8. Terminal branches
9. Atrioventricular nodal artery
10. Septal branches

1. Catheter with tip in orifice of left coronary artery
2. Left coronary artery, main stem
3. Intermediate ramus
4. Anterior interventricular artery (left anterior descending artery)
5. Anterior diagonal artery
6. Septal branches
7. Left anterior descending artery at apex of heart
8. Atrial branches
9. Circumflex artery
10. Anterior marginal artery
11. Obtuse marginal artery
12. Posterior marginal artery
13. Catheter in aorta

Table 5-1. Arterial Blood Supply of the Heart

	Branches	Structures Supplied
Right coronary artery	Sinoatrial (SA) nodal artery	Right atrium
	Right marginal artery	Right ventricle
	Atrioventricular (AV) nodal artery	SA node
	Terminal branches	AV node
	Posterior interventricular artery*	Interventricular septum
	Septal branches	
Left coronary artery	Circumflex artery	Left atrium
	Anterior marginal artery	Left ventricle
	Obtuse marginal artery	Interventricular septum
	Atrial branches	
	Posterior marginal artery	
	Anterior interventricular artery†	
	Anterior diagonal artery	
	Septal branches	

*The blood supply of the heart is considered right-side—dominant if the posterior interventricular artery arises from the right coronary artery. It is considered left-side—dominant if the posterior interventricular artery arises from the left coronary artery.
†The anterior interventricular artery also is called the left anterior descending artery (LAD).

IV. BLOOD SUPPLY (Figure 5-2; Table 5-1). Coronary artery occlusion occurs most commonly in the anterior interventricular artery [also known as the left anterior descending artery (LAD)], followed by the right coronary artery, and then the circumflex artery. Blood flow in the coronary arteries is maximal during diastole and minimal during systole.

V. VENOUS DRAINAGE

A. The **great cardiac vein** follows the **anterior interventricular artery** and drains into the **coronary sinus.**

B. The **middle cardiac vein** follows the **posterior interventricular artery** and drains into the coronary sinus.

C. The **small cardiac vein** follows the **right marginal artery** and drains into the coronary sinus.

D. The **anterior cardiac veins** are found on the anterior aspect of the right ventricle and drain directly into the right atrium.

E. The **smallest cardiac veins** begin within the wall of the heart and drain directly into the nearest heart chamber.

◀ **Figure 5-2.** Blood supply of the heart. (*A*) Sternocostal surface of the heart. (*B*) Diaphragmatic surface of the heart. (*C*) Right anterior oblique arteriogram of the right coronary artery. (*D*) Right anterior oblique arteriogram of the left coronary artery. *A* = atrial branches; *AD* = anterior diagonal artery; *AIV* = anterior interventricular artery; *AM* = anterior marginal artery; *AV* = atrioventricular nodal artery; *C* = circumflex artery; *L* = left coronary artery; *OM* = obtuse marginal artery; *PIV* = posterior interventricular artery; *PM* = posterior marginal artery; *R* = right coronary artery; *RM* = right marginal artery; *S* = septal branches; *SA* = sinoatrial nodal artery; *TB* = terminal branches. (*C* and *D* reprinted with permission from Fleckenstein P, Tranum-Jensen J: *Anatomy in Diagnostic Imaging.* Philadelphia, WB Saunders, 1993, pp 232, 233.)

VI. VALVES AND AUSCULTATION SITES (Figure 5-3)

A. The **pulmonary valve** is the outflow valve of the right ventricle. It is composed of three cusps (right, left, and posterior) that fit closely together when they are closed. It sometimes is referred to as a **semilunar valve.** It can be auscultated at the **edge of the sternum at left intercostal space 2.**

B. The **aortic valve** is the outflow valve of the left ventricle. It is composed of three cusps (right, left, and posterior) that fit closely together when they are closed. The aortic valve sometimes is referred to as a **semilunar valve.** It can be auscultated at the **edge of the sternum at right intercostal space 2.**

C. The **mitral (left atrioventricular) valve** is located between the left atrium and the left ventricle. It is composed of two cusps (anterior and posterior) both of which are tethered to **papillary muscles** by **chorda tendineae.** It can be auscultated at the **cardiac apex at left intercostal space 5.**

D. The **tricuspid (right atrioventricular) valve** is located between the right atrium and the right ventricle. It is composed of three cusps (anterior, posterior, and septal) all of which are tethered to **papillary muscles** by **chorda tendineae.** It can be auscultated **over the sternum at intercostal space 5.**

VII. CONDUCTION SYSTEM

A. The **sinoatrial (SA) node** is the "pacemaker" of the heart. It is located just beneath the pericardium, at the junction of the SVC and the right atrium. Impulses spread from the SA node throughout the right atrium, to the left atrium, and eventually to the atrioventricular (AV) node.

B. The **AV node** is located just beneath the endocardium, on the right side of the interatrial septum, near the ostium of the coronary sinus.

C. The **bundle of His** travels in the subendocardial layer on the right side of the interventricular septum. It divides into the **right** and **left bundle branches.** The left bundle

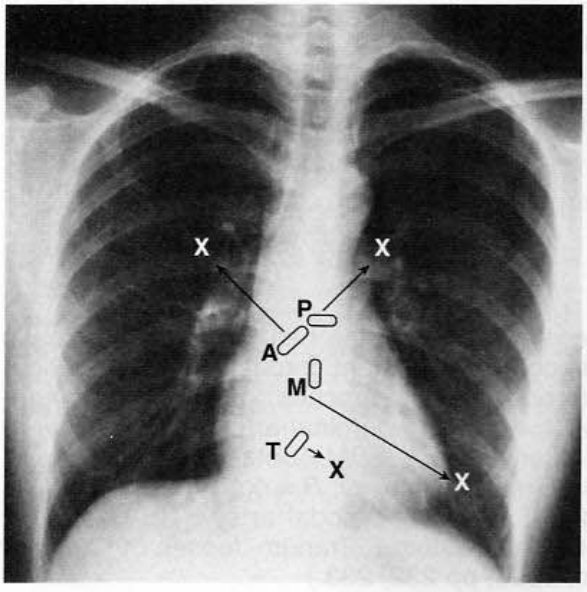


Figure 5-3. Posteroanterior radiograph of the thorax. Note the location of the pulmonary *(P),* aortic *(A),* mitral *(M),* and tricuspid *(T)* valves, along with their respective auscultation sites *(X).* The auscultation sites are located downstream of the blood flow through the valve (arrows). (Adapted with permission from Fleckenstein P, Tranum-Jensen J: *Anatomy in Diagnostic Imaging.* Philadelphia, WB Saunders, 1993, p 202.)

branch divides further into a **thin anterior division** and a **thick posterior division.** All of the branches terminate in a complex network of **Purkinje myocytes.**

VIII. NEURAL REGULATION OF THE HEART.

The autonomic nervous system only **modulates** the myogenic heartbeat.

A. The **parasympathetic system** decreases the heart rate. The cell bodies of preganglionic neurons are located in the **dorsal nucleus of the vagus** and the **nucleus ambiguus** of the medulla. The axons of preganglionic neurons run in the **vagus nerve (cranial nerve X)** and use **acetylcholine** as a neurotransmitter. The cell bodies of postganglionic neurons are located **near the SA and AV nodes.** The axons of postganglionic neurons terminate on the SA node and the AV node and use **acetylcholine** as a neurotransmitter.

B. The **sympathetic system** increases the heart rate. The cell bodies of the preganglionic neurons are located in the **intermediolateral cell column** of the spinal cord. The axons of the preganglionic neurons enter the **paravertebral ganglia** and travel to the **stellate** and **middle cervical ganglia,** using **acetylcholine** as a neurotransmitter. The cell bodies of the postganglionic neurons are located in the **stellate** and **middle cervical ganglia.** The axons of the postganglionic neurons are distributed to the myocardium via accompanying blood vessels and use **norepinephrine** as a neurotransmitter.

IX. CLINICAL CONSIDERATIONS

A. Congenital heart malformations

1. **Tetralogy of Fallot** is caused by abnormal migration of neural crest cells that leads to skewed development of the aorticopulmonary septum. It results in a condition classically characterized by **pulmonary stenosis, overriding aorta, interventricular septal defect,** and **right ventricular hypertrophy**. The resultant **right-to-left shunting** of blood leads to **cyanosis**.

2. **Membranous ventricular septal defect (VSD)** is caused by incomplete fusion of the **right bulbar ridge, left bulbar ridge**, and **atrioventricular cushions.** This defect results in a condition in which an opening between the right and left ventricles allows **left-to-right shunting** of blood through the interventricular (IV) foramen. Patients with left-to-right shunting complain of **excessive fatigue on exertion**. Initially, a membranous ventricular septal defect is associated with left-to-right shunting of blood, increased pulmonary blood flow, and pulmonary hypertension. Later, the pulmonary hypertension causes marked proliferation of the tunica intima and tunica media of the pulmonary muscular arteries and arterioles, thereby narrowing their lumen. Ultimately, pulmonary resistance becomes higher than systemic resistance and causes **right-to-left shunting** of blood and **cyanosis**. At this stage, the condition is called the **Eisenmenger complex**.

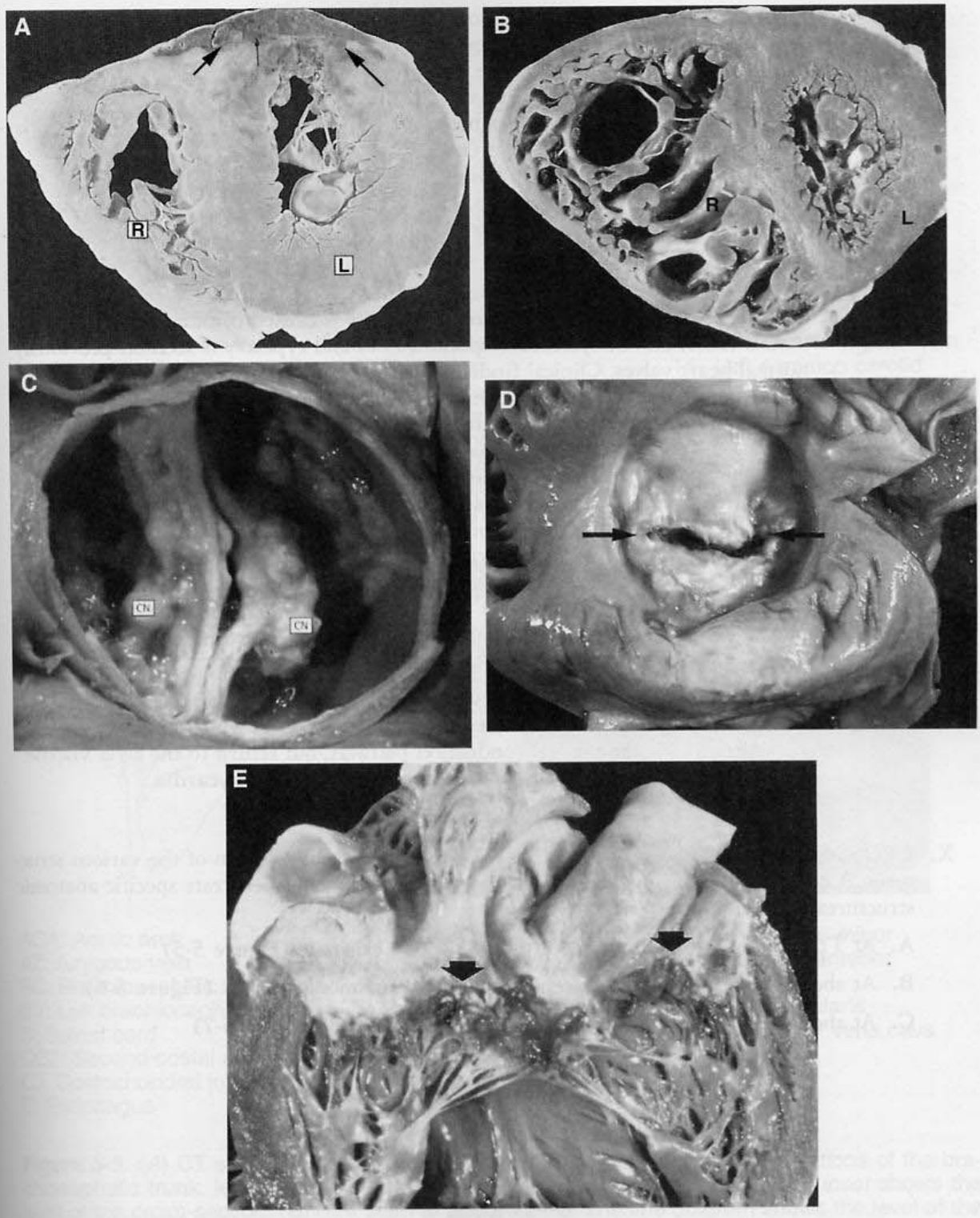
3. **Patent ductus arteriosus (PDA)** occurs when the ductus arteriosus, a connection between the left pulmonary artery and the arch of the aorta, does not close. Normally, the ductus arteriosus closes via smooth muscle contraction within a few hours after birth and forms the ligamentum arteriosum. PDA causes a **left-to-right shunting** of blood from the aorta back into the pulmonary circulation. A PDA is very common in premature infants and also may result from maternal rubella infection during pregnancy. Prostaglandin E, intrauterine asphyxia, and neonatal asphyxia sustain patency of the ductus arteriosus. Prostaglandin inhibitors (e.g.,

indomethacin), acetylcholine, histamine, and catecholamines promote closure of the ductus arteriosus.

B. Other disorders (Figure 5-4)

1. **Ischemic heart disease. Angina pectoris** most commonly is caused by atherosclerotic disease. It results from myocardial ischemia that falls short of inducing cellular necrosis. Clinical findings include: pain that is precipitated by exertion, but relieved by rest; a sensation of pressure or burning in the chest that may last **as long as 20 minutes;** pain radiating to the arm, jaw, and neck; and tachycardia.
2. **Acute myocardial infarction (MI; "heart attack")** most commonly is caused by atherosclerotic disease. It results from myocardial ischemia that induces cellular necrosis. Clinical findings include: onset at rest (usually); a sensation of pressure or burning in the chest that lasts **longer than 30 minutes;** pain radiating to the arm, jaw, and neck; nausea or vomiting; sweating; shortness of breath; and tachycardia. MIs may be silent and without consequence. Complications of MI include congestive heart failure; papillary muscle rupture, indicated by acute onset of congestive heart failure with holosystolic murmur; and life-threatening arrhythmias, common in the first 24 hours after MI. Electrocardiogram (ECG) findings include: **ST segment elevation** immediately after the MI. **Later, falling ST segments** are observed, and **Q waves** and **inverted T waves** appear. Cardiac enzyme levels include elevated **total creatine kinase (CK)** and **CK-2 fraction** 6–12 hours after MI; elevated **troponin** levels 12 hours after MI; and elevated **lactate dehydrogenase (LDH)** levels, indicated by a **reversed LDH1:LDH2 ratio,** 24 hours after MI. Treatments include: sublingual nitroglycerin; beta-blockers to relieve tachycardia and hypertension; streptokinase IV or tissue plasminogen activator to reduce the amount of infarcted tissue, if administered within 6 hours of MI; atropine to relieve bradycardia; and heparinization and warfarin therapy to prevent ventricular aneurysms, thrombopulmonary embolisms, and deep vein thrombosis.
3. **Cor pulmonale (pulmonary hypertensive heart disease)** is right ventricular dilation caused by pulmonary hypertension. **Acute cor pulmonale** is right ventricular dilation that follows a large thrombopulmonary embolism. **Chronic cor pulmonale** is right ventricular hypertrophy followed by dilation that is caused by prolonged obstruction of pulmonary vasculature (e.g., emphysema).
4. **Calcific valve disease** occurs when valves become thickened and distorted by fibrous scarring and **calcium nodules.** It most commonly affects the **aortic valve.** Calcific valve disease renders the valve cusps immobile and impairs blood flow from the left ventricle during systole, thereby leading to heart failure.

Figure 5-4. (*A*) Gross specimen of a myocardial infarction. The left ventricular myocardium is thickened as a result of persistent hypertension. Note the discoloration of the left ventricular wall and part of the interventricular septum as a result of the infarction (*arrows*). *L* = left ventricle; *R* = right ventricle. (*B*) Gross specimen of chronic cor pulmonale. Note the dilated right ventricle (*R*) with hypertrophied trabeculae. The left ventricle (*L*) has been compressed by the right ventricular enlargement. (*C*) Gross specimen of calcific valve disease. Note the congenitally malformed bicuspid (rather than the standard tricuspid) aortic valve, which is thickened and distorted by calcium nodules (*CN*). (*D*) Gross specimen of rheumatic heart disease. Note the "fish mouth" or "button-hole" stenosis (*arrows*) of the mitral valve caused by fibrotic thickening and the row of vegetation along the line of closure. (*E*) Gross specimen of infective endocarditis. Note the large, friable vegetations (*arrows*) on the mitral valve. (*A* adapted and *C* reprinted with permission from Stevens A, Lowe J: *Human Histology,* 2nd ed. St. Louis, Mosby, 1997, pp 152, 155; *B* adapted and *D* and *E* reprinted with permission from Cotran RS, Kumor V, Robbins SL: *Robbins' Pathologic Basis of Disease,* 5th ed. Philadelphia, WB Saunders, 1994, pp 543, 550, 552.)


A
R
L
B
R
L
C
CN
CN
D
E

5. **Rheumatic heart disease** results from **rheumatic fever.** Acute rheumatic fever typically follows pharyngitis caused by **group A β-hemolytic streptococci.** Anti-streptococcal antibodies made by the patient cross-react with host connective tissue (e.g., heart valves), leading to rheumatic heart disease. The **mitral valve** most commonly is affected. The valve leaflets become red and swollen, fibrosis develops, and a row of small, wart-like vegetations (verrucae) appears along the line of closure. Rheumatic heart disease leads to **"fish mouth,"** or **"button-hole," stenosis** of the mitral valve. Finally, **Aschoff bodies,** which are pathognomonic lesions consisting of perivascular, fibrinoid, necrosis-surrounded inflammatory cells (giant Aschoff cells) develop.

6. **Infective endocarditis** is the colonization of heart valves with bacteria.
   a. **Acute bacterial endocarditis** most commonly is caused by *Staphylococcus aureus* (50%) and *Streptococcus* species (35%) and typically is seen on previously normal heart valves. Clinical findings include: **Janeway lesions** (erythematous, nontender lesions on the palms and soles), **splinter hemorrhages** in the nail beds, high fever with chills, hematuria, petechiae, and splenomegaly. Large, friable vegetations on the heart valves may lead to systemic septic emboli or perforation of the heart valve, causing valvular incompetence.
   b. **Subacute bacterial endocarditis** is caused by *Staphylococcus epidermidis*, *Streptococcus viridans*, *Enterococcus* species, or gram-negative bacilli. It typically is seen on previously abnormal heart valves. Clinical findings include: Roth spots (retinal hemorrhages), Osler nodes (erythematous, tender lesions on the fingers and toes), fatigue, low-grade fever without chills, anemia, hematuria, and splenomegaly.

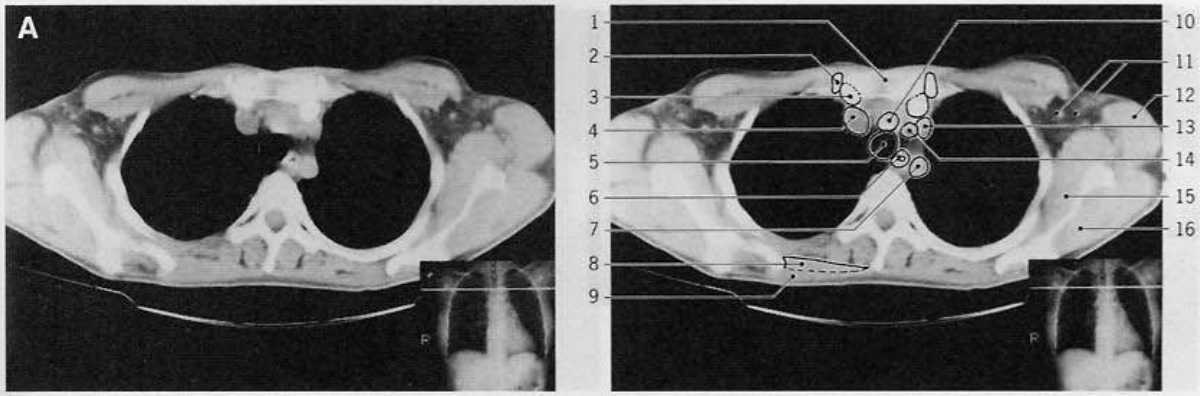
7. **Wolff-Parkinson-White syndrome** is a congenital disorder in which there is an **accessory conduction pathway** between the atria and the ventricles. Usually, this condition is asymptomatic. A **re-entry loop** may develop in which impulses travel to the ventricles via the normal conduction pathway, but return to the atria via the accessory conduction pathway, causing **supraventricular tachycardia.**

X. **CROSS-SECTIONAL ANATOMY.** Note the anteroposterior position of the various structures. A bullet or knife wound at a specific vertebral level would penetrate specific anatomic structures in an anteroposterior direction.

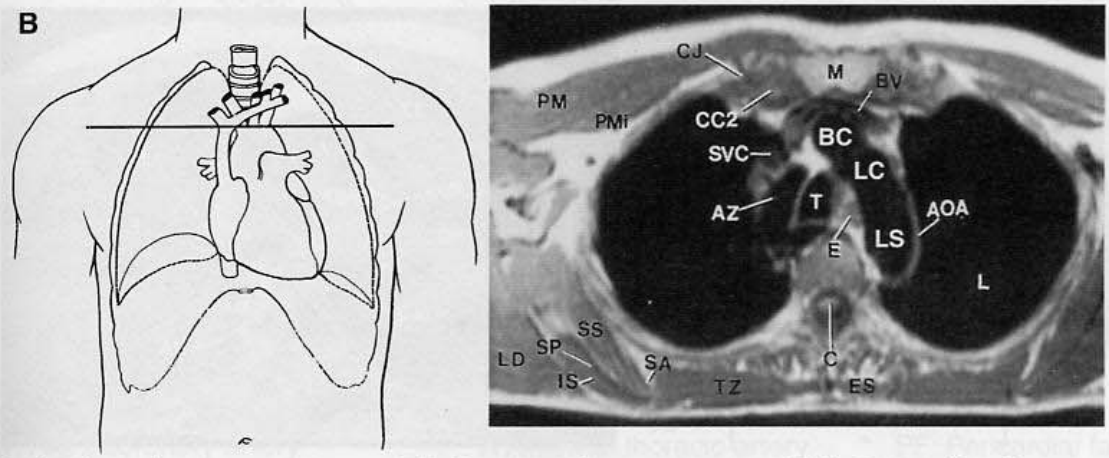
   A. At T2–3, where three branches of the aortic arch originate **(Figure 5-5)**

   B. At about T5–6, through the ascending aorta and pulmonary trunk **(Figure 5-6)**

   C. At about T7–8, through the four chambers of the heart **(Figure 5-7)**

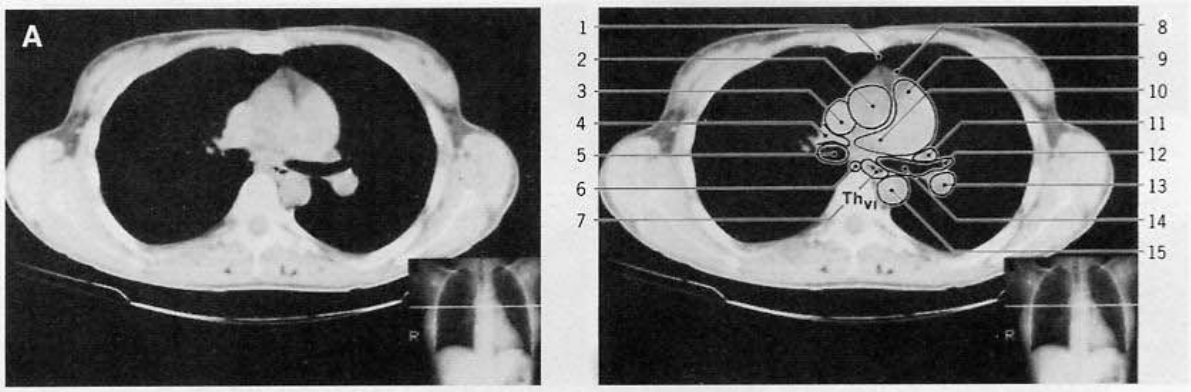


1. Manubrium of sternum
2. First rib
3. Sternal end of clavicle
4. Right brachiocephalic vein
5. Trachea
6. Esophagus
7. Left subclavian artery
8. Rhomboideus
9. Trapezius
10. Brachiocephalic trunk
11. Axillary fat with lymph nodes and vessels
12. Latissimus dorsi and teres major (arms elevated)
13. Left internal jugular vein
14. Left common carotid artery
15. Subscapularis
16. Infraspinatus

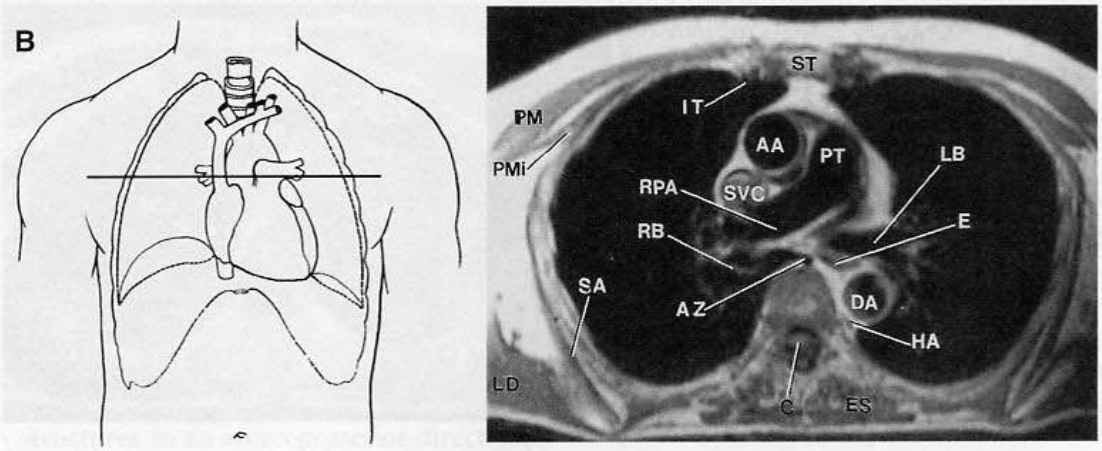


AOA: Aortic arch
AZ: Azygous vein
BC: Brachiocephalic artery
BV: Left brachiocephalic vein
C: Spinal cord
CC2: Second costal cartilage
CJ: Costochondral junction
E: Esophagus
ES: Erector spinae
IS: Infraspinatus
L: Lung
LC: Left common carotid artery
LS: Left subclavian artery
M: Manubrium
PM: Pectoralis major
PMi: Pectoralis minor
SA: Serratus anterior
SP: Scapula
SS: Subscapularis
SVC: Superior vena cava
T: Trachea
TZ: Trapezius

Figure 5-5. (*A*) CT scan (labeled and unlabeled) at about T2—3. Note the relations of the brachiocephalic trunk, left common carotid artery, and left subclavian artery. The *inset* shows the level of the cross-section. (*B*) MRI scan at about T2—3. The line diagram shows the level of the cross-section. (*A* reprinted with permission from Fleckenstein P, Tranum-Jensen J: *Anatomy in Diagnostic Imaging*. Philadelphia, WB Saunders, 1993, p 209; *B* adapted with permission from Barrett CP, Anderson LD, Holder LE, et al: *Primer of Sectional Anatomy with MRI and CT Correlation,* 2nd ed. Baltimore, Williams & Wilkins, 1994, pp 53, 54.)

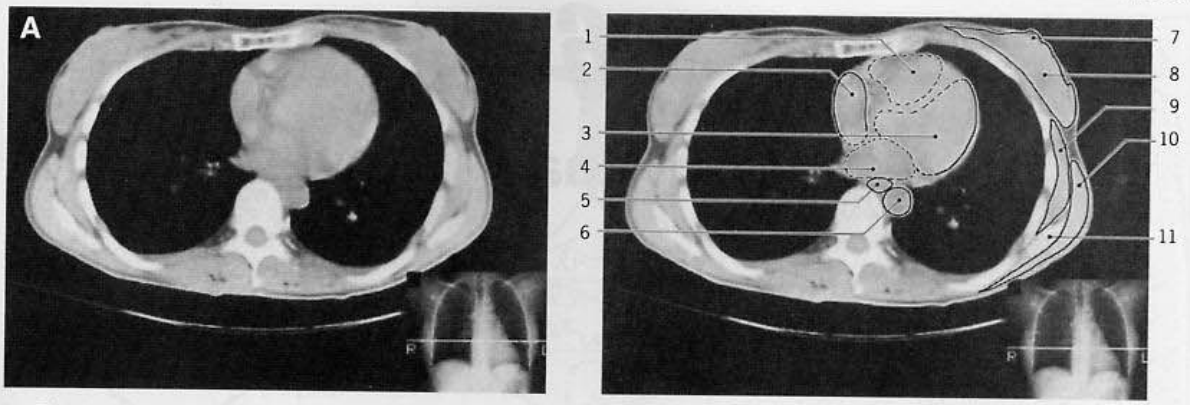


1. Anterior mediastinum
2. Ascending aorta
3. Superior caval vein
4. Right superior pulmonary vein and apical branches of right pulmonary artery
5. Right intermediate bronchus
6. Azygous vein
7. Esophagus
8. Pericardium
9. Pulmonary trunk
10. Right pulmonary artery
11. Left superior pulmonary vein
12. Left superior lobar bronchus
13. Left pulmonary artery
14. Left principal bronchus
15. Thoracic aorta

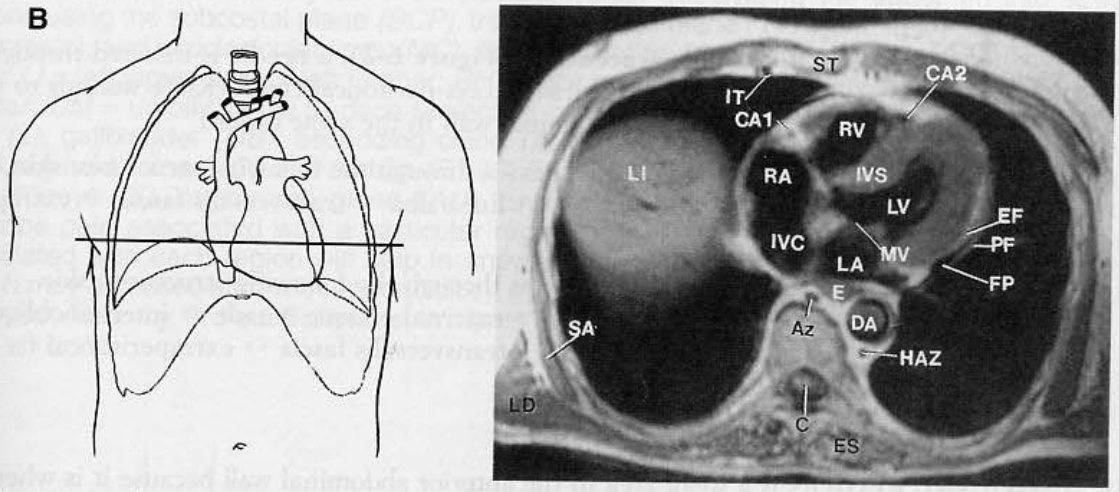


AA: Ascending aorta
AZ: Azygous vein
C: Spinal cord
DA: Descending aorta
E: Esophagus
ES: Erector spinae
HA: Hemiazygous vein
IT: Internal thoracic artery
LB: Left main bronchus
LD: Latissimus dorsi
PM: Pectoralis major
PMi: Pectoralis minor
PT: Pulmonary trunk
RB: Right main bronchus
RPA: Right pulmonary artery
SA: Serratus anterior
ST: Sternum
SVC: Superior vena cava

Figure 5-6. (*A*) CT scan (labeled and unlabeled) at about T5—6. Note the position of the ascending aorta and the pulmonary trunk. The *inset* shows the level of the cross-section. (*B*) MRI scan at about T5—6. The line diagram shows the level of the cross-section. (*A* reprinted with permission from Fleckenstein P, Tranum-Jensen J: *Anatomy in Diagnostic Imaging.* Philadelphia, WB Saunders, 1993, p 214; *B* reprinted with permission from Barrett CP, Anderson LD, Holder LE, et al: *Primer of Sectional Anatomy with MRI and CT Correlation,* 2nd ed. Baltimore, Williams & Wilkins, 1994, pp 59, 60.)



1. Right ventricle
2. Right atrium
3. Left ventricle
4. Left atrium
5. Esophagus
6. Thoracic aorta
7. Nipple
8. Body of mammary gland
9. Serratus anterior
10. Latissimus dorsi
11. Inferior angle of scapula



Az: Azygous vein
C: Spinal cord
CA1: Right coronary artery
CA2: Left anterior descending artery
DA: Descending aorta
E: Esophagus
EF: Epicardial fat
ES: Erector spinae
FP: Fibrous pericardium
HAZ: Hemiazygous vein
IT: Internal thoracic artery
IVC: Inferior vena cava
IVS: Interventricular septum
LA: Left atrium
LD: Latissimus dorsi
LI: Liver
LV: Left ventricle
MV: Mitral valve
PF: Pericardial fat
RA: Right atrium
RV: Right ventricle
SA: Serratus anterior
ST: Sternum

Figure 5-7. (*A*) CT scan (labeled and unlabeled) at about T7—8. Note the position of the four chambers of the heart. The *inset* shows the level of the cross-section. (*B*) MRI scan at about T7—8. The line diagram shows the level of the cross-section. It is important to know the arrangement of the heart chambers in an anteroposterior direction. A typical clinical vignette question may ask about a patient who is shot through the sternum. In what order would the bullet pass through the chambers of the heart before it exits the back? (*A* reprinted with permission from Fleckenstein P, Tranum-Jensen J: *Anatomy in Diagnostic Imaging.* Philadelphia, WB Saunders, 1993, p 219; *B* reprinted with permission from Barrett CP, Anderson LD, Holder LE, et al: *Primer of Sectional Anatomy with MRI and CT Correlation,* 2nd ed. Philadelphia, Williams & Wilkins, 1994, pp 69, 70.)

6

Abdominal Wall

I. **ABDOMINAL REGIONS (Figure 6-1).** The abdomen can be divided topographically into nine regions: **right hypochondriac, epigastric, left hypochondriac, right lumbar, umbilical, left lumbar, right inguinal, hypogastric,** and **left inguinal.**

II. **CLINICAL PROCEDURE.** In **paracentesis (Figure 6-2),** a needle is inserted through the layers of the abdominal wall to withdraw excess peritoneal fluid. (Knife wounds to the abdomen penetrate the layers of the abdominal wall in the same order.)

A. In the **midline approach,** the needle passes through the following structures: skin → superficial fascia (Camper and Scarpa) → linea alba → transversalis fascia → extraperitoneal fat → parietal peritoneum.

B. In the **flank approach,** the needle passes through the following structures: skin → superficial fascia (Camper and Scarpa) → external oblique muscle → internal oblique muscle → transverse abdominis muscle → transversalis fascia → extraperitoneal fat → parietal peritoneum.

III. **INGUINAL REGION** is a weak area in the anterior abdominal wall because it is where the testes and spermatic cord (in males) or the round ligament of the uterus (in females) penetrates during embryologic development.

A. The **inguinal ligament** is the coiled lower border of the **external oblique muscle** and extends from the anterior-superior iliac spine to the pubic tubercle.

B. The **deep inguinal ring** is an oval opening in the **transversalis fascia** located lateral to the inferior epigastric artery.

C. The **superficial inguinal ring** is a triangular defect of the **external oblique muscle** located lateral to the pubic tubercle.

D. The **inguinal canal** begins at the deep inguinal ring and ends at the superficial inguinal ring. It transmits the **spermatic cord** (in males) or the **round ligament of the uterus** (in females).

E. **Hernias (Figure 6-3)**

1. **Types** include **direct inguinal hernia, indirect inguinal hernia,** and **femoral hernia.**

2. **Surgical repair**

a. In the **Bassini repair,** the transversalis fascia and **conjoint tendon** (combined tendinous insertion of the transverse abdominis muscle and internal

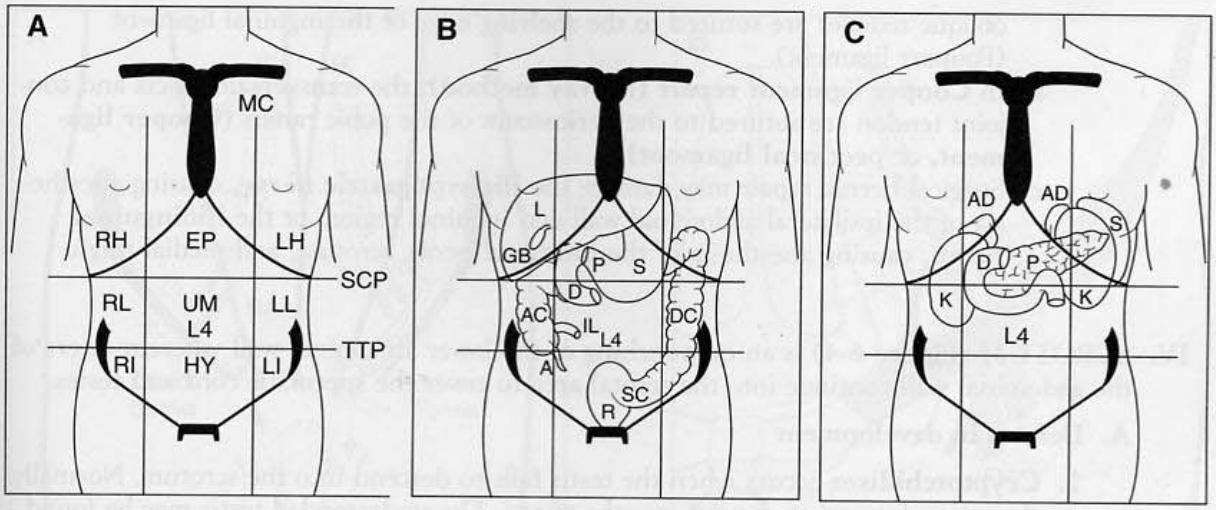


Figure 6-1. *(A)* A commonly used clinical method for subdividing the abdomen into specific regions using the subcostal plane *(SCP),* transtubercular plane (*TTP;* joining the tubercles of the iliac crests), and midclavicular lines *(MC). EP* = epigastric; *HY* = hypogastric; *LH* = left hypochondriac; *LI* = left inguinal; *LL* = left lumbar; *RH* = right hypochondriac; *RI* = right inguinal; *RL* = right lumbar; *UM* = umbilical. *(B)* Surface projection of the stomach *(S),* pylorus *(P),* duodenum *(D),* liver *(L),* gallbladder *(GB),* ascending colon *(AC),* appendix *(A),* ileum *(IL),* descending colon *(DC),* sigmoid colon *(SC),* and rectum *(R). (C)* Surface projection of the duodenum *(D),* pancreas *(P),* kidneys *(K),* suprarenal gland *(AD),* and spleen *(S).* Many clinical vignette questions describe pain associated with a particular region of the abdomen. Knowing which viscera are associated with each region will help in answering the question (e.g., pain in the right lumbar region may be associated with appendicitis). (Adapted with permission from Moore KL: *Clinically Oriented Anatomy,* 3rd ed. Baltimore, Williams & Wilkins, 1992, pp 130, 131, 174.)

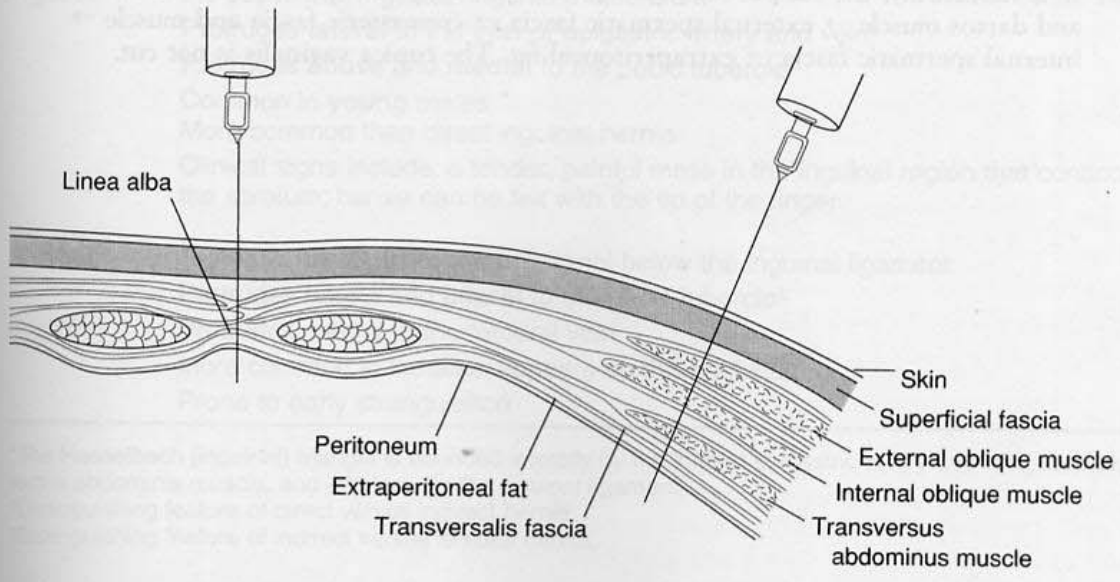


Figure 6-2. A transverse section through the anterior abdominal wall shows the various layers that are penetrated by a needle during paracentesis, or by a knife wound. (Adapted with permission from Moore KL: *Clinically Oriented Anatomy,* 3rd ed, Baltimore, Williams & Wilkins, 1992, p 134.)

oblique muscle) are sutured to the shelving edge of the inguinal ligament (Poupart ligament).

b. In **Cooper ligament repair (McVay method),** the transversalis fascia and conjoint tendon are sutured to the periosteum of the pubic ramus **(Cooper ligament,** or **pectineal ligament).**

c. Surgical hernia repair may damage the **iliohypogastric nerve,** causing anesthesia of the ipsilateral abdominal wall and inguinal region, or the **ilioinguinal nerve,** causing anesthesia of the ipsilateral penis, scrotum, and medial thigh.

IV. SCROTUM (Figure 6-4) is an outpouching of the lower abdominal wall whereby layers of the abdominal wall continue into the scrotal area to cover the spermatic cord and testes.

A. Defects in development

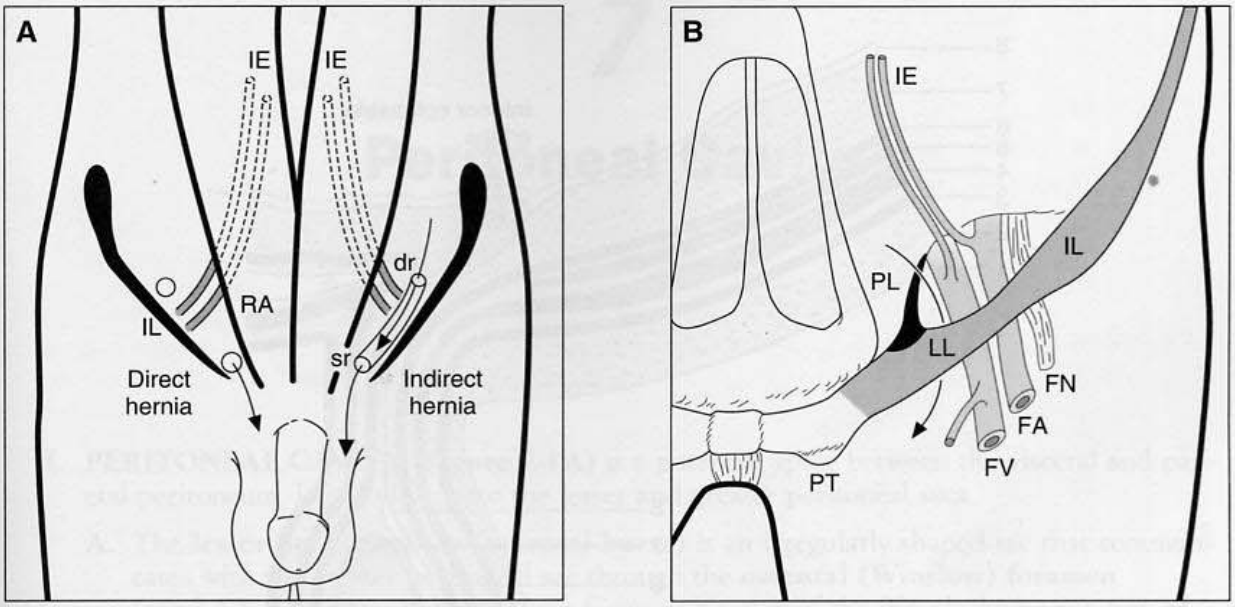
1. **Cryptorchidism** occurs when the testis fails to descend into the scrotum. Normally, the testes descend at about 3 months of age. The undescended testis may be found within the inguinal canal or abdominal cavity. Bilateral cryptorchidism results in sterility.

2. **Hydrocele** occurs when a small patency of the **processus vaginalis** remains from embryologic development. The peritoneal fluid then can flow into the processus vaginalis, creating a fluid-filled cyst near the testes.

B. Cancer. Cancer of the scrotum metastasizes to the superficial inguinal nodes. Cancer of the testes metastasizes to the deep lumbar nodes near the renal hilus because the testes develop embryologically within the abdominal cavity and then descend into the scrotum.

C. Trauma. Extravasated urine from a saddle injury will leak into the superficial perineal space located between Colles fascia and the dartos muscle (layer 2) and the external spermatic fascia (layer 3) [see Figure 6-4].

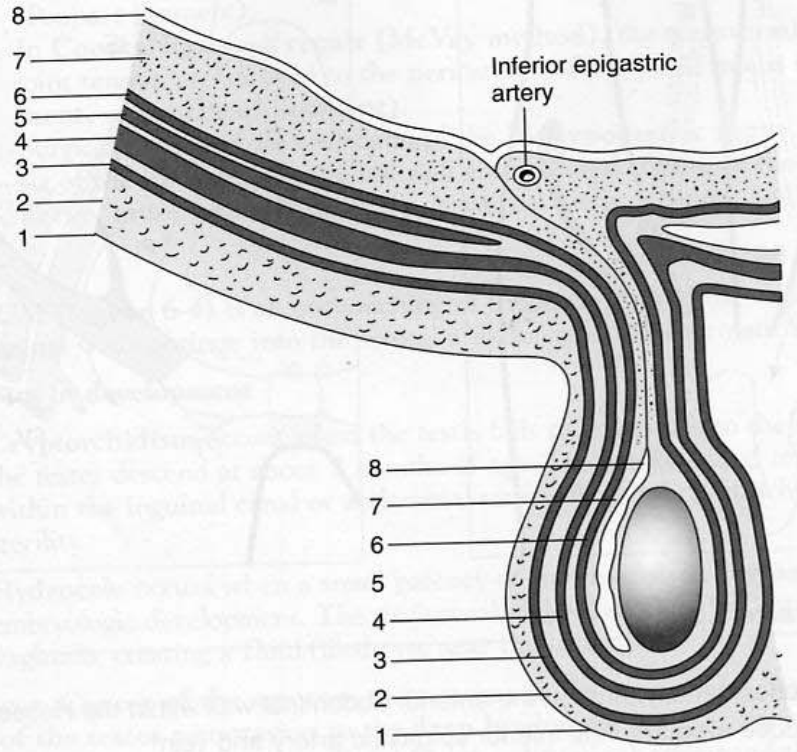
D. In a vasectomy, the scalpel cuts through the following structures: skin → Colles fascia and dartos muscle → external spermatic fascia → cremasteric fascia and muscle → internal spermatic fascia → extraperitoneal fat. The tunica vaginalis is not cut.



Type of Hernia	Characteristics
Direct inguinal	Protrudes directly through the anterior abdominal wall within the Hesselbach triangle*
	Protrudes **medial** to the inferior epigastric artery and vein†
	Common in **older** males; rare in women
	Clinical signs include: a mass in the inguinal region that protrudes on straining and disappears at rest (i.e., it is easily reduced), constipation, and prostate enlargement; hernia can be detected with the pulp of the finger
Indirect inguinal	Protrudes through the deep inguinal ring to enter the inguinal canal; may exit through the superficial inguinal ring into the scrotum
	Protrudes **lateral** to the inferior epigastric artery and vein†
	Protrudes **above** and **medial** to the pubic tubercle‡
	Common in **young** males More common than direct inguinal hernia
	Clinical signs include: a tender, painful mass in the inguinal region that continues into the scrotum; hernia can be felt with the tip of the finger
Femoral	Protrudes through the femoral canal below the inguinal ligament
	Protrudes **below** and **lateral** to the pubic tubercle‡
	Protrudes medial to the femoral vein
	More common in females; appears on the right side
	Prone to early strangulation

*The Hesselbach (inguinal) triangle is bounded laterally by the inferior epigastric artery and vein, medially by the rectus abdominis muscle, and inferiorly by the inguinal ligament.
†Distinguishing feature of direct versus indirect hernia.
‡Distinguishing feature of indirect versus femoral hernia.

Figure 6-3. *(A)* Anatomy associated with direct and indirect inguinal hernias. *(B)* Anatomy associated with a femoral hernia. *dr* = deep inguinal ring; *IE* = inferior epigastric artery and vein; *FA* = femoral artery; *FN* = femoral nerve; *FV* = femoral vein; *IL* = inguinal ligament; *LL* = lacunar ligament; *PL* = pectineal (Cooper) ligament; *PT* = pubic tubercle; *RA* = rectus abdominis muscle; *sr* = superficial inguinal ring.



Layers of Abdominal Wall	Coverings of Testes and Spermatic Cord
1. Skin	→ Skin (Scrotum)
2. Superficial fascia (Camper and Scarpa)	→ Colles fascia and dartos muscle (Scrotum)
Superficial perineal space (extravasated urine)	
3. External oblique muscle	→ External spermatic fascia
4. Internal oblique muscle	→ Cremasteric fascia and muscle
5. Transverse abdominus muscle	Does not continue into scrotal area
6. Transversalis fascia	→ Internal spermatic fascia
7. Extraperitoneal fat	→ Extraperitoneal fat
8. Parietal peritoneum	→ Tunica vaginalis

Figure 6-4. Layers of the abdominal wall continue into the scrotal area as covering of the spermatic cord and testes. The transverse abdominis muscle does not continue into the scrotal area, but instead, joins with the tendon of the internal oblique muscle to form the conjoint tendon. Extravasated urine from a straddle injury leaks between layers 2 and 3. (Adapted with permission from Moore KL: *Clinically Oriented Anatomy*, 3rd ed, Baltimore, Williams & Wilkins, p 139.)

7

Peritoneal Cavity

I. **PERITONEAL CAVITY (Figure 7-1A)** is a potential space between the visceral and parietal peritoneum. It is divided into the lesser and greater peritoneal sacs.

A. The **lesser peritoneal sac (omental bursa)** is an irregularly shaped sac that communicates with the greater peritoneal sac through the **omental (Winslow) foramen (see I C).** The lesser peritoneal sac forms as a result of the 90° clockwise rotation of the stomach that occurs during embryologic development. Its boundaries are as follows:

1. **Anterior:** liver, stomach, and lesser omentum
2. **Posterior:** diaphragm
3. **Right side:** liver
4. **Left side:** gastrosplenic and splenorenal ligaments

B. The **greater peritoneal sac** is the remainder of the peritoneal cavity, extending from the diaphragm to the pelvis. The greater peritoneal sac contains a number of pouches, recesses, and paracolic gutters through which peritoneal fluid circulates.

1. **Paracolic gutters** are channels that run along the ascending and descending colon. Normally, peritoneal fluid flows **upward** through the paracolic gutters to the **subphrenic recess,** where it enters the lymphatics associated with the diaphragm.
2. **Excess peritoneal fluid** as a result of peritonitis or ascites flows downward through the paracolic gutters to the **rectovesical pouch** (in males) or the **rectouterine pouch** (in females) when the patient is **sitting** or **standing.**
3. **Excess peritoneal fluid** as a result of peritonitis or ascites flows upward through the paracolic gutters to the **subphrenic recess** and the **hepatorenal recess** when the patient is in the **supine position.** The hepatorenal recess is the **lowest** part of the peritoneal cavity when the patient is in the supine position. The patient may have shoulder pain (referred pain) caused by irritation of the phrenic nerve (nerve roots C3, C4, and C5).

C. The **omental (Winslow) foramen** is the opening, or connection, between the lesser and greater peritoneal sacs. If the surgeon places a finger in the omental foramen, the inferior vena cava lies posterior and the portal vein lies anterior to his or her finger.

II. **OMENTUM** (Figure 7-1B)

A. The **lesser omentum** is a fold of peritoneum that extends from the porta hepatis of the liver to the lesser curvature of the stomach. It consists of the **hepatoduodenal ligament** and the **hepatogastric ligament.** The **portal triad** lies in the free margin of the hepatoduodenal ligament. It consists of:

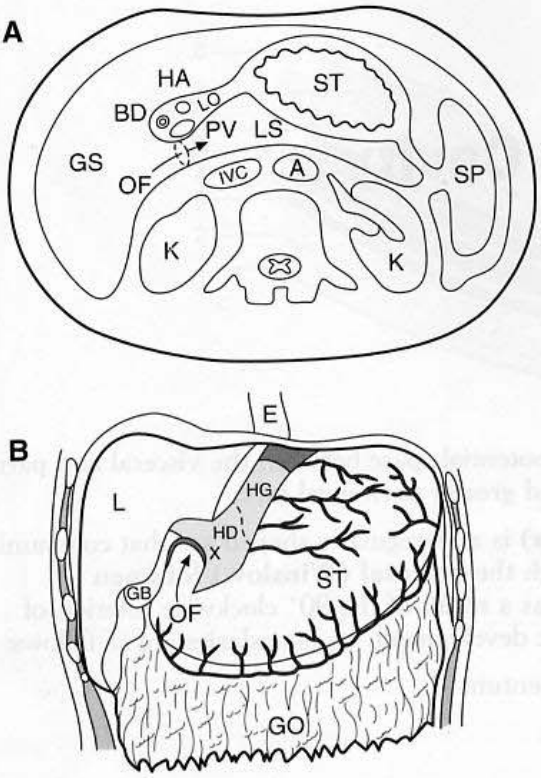


Figure 7-1. (*A*) Cross-section of the abdomen showing the peritoneal cavity. The greater peritoneal sac (*GS*) and lesser peritoneal sac (*LS*) are connected by the omental foramen (*OF; arrow*). The portal triad is shown at the free margin of the hepatoduodenal ligament of the lesser omentum (*LO*). *A* = aorta; *BD* = common bile duct; *HA* = hepatic artery; *IVC* = inferior vena cava; *K* = kidney; *PV* = portal vein; *SP* = spleen; *ST* = stomach. (*B*) Anterior dissection of the stomach. The lesser omentum, consisting of the hepatoduodenal ligament (*HD*) and the hepatogastric ligament (*HG*), and the greater omentum (*GO*) are shown. The left part of the liver is cut away to expose the omental foramen (*OF*) and the portal triad (*X*). *E* = esophagus; *GB* = gallbladder; *L* = liver; *ST* = stomach. (*A* and *B* adapted with permission from Moore KL: *Clinically Oriented Anatomy,* 3rd ed, Baltimore, Williams & Wilkins, 1992, pp 153, 157.)

1. The **portal vein,** which lies posterior
2. The **common bile duct,** which lies anterior and to the right
3. The **hepatic artery,** which lies anterior and to the left.

B. The **greater omentum** is a fold of peritoneum that hangs down from the greater curvature of the stomach. It is known as the "abdominal policeman" because it adheres to areas of inflammation.

III. INTRAPERITONEAL AND EXTRAPERITONEAL VISCERA are listed in Table 7-1.

Table 7-1.
Intraperitoneal and Extraperitoneal Viscera

Intraperitoneal	Retroperitoneal
Stomach	Parts 2, 3, and 4 of duodenum
Part 1 of duodenum	Ascending colon
Jejunum	Descending colon
Ileum	Rectum
Cecum	Head, neck, and body of pancreas
Appendix	Kidneys
Transverse colon	Ureters
Sigmoid colon	Suprarenal gland
Liver	Abdominal aorta
Gallbladder	Inferior vena cava
Tail of pancreas	
Spleen	

8

Abdominal Vasculature

I. ABDOMINAL AORTA (Figure 8-1)

A. Major branches

1. **Celiac trunk, superior mesenteric artery, renal arteries, gonadal arteries, inferior mesenteric artery,** and **common iliac arteries.** The **celiac trunk** is located at vertebral level **T12** and supplies the viscera that derive embryologically from the **foregut** (i.e., intraabdominal portion of esophagus, stomach, upper part of duodenum, liver, gallbladder, and pancreas). It further branches into the following structures:
   a. **Left gastric artery**
   b. **Splenic artery**
   c. **Common hepatic artery**
2. The **superior mesenteric artery** is located at vertebral level **L1** and supplies the viscera that derive embryologically from the **midgut** (i.e., lower part of duodenum, jejunum, ileum, cecum, appendix, ascending colon, and proximal two-thirds of the transverse colon).
3. The **renal arteries** supply the kidneys.
4. The **gonadal arteries** supply the testes or ovaries.
5. The **inferior mesenteric artery** is located at vertebral level **L3** and supplies the viscera that derive embryologically from the **hindgut** (i.e., distal one-third of transverse colon, descending colon, sigmoid colon, and upper portion of rectum). The **common iliac arteries** are the terminal branches of the abdominal aorta.

B. Clinical considerations

1. **Abdominal aortic aneurysm (AAA)** typically is seen below vertebral level L1 (i.e., below the renal arteries and superior mesenteric artery) in elderly men with atherosclerosis. The most common site of a ruptured AAA is below the renal arteries in the **left posterolateral wall (retroperitoneal).** In a patient with a ruptured AAA, the first step is immediate compression of the aorta against the vertebral bodies **above the celiac trunk.** During a transabdominal surgical approach to correct a ruptured AAA, the **left renal vein is** put in jeopardy. The **inferior mesenteric artery** usually lies in the middle of an AAA. Clinical findings include: sudden onset of severe, central abdominal pain that may radiate to the back; a pulsatile, tender abdominal mass; and hypotension and delirium, if rupture occurs. Surgical complications include: **ischemic colitis** as a result of ligation of the inferior mesenteric artery and **spinal cord ischemia** as a result of ligation of the great radicular artery (artery of Adamkiewicz; see Chapter 2 II D).

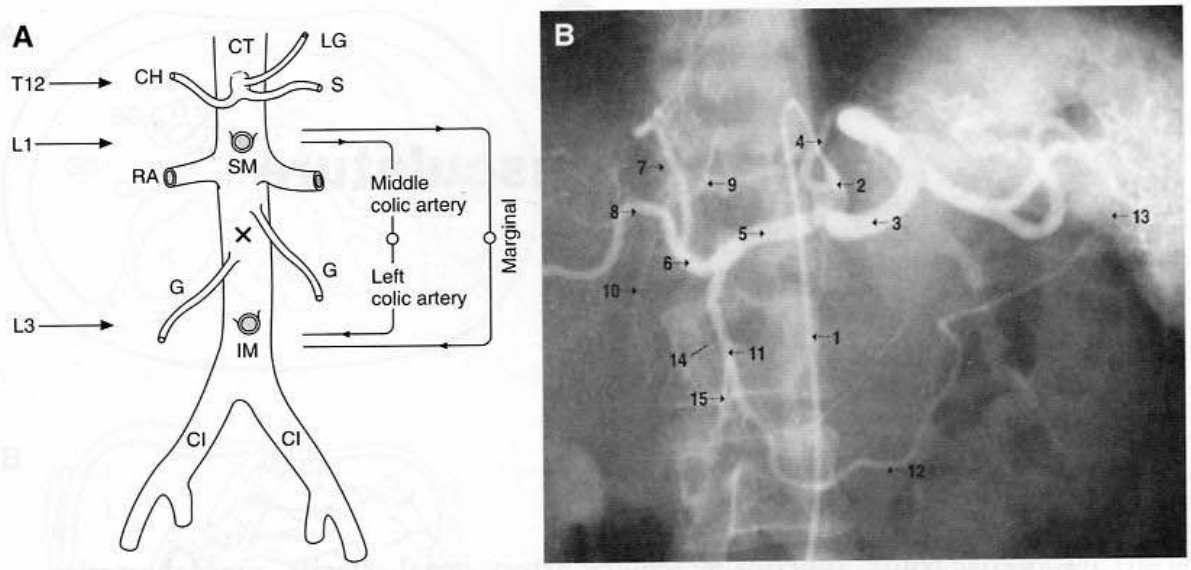


Figure 8-1. (*A*) The major branches of the abdominal aorta. The abdominal vasculature has a fairly robust collateral circulation. Any blockage (*X*) between the superior mesenteric artery (*SM*; at vertebral level L1) and inferior mesenteric artery (*IM*; at vertebral level L3) causes blood to be diverted along either or both of two routes of collateral circulation. The first route uses the middle colic artery, which is a branch of the SM artery, which anastomoses with the left colic artery, a branch of the IM artery. The second route uses the marginal artery. *CH* = common hepatic artery; *CI* = common iliac artery; *CT* = celiac trunk; *G* = gonadal artery; *LG* = left gastric artery; *RA* = renal artery; *S* = splenic artery. *T12, L1,* and *L3* indicate the vertebral levels of the various branches. (*B*) Arteriogram showing other arteries in the vicinity. *1* = catheter in aorta; *2* = catheter in celiac trunk; *3* = splenic artery; *4* = left gastric artery; *5* = common hepatic artery; *6* = hepatic artery proper; *7* = left hepatic artery; *8* = right hepatic artery; *9* = right gastric artery; *10* = cystic artery; *11* = gastroduodenal artery; *12* = right gastroepiploic artery; *13* = left gastroepiploic artery; *14* = posterior superior pancreaticoduodenal artery; *15* = anterior superior pancreaticoduodenal artery. (*A* adapted with permission from Moore KL: *Clinically Oriented Anatomy,* 3rd ed. Baltimore, Williams & Wilkins, 1992, p 168; *B* adapted with permission from Ryan S, McNicholas M: *Anatomy for Diagnostic Imaging.* London, WB Saunders, 1994, p 156.)

2. **Acute mesenteric ischemia** most commonly is caused by an embolism within the **superior mesenteric artery**. Clinical signs include: severe abdominal pain that is out of proportion to the physical findings. There is no evidence of peritonitis. Acute mesenteric ischemia usually occurs in elderly patients who have a history of heart disease and are taking digoxin (a potent splanchnic vasoconstrictor).
3. **Gradual occlusion** most commonly is seen in atherosclerotic patients, at the bifurcation of the abdominal aorta. It may result in **claudication** (i.e., pain in the legs when walking) and **impotence** as a result of the lack of blood to the internal iliac arteries.

II. VENOUS DRAINAGE OF THE ABDOMEN (Figure 8-2)

A. Azygous venous system

1. The **azygous vein** ascends on the right side of the vertebral column and drains blood from the inferior vena cava (IVC) to the superior vena cava (SVC).

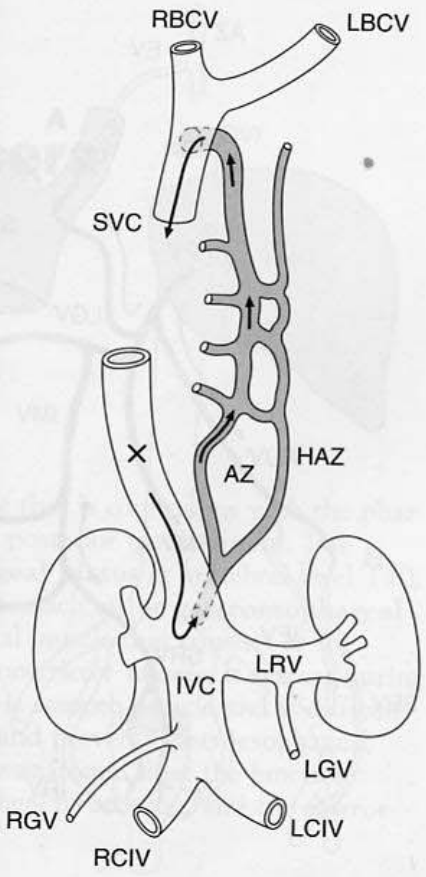


Figure 8-2. Diagram of the azygous venous system and the inferior vena cava (*IVC*). Note that the left gonadal vein (*LGV*) drains into the left renal vein (*LRV*). This pathway has clinical implications in males (e.g., left testicular varicocele). The azygous vein provides a route of collateral venous return (*arrows*) if the IVC is blocked (*X*). *AZ* = azygous vein; *HAZ* = hemiazygous vein; *LBCV* = left brachiocephalic vein; *LCIV* = left common iliac vein; *RBCV* = right brachiocephalic vein; *RCIV* = right common iliac vein; *RGV* = right gonadal vein; *SVC* = superior vena cava.

2. The **hemiazygous vein** ascends on the left side of the vertebral column and drains blood from the left renal vein to the azygous vein.

B. The **inferior vena cava (IVC)** is formed by the union of the right and left common iliac veins at vertebral level L5, drains all the blood from below the diaphragm (even portal blood from the gastrointestinal tract after it percolates through the liver) to the right atrium. The IVC may be damaged during surgical repair of a herniated intervertebral disk. The IVC above the kidneys (suprarenal) should never be ligated because the mortality rate is 100%. The IVC below the kidneys (infrarenal) may be ligated, although the mortality rate is 50%. The **right gonadal vein** drains directly into the IVC; the **left gonadal vein** drains into the left renal vein. This anatomy is important to remember: in a woman, **right-sided hydronephrosis** may indicate thrombosis of the right ovarian vein, which would constrict the ureter because the right ovarian vein crosses the ureter to drain into the IVC; in a man, **left-sided testicular varicocele** may indicate occlusion of the **left testicular vein** or **left renal vein** by a malignant tumor of the kidney. If the IVC is blocked by either a malignant retroperitoneal tumor or a large blood clot (thrombus), two **routes of collateral venous return** are followed: (1) azygous vein → superior vena cava → right atrium; and (2) lumbar veins → external and internal vertebral venous plexuses → cranial dural sinuses → internal jugular vein → right atrium.

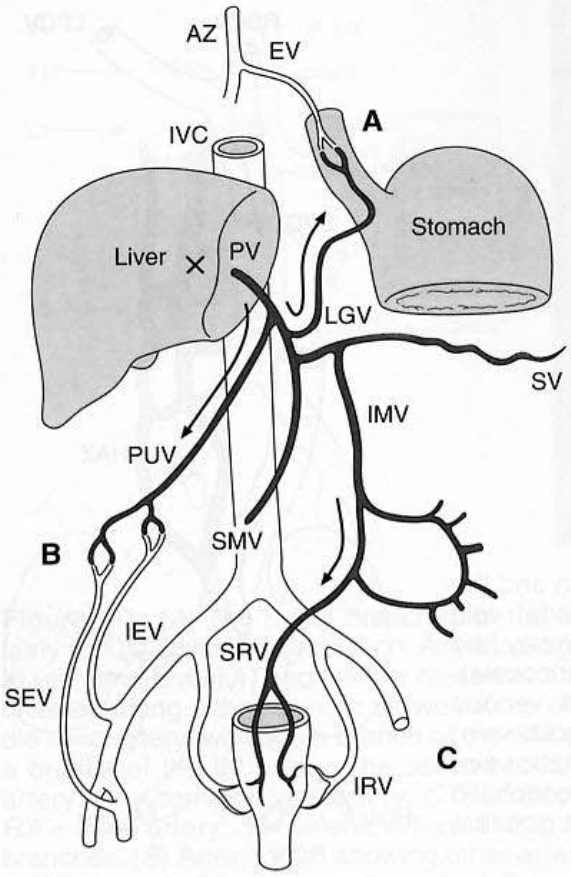


Figure 8-3. The hepatic portal system. Note the three main sites (*A, B,* and *C*) of portal—IVC (caval) anastomosis. In portal hypertension, in which blood flow through the liver is severely reduced (*X*), these anastomoses provide collateral circulation (*arrows*) through the IVC back to the heart. *AZ* = azygous vein; *EV* = esophageal vein; *IEV* = inferior epigastric vein; *IMV* = inferior mesenteric vein; *IRV* = inferior rectal vein; *IVC* = inferior vena cava; *LGV* = left gastric vein; *PUV* = paraumbilical vein; *PV* = portal vein; *SEV* = superior epigastric vein; *SMV* = superior mesenteric vein; *SRV* = superior rectal vein; *SV* = splenic vein. (Adapted with permission from Moore KL: *Clinically Oriented Anatomy,* 3rd ed. Baltimore, Williams & Wilkins, 1992, p 210.)

Site of Anastomosis	Clinical Sign	Veins Involved in Portal ↔ Inferior Vena Caval Anastomosis
A. Esophagus	Esophageal varices	Left gastric vein ↔ esophageal vein
B. Umbilicus	Caput medusa	Paraumbilical vein ↔ superficial and inferior epigastric veins
C. Rectum	Hemorrhoids	Superior rectal vein ↔ middle and inferior rectal veins

III. HEPATIC PORTAL SYSTEM (Figure 8-3). The term "portal" refers to a vein interposed between two capillary beds (i.e., capillary bed–vein–capillary bed). The hepatic portal system consists of the following vascular structures: capillaries of the gastrointestinal tract → portal vein → hepatic sinusoids. The **portal vein** is formed posterior to the neck of the pancreas by the union of the **splenic vein** and **superior mesenteric vein**. The **inferior mesenteric vein** usually ends by joining the splenic vein. The blood within the portal vein carries high levels of nutrients from the gastrointestinal tract as well as products of red blood cell destruction from the spleen. **Portal–IVC (caval) anastomosis** becomes clinically relevant when **portal hypertension** occurs. Portal hypertension causes blood within the portal vein to reverse its flow and enter the IVC to return to the heart. The three main sites of portal–IVC anastomosis are the esophagus, umbilicus, and rectum. Clinical signs of portal hypertension include: vomiting copious amounts of blood, a history of alcoholism, liver cirrhosis, schistosomiasis, enlarged abdomen as a result of ascites fluid, and splenomegaly.

9

Abdominal Viscera

I. ESOPHAGUS

A. General features.

The **esophagus** is a muscular tube that is continuous with the pharynx and runs in the thorax through the superior and posterior mediastinum. The esophagus pierces the diaphragm to form the **esophageal hiatus** at vertebral level T10, where it enters the abdominal cavity and meets the stomach at the **gastroesophageal junction**. The **upper esophageal sphincter** is skeletal muscle that consists of the cricopharyngeus muscle and the inferior pharyngeal constrictor muscle. It relaxes during swallowing. The **lower esophageal sphincter (LES)** is smooth muscle and is difficult to identify anatomically. It relaxes during swallowing and prevents gastroesophageal reflux. The esophagus is naturally constricted at three anatomic sites: the junction between the pharynx and esophagus, the level of tracheal bifurcation, and the gastroesophageal junction.

B. Clinical considerations

1. An **enlarged left atrium** may constrict the esophagus because of the close anatomic relation of these structures.
2. **Bronchogenic carcinoma** may indent the esophagus as a result of enlargement of the mediastinal lymph nodes. This indentation is seen radiologically during a barium swallow.
3. **Malignant tumors of the esophagus** most commonly occur in the lower one-third of the esophagus and metastasize below the diaphragm to the **celiac lymph nodes.**
4. **Forceful vomiting**, which may tear the posterior wall of the esophagus, often is seen in alcoholism, bulimia, and pregnancy. Clinical findings include severe retrosternal pain after vomiting and extravasated contrast medium. **Mallory-Weiss tears** involve only the mucosal and submucosal layers. **Boerhaave syndrome** involves tears through all layers of the esophagus.
5. A **sliding hiatal hernia** occurs when the stomach and the gastroesophageal junction herniate through the diaphragm into the thorax. Clinical findings include: deep burning retrosternal pain and reflux of gastric contents into the mouth (i.e., heartburn), both of which are accentuated when the patient is in the supine position.
6. A **paraesophageal hiatal hernia** occurs when only the stomach herniates through the diaphragm into the thorax. There is no reflux of gastric contents, but strangulation or obstruction may occur.
7. **Achalasia** is failure of the LES to relax during swallowing, probably because of absence of the myenteric plexus. Clinical findings include progressive dysphagia (difficulty in swallowing). Barium swallow shows a dilated esophagus above the LES

and distal stenosis at the LES ("bird beak"). **Chagas disease** (caused by *Trypanosoma cruzi*) may lead to achalasia.

8. **Esophageal reflux** is caused by dysfunction of the LES that allows gastric acid to reenter the lower esophagus. Clinical findings include: substernal pain and heartburn, which may worsen with bending or lying down. **Scleroderma** may be a systemic cause of esophageal reflux.

9. **Esophageal strictures (narrowing)**
   a. **Caustic strictures** are the result of injury caused by ingestion of caustic agents (e.g., drain openers, oven cleaners).
   b. **Other strictures** are caused by recurrent mucosal destruction as a result of gastric acid reflux. These strictures most often occur at the gastroesophageal junction.

10. **Barrett esophagus** is the replacement of stratified squamous epithelium with gastric epithelium in the distal esophagus. Clinical findings include: a long history of heartburn or other reflux symptoms that may lead to esophageal adenocarcinoma.

II. STOMACH (Figure 9-1)

A. General features. The stomach is a muscular organ that functions in food digestion and storage. The stomach is divided into four parts:

1. The **cardia,** near the gastroesophageal junction
2. The **fundus,** above the gastroesophageal junction
3. The **body,** between the fundus and antrum

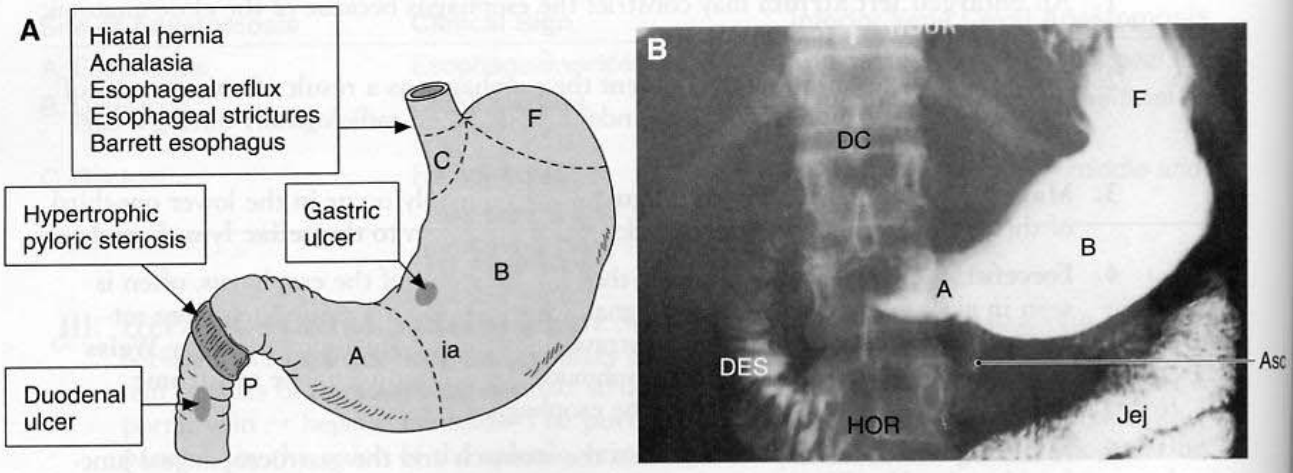


Figure 9-1. (*A*) Diagram showing the various parts of the stomach. High-yield clinical considerations associated with the esophagus, stomach, and duodenum are indicated. *A* = antrum; *B* = body; *C* = cardia; *F* = fundus; *ia* = incisura angularis; *P* = pylorus. (*B*) Radiograph after barium swallow. Note the parts of the stomach and duodenum. *A* = antrum; *Asc* = ascending part of the duodenum; *B* = body; *DC* = duodenal cap, or superior part of the duodenum; *Des* = descending part of the duodenum; *F* = fundus; *Hor* = horizontal part of the duodenum; *Jej* = jejunum. (*A* adapted with permission from Jarrell BE, Carabasi RA III: *NMS Surgery,* 3rd ed. Baltimore, Williams & Wilkins, 1996, p 183; *B* adapted with permission from Ryan S, McNicholas M: *Anatomy for Diagnostic Imaging.* London, WB Saunders, 1994, p 158.)

4. The **antrum,** the distal part of the stomach that begins at the **incisura angularis** and ends at the **pylorus**. The pylorus is a well-defined muscular sphincter that controls movement of food out of the stomach and prevents reflux of duodenal contents into the stomach.

B. Clinical considerations

1. **Gastric ulcers** most often occur within the **body of the stomach** along the **lesser curvature** above the **incisura angularis.** They occur at a histologic transition zone where the gastric glands change from predominantly parietal cells (HCl-producing) to G cells (gastrin-producing). They are caused by **damage to the mucosal barrier** (because of decreased production of mucus and bicarbonate), usually as a result of smoking, excessive salicylate ingestion, or the use of nonsteroidal anti-inflammatory drugs. Approximately 70% of patients have associated *Helicobacter pylori* infection. Clinical findings include burning pain in the epigastric or left hypochondriac region that **increases after a meal**. Treatment is the same as for duodenal ulcers (see III B 1).

2. **Hypertrophic pyloric stenosis** is a congenital condition that presents within weeks after birth. Clinical findings include: projectile vomiting containing no bile, visible peristalsis from the left hypochondriac to the right hypochondriac region, and a hard, mobile mass palpated in the epigastric region.

3. **Dumping syndrome** is abnormally rapid emptying of **hyperosmotic** stomach contents (especially high-carbohydrate foods) into the jejunum within 30 minutes after a meal ("early dumping") or 1 to 3 hours after a meal ("late dumping"). It usually occurs after a partial gastrectomy or vagotomy is performed to treat an ulcer or obesity. Clinical findings include: epigastric discomfort, borborygmi (rumbling sounds caused by gas movement), palpitations, dizziness, diarrhea, and hypoglycemia.

4. **Cancer of the stomach** may metastasize to the supraclavicular lymph nodes (Virchow nodes) on the left side. These nodes can be palpated within the posterior triangle of the neck.

III. DUODENUM (see Figure 9-1)

A. General features. The duodenum is divided into four parts.

1. The **superior part** is intraperitoneal and begins at the pylorus of the stomach **(gastroduodenal junction)**, which is marked by the **prepyloric vein**. Radiologists refer to this part of the duodenum as the **duodenal cap,** or **bulb**. The superior part has a mesentery and is, therefore, mobile. Posterior relationships include the **common bile duct** and **gastroduodenal artery**.

2. The **descending part** is retroperitoneal and receives the **common bile duct** and **main pancreatic duct** on its posterior or medial wall at the **hepatopancreatic ampulla** (ampulla of Vater).

3. The **horizontal part** is retroperitoneal and runs horizontally across vertebra L3 between the superior mesenteric artery anteriorly and the aorta and inferior vena cava posteriorly. In severe abdominal injuries, this part of the duodenum may be crushed against vertebra L3.

4. The **ascending part** is intraperitoneal and ascends to meet the jejunum at the duodenojejunal flexure, which is supported by the **ligament of Treitz.** This ligament is the cranial end of the dorsal mesentery.

B. Clinical considerations

1. **Duodenal ulcers** most often occur in the superior part of the duodenum (i.e, at the **duodenal cap**). They are caused by **damage to the mucosal barrier** (caused by decreased mucus and bicarbonate production) and **hypersecretion of gastric acid.** Almost 100% of patients have associated *Helicobacter pylori* infection. Clinical findings include severe pain in the epigastric region that **decreases after a meal.** Treatment includes: H_2 receptor antagonists (e.g., cimetidine, ranitidine, nizatidine, famotidine), antacids, sucralfate (a viscous material that provides a protective barrier), omeprazole (H+-K+ ion pump inhibitor), bismuth, metronidazole, and tetracycline. The surgical procedure of choice is a **proximal gastric vagotomy,** which transects only the vagus nerve (cranial nerve X) fibers to the distal esophagus and fundus of the stomach and results in decreased gastric acid secretion.
2. **Perforations** occur most often with ulcers located on the **anterior** surface of the duodenum. Perforations occur less often with ulcers on the **posterior** surface; however, these may erode the **gastroduodenal artery,** causing severe hemorrhage.

IV. JEJUNUM, ILEUM, AND LARGE INTESTINE. General features are listed in Table 9-1.

A. Celiac disease is hypersensitivity to **gluten** and **gliadin protein,** found in wheat and other grains. When gluten-containing foods are ingested, a large number of lymphocytes, plasma cells, macrophages, and eosinophils accumulate within the lamina propria of the intestinal mucosa. These factors may contribute to the immunologic damage to the mucosa. Gliadin antibodies usually are detectable in the blood. Clinical findings include: chronic diarrhea, flatulence, weight loss, and fatigue.

Table 9-1.
Characteristics of the Small and Large Intestine

Jejunum	Ileum	Large Intestine
Villi (long, finger-shaped)	Villi (short, club-shaped)	No villi
Intestinal glands (crypts) >3 cm in diameter	Intestinal glands (crypts) < 3 cm in diameter	Intestinal glands (crypts) ≈ 6–9 cm in diameter
Large, numerous, and palpable circular folds*	Small and few circular folds that disappear distally	No circular folds
Initial 2/5 of the small intestine	Terminal 3/5 of the small intestine	–
Located in the umbilical region on the left side of the abdomen	Located in the hypogastric and inguinal regions on the right side of the abdomen	–
Long vasa recta	Short vasa recta	**Teniae coli** (three longitudinal bands of smooth muscle) are present
Main site of absorption	Site of vitamin B_{12} absorption	
Often empty (no fecal contents)	Prominent Peyer patches	**Appendices epiploicae** (fatty tags)
Thicker wall, more vascular, and redder than ileum in a living person	Terminal ileum ends several centimeters above the cecal tip	**Haustra** (sacculations of the wall) separated by the plicae semilunaris

*Folds of the mucosa and submucosa (also called **plicae circularis** or **valves of Kerckring**).

B. **Crohn disease** is a chronic granulomatous inflammatory bowel disease that most commonly affects the **ileum.** As the disease progresses, ulcers coalesce into long, serpentine ulcers ("linear ulcers") that are oriented along the long axis of the bowel. A classic feature is the clear demarcation between diseased bowel segments and adjacent uninvolved segments ("skip areas"). Clinical findings include: a mass in the right lower quadrant of the abdomen, intermittent bouts of diarrhea, fever, weight loss, and weakness. Complications include strictures of the intestinal lumen and the formation of fistulas.

C. **Appendicitis** begins with obstruction of the appendix lumen by a fecal concretion (fecalith) and lymphoid hyperplasia, followed by distension of the appendix. Clinical findings include: initial pain in the umbilical or epigastric region, later pain localizing to the right lumbar region, nausea, vomiting, anorexia, and tenderness to palpation and percussion in the right lumbar region. Complications may include peritonitis as a result of rupture of the appendix. **McBurney point** is located by drawing a line from the right anterior superior iliac spine to the umbilicus. The midpoint of this line locates the root of the appendix. The appendix is intraperitoneal, being suspended by the **mesoappendix**, and usually is found in the **retrocecal fossa,** although its position is variable.

D. **Toxic megacolon** usually is a dilation of the transverse colon that results in perforation of the colonic wall. Clinical signs include: abdominal pain, fever, and leukocytosis.

E. **Ogilvie syndrome** is most commonly a dilation of the cecum and often is seen in critically ill or bedridden patients.

V. GALLBLADDER, EXTRAHEPATIC BILIARY DUCTS, AND BILE (Figure 9-2)

A. General features

1. The **gallbladder** is divided into the **fundus** (anterior portion), **body**, and **neck** (posterior portion). A small pouch **(Hartmann pouch)** may extend from the neck as a result of pathologic changes and is a common site for gallstones to lodge. **Rokitansky-Aschoff sinuses** occur when the mucosa of the gallbladder penetrates deep into the muscularis externa. They are an early indicator of pathologic changes (e.g., acute cholecystitis, gangrene). The arterial blood supply is through the **cystic artery,** a branch of the right hepatic artery. Venous drainage is through **cystic veins** that empty into the portal vein or directly into liver sinusoids. Lymphatic drainage is into **hepatic** and **pancreaticoduodenal** lymph nodes. Sensory nerve fibers for pain from the gallbladder travel with the **greater thoracic splanchnic nerve** to spinal levels T7–10. Motor nerve fibers for contraction of the gallbladder and relaxation of the sphincter of Oddi (which stimulates bile release into the small intestine) are pre- and postganglionic parasympathetic neurons of the **vagus nerve (CN X). Cholecystokinin (CCK),** a hormone secreted from I cells of the small intestine, mimics the parasympathetic functions of CN X on the gallbladder and sphincter. Motor nerve fibers for relaxation of the gallbladder and contraction of the sphincter of Oddi (which inhibits bile release into the small intestine) are preganglionic sympathetic neurons of the **greater thoracic splanchnic nerve** and postganglionic sympathetic neurons of the **celiac plexus**. Functions of the gallbladder include: storage of bile, concentration of bile (approximately tenfold) through absorption of water and electrolytes, acidification of bile, addition of mucus ("white bile") to bile, and release of bile through the simultaneous contraction of the gallbladder and relaxation of the sphincter of Oddi.

2. **Extrahepatic biliary ducts.** The **right and left hepatic ducts** join after leaving the liver to form the **common hepatic duct.** The common hepatic duct is joined at an acute angle by the **cystic duct** to form the **common bile duct.** The cystic duct

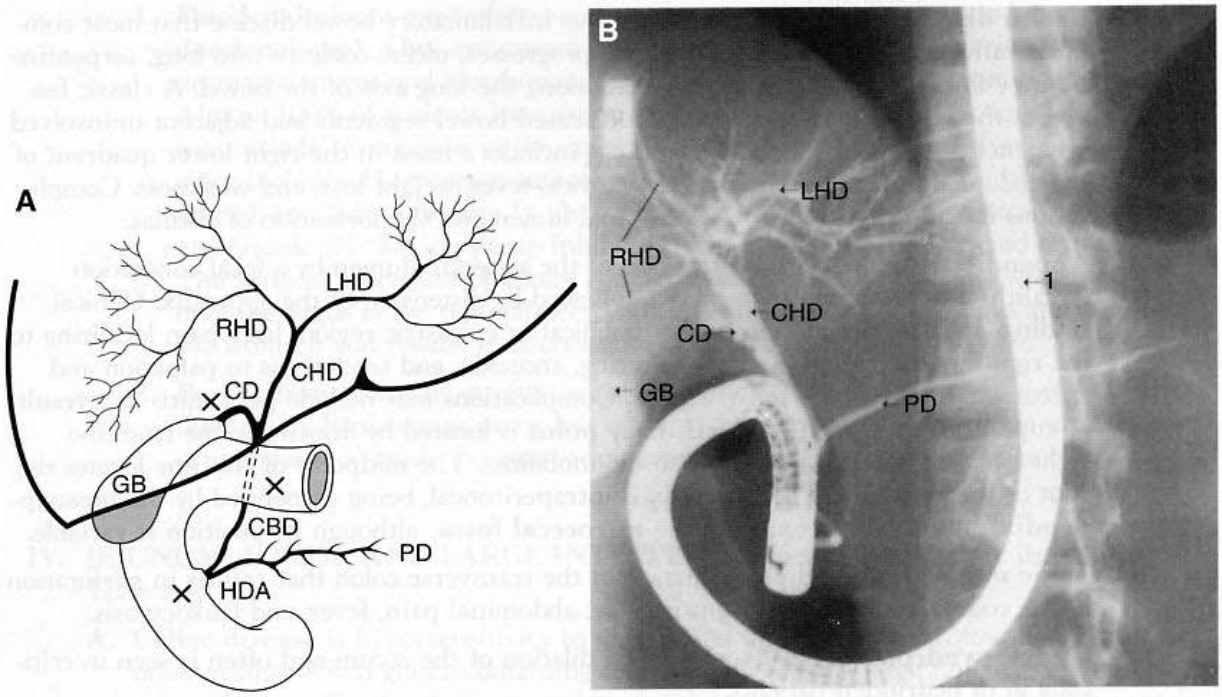


Figure 9-2. (*A*) The gallbladder and biliary tree. Note the termination of the common bile duct (*CBD*) at the hepatoduodenal ampulla (*HDA*) along with the pancreatic duct (*PD*). Note the three main sites (*X*) of gallstone obstruction. (*B*) Cholangiogram. *1* = endoscope; *CD* = cystic duct; *CHD* = common hepatic duct; *GB* = gallbladder; *LHD* = left hepatic duct; *RHD* = right hepatic duct. (*A* adapted with permission from Jarrell BE, Carabasi RA: *NMS Surgery,* 3rd ed. Baltimore, Williams & Wilkins, 1996, p 250; *B* adapted with permission from Ryan S, McNicholas M: *Anatomy for Diagnostic Imaging.* London, WB Saunders, 1994, p 173.)

drains bile from the gallbladder. The mucosa of the cystic duct is arranged in a spiral fold with a core of smooth muscle known as the **spiral valve (valve of Heister)**. The spiral valve keeps the cystic duct open constantly so that bile can flow freely in either direction. The common bile duct passes posterior to the pancreas and ends at the **hepatoduodenal ampulla (ampulla of Vater),** where it joins the **pancreatic duct**. The **sphincter of Oddi** is an area of thickened smooth muscle that surrounds the bile duct as it traverses the ampulla.

3. **Bile** is produced primarily by hepatocytes, at an average rate of 600 ml/day. It is composed primarily of: water, electrolytes, bilirubin glucuronide (bile pigment), cholic acid and chenodeoxycholic acid conjugated to glycine or taurine (bile salts), cholesterol and lecithin (lipids), calcium, and secretory IgA. Its function is to emulsify fats. **Lactated Ringer solution** is a good replacement fluid for bile loss.

B. Clinical considerations

1. **Gallstones** form when bile salts and lecithin are overwhelmed by cholesterol. Most stones consist of **cholesterol (major component), bilirubin, and calcium**. There are three main types:
   a. **Cholesterol stones** are large and smooth. They are associated with: obesity, Crohn disease, cystic fibrosis, clofibrate administration, estrogen use, and rapid weight loss. They are common in the general population of the United States, with a noticeably higher rate among Native Americans.

b. **Pigment (bilirubin) stones** are smooth and green or black. They are associated with: chronic red blood cell hemolysis (e.g., sickle cell anemia, spherocytosis), alcoholic cirrhosis, and biliary infection, and are most common in persons of Asian descent.

c. **Calcium bilirubinate stones** are associated with infection or inflammation of the biliary tree.

2. **Gallstone obstruction** occurs at three clinically important sites:

a. **Within the cystic duct.** A stone may transiently lodge within the cystic duct and cause epigastric pain **(biliary colic)**. An entrapped stone obstructs bile flow from the gallbladder, which results in inflammation of the gallbladder **(acute cholecystitis)** and causes pain to shift to the right hypochondriac region. Bile becomes concentrated and precipitates in the gallbladder, where it forms a layer of high-density material called **"milk of calcium" bile** because it contains a large amount of calcium carbonate. Bile flow from the liver remains open (i.e., **no jaundice**). This situation may lead to **Mirizzi syndrome,** in which a large gallstone impacted in the cystic duct extrinsically obstructs the nearby common hepatic duct.

b. **Within the common bile duct.** A stone entrapped within the common bile duct obstructs bile flow from the gallbladder and the liver, and causes inflammation of both. **Jaundice** is common, and is first observed clinically **under the tongue.** The jaundice is moderate, and fluctuates, because a stone rarely causes complete blockage of the lumen.

c. **At the hepatoduodenal ampulla.** If a stone becomes entrapped at the ampulla, it obstructs bile flow from both the gallbladder and the liver. The pancreatic duct also may be blocked. **Jaundice** and **pancreatitis** are common.

VI. LIVER (Figure 9-3)

A. General features.

The liver is divided, in classic anatomy, into the **right lobe** and the **left lobe** by the **interlobar fissure,** which is an invisible line that runs from the gallbladder to the inferior vena cava, **quadrate lobe**, and **caudate lobe**. The left lobe contains the **falciform ligament** (a derivative of the ventral mesentery) with the **ligamentum teres** (a remnant of the left umbilical vein) along its inferior border. The **bare area** of the liver is located on the diaphragmatic surface and is devoid of peritoneum. The liver is secured in its anatomic location by attachment of the hepatic veins to the inferior vena cava. This arrangement allows for very little rotation of the liver during surgery.

B. Clinical considerations

1. **Liver biopsies** often are performed by needle puncture through right intercostal space 8, 9, or 10 just after the patient exhales. The needle passes through the following structures: skin → superficial fascia → external oblique muscle → intercostal muscles → costal parietal pleura → costodiaphragmatic recess → diaphragmatic parietal pleura → diaphragm → peritoneum.

2. **Congenital biliary atresia** affects the development of the intrahepatic and extrahepatic bile ducts. It usually presents within weeks after birth and is the most common cause of persistent jaundice in infancy. Clinical findings include: jaundice (does not start immediately after birth, as in physiological jaundice); dark urine; and clay-colored stools. Liver biopsy shows bile duct proliferation with dilation of bile canaliculi and bile plugs.

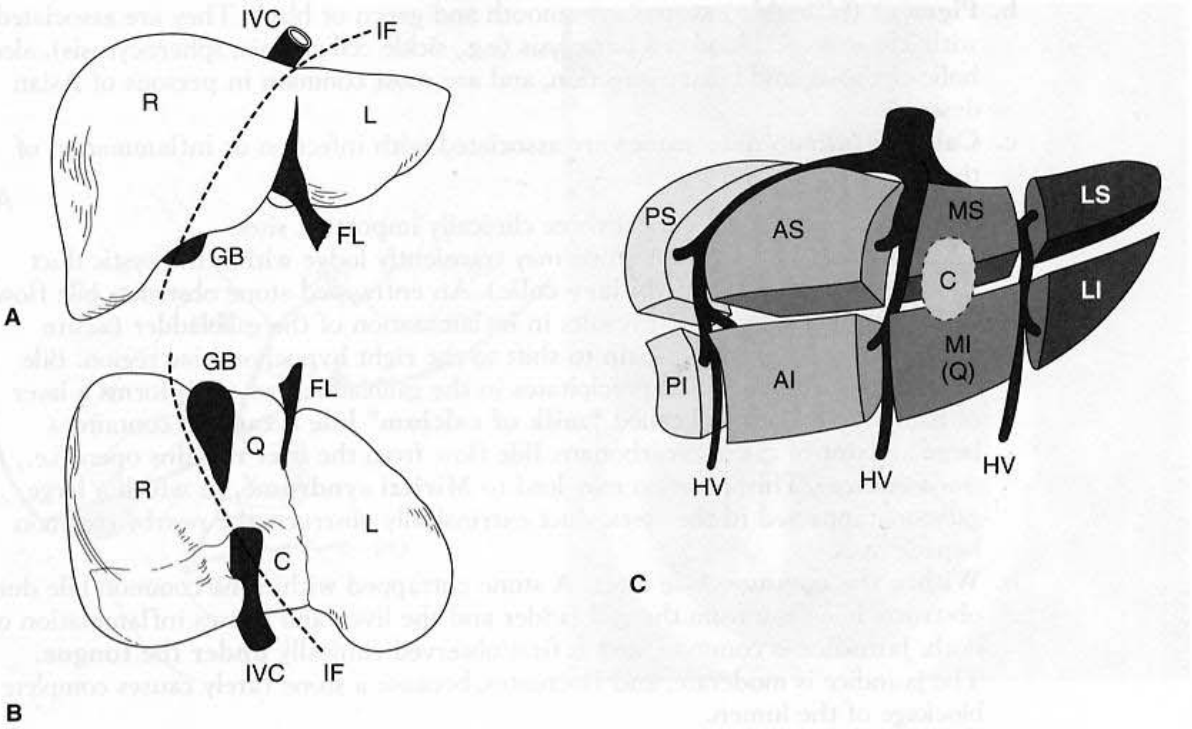


Figure 9-3. (*A*) Anterior surface of the liver. Note the right (*R*) and left (*L*) lobes, which are divided by the interlobar fissure (*IF*). *FL* = falciform ligament; *GB* = gallbladder; *IVC* = inferior vena cava. (*B*) Inferior surface of the liver. Note the quadrate (*Q*) and caudate lobes (*C*). (*C*) The five liver segments and nine liver subsegments used in liver resectioning. The five liver segments include the posterior and anterior segments of the right lobe, the medial and lateral segments of the left lobe, and the caudate lobe. Note the hepatic veins (*HV*) at the periphery of the liver segments. The nine liver subsegments include the posterior superior (*PS*), posterior inferior (*PI*), anterior superior (*AS*), anterior inferior (*AI*), medial superior (*MS*), medial inferior (*MI*) [which corresponds to the classic quadrate lobe (*Q*)], lateral superior (*LS*), lateral inferior (*LI*), and classic caudate lobe (*C*).

3. **Primary biliary cirrhosis** is caused by granulomatous destruction of medium-sized **intrahepatic bile ducts.** Cirrhosis appears late in the course of the disease. Primary biliary cirrhosis is characterized by **mitochondrial pyruvate dehydrogenase autoantibodies,** the role of which is not clear.

4. **Primary sclerosing cholangitis** is caused by inflammation, fibrosis, and segmental dilation of both the **intrahepatic and the extrahepatic bile ducts.** It often occurs in association with chronic ulcerative colitis. Clinical findings include: right hypochondriac region pain or painless jaundice, no fever or chills, pruritus, fatigue, and nausea.

5. Surgical **resection of the liver** may be performed by removing one of the **liver segments** (five total segments) or one of the **liver subsegments** (nine total subsegments). **Hepatic veins** form the surgical landmarks that mark the periphery of a liver segment during segmental resection. (Recall that **pulmonary veins** form the surgical landmarks that mark the periphery of a bronchopulmonary segment during segmental resection of the lung.)

VII. PANCREAS

A. General features. The pancreas is a retroperitoneal organ that has five parts.

1. The **uncinate process** develops embryologically from the **ventral pancreatic bud.**
2. The **head** develops embryologically from the **ventral pancreatic bud** and the **dorsal pancreatic bud.** It lies in the duodenal C-loop.
3. The **neck** develops embryologically from the **dorsal pancreatic bud.** It lies at the confluence of the inferior mesenteric vein and splenic vein.
4. The **body** develops embryologically from the **dorsal pancreatic bud.**
5. The **tail** develops embryologically from the **dorsal pancreatic bud.** It is related to the spleen.

B. Clinical considerations

1. An **annular pancreas** occurs when the ventral pancreatic bud fuses with the dorsal pancreatic bud both dorsally and ventrally, forming a **ring of pancreatic tissue** around the duodenum. It is associated with **obstruction of the duodenum** shortly after birth.
2. **Acute pancreatitis** is inflammation of the pancreas that usually is associated with biliary tract disease or alcoholism. Clinical findings include: pain in the epigastric region that radiates to the back, nausea, vomiting, elevated amylase or lipase levels, and retroperitoneal hemorrhage that may lead to flank ecchymosis (Turner sign) or periumbilical ecchymosis (Cullen sign).
3. **Pancreatic adenocarcinoma** is a very aggressive malignant tumor that usually occurs within the head of the pancreas. It has a poor prognosis and usually has already metastasized at the time of presentation. Clinical findings include: epigastric pain that radiates to the back, weight loss, and obstructive jaundice. Surgical treatment is pancreaticoduodenectomy **(Whipple procedure)**, which removes the head of the pancreas, the duodenum, the distal common bile duct, the gallbladder, and the distal stomach.

VIII. CROSS-SECTIONAL ANATOMY

A. At approximately T12, where the portal triad is located (Figure 9-4)

B. At the level of the gallbladder (Figure 9-5)

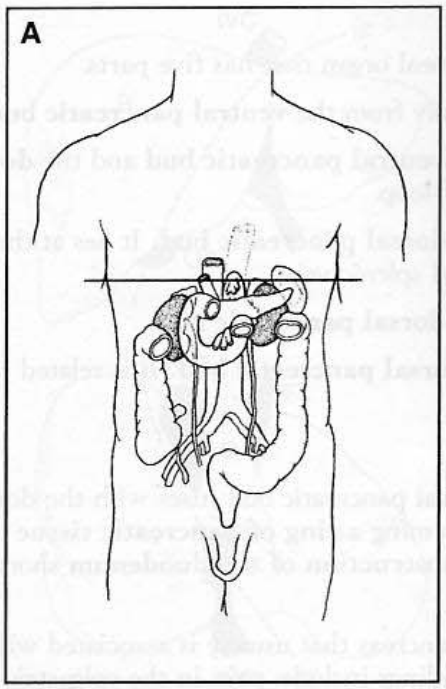
C. At the level of the hilum of the kidneys (Figure 9-6)

IX. RADIOLOGY

A. Radiograph of the stomach and small intestine after a barium meal (Figure 9-7)

B. Anteroposterior radiograph of the large intestine after a barium enema (Figure 9-8)

C. Ultrasonography and hepatobiliary iminodiacetic acid (HIDA) scan of gallstones (Figure 9-9)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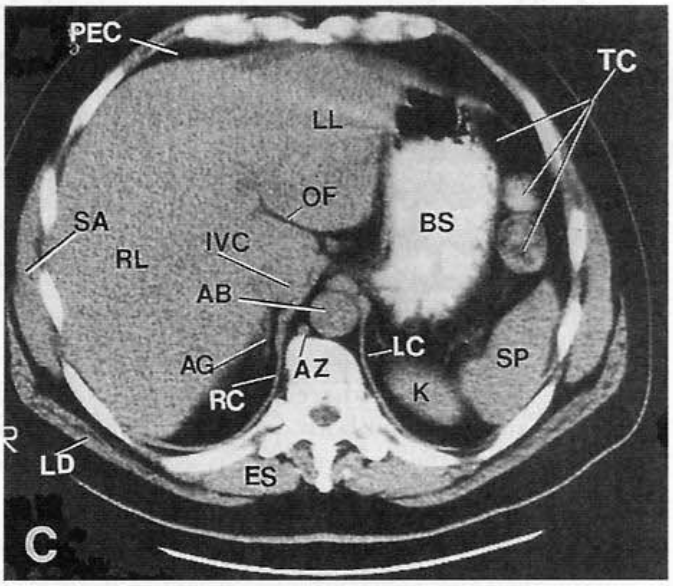
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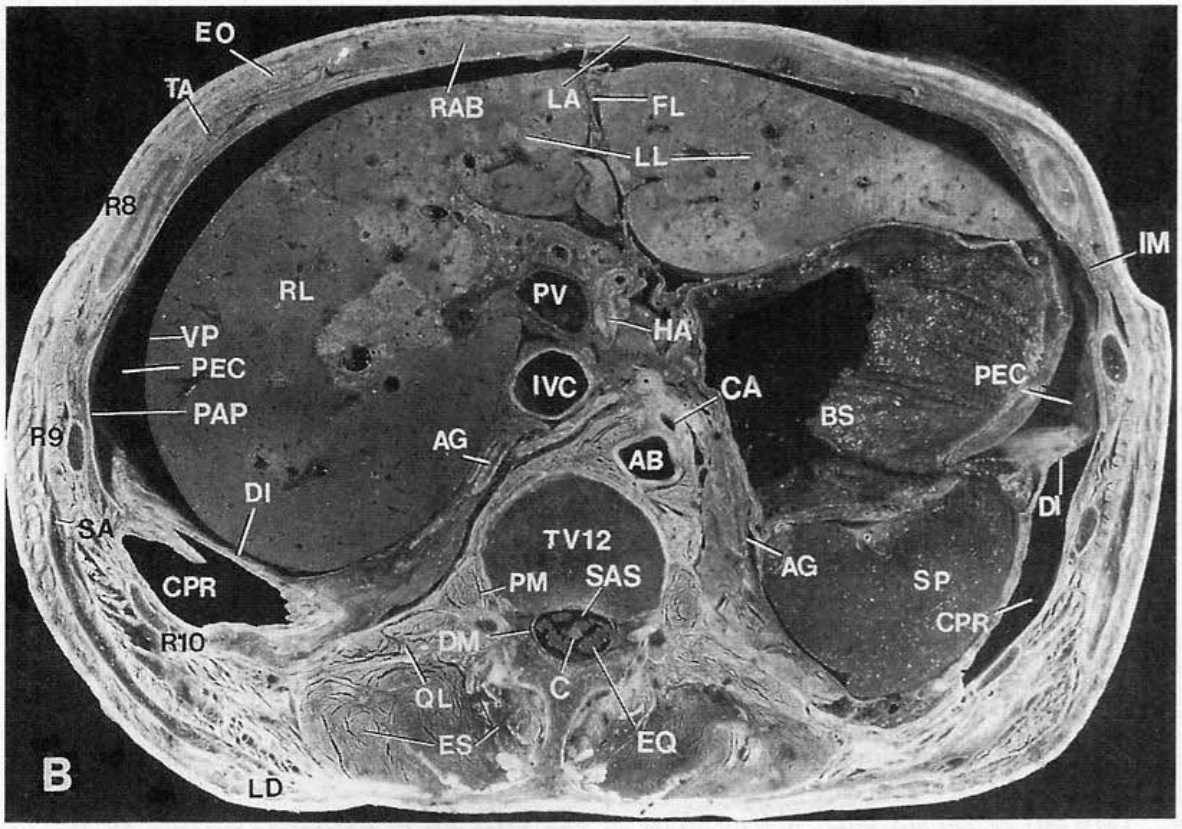
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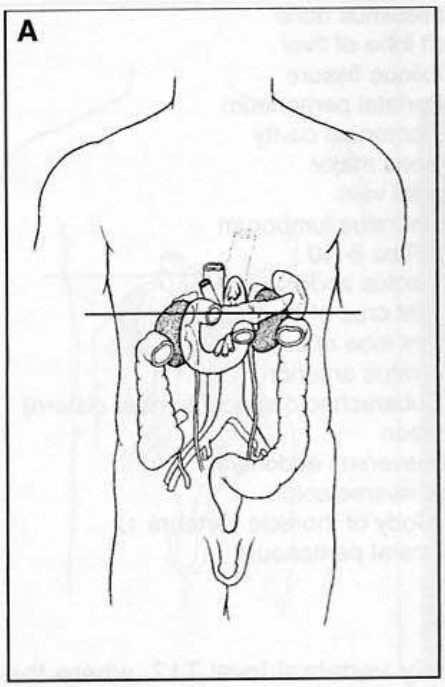
AB: Abdominal aorta
AG: Adrenal gland
AZ: Azygous vein
BS: Body of stomach
C: Sacral spinal cord
CA: Celiac artery
CPR: Posterior costophrenic recess
DI: Diaphragm
DM: Dura mater
EO: External abdominal oblique
EQ: Cauda equina
ES: Erector spinae
FL: Falciform ligament
HA: Common hepatic artery
IM: Intercostal muscles
IVC: Inferior vena cava
K: Kidney
LA: Linea alba
LC: Left crus of diaphragm
LD: Latissimus dorsi
LL: Left lobe of liver
OF: Oblique fissure
PAP: Parietal peritoneum
PEC: Peritoneal cavity
PM: Psoas major
PV: Portal vein
QL: Quadratus lumborum
R8-10: Ribs 8–10
RAB: Rectus abdominis
RC: Right crus of diaphragm
RL: Right lobe of liver
SA: Serratus anterior
SAS: Subarachnoid space (lumbar cistern)
SP: Spleen
TA: Transversus abdominis
TC: Transverse colon
TV12: Body of thoracic vertebra 12
VP: Visceral peritoneum

◀ **Figure 9-4.** Cross-section and CT scan at approximately vertebral level T12, where the portal triad is located. (*A*) Schematic diagram showing where the cross-section was taken. (*B*) Cross-section through a cadaver. (*C*) CT scan. Note the various structures indicated by the key. In addition, note the psoas major and quadratus lumborum muscles along the sides of the vertebral body. The right and left lobes of the liver are shown in relation to the portal vein, common hepatic artery, and inferior vena cava. The right adrenal gland lies posterolateral to the inferior vena cava. The left adrenal gland lies between the body of the stomach and the abdominal aorta. (Reprinted with permission from Barrett CP, Anderson LD, Holder LE, et al: *Primer of Sectional Anatomy With MRI and CT Correlation,* 2nd ed. Baltimore, Williams & Wilkins, 1994, pp 75, 76.)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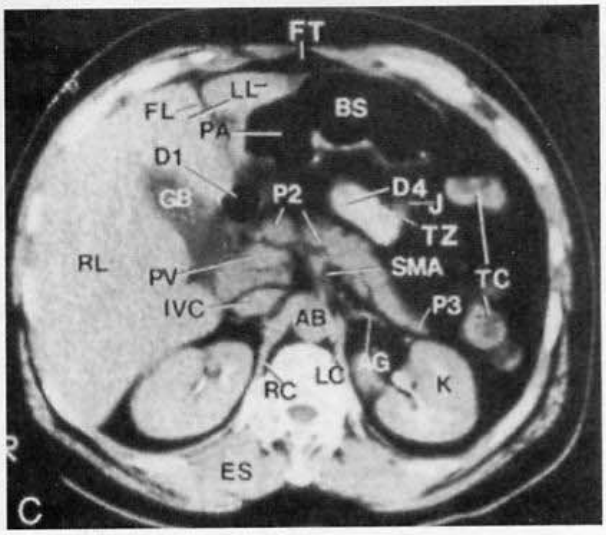
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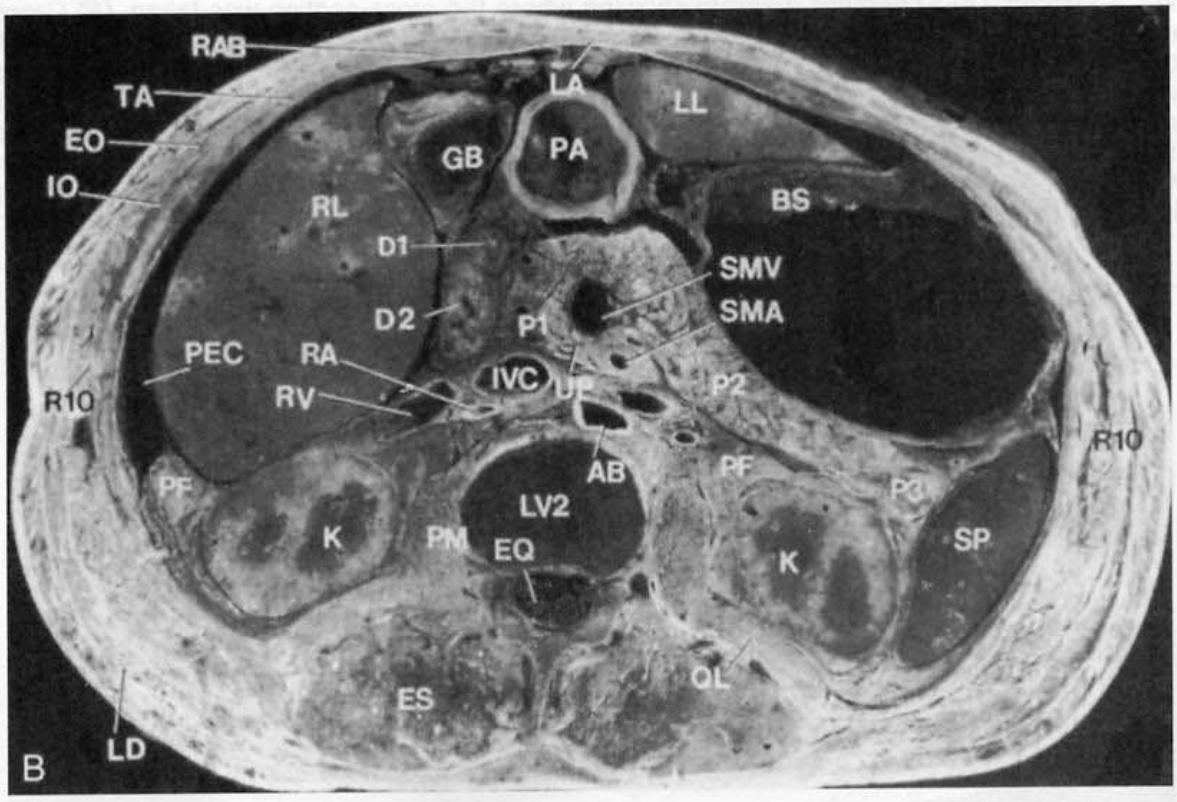
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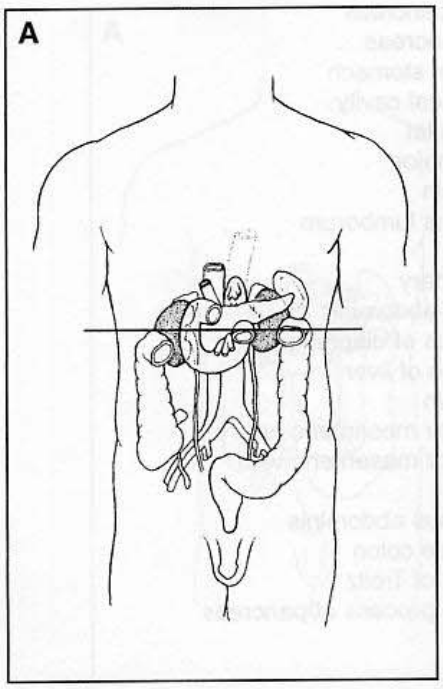
AB: Abdominal aorta
AG: Adrenal gland
BS: Body of stomach
D1: First part of duodenum
D2: Second part of duodenum
D4: Fourth part of duodenum
EO: External abdominal oblique
EQ: Cauda equina
ES: Erector spinae
FL: Falciform ligament
FT: Fat
GB: Gallbladder
IO: Internal abdominal oblique
IVC: Inferior vena cava
J: Jejunum
K: Kidney
LA: Linea alba
LC: Left crus of diaphragm
LD: Latissimus dorsi
LL: Left lobe of liver
LV2: Body of lumbar vertebra 2
P1: Head of pancreas
P2: Body of pancreas
P3: Tail of pancreas
PA: Antrum of stomach
PEC: Peritoneal cavity
PF: Perirenal fat
PM: Psoas major
PV: Portal vein
QL: Quadratus lumborum
R10: Rib 10
RA: Renal artery
RAB: Rectus abdominis
RC: Right crus of diaphragm
RL: Right lobe of liver
RV: Renal vein
SMA: Superior mesenteric artery
SMV: Superior mesenteric vein
SP: Spleen
TA: Transversus abdominis
TC: Transverse colon
TZ: Ligament of Treitz
UP: Uncinate process of pancreas

◀ **Figure 9-5.** Cross-section and CT scan at the level of the gallbladder. (*A*) Schematic diagram showing where the cross-section was taken. (*B*) Cross-section through a cadaver. (*C*) CT scan. Note the various structures as indicated by the key. The second part of the duodenum is adjacent to the head of the pancreas. The body of the pancreas extends to the left, posterior to the stomach. The tail of the pancreas reaches the spleen. The uncinate process of the pancreas lies posterior to the superior mesenteric artery. The gallbladder lies between the right and left lobes of the liver just to the right of the antrum of the stomach. Note the location of the adrenal gland (AG). A large mass in this area indicates a pheochromocytoma or neuroblastoma, both of which are associated with the adrenal medulla. (Reprinted with permission from Barrett CP, Anderson LD, Holder LE, et al: *Primer of Sectional Anatomy With MRI and CT Correlation,* 2nd ed. Baltimore, Williams & Wilkins, 1994, pp 79, 80.)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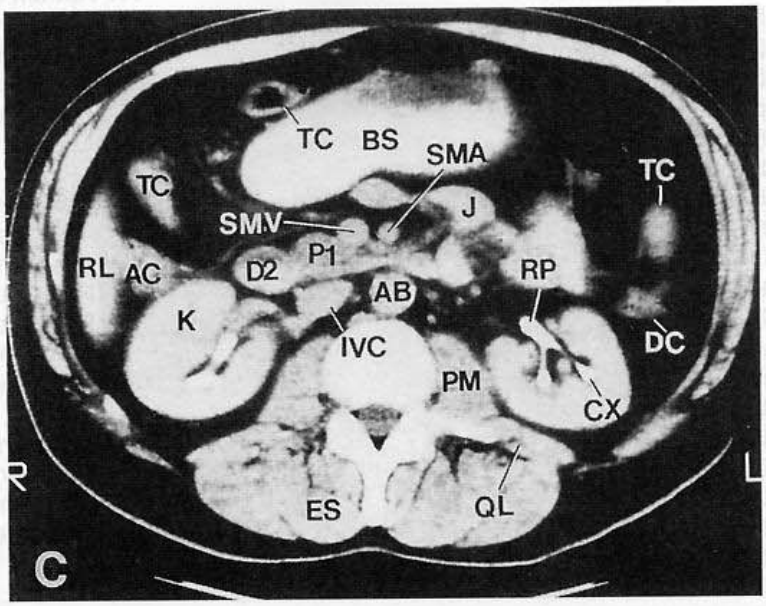
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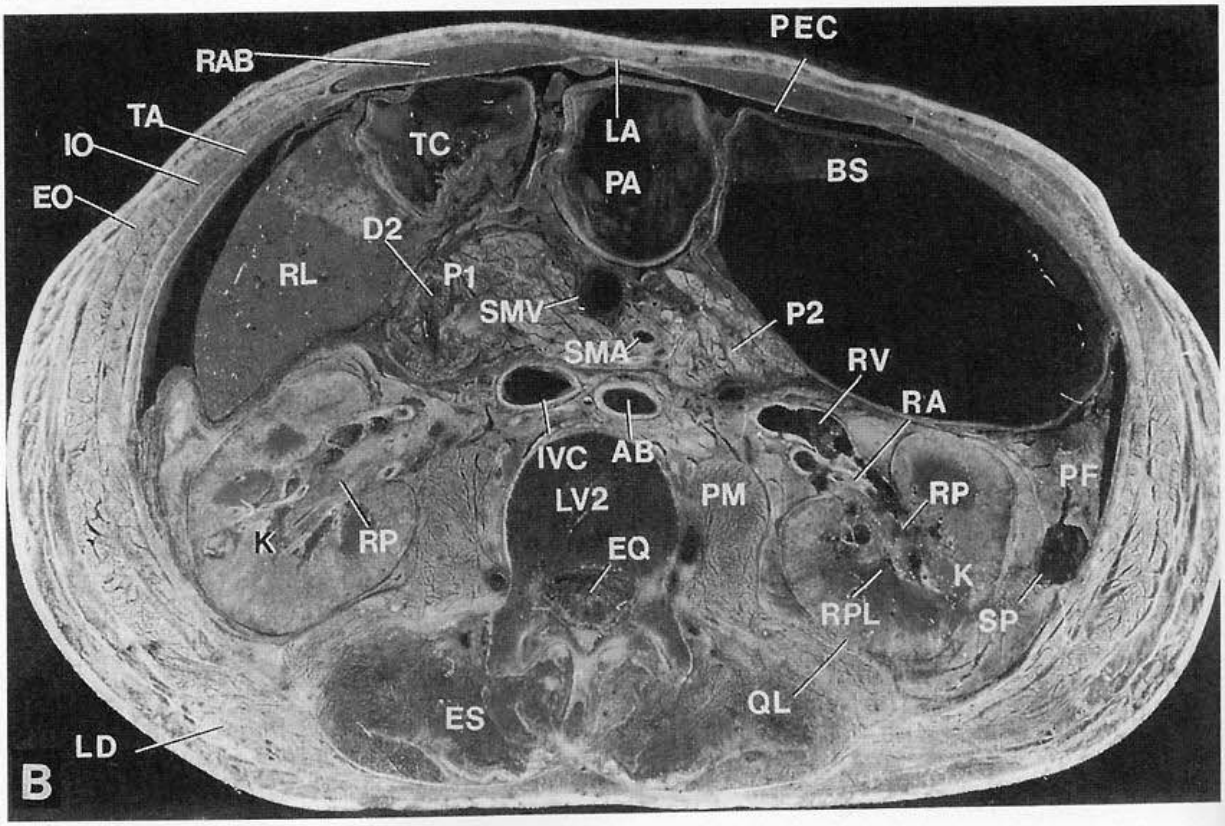
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AB: Abdominal aorta
AC: Ascending colon
BS: Body of stomach
CX: Renal calyx (minor)
D2: Second part of duodenum
DC: Descending colon
EO: External abdominal oblique
EQ: Cauda equina
ES: Erector spinae
IO: Internal abdominal oblique
IVC: Inferior vena cava
J: Jejunum
K: Kidney
LA: Linea alba
LD: Latissimus dorsi
LV2: Body of lumbar vertebra 2
P1: Head of pancreas
P2: Body of pancreas
PA: Antrum of stomach
PEC: Peritoneal cavity
PF: Perirenal fat
PM: Psoas major
QL: Quadratus lumborum
RA: Renal artery
RAB: Rectus abdominis
RL: Right lobe of liver
RP: Renal pelvis
RPL: Renal papilla
RV: Renal vein
SMA: Superior mesenteric artery
SMV: Superior mesenteric vein
SP: Spleen (lower tip)
TA: Transversus abdominis
TC: Transverse colon

◀ **Figure 9-6.** Cross-section and CT scan at the level of the hilum of the kidney. (*A*) Schematic diagram showing where the cross-section was taken. (*B*) Cross-section through a cadaver. (*C*) CT scan. Note the various structures as indicated by the key. The inferior vena cava and the abdominal aorta lie side by side as both vessels pass posterior to the pancreas. The second part of the duodenum contacts the right kidney and the right lobe of the liver. The left renal vein lies anterior to the renal artery. (Reprinted with permission from Barrett CP, Anderson LD, Holder LE, et al: *Primer of Sectional Anatomy With MRI and CT Correlation,* 2nd ed. Baltimore, Williams & Wilkins, 1994, pp 81, 82.)

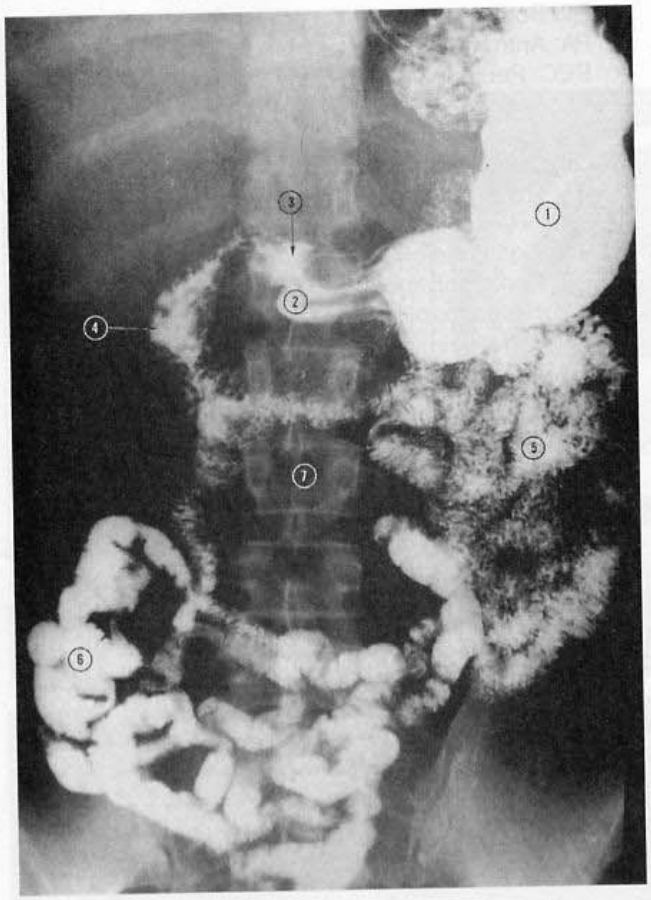
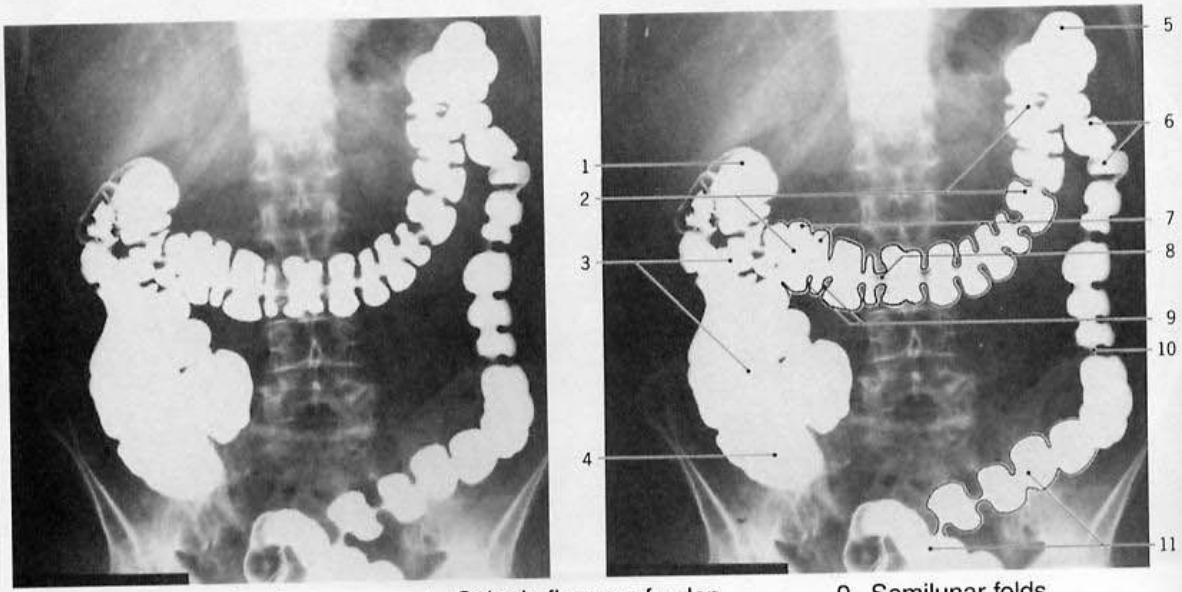


Figure 9-7. Radiograph of the stomach and small intestines after a barium meal. Note the structures indicated: *1* = body of the stomach; *2* = pylorus; *3* = duodenal cap; *4* = descending duodenum; *5* = jejunum on the left side of the abdomen; *6* = ileum on the right side of the abdomen; *7* = vertebra L3. (Reprinted with permission from Pansky B: *Review of Gross Anatomy,* 6th ed. New York, McGraw-Hill, 1996, p 415.)



1. Hepatic flexure of colon
2. Transverse colon
3. Ascending colon
4. Cecum
5. Splenic flexure of colon
6. Descending colon
7. Haustra
8. Peristaltic contraction
9. Semilunar folds
10. Peristaltic contraction
11. Sigmoid colon

Figure 9-8. Radiograph of the large intestine after a barium enema. Note the structures indicated in the key. (Reprinted with permission from Fleckenstein P, Tranum-Jensen J: *Anatomy in Diagnostic Imaging.* Philadelphia, WB Saunders, 1996, p 267.)

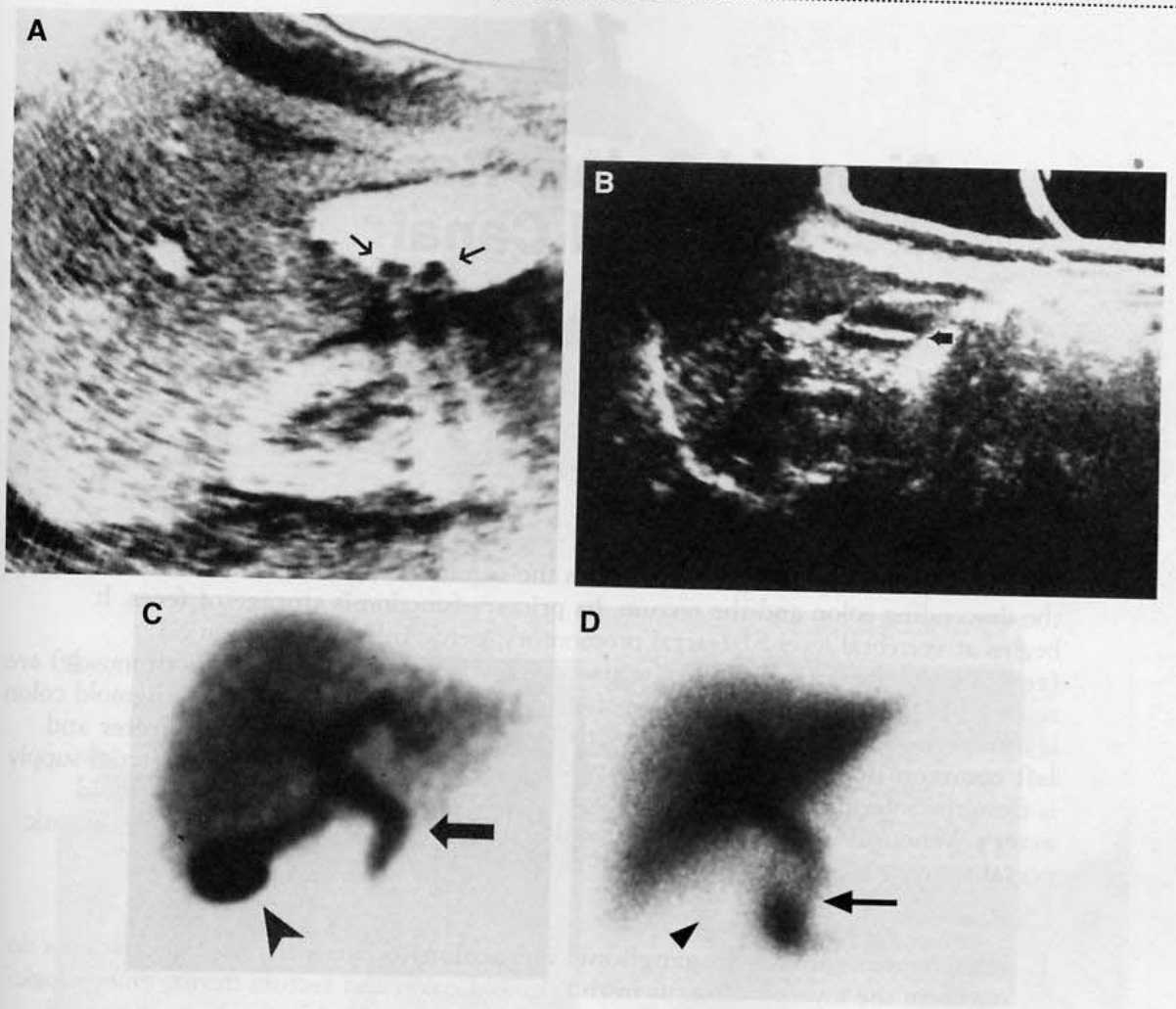


Figure 9-9. (*A*) Sonogram of the gallbladder. Note the two gallstones within the gallbladder (*arrows*). Ultrasonography usually elicits the Murphy sign, in which the patient reports pain as the operator presses on the gallbladder. (*B*) Sonogram of the gallbladder. Note the horizontal band of gallstones (*arrow*). (*C*) Hepatobiliary iminodiacetic acid (HIDA) scan of a healthy patient. HIDA uses the radionuclide ^{99m}Tc attached to lidocaine analogs bound to iminodiacetic acid. This compound is injected intravenously, processed by hepatocytes, and excreted into the bile. In a healthy person, filling of the liver, gallbladder, and biliary tract occurs within 60 minutes after injection. Note the filling of the liver, gallbladder (*arrowhead*), and common bile ducts (*arrow*) within 60 minutes after injection. (*D*) HIDA scan of a patient with acute cholecystitis. Note that the gallbladder (*arrowhead*) has not filled 90 minutes after injection, which is diagnostic of a blockage. However, the liver and common bile duct (*arrow*) are filled. Because most gallstones are composed of cholesterol (and, therefore, are radiolucent), plain abdominal radiographs often are of little value. Therefore, ultrasonography and HIDA are the methods of choice for diagnosis. (*A-C* reprinted with permission from Freedman M: *Clinical Imaging: An Introduction to the Role of Imaging in Clinical Practice.* New York, Churchill Livingstone, 1988, pp 368, 369; *A* and *B* courtesy of R. Sanders, MD; *D* reprinted with permission from Levy RC, Hawkins H, Barsan WG: *Radiology in Emergency Medicine.* St. Louis, CV Mosby, 1986, p 234.)

10

Sigmoid Colon, Rectum, and Anal Canal

I. SIGMOID COLON (Figure 10-1)

A. General features.

The **sigmoid colon** is the segment of the large intestine between the descending colon and the rectum. Its primary function is **storage of feces**. It begins at vertebral level S1 (sacral promontory; pelvic inlet) and ends at S3 **(rectosigmoid junction),** where **teniae coli** (longitudinal bands of smooth muscle) are replaced by a complete circular layer of smooth muscle of the rectum. The sigmoid colon is intraperitoneal, being suspended by the **sigmoid mesocolon**. The **left ureter** and **left common iliac artery** lie at the apex of the sigmoid mesocolon. The arterial supply is from the inferior mesenteric artery via the **sigmoid arteries** and **rectosigmoid artery**. Venous drainage is to the sigmoid veins → inferior mesenteric vein → hepatic portal system.

B. Clinical considerations

1. **Hirschsprung disease (aganglionic megacolon)** occurs when neural crest cells do not form the myenteric plexus in the sigmoid colon and rectum during embryologic development. This condition results in absence of peristalsis, fecal retention, and abdominal distension.

2. **Diverticulosis** is the presence of diverticula (abnormal pouchs or sacs). It is most commonly found in the sigmoid colon in patients older than 60 years of age. It is associated with a low-fiber, modern, Western diet. Perforation or inflammation of the diverticula results in **diverticulitis.** Clinical signs of diverticulitis include: pain in the left lumbar region, a palpable inflammatory mass in the left lumbar region, fever, leukocytosis, ileus, and peritonitis.

3. **Flexible sigmoidoscopy** permits examination of the sigmoid colon and rectum. During sigmoidoscopy, the large intestine may be punctured if the angle at the rectosigmoid junction is not negotiated properly. At the rectosigmoid junction, the sigmoid colon bends in an **anterior direction and to the left.** During sigmoidoscopy, the transverse rectal folds (Houston valves) also must be negotiated.

4. **Colostomy.** The sigmoid colon often is used in a **colostomy** because of the mobility provided by the sigmoid mesocolon (mesentery). An ostomy is an intestinal diversion that brings a portion of the gastrointestinal tract out through the **rectus abdominis muscle**. A colostomy may ablate the pelvic nerve plexus, resulting in loss of ejaculation or loss of erection in men, retention of urine in the bladder, and decreased peristalsis in the remaining colon.

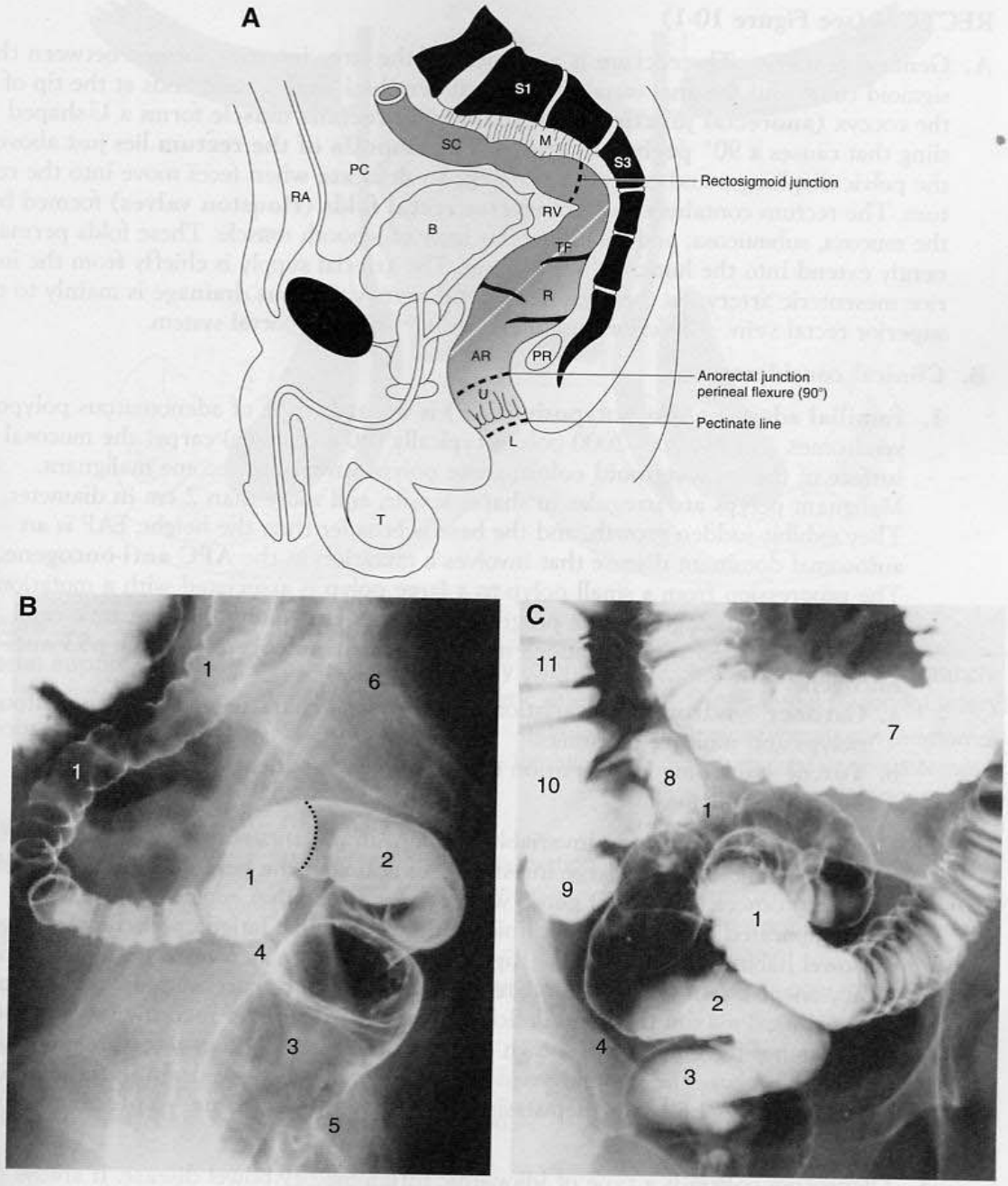


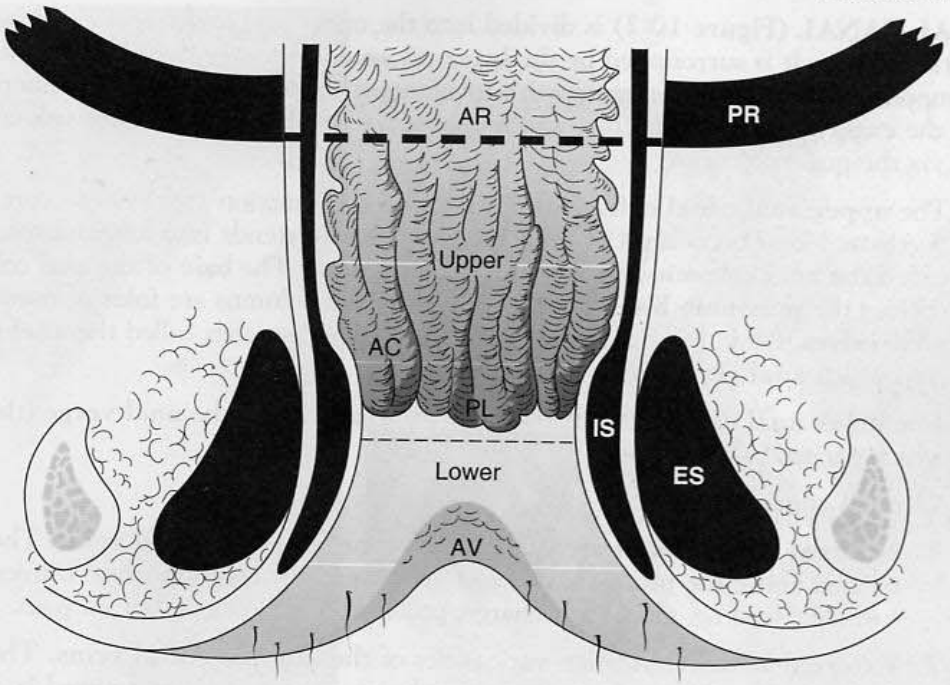
Figure 10-1. (*A*) Sagittal view of the male pelvis. The sigmoid colon (*SC*) extends from vertebral level S1 to S3, suspended by the sigmoid mesocolon (*M*), and ends at the rectosigmoid junction. The rectum (*R*) and ampulla of the rectum (*AR*) are shown along with the transverse rectal folds (*TF*). The rectum ends at the anorectal junction (*dotted line*), at the tip of the coccyx, where the puborectalis muscle (*PR*) maintains a 90° perineal flexure. The anal canal is divided into upper (*U*) and lower (*L*) regions by the pectinate line. *RV* = rectovesical pouch. *B* = bladder; *PC* = peritoneal cavity; *RA* = rectus abdominus; *T* = testis. (*B*) Lateral barium radiograph. *Dotted line* = rectosigmoid junction. (*C*) Anteroposterior barium radiograph. *1* = sigmoid colon; *2* = rectum; *3* = ampulla of the rectum; *4* = transverse fold (Houston valve); *5* = perineal flexure (90°); *6* = sacrum; *7* = transverse colon; *8* = terminal ileum; *9* = cecum; *10* = ileocecal valve; *11* = ascending colon. (*A* adapted with permission from Moore KL: *Clinically Oriented Anatomy,* 3rd ed. Baltimore, Williams & Wilkins, 1992; *B* and *C* adapted with permission from Fleckenstein P, Tranum-Jensen J: *Anatomy in Diagnostic Imaging.* Philadelphia, WB Saunders, 1996, p 268.)

II. RECTUM (see Figure 10-1)

A. General features. The **rectum** is a segment of the large intestine located between the sigmoid colon and the anal canal. It begins at vertebral level S3 and ends at the tip of the coccyx **(anorectal junction),** where the **puborectalis muscle** forms a U-shaped sling that causes a 90° **perineal flexure.** The **ampulla of the rectum** lies just above the pelvic diaphragm and generates the **urge to defecate** when feces move into the rectum. The rectum contains three **transverse rectal folds (Houston valves)** formed by the mucosa, submucosa, and inner circular layer of smooth muscle. These folds permanently extend into the lumen of the rectum. The arterial supply is chiefly from the inferior mesenteric artery via the **superior rectal artery.** Venous drainage is mainly to the superior rectal vein → inferior mesenteric vein → hepatic portal system.

B. Clinical considerations

1. **Familial adenomatous polyposis (FAP)** is the archetype of adenomatous polyposis syndromes. In FAP, 500–2000 polyps typically (60% of cases) carpet the mucosal surface of the **rectosigmoid colon;** these polyps invariably become malignant. Malignant polyps are irregular in shape, sessile, and more than 2 cm in diameter. They exhibit sudden growth, and the base is broader than the height. FAP is an autosomal dominant disease that involves a mutation in the **APC anti-oncogene.** The progression from a small polyp to a large polyp is associated with a mutation in the *ras* **proto-oncogene.** The progression from a large polyp to metastatic carcinoma is associated with mutations in the **DCC anti-oncogene** and the **p53 anti-oncogene.**
   a. **Gardner syndrome** is a variation of FAP that is characterized by adenomatous polyps and multiple osteomas.
   b. **Turcot syndrome** is a variation of FAP in which patients have adenomatous polyps and gliomas.
2. **Colonic adenocarcinoma** invariably develops in patients with FAP. It accounts for 98% of all cancers in the large intestine. Mutations in the hereditary nonpolyposis colorectal cancer **(HNPCC) gene,** which codes for a DNA repair enzyme, have been implicated in some cases. Clinical findings include: fatigue, weakness, change in bowel habits, and weight loss. Right-sided tumors are associated with iron deficiency anemia. Left-sided tumors are associated with obstruction and bloody stools. It is a clinical maxim that iron deficiency anemia in an older man indicates adenocarcinoma of the colon until shown otherwise. Metastasis occurs most commonly to the **liver,** because the sigmoid veins and superior rectal veins drain into the hepatic portal system. A posterior metastasis may involve the **sacral nerve plexus,** causing sciatica.
3. **Ulcerative colitis** is a type of idiopathic inflammatory bowel disease. It always involves the rectum and extends proximally for varying distances. The inflammation is continuous, that is, there are no "skip areas" such as those seen in Crohn disease. Clinical signs include: bloody diarrhea with mucus and pus, malaise, fever, weight loss, and anemia. Ulcerative colitis may lead to toxic megacolon.
4. **Rectal prolapse** is the protrusion of the **full thickness of the rectum** through the anus. (It should be distinguished from **mucosal prolapse,** which is the protrusion of just the rectal mucosa through the anus). Clinical findings include: bowel protruding through the anus, bleeding, anal pain, mucous discharge, and anal incontinence caused by stretching of the **internal and external anal sphincters** or stretch injury to the **pudendal nerve.**



Feature	Upper Anal Canal	Lower Anal Canal
Arterial supply	Superior rectal artery (branch of inferior mesenteric artery)	Inferior rectal artery (branch of internal pudendal artery)
Venous drainage	Superior rectal vein → inferior mesenteric vein → hepatic portal system	Inferior rectal vein → internal pudendal vein → internal iliac vein → inferior vena cava
Lymphatic drainage	Deep nodes	Superficial inguinal nodes
Innervation	Motor: autonomic innervation of internal anal sphincter (smooth muscle)	Motor: somatic innervation (pudendal nerve) of external anal sphincter (striated muscle)
	Sensory: stretch sensation, no pain sensation	Sensory: pain, temperature, touch sensation
Embryologic derivation	Endoderm (hindgut)	Ectoderm (proctodeum)
Epithelium	Simple columnar	Stratified squamous
Tumors	No palpable enlarged superficial nodes	Palpable enlarged superficial nodes
	No pain	Pain
Hemorrhoids	Internal hemorrhoids (varicosities of superior rectal veins)	External hemorrhoids (varicosities of inferior rectal veins)
	Covered by rectal mucosa	Covered by skin
	No pain	Pain

Figure 10-2. Diagram of the anal canal. Note the following structures: ampulla of the rectum (*AR*), puborectalis muscle (*PR*), anal columns (*AC*), anal verge (*AV*), pectinate line (*PL;* thin dotted line), internal anal sphincter (*IS*), and external anal sphincter (*ES*). Thick dotted line marks the anorectal junction. (Adapted with permission from Ernest WA: *NMS Anatomy,* 2nd ed. Media, PA, Harwal, 1990, p 225.)

III. ANAL CANAL (Figure 10-2) is divided into the upper and lower anal canal by the **pectinate line**. It is surrounded by the **internal anal sphincter,** which is a continuation of smooth muscle from the rectum, with involuntary control via autonomic innervation, and the **external anal sphincter,** which consists of striated muscle under voluntary control via the pudendal nerve.

A. The **upper anal canal** extends from the anorectal junction (perineal flexure) to the pectinate line. The mucosa of the upper anal canal extends into longitudinal folds called the **anal columns,** or **columns of Morgagni.** The base of the anal columns defines the **pectinate line.** At the base of the anal columns are folds of tissue called the **anal valves.** Behind the anal valves are small, blind pouches called the **anal sinuses** into which **anal glands** open.

B. The **lower anal canal** extends from the pectinate line to the **anal verge** (the point at which perianal skin begins).

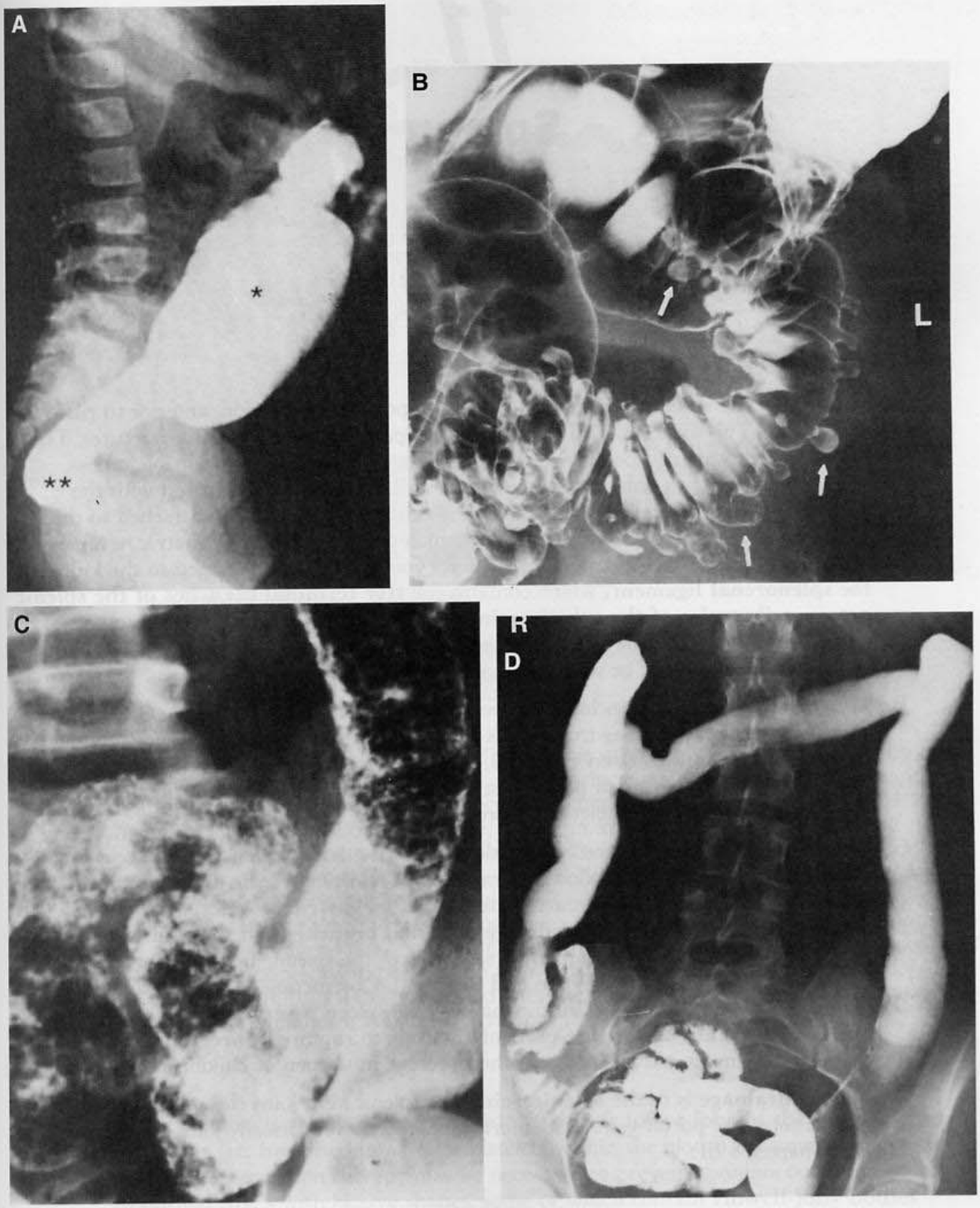
C. Clinical considerations

1. **Internal hemorrhoids** are varicosities of the **superior rectal veins.** They are located above the pectinate line and are covered by rectal mucosa. Clinical findings include: bleeding, mucous discharge, prolapse, and pruritus, but no pain.
2. **External hemorrhoids** are varicosities of the **inferior rectal veins.** They are located below the pectinate line, near the anal verge, and are covered by skin. Clinical findings include: bleeding, swelling, and pain.

IV. DEFECATION REFLEX. When feces are present, sensory impulses from **pressure-sensitive receptors** within the ampulla of the rectum travel to sacral spinal cord levels. Motor impulses travel with the **pelvic splanchnic nerves (parasympathetics; S2–4),** which increase peristalsis and relax the internal anal sphincter. If the external anal sphincter and puborectalis muscle also are relaxed, defecation takes place with the help of contraction of the anterior abdominal wall muscles and closure of the glottis. If the external anal sphincter and puborectalis muscle are voluntarily contracted via the **pudendal nerve,** defecation is delayed, and the feces move back into the sigmoid colon for storage. The **hypogastric plexus** and **lumbar splanchnic nerves (sympathetics)** decrease peristalsis and maintain tone of the internal anal sphincter.

V. RADIOLOGY. Radiologic features of Hirschsprung disease, diverticulosis, FAP, and ulcerative colitis (Figure 10-3)

Figure 10-3. (*A*) Hirschsprung disease. Lateral radiograph of the colon after a barium enema in a 3-year-old girl with aganglionic megacolon. The upper segment (*) of normal colon is distended with fecal material. The distal segment (**) of the colon is narrow; this is the portion of colon where the myenteric plexus of ganglion cells is absent. (*B*) Diverticulosis. Barium radiograph of the sigmoid colon showing numerous small outpouchings, or diverticula (*arrows*), from the colonic lumen. These diverticula are filled with barium and fecal material. (*C*) Familial adenomatous polyposis. This radiograph, taken after a barium enema, shows numerous adenomatous polyps carpeting the mucosal surface of the descending and rectosigmoid portions of the colon. (*D*) Ulcerative colitis. This barium radiograph shows ulcerative colitis involving the rectum and extending proximally to the ascending colon. Note the smooth border of the colon due to the lack of haustra. (*A* reprinted with permission from Behrman RE, Kliegman RM, Arvin AM: *Nelson's Textbook of Pediatrics,* 15th ed. Philadelphia, WB Saunders, 1996; *B* and *D* reprinted with permission from Rosenbaum HD, Hildner JH: *Basic Clinical Diagnostic Radiology,* pp 241, 243. Baltimore, University Park Press, 1984; *C* reprinted with permission from Eisenberg RL: *Gastrointestinal Radiology: A Pattern Approach.* Philadelphia, JB Lippincott, 1987, p 355.)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11

Spleen

I. ANATOMY AND FUNCTION (Figure 11-1)

A. Anatomy. The **spleen** is located in the left hypochondriac region, anterior to ribs 9, 10, and 11. This location puts the spleen in jeopardy in the case of rib fractures. The spleen does not extend below the costal margin, so it is not easily palpable unless splenomegaly (i.e., an enlarged spleen) is present. The spleen is palpated with the patient in a right lateral decubitus position with the leg flexed. It is attached to the stomach by the **gastrosplenic ligament,** which contains the **short gastric arteries and veins** and the **left gastroepiploic artery and vein.** It is attached to the kidney by the **splenorenal ligament,** which contains the **five terminal branches of the splenic artery, tributaries of the splenic vein**, and the **tail of the pancreas. Accessory spleens** are found in 20% of the population. They usually are located near the hilum, the tail of the pancreas, or within the gastrosplenic ligament.

B. Functions of the spleen include: removal of old or abnormal red blood cells (RBCs); removal of inclusion bodies from RBCs [e.g., **Howell-Jolly bodies** (nuclear remnants), **Pappenheimer bodies** (iron granules), or **Heinz bodies** (denatured hemoglobin)]; removal of poorly opsonized pathogens; production of immunoglobulin (Ig) M by plasma cells; storage of platelets; and protection from infection.

C. The **arterial supply** is from the **splenic artery** (the largest branch of the celiac trunk). The splenic artery has the following branches: **dorsal pancreatic artery, great pancreatic artery, caudal pancreatic arteries, short gastric arteries,** and **left gastroepiploic artery,** and ends with **five terminal branches.** These terminal branches of the splenic artery supply individual segments of the spleen, and there are no anastomoses between them (i.e., they are **end arteries**). Obstruction or ligation of any terminal branch results in **splenic infarction** (i.e., the spleen is very prone to infarction). **Splenic artery aneurysms** are particularly likely to rupture in **pregnant women,** so these aneurysms should be resected when present in women of childbearing age.

D. Venous drainage is to the **splenic vein.** The splenic vein joins the superior mesenteric vein to form the portal vein. The inferior mesenteric vein usually joins the splenic vein (see Chapter 8 III).

II. CLINICAL CONSIDERATIONS

A. Splenectomy is surgical removal of the spleen. Several nearby anatomic structures may be injured during splenectomy, including the **gastric wall (stomach)**, if the short gastric arteries are compromised; the **tail of the pancreas**, if the caudal pancreatic arteries are compromised or during manipulation of the splenorenal ligament; and the **left kidney**, during manipulation of the splenorenal ligament. The most common complication

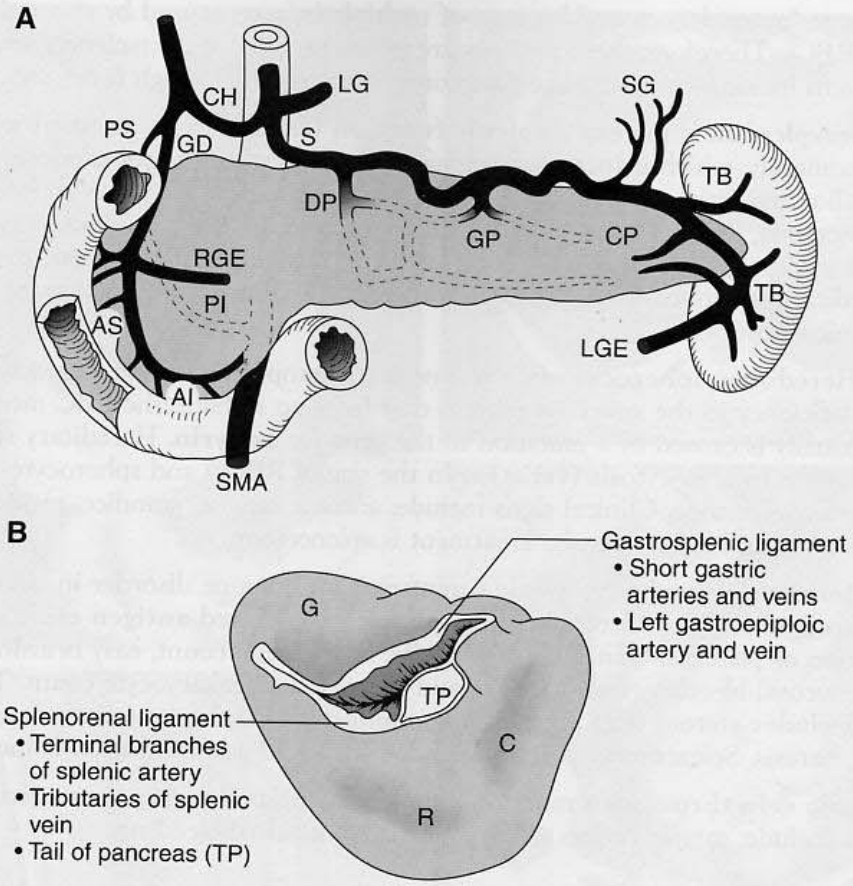

Figure 11-1. (*A*) Arterial supply of the spleen. The splenic artery (*S*) is the largest branch of the celiac trunk. *AI* = anterior-inferior pancreaticoduodenal artery; *AS* = anterior-superior pancreaticoduodenal artery; *CH* = common hepatic artery; *CP* = caudal pancreatic arteries; *DP* = dorsal pancreatic artery; *GD* = gastroduodenal artery; *GP* = great pancreatic artery; *LG* = left gastric artery; *LGE* = left gastroepiploic artery; *PI* = posterior-inferior pancreaticoduodenal artery; *PS* = posterior-superior pancreaticoduodenal artery; *RGE* = right gastroepiploic artery; SG = short gastric arteries; *SMA* = superior mesenteric artery; *TB* = terminal branches of the splenic artery. (*B*) Visceral surface of the spleen. The gastrosplenic ligament and splenorenal ligament are shown, along with the structures they contain. *C* = colon depression; *G* = gastric depression; *R* = renal depression. (*A* adapted with permission from Ernest WA: *NMS Anatomy,* 2nd ed. Media, PA, Harwal Publishing, 1990, p 213; *B* adapted with permission from Moore KL: *Clinically Oriented Anatomy,* 3rd ed. Baltimore, Williams & Wilkins, 1992, p 175.)

of splenectomy is **atelectasis (collapse) of the left lower lobe of the lung. Thrombocytosis** (i.e, increased number of platelets within the blood) is common postoperatively; anticoagulation therapy may be necessary to prevent spontaneous thrombosis. Abnormal RBCs with bizarre shapes, some of which contain **Howell-Jolly bodies** (nuclear remnants), are found in the blood postoperatively.

B. Overwhelming postsplenectomy sepsis. After splenectomy, patients (especially children) are at great risk for **bacterial septicemia** because of decreased opsonic production, decreased IgM levels, and decreased clearance of bacteria from the blood. The pathogens most commonly involved are ***Streptococcus pneumoniae***, *Haemophilus* ***influenzae***, and ***Neisseria meningitidis***. Patients with **sickle cell anemia** usually

undergo "autosplenectomy" because of multiple infarcts caused by stagnation of abnormal RBCs. Therefore, these patients are prime targets for postsplenectomy sepsis. Clinical signs include: influenza-like symptoms that progress to high fever, shock, and death.

C. **Hypersplenism** is increased **splenic function** (i.e., not to be confused with splenomegaly, which is increased splenic size). Clinical findings include: anemia, leading to pallor and fatigue; leukopenia, leading to increased susceptibility to infection; thrombocytopenia, leading to easy bruising and nosebleeds; and a compensatory increase in bone marrow activity. Hypersplenism may be caused by hematopoietic disorders (e.g., hereditary spherocytosis, thalassemia) or immune disorders (e.g., immune thrombocytopenic purpura).

1. **Hereditary spherocytosis** is a genetic hematopoietic disease characterized by a deficiency in the **spectrin** protein that helps to stabilize the RBC membrane and usually is caused by a mutation in the gene for **ankyrin**. Hereditary spherocytosis results in anisocytosis (variation in the size of RBCs) and spherocytes with no central pallor zone. Clinical signs include: anemia, fatigue, jaundice, pigmented gallstones, and splenomegaly. Treatment is splenectomy.

2. **Immune thrombocytopenic purpura** is an immune disorder in which circulating antibodies (IgG) directed against **platelet-associated antigen** cause rapid destruction of platelets. Clinical signs include: low platelet count, easy bruising, petechiae, mucosal bleeding, menorrhagia, and increased megakaryocyte count. Treatment includes: steroid (e.g., prednisone) administration, platelet transfusions, and plasmapheresis. Splenectomy is recommended if steroid administration is ineffective.

D. **Splenic vein thrombosis** most commonly is associated with **pancreatitis.** Clinical signs include: gastric varices and upper gastrointestinal bleeding.

III. **RADIOLOGY.** Anteroposterior barium radiograph of splenomegaly, computed tomographic (CT) scan of traumatic spleen rupture, aortogram of traumatic spleen rupture, and CT scan of traumatic spleen rupture (Figure 11-2).

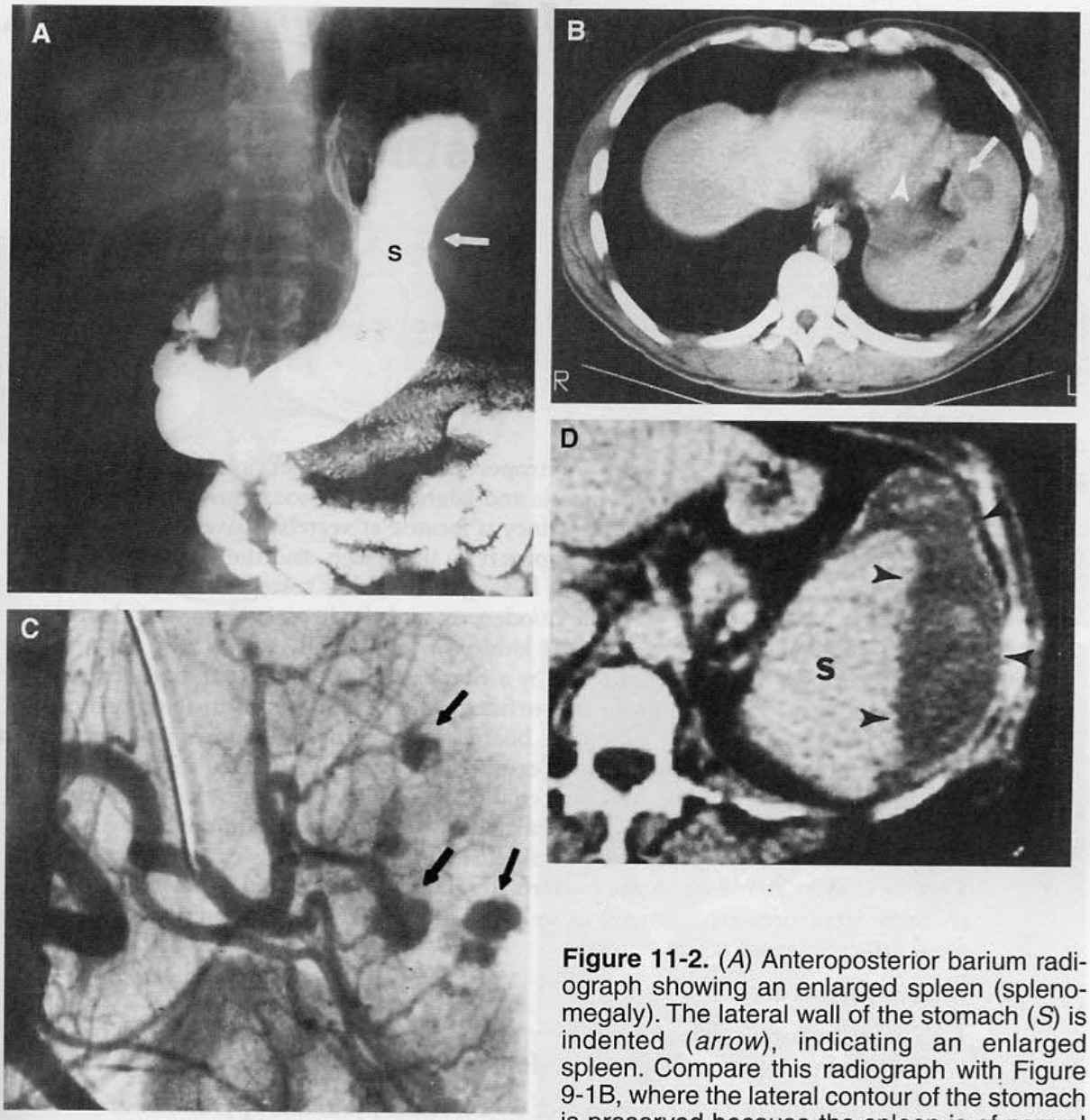

Figure 11-2. (*A*) Anteroposterior barium radiograph showing an enlarged spleen (splenomegaly). The lateral wall of the stomach (*S*) is indented (*arrow*), indicating an enlarged spleen. Compare this radiograph with Figure 9-1B, where the lateral contour of the stomach is preserved because the spleen is of normal size. Splenomegaly commonly is found in patients with liver cirrhosis or portal hypertension and right-sided heart failure. (*B*) CT scan of a traumatic spleen rupture. The spleen is the organ that is most commonly injured in car accidents (the liver is a close second). Note the splenic rupture or laceration (*arrowhead*) and the intrasplenic hematoma (*arrow*). Clinical signs of splenic rupture are hypotension, pain in the left hypochondriac region, and Kerr sign (referred pain to the left shoulder). In addition to trauma, splenic rupture is associated with infectious mononucleosis, malaria, and sepsis. (*C*) Aortogram of a traumatic spleen rupture. Note the large globular areas of extravasated contrast material (*arrows*). (*D*) CT scan of a traumatic spleen rupture. Note the large subcapsular hematoma (*arrowheads*), which appears as a crescentic mass conforming to the shape of the spleen (*S*). Balance sign is the presence of a palpable, tender, enlarged mass in the left hypochondriac region due to a subcapsular hematoma.[*A* adapted with permission from Freedman M: *Clinical Imaging: An Introduction to the Role of Imaging in Clinical Practice.* New York, Churchill Livingstone, 1988, p 339; *B* adapted with permission from Levy RC, Hawkins H, Barsan WG: *Radiology in Emergency Medicine.* St. Louis, CV Mosby, 1986, p 192; *C* adapted and *D* reprinted with permission from Kohler RE: Spleen. In Lee JKT, Sagel SS, Stanley RJ (eds): *Computed Body Tomography.* New York, Raven Press, 1983.]

12

Urinary System

I. KIDNEYS (Figure 12-1)

A. General features.

The kidneys are retroperitoneal organs that lie on the ventral surface of the quadratus lumborum muscle and lateral to the psoas muscle and vertebral column. The upper pole of the left kidney is located at vertebral level T12 and is related to the 11th and 12th ribs, the pancreas, the spleen, and the splenic flexure of the colon. The upper pole of the right kidney is located at vertebral level L1 and is related to the 12th rib, the liver, the duodenum, and the hepatic flexure of the colon. The right kidney is lower than the left kidney because the liver is located on the right side. The kidneys are covered directly by a fibrous capsule **(renal, or true, capsule)** that can be stripped readily from the surface of the kidney, except in some pathologic conditions that cause strong adherence because of scarring. The kidneys are further surrounded by the **perirenal fascia of Gerota (false capsule),** which is important in staging renal cell carcinoma. The perirenal fascia of Gerota defines the **perirenal space** that contains the **kidney, adrenal gland, ureter, gonadal artery and vein,** and **perirenal fat**. Any fat located outside the perirenal space is called **pararenal fat.** This fat is most abundant in the posterolateral area. In the **renal hilus,** the following anatomic structures are arranged in an anterior-to-posterior direction: renal vein → renal artery → renal pelvis.

B. Internal structure

1. The outer **cortex** is located directly below the renal capsule and extends between the renal pyramids as the **renal columns (columns of Bertin).**
2. The inner **medulla** is composed of **5–11 renal pyramids (pyramids of Malpighi),** whose tips terminate as **5–11 renal papillae.**
3. The collecting system of the kidney includes:
   a. **5–11 minor calyces,** which are cup-shaped structures that surround each renal papilla
   b. **2 or 3 major calyces,** which are formed by the fusion of minor calyces
   c. The **renal pelvis,** which is the main urine collection chamber and is continuous with the ureter at the ureteropelvic junction

C. Vascular supply

1. The **renal artery** branches into five **segmental arteries**. Four **anterior segmental arteries** supply anterior segments of the kidney, and one **posterior segmental artery** supplies the posterior segment. Segmental arteries have the following clinical importance:
   a. Because collateral circulation between segmental arteries (i.e., end arteries) is limited, an **avascular line (Brodel white line)** between the anterior and posterior

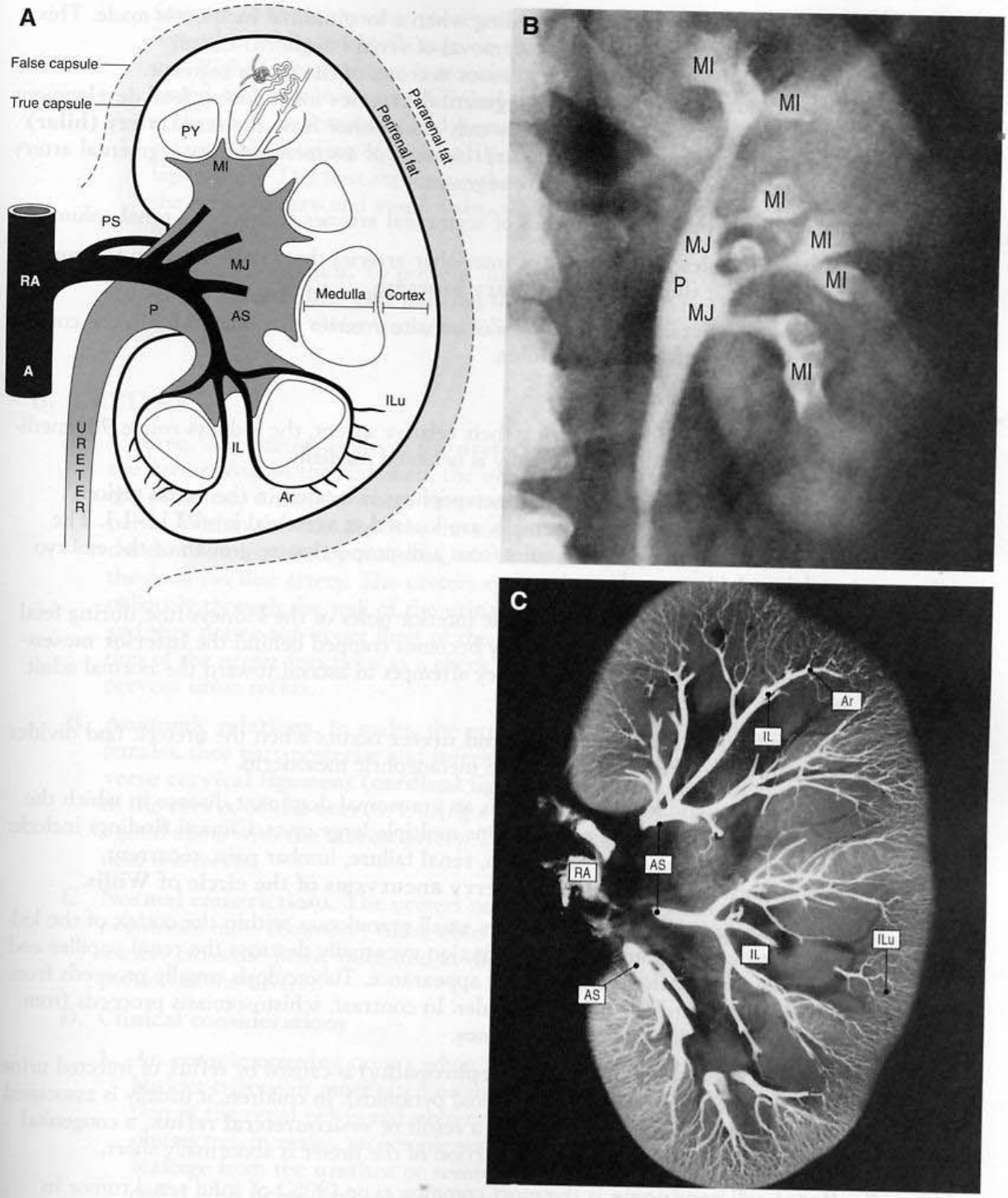

Figure 12-1. (*A*) General features of the kidney, collecting system, and blood supply. (*B*) IVP of the kidney collecting system. Note that the normal minor calyx is cup-shaped. (*C*) Arteriogram of the kidney vasculature. *A* = aorta; *Ar* = arcuate artery; *AS* = anterior segmental artery; *IL* = interlobar artery; *ILu* = interlobular artery; *MI* = minor calyx; *MJ* = major calyx; *P* = renal pelvis; *PY* = pyramid; *PS* = posterior segmental artery; *RA* = renal artery. (*A* adapted with permission from Henrikson, RC, Kaye GI, Mazurkiewicz JE: *NMS Histology*. Baltimore, Williams & Wilkins, 1997, p 327; *B* adapted with permission from Fleckenstein P, Tranum-Jensen J: *Anatomy in Diagnostic Imaging*. Philadelphia, WB Saunders, 1993, p 282; *C* adapted with permission from Stevens A, Lowe J: *Human Histology,* 2nd ed. St. Louis, Mosby, 1997, p 277.)

segments permits minimal bleeding when a longitudinal incision is made. This approach is useful for surgical removal of renal (staghorn) calculi.

b. Ligation of a segmental artery causes necrosis of the entire segment.

c. **Supernumerary (aberrant) segmental arteries** form during fetal development and persist into adulthood. They may arise either from the renal artery **(hilar)** or directly from the aorta **(polar)**. Ligation of a supernumerary segmental artery results in necrosis of the entire segment.

2. **Interlobar arteries** are branches of segmental arteries that enter a renal column.

3. **Arcuate arteries** are branches of interlobar arteries that travel between the cortex and medulla at the **corticomedullary junction**.

4. **Interlobular arteries** are branches of arcuate arteries that travel within the cortex to terminate as **afferent arterioles**.

D. Clinical considerations

1. **Rotation of the kidney.** During their relative ascent, the kidneys rotate 90° medially so that the renal hilus normally is oriented medially.

2. **Ascent of the kidney.** The fetal metanephros is located in the sacral region, although the adult kidneys normally are located at vertebral level T12–L3. The change in location (ascent) results from a disproportionate growth of the embryo caudal to the metanephros.

3. **Horseshoe kidney** occurs when the inferior poles of the kidneys fuse during fetal development. The horseshoe kidney becomes trapped behind the **inferior mesenteric artery** as the horseshoe kidney attempts to ascend toward the normal adult location.

4. **Duplication of the renal pelvis and ureter** occurs when the ureteric bud divides prematurely before it penetrates the metanephric mesoderm.

5. **Adult polycystic kidney disease** is an autosomal dominant disease in which the kidney is enlarged because it contains multiple large cysts. Clinical findings include: bilateral flank masses, hypertension, renal failure, lumbar pain, recurrent pyelonephritis, hepatic cysts, and **berry aneurysms of the circle of Willis**.

6. **Genitourinary tuberculosis** causes small granulomas within the cortex of the kidney, usually near glomeruli. The infection eventually destroys the renal papillae and gives the minor calyces an irregular appearance. Tuberculosis usually proceeds from the kidney toward the urinary bladder. In contrast, schistosomiasis proceeds from the urinary bladder toward the kidney.

7. **Chronic pyelonephritis (reflux nephropathy)** is caused by reflux of infected urine from the bladder into the kidney (renal pyramids). In children, it usually is associated with repeated bacterial infections as a result of **vesicoureteral reflux,** a congenital anomaly in which the intramural portion of the ureter is abnormally short.

8. **Renal cell carcinoma** is the most common type (90%) of solid renal tumor in adults. Its etiology is unknown, but it appears to arise from the **proximal convoluted tubule**. It is associated with **von Hippel-Lindau disease**. Renal cell carcinoma is resistant to chemotherapy as a result of the expression of the **multidrug resistant (MDR) gene,** or **P-glycoprotein**. It may thrombose to the **renal vein** or the **inferior vena cava.** Clinical findings include: hematuria, flank pain, weight loss, left testicular varicocele in males, and flank mass.

9. **Kidney trauma** is suspected in the following situations: fracture of the lower ribs,

fracture of the transverse processes of the lumbar vertebrae, gunshot or knife wound over the lower rib cage, or after a car accident when seatbelt marks are present. Right kidney trauma is associated with liver trauma; left kidney trauma is associated with spleen trauma. Clinical findings include: flank mass or tenderness, flank ecchymosis, hypotension, and hematuria. An absolute indication for renal exploration is the finding of a **pulsatile or expanding retroperitoneal hematoma** at laparotomy. The first structures that should be isolated during renal exploration are the **renal artery** and **renal vein,** which are located superior to the inferior mesenteric artery.

10. **Surgical approach.** To prevent inadvertent entry into the pleural space, the incision is made **below and parallel to the 12th rib**. The incision may be extended to the front of the abdomen by traveling parallel to the inguinal ligament.

II. URETERS

A. Course. The ureters begin at the **ureteropelvic junction,** where the renal pelvis joins the ureter. Within the abdomen, the ureters descend retroperitoneally and anterior to the psoas major muscle, where they cross the pelvic inlet to enter the minor (true) pelvis. Within the minor pelvis, the ureters descend retroperitoneally and anterior to the common iliac artery and vein, where they may be compromised by an aneurysm of the common iliac artery. The ureters end at the **ureterovesical junction** by traveling obliquely through the wall of the urinary bladder **(intramural portion of the ureter),** and they define the upper limit of the **urinary bladder trigone**. The intramural portion of the ureter functions as a check valve **(ureterovesical valve of Sampson)** to prevent urine reflux.

B. Anatomic relations. In males, the ureters pass posterior to the **ductus deferens**. In females, they pass posterior and inferior to the **uterine artery,** which lies in the **transverse cervical ligament (cardinal ligament of Mackenrodt)**, and lie 1–2 cm lateral to the **cervix of the uterus**. During a hysterectomy, the ureter inadvertently may be ligated along with the uterine artery. The critical area of ligation of the uterine artery is near the cervix.

C. Normal constrictions. The ureters normally are constricted at three sites where kidney stones most commonly cause obstruction: at the ureteropelvic junction, where the ureters cross the pelvic inlet, and at the ureterovesical junction (along the intramural portion of the ureter).

D. Clinical considerations

1. An **ectopic opening** occurs when the ureter opens at a site other than the urinary bladder trigone. It most often occurs with the congenital anomaly known as duplication of the renal pelvis and ureter. Ureters with an ectopic opening usually are obstructed. In males, an ectopic opening most commonly is associated with **urine leakage** from the **urethra** or **seminal vesicle.** In females, it most commonly is associated with **urine leakage** from the **urethra, vestibule of the vagina,** or **vagina.**

2. **Obstruction by renal calculi ("kidney stones") (Figure 12-2)** occurs most often at the three sites where the ureter normally is constricted (see II C), causing **unilateral hydronephrosis**. Clinical findings include: intermittent excruciating pain in the flank, abdomen, or testicular or vulvar region that radiates into the inner thigh, depending on the obstruction site. Fever, hematuria, and decreased urine output may be present, and the patient typically assumes a posture with a severe ipsilateral costovertebral angle. Types of kidney stones include:

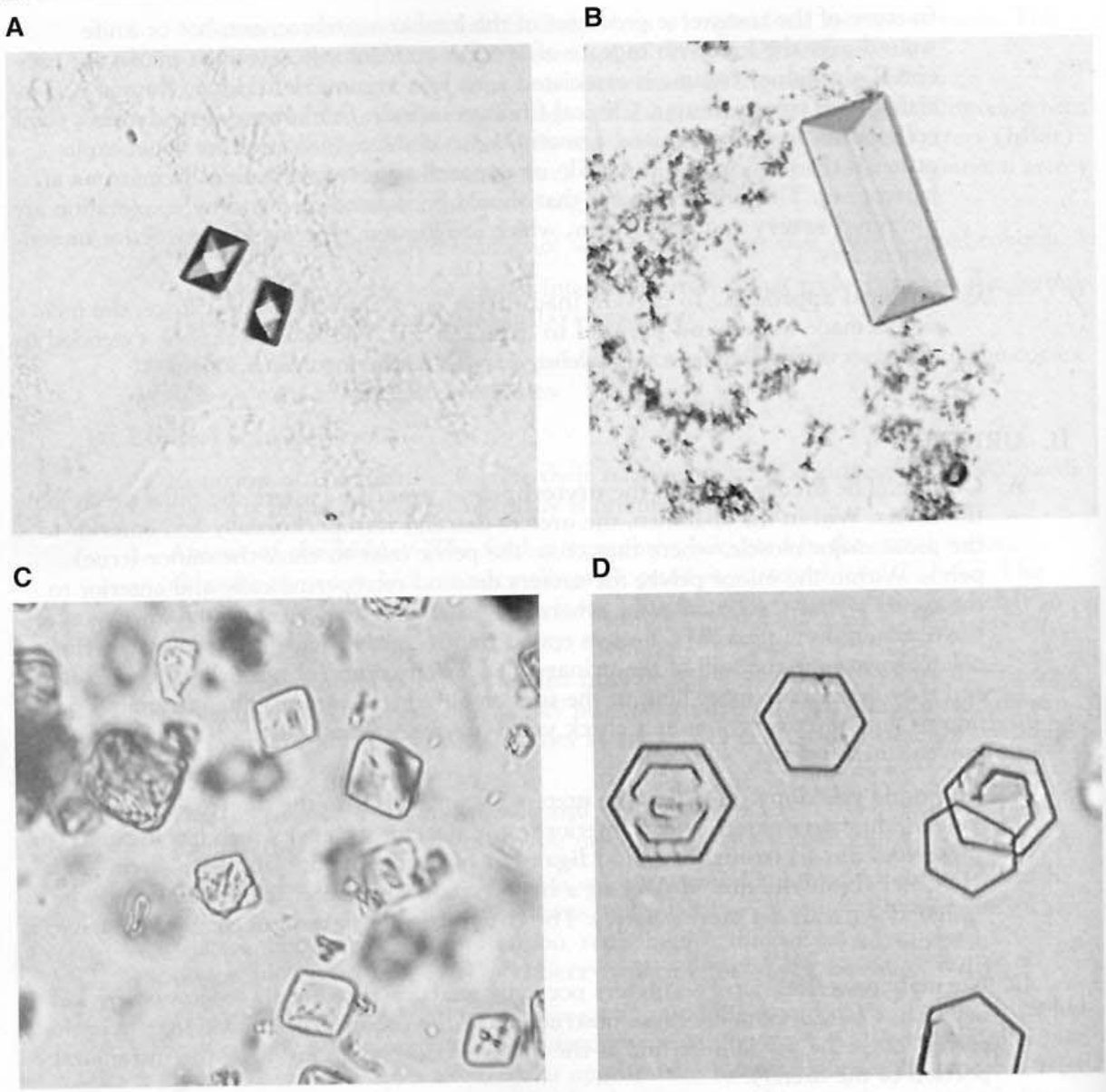

Figure 12-2. Calculi (kidney stones). (*A*) Photograph of calcium oxalate calculi shows that these kidney stones are colorless, octahedral-shaped crystals that look like small squares crossed by intersecting diagonal lines. These are the most common (80%) type of kidney stone. (*B*) Photograph of magnesium ammonium sulfate (struvite or triple phosphate) calculi shows that these kidney stones are colorless, rectangular, prism-shaped crystals. These are the second most common (15%) type of kidney stone. (*C*) Photograph of uric acid calculi shows that these kidney stones are yellow or red-brown, diamond or rhombic prism-shaped crystals. These are the third most common (5%) type of kidney stone. (*D*) Photograph of cystine calculi shows that these kidney stones are colorless, refractive, and hexagonal-shaped crystals. These are the least common (1%) type of kidney stone. (A—D reprinted with permission from Graff L: *A Handbook of Routine Urinalysis.* Philadelphia, JB Lippincott, 1983, pp 93, 144, 151, 173.)

a. **Calcium oxalate calculi** are radiopaque and, by urinalysis, are colorless octahedral-shaped crystals that look like small squares crossed by intersecting diagonal lines. They are the most common (40%) type of kidney stone and form when the urine is at an acid (< 6.0) or neutral pH (7.0). They are associated with: absorptive hypercalcemia, vitamin D intoxication, hyperparathyroidism, milk-alkali syndrome, and renal tubular acidosis (all of which cause **hypercalcemia**), ethylene glycol poisoning, diabetes, and liver disease.

b. **Magnesium ammonium sulfate (struvite)** or **triple phosphate calculi** are radiopaque and, by urinalysis, are colorless, rectangular, prism-shaped crystals. They are the second most common (15%) type of kidney stone and form when the urine is at an alkaline pH (> 7.4). They usually form **staghorn calculi**. They are associated with urinary tract infections caused by urea-splitting bacteria (e.g., *Proteus vulgaris*, *Providencia* species, *Pseudomonas* species, *Klebsiella* species, *Staphylococcus* species).

c. **Uric acid calculi** are radiolucent and, by urinalysis, are yellow or red-brown, diamond or rhombic prism-shaped crystals. They are the third most common (5%) type of kidney stone and form when the urine is at an acid pH (< 6.0). They are associated with gout, leukemia, Lesch-Nyhan syndrome, and myeloproliferative disorders.

d. **Cystine calculi** are faintly radiopaque. They are flat, yellow, and hexagonal. They are the least common (1%) type of kidney stone and form when the urine is at an acid pH (< 6.0). Cystine calculi are caused by **cystinuria**, an autosomal recessive disorder that results in defective renal tubular reabsorption of the amino acids cystine, ornithine, arginine, and lysine.

III. URINARY BLADDER (Figure 12-3)

A. Surfaces

1. **Posterior surface (fundus, or base).** In males, the posterior surface of the bladder is related to the **rectovesical pouch, rectum, seminal vesicles**, and **ampulla of the ductus deferens**. In females, the posterior surface is related to the **anterior wall of the vagina.**

2. **Anterior surface.** In both males and females, the anterior surface is related to the **pubic symphysis** and **retropubic space of Retzius**.

3. **Superior surface.** In males, the superior surface is related to the **peritoneal cavity**. In females, this surface is related to the **vesicouterine pouch (peritoneal cavity)** and **uterus.**

4. **Apex.** In both males and females, the apex is related to the **median umbilical ligament,** or **urachus** (a remnant of the allantois in the fetus); the two **medial umbilical ligaments** (remnants of the right and left umbilical arteries in the fetus); and the two **lateral umbilical ligaments,** which are elevations formed by the right and left inferior epigastric arteries and veins.

5. **Neck.** In males, the neck of the bladder is related to the **prostate gland** and **prostatic urethra**. In females, it is related to the **urogenital diaphragm**.

B. Internal structure.

The mucosal lining is composed of **transitional epithelium**. The walls are composed of a layer of smooth muscle **(detrusor muscle)**. The **trigone of the bladder** is located on the posterior surface of the bladder, and its limits are defined superiorly by the openings of the ureters and inferiorly by the urethra.

C. Clinical considerations

1. **Location.** In infants, the empty bladder lies within the **abdominal cavity.** In

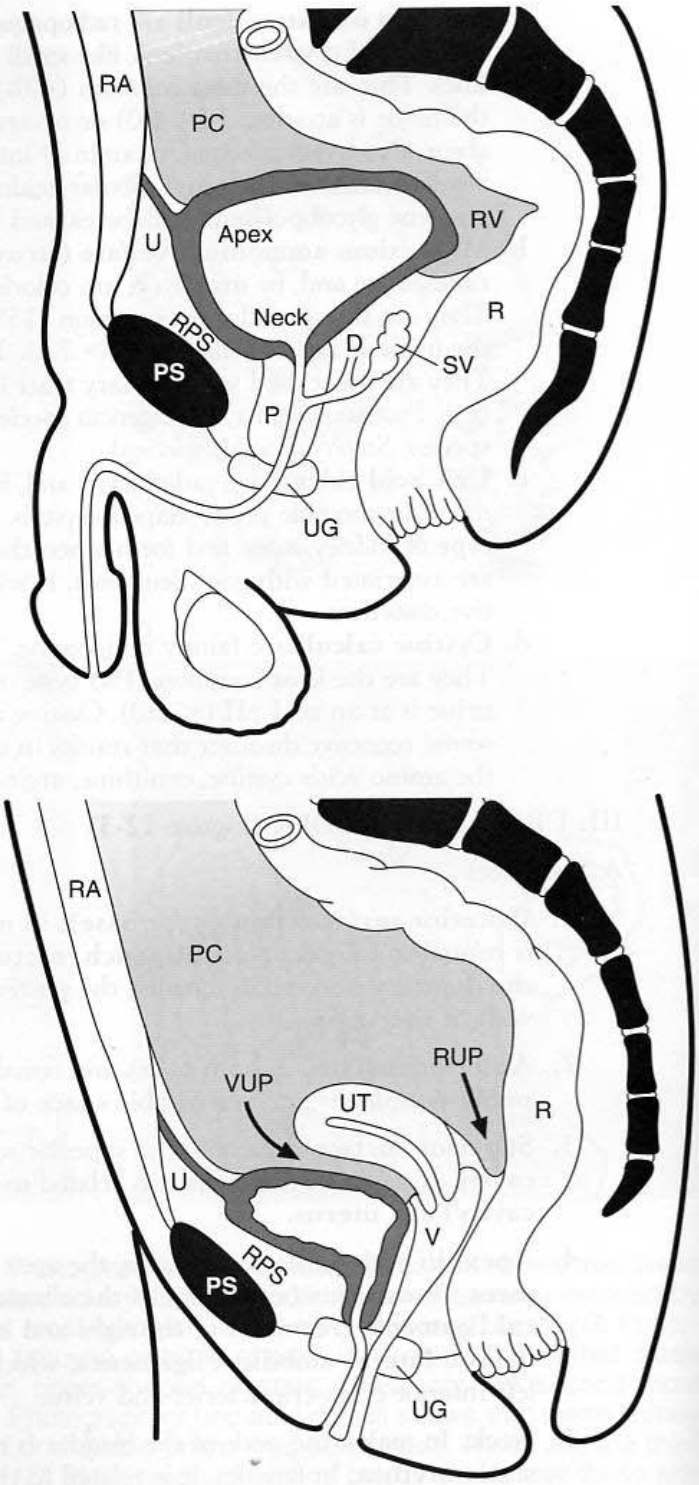

Figure 12-3. (*A*) Sagittal section through the male pelvis showing the various anatomic relations of the urinary bladder. *D* = ductus deferens; *P* = prostate gland; *PC* = peritoneal cavity (*shaded*); *PS* = pubic symphysis bone; *R* = rectum; *RA* = rectus abdominis muscle; *RPS* = retropubic space of Retzius; *RV* = rectovesical pouch; *SV* = seminal vesicle; *U* = urachus; *UG* = urogenital diaphragm. (*B*) Sagittal section through the female pelvis showing the various anatomic relations of the urinary bladder. These anatomic relations are important because clinical vignette questions may discuss urinary bladder pathology and ask what surrounding structures are affected. *RUP* = rectouterine pouch of Douglas; *UT* = uterus; U = urachus; *V* = vagina; *VUP* = vesicouterine pouch.

adults, the empty bladder lies within the **minor pelvis**. As the adult bladder fills, it rises out of the minor pelvis, above the pelvic inlet, and may extend as high as the umbilicus. In acute retention of urine, a needle may be passed through the anterior abdominal wall [skin → superficial fascia (Camper and Scarpa) → linea alba → transversalis fascia → extraperitoneal fat → bladder wall] without entering the peritoneal cavity to remove the urine from the bladder **(suprapubic cystostomy)**.

2. **Urine leakage as a result of trauma (Figure 12-4)**
   a. **Rupture of the superior wall (dome),** usually caused by compression on a full bladder, results in intraperitoneal extravasation of urine within the **peritoneal cavity.**
   b. **Rupture of the anterior wall,** usually caused by a fractured pelvis (e.g., as a result of a car accident) that punctures the bladder, results in extraperitoneal extravasation of urine within the **retropubic space of Retzius.**
   c. **Rupture of the urethra above the urogenital diaphragm,** usually caused by a fractured pelvis or improper insertion of a catheter, causes extraperitoneal extravasation of urine within the **retropubic space of Retzius.**
   d. **Rupture of the urethra just below the urogenital diaphragm** is the most common type of urine leakage injury. It usually is caused by a **straddle injury** (e.g., falling against a bicycle crossbar) that results in extraperitoneal extravasa-

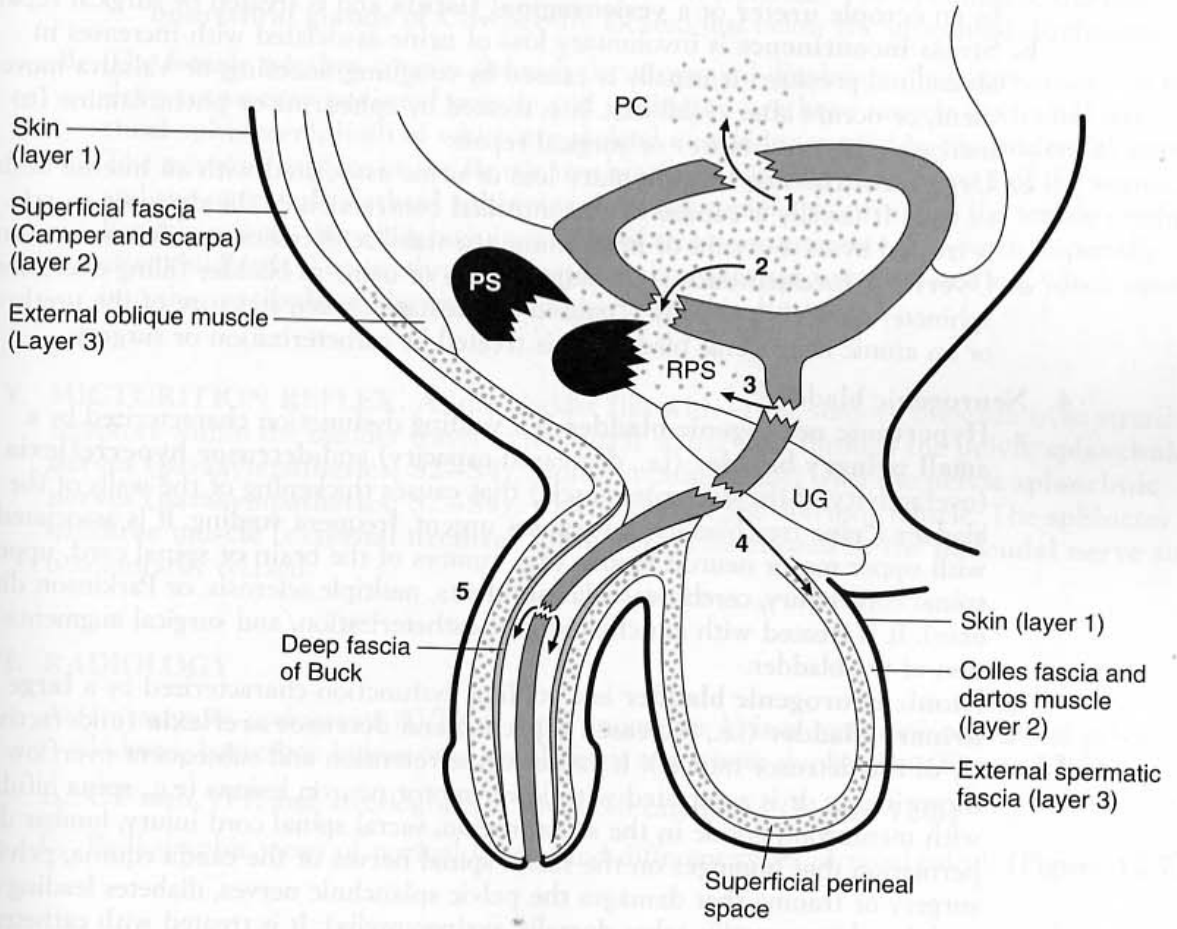

Figure 12-4. The five areas of trauma that cause urine leakage. *1* = Rupture of the superior wall of the urinary bladder results in extravasation of urine into the peritoneal cavity *(PC)*. *2* = Rupture of the anterior wall of the urinary bladder results in extravasation of urine into the retropubic space of Retzius *(RPS)*. *3* = Rupture of the urethra above the urogenital diaphragm *(UG)* results in extravasation of urine into the retropubic space of Retzius. *4* = Rupture of the urethra below the urogenital diaphragm results in extravasation of urine into the superficial perineal space. Note that extravasated urine within the superficial perineal space can extend into the scrotal, penile, and anterior abdominal wall areas. *5* = Rupture of the penile urethra results in extravasation of urine beneath the deep fascia of Buck and will remain confined to the penis. *PS* = pubic symphysis; *dots* = urine.

tion of urine within the **superficial perineal space** and extending into the scrotal, penile, and anterior abdominal wall areas (urine does *not* extend into the thigh region or anal triangle). The superficial perineal space is located between Colles fascia and the dartos muscle (layer 2; see Figure 6-4) and the external spermatic fascia (layer 3; see Figure 6-4). Clinical findings include: blood at the urethral meatus, ecchymosis, painful swelling of the scrotal and perineal areas, and tender enlargement in the suprapubic region as a result of a full bladder.

e. **Rupture of the penile urethra,** caused by a crushing injury to the penis, results in extraperitoneal extravasation of urine **beneath the deep fascia of Buck.** If the deep fascia of Buck is not torn, extravasation is confined to the penis; however, if the trauma also tears the deep fascia of Buck, then extravasation of urine occurs within the **superficial perineal space.**

3. **Urine leakage as a result of incontinence**
   a. **Total incontinence** is continuous involuntary loss of urine. It usually is caused by an **ectopic ureter** or a **vesicovaginal fistula** and is treated by surgical repair.
   b. **Stress incontinence** is involuntary loss of urine associated with increases in abdominal pressure. It usually is caused by coughing, sneezing, or Valsalva movement, or occurs after childbirth. It is treated by ephedrine or phentolamine (to increase outlet resistance) or surgical repair.
   c. **Urge incontinence** is involuntary loss of urine associated with an intense desire to void. It usually is caused by uncontrolled contraction of the detrusor muscle. It is treated by oxybutynin or imipramine (to stabilize detrusor muscle contraction).
   d. **Overflow incontinence** is involuntary loss of urine as bladder filling overcomes sphincter control. It usually is caused by prostate cancer, stricture of the urethra, or an atonic neurogenic bladder. It is treated by catheterization or surgery.

4. **Neurogenic bladder**
   a. **Hypertonic neurogenic bladder** is a voiding dysfunction characterized by a **small urinary bladder** (i.e., decreased capacity) and **detrusor hyperreflexia** (overactivity of the detrusor muscle) that causes thickening of the walls of the bladder ("pine tree bladder"). It causes urgent, frequent voiding. It is associated with upper motor neuron lesions (e.g., tumors of the brain or spinal cord, upper spinal cord injury, cerebrovascular accidents, multiple sclerosis, or Parkinson disease). It is treated with anticholinergics, catheterization, and surgical augmentation of the bladder.
   b. **Atonic neurogenic bladder** is a voiding dysfunction characterized by a **large urinary bladder** (i.e., increased capacity) and **detrusor areflexia** (underactivity of the detrusor muscle). It causes urine retention and subsequent overflow incontinence. It is associated with lower motor neuron lesions (e.g., spina bifida with meningomyelocele in the sacral region, sacral spinal cord injury, lumbar disk herniation that impinges on the sacral spinal nerves or the cauda equina, pelvic surgery or trauma that damages the pelvic splanchnic nerves, diabetes leading to peripheral neuropathy, tabes dorsalis, syringomyelia). It is treated with catheterization or surgical diversion of urine.

5. **Transitional cell carcinoma** is the most common type of tumor found in the bladder (> 90%). It is staged as Tis (carcinoma in situ), T1 (invasion of the lamina propria and submucosa), T2 (invasion of superficial muscle), T3 (invasion of deep muscle and surrounding fat), and T4 (invasion of other organs). Clinical findings include painless hematuria.

6. **Cystocele** occurs when the wall of the urinary bladder prolapses into the anterior wall of the vagina.

IV. URETHRA

A. The **male urethra** has three components.

1. The **prostatic urethra** courses through (and is surrounded by) the prostate gland. Its posterior wall contains an elevation called the **urethral crest** that contains the openings of the **ejaculatory ducts.** The openings of the **prostatic ducts** are located lateral to the urethral crest.
2. The **membranous urethra** courses through the urogenital diaphragm. It is surrounded by the **deep transverse perineal muscle** and **sphincter urethrae muscle (external urethral sphincter),** both of which are skeletal muscle innervated by the **pudendal nerve.**
3. The **penile (spongy, or cavernous) urethra** courses through the penis and is surrounded by the **corpus spongiosum.** It enlarges into the **fossa navicularis** just before it terminates at the **external urethral orifice.** The openings of the **bulbourethral glands of Cowper** are located just below the urogenital diaphragm.

B. The **female urethra** courses through the urogenital diaphragm. It is surrounded by the **deep transverse perineal muscle** and **sphincter urethrae muscle (external urethral sphincter),** both of which are skeletal muscle innervated by the **pudendal nerve.** The posterior surface of the female urethra fuses with the anterior wall of the vagina, and the **external urethral sphincter** does not completely surround the female urethra. For this reason, there is a high incidence of stress incontinence in women, especially after childbirth. The urethra terminates at the **external urethral orifice,** which opens into the **vestibule of the vagina** between the labia minora.

V. MICTURITION REFLEX.

As the bladder fills with urine, sensory impulses from stretch receptors within the bladder travel to the sacral spinal cord through the **pelvic splanchnic nerves (parasympathetics; S2–S4).** Motor impulses travel with the **pelvic splanchnic nerves (parasympathetics; S2–S4),** which contract the detrusor muscle. The **sphincter urethrae muscle (external urethral sphincter)** is innervated by the **pudendal nerve** and is voluntarily relaxed.

VI. RADIOLOGY

A. Intravenous pyelograms (IVP) of renal anomalies: kidney malrotation, bilateral pelvic kidneys, horseshoe kidney, and renal pelvis and ureter duplication **(Figure 12-5)**

B. CT scan, IVP, and arteriogram of renal cell carcinoma **(Figure 12-6)**

C. Radiographic views of normal kidney and different types of renal calculi **(Figure 12-7)**

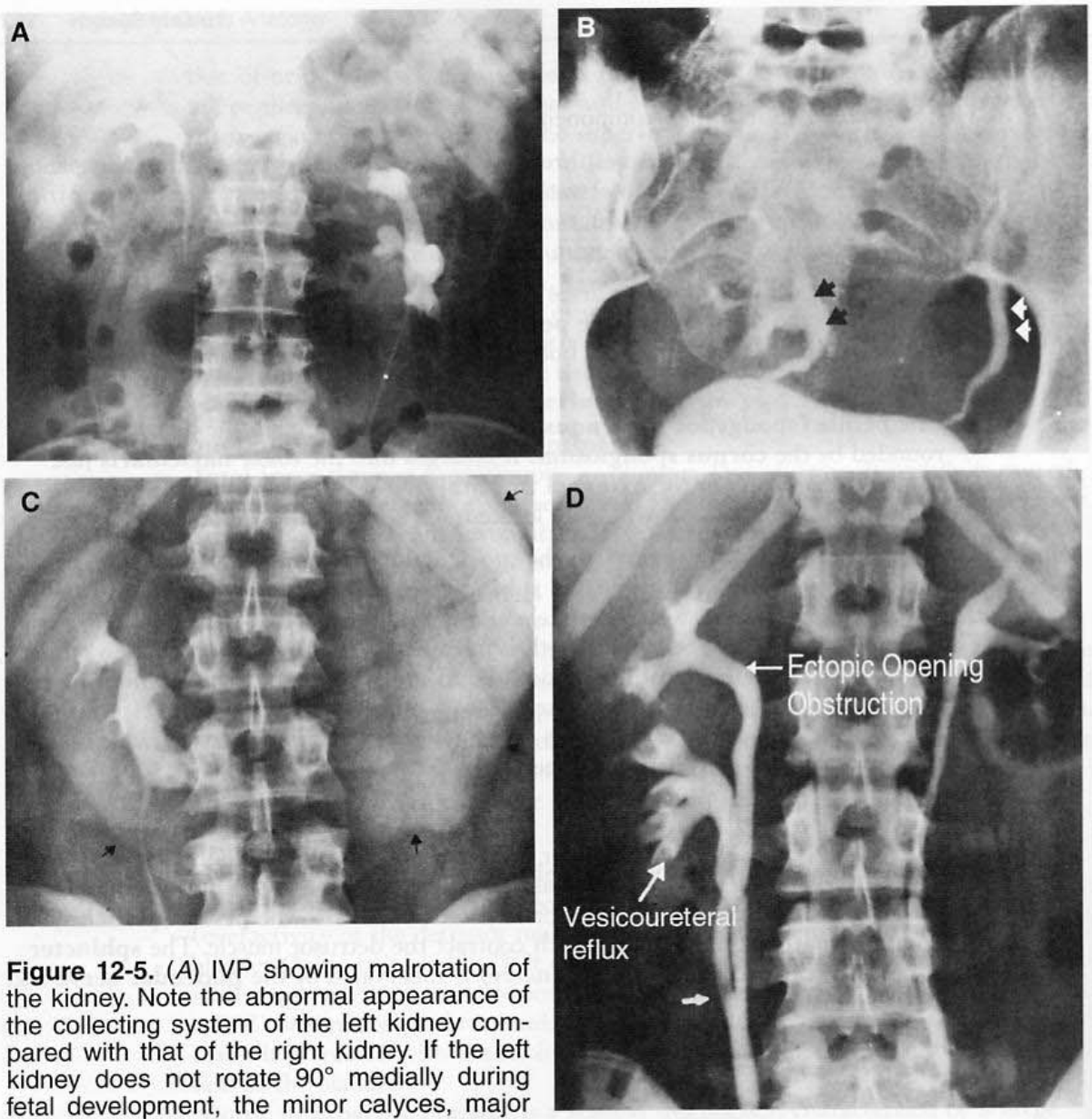

Figure 12-5. (*A*) IVP showing malrotation of the kidney. Note the abnormal appearance of the collecting system of the left kidney compared with that of the right kidney. If the left kidney does not rotate 90° medially during fetal development, the minor calyces, major calyces, and renal pelvis are oriented in the sagittal plane instead of the longitudinal plane. Note that the ureter also is displaced laterally. Note also that the left kidney is abnormally lower than the right kidney. The right kidney ascended and rotated normally, whereas the left kidney ascended and rotated abnormally. (*B*) IVP showing bilateral pelvic kidneys, resulting from the failure of both kidneys to ascend normally. *Arrows* indicate the collecting systems of both kidneys. The pelvis is the most common location of an ectopic kidney, a condition that usually occurs in boys, and usually on the left side. Approximately 50% of pelvic kidneys have some pathology, with poor function. (*C*) IVP showing a horseshoe kidney *(arrows)*, which results from fusion of the inferior poles of both kidneys during fetal development. The left side of the horseshoe kidney shows delayed filling of the calyces (compared with the right side), probably because of an obstruction. (*D*) Duplication of the renal pelvis and the upper portion of the ureter of the right kidney. In this case, the two ureters on the right side fuse into a single ureter at vertebral level L4 (*arrow*). However, the two ureters may remain separate throughout their course and open separately as follows: the ureter from the lower pole of the kidney may open at the urinary bladder trigone, whereas the ureter from the upper pole of the kidney usually has an ectopic opening and is obstructed. In addition, this congenital anomaly often is associated with backflow of urine from the urinary bladder up the ureter (vesicoureteral reflux). This backflow most commonly occurs up the ureter to the lower pole of the kidney. (*A-C* reprinted and *D* adapted with permission from Eisenberg RL: *Diagnostic Imaging in Surgery.* New York, McGraw-Hill, 1987, pp 531—533.)

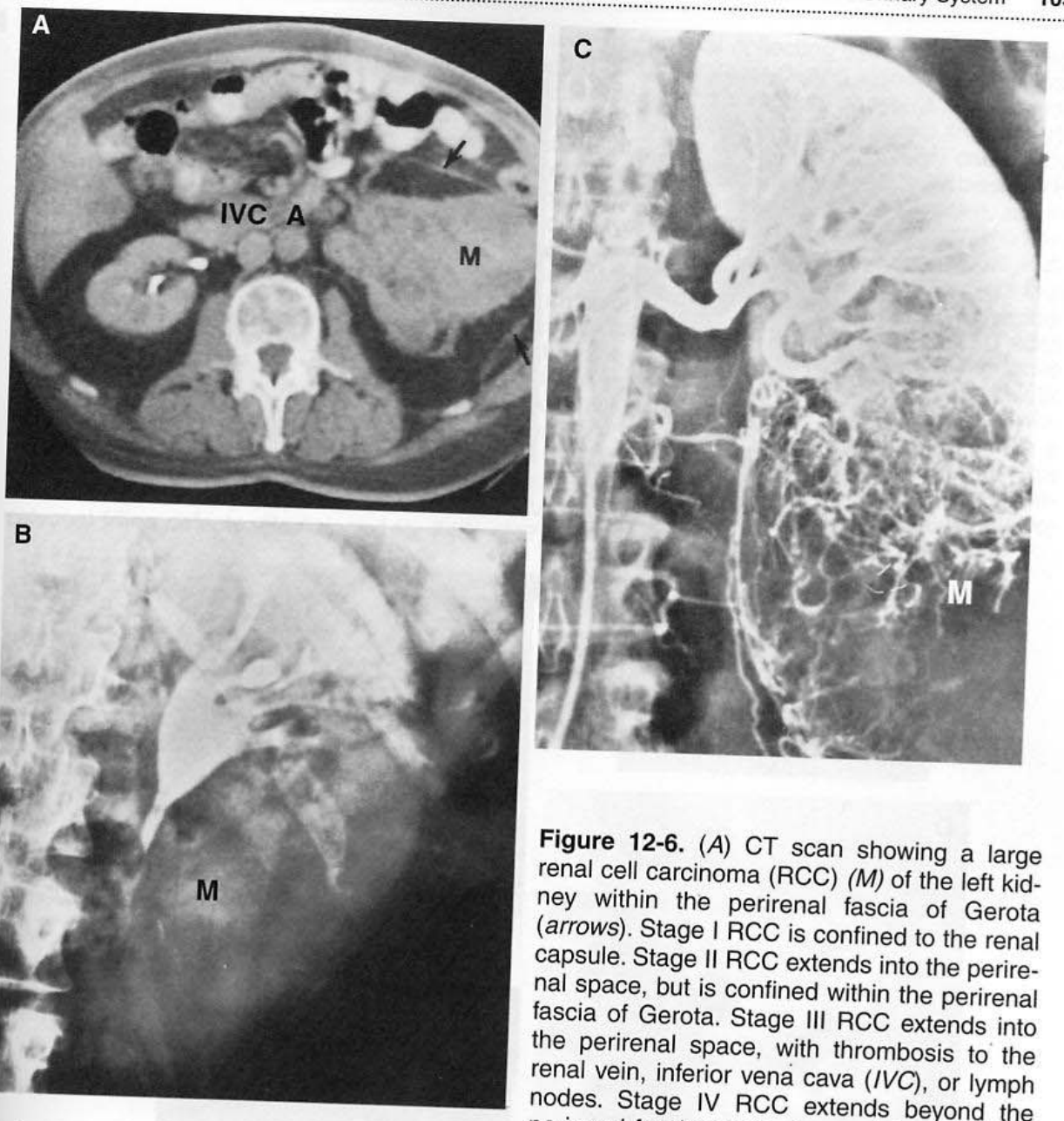

Figure 12-6. (*A*) CT scan showing a large renal cell carcinoma (RCC) *(M)* of the left kidney within the perirenal fascia of Gerota (*arrows*). Stage I RCC is confined to the renal capsule. Stage II RCC extends into the perirenal space, but is confined within the perirenal fascia of Gerota. Stage III RCC extends into the perirenal space, with thrombosis to the renal vein, inferior vena cava (*IVC*), or lymph nodes. Stage IV RCC extends beyond the perirenal fascia of Gerota, resulting in distant metastasis. *A* = aorta. (*B*) IVP of RCC that has displaced the calyces upward (i.e., an RCC is never drained by a calyx). The following normal kidney bulges may be confused with RCC: a persistent fetal lobation pattern, a dromedary hump on the lateral border of the left kidney caused by the normal impression of the spleen, or a large renal column of Bertin. All normal kidney bulges are drained by a calyx. (*C*) Arteriogram of RCC. Note the haphazard vascular pattern within the RCC *(M)* compared with the normal pattern within the upper pole of the left kidney. An arteriogram also may be used to show the difference between an RCC, which shows a haphazard vascular pattern, and a large renal cyst, which is avascular. [*A* adapted with permission from McClennan BL, Lee JKT: Kidney. In Lee JKT, Sagel SS, Stanley RJ (eds): *Computed Body Tomography.* New York, Raven Press, 1983; *B* and *C* adapted with permission from Freedman M: *Clinical Imaging: An Introduction to the Role of Imaging in Clinical Practice.* New York, Churchill Livingstone, 1988, pp 452, 453.]

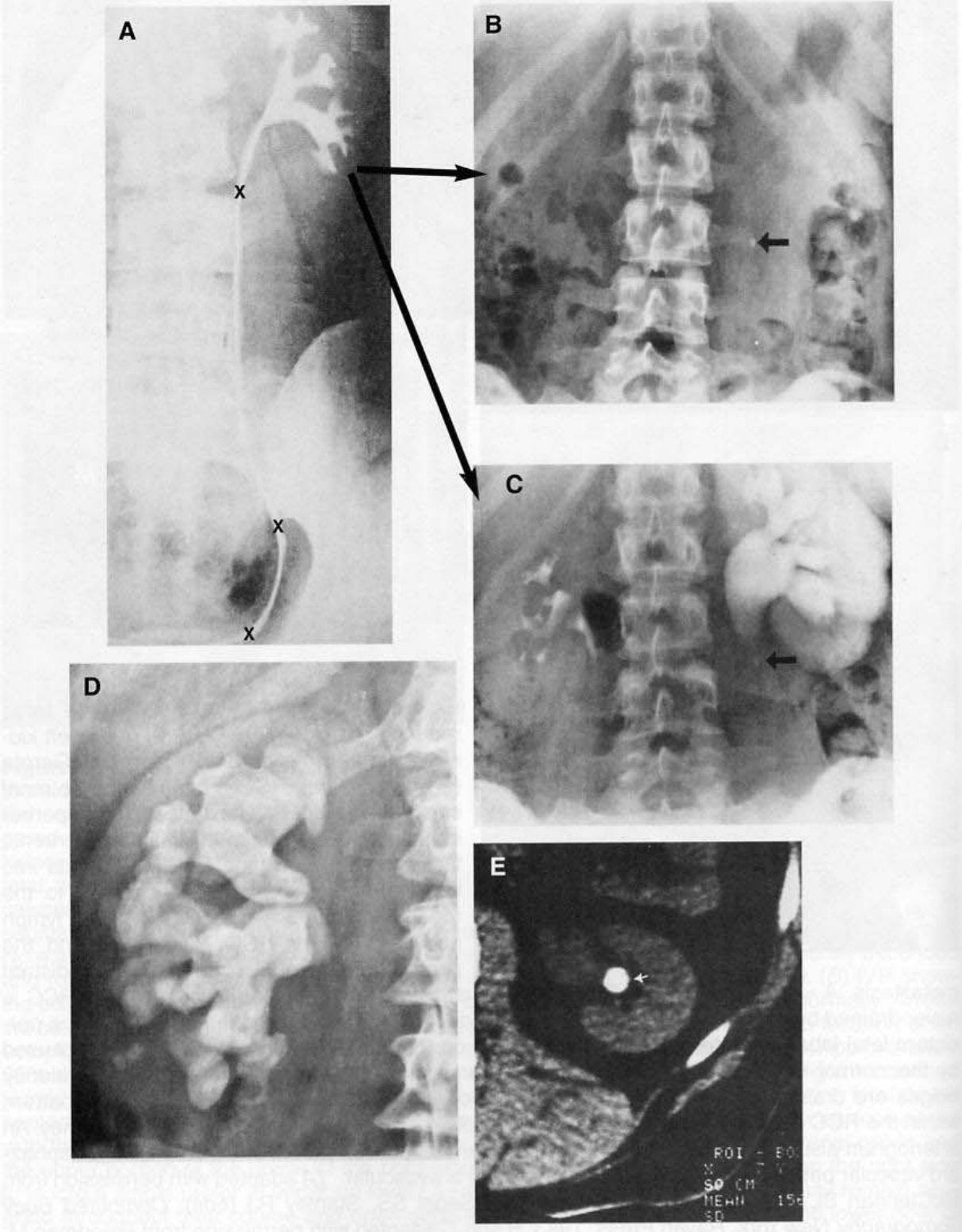
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Figure 12-7. (*A*) IVP showing a normal kidney, with the normal collecting system of the kidney and the ureter. The ureters normally are constricted at three sites *(X)*, and kidney stones most commonly cause obstruction at these sites. (*B*) Anteroposterior radiograph of renal calculi. A kidney stone (*arrow*) is located at the ureteropelvic junction (junction of the renal pelvis and ureter). (*C*) IVP of renal calculi. Unilateral hydronephrosis (dilation of the collecting system) caused by kidney stone obstruction at the ureteropelvic junction (*arrow*). In renal calculi, the classic IVP findings are: a very dense nephrogram in acute obstruction, a greatly delayed pyelogram, significantly delayed opacification of urine in an obstructed system, and atrophy of the kidney with narrowing of the kidney parenchyma in chronic obstruction. (*D*) IVP showing staghorn calculi. Kidney stones may conform to the shape of all or part of the collecting system. Kidney stones that fill at least two adjacent calyces are called staghorn calculi. These calculi usually are magnesium ammonium sulfate (struvite or triple phosphate) calculi caused by bacterial infection. (*E*) CT scan of renal calculi showing a kidney stone (*arrow*) within the calyces. All kidney stones appear dense on CT scans (in contrast to routine radiographs). (*A* adapted with permission from Pansky B: *Review of Gross Anatomy,* 6th ed. New York, McGraw-Hill, 1996, p 443; *B* and *C* adapted with permission from Eisenberg RL: *Diagnostic Imaging in Surgery.* New York, McGraw-Hill, 1987, p 542; *D* reprinted with permission from Freedman M: *Clinical Imaging: An Introduction to the Role of Imaging in Clinical Practice.* New York, Churchill Livingstone, 1988, p 435; *E* reprinted with permission from Parienty RA, Ducellier R, Pradel J-M et al: Diagnostic value of CT numbers in pelvocalyceal filling defects. *Radiology* 145: 743—747, 1977.)

13

Suprarenal (Adrenal) Glands

I. GENERAL FEATURES

A. The right suprarenal gland is pyramid-shaped. Its apex projects superiorly, and its base surrounds the kidney. The left suprarenal gland is shaped like a **half-moon.** It covers the superior aspect of the kidney and extends inferiorly along the medial aspect.

B. The **arterial supply** is from the inferior phrenic artery via the **superior suprarenal artery;** the aorta via the **middle suprarenal artery;** and the renal artery via the **inferior suprarenal artery**.

C. **Venous drainage** is to the **right suprarenal vein,** which empties into the inferior vena cava, and the **left suprarenal vein,** which empties into the left renal vein. The venous drainage is particularly important during **adrenalectomy** because the suprarenal vein must be ligated as soon as possible to prevent the release of catecholamines (epinephrine and norepinephrine) into the circulation. In addition, the adrenal medulla receives venous blood that drains from the cortex, which has a high concentration of cortisol. Synthesis of **phenylethanolamine-N-methyltransferase** (a key enzyme in the synthesis of epinephrine) requires high levels of cortisol, which is carried through venous blood from the cortex.

II. ADRENAL CORTEX is derived embryologically from mesoderm and is divided into three areas.

A. **Zona glomerulosa** accounts for 15% of the cortical volume and secretes **aldosterone,** which is controlled by the **renin-angiotensin system.**

B. **Zona fasciculata** accounts for 78% of the cortical volume and secretes **cortisol,** which is controlled by **corticotropin-releasing factor (CRF)** and **adrenocorticotropic hormone (ACTH),** from the hypothalamus and the adenohypophysis, respectively.

C. **Zona reticularis** accounts for 7% of the cortical volume and secretes **dehydroepiandrosterone (DHEA)** and **androstenedione,** which are controlled by **CRF** and **ACTH,** from the hypothalamus and adenohypophysis, respectively.

D. **Clinical considerations (Table 13-1)**

1. **Primary hyperaldosteronism**
   a. **Cause.** Elevated levels of aldosterone most commonly are caused by an aldosterone-secreting adenoma **(Conn syndrome)** within the zona glomerulosa or by adrenal hyperplasia.
   b. **Clinical findings** include: hypertension, hypernatremia as a result of increased sodium ion reabsorption, weight gain as a result of water retention, hypokalemia because of increased potassium secretion, and decreased plasma renin levels.

Table 13-1.
Laboratory Findings Used to Diagnose Adrenal Gland Disorders*

Clinical Condition	Suppression with Dexamethasone Test†	Plasma Levels			
		Aldosterone	Cortisol	Androgens	ACTH
Primary hyperaldosteronism (Conn syndrome)		High			
Cushing syndrome					
ACTH adenoma	Positive		High		High
Adrenal adenoma	Negative		High		Low
Normal patient	Positive		Normal		Normal
Congenital adrenal hyperplasia					
21-hydroxylase deficiency		Low	Low	High	High
11β-hydroxylase deficiency		Low	Low	High	High
Addison disease (primary adrenal insufficiency)		Low	Low	Low	High
Secondary adrenal insufficiency		Normal	Low	Low	Low

ACTH = adrenocorticotropic hormone.
*Many clinical vignette questions include the plasma levels of various hormones or the results of a dexamethasone test. Knowing which hormone levels are increased, decreased, normal, or not applicable in certain clinical conditions will be of great assistance in answering these questions.
†The **dexamethasone suppression test** is based on the ability of dexamethasone (a synthetic glucocorticoid) to inhibit the secretion of ACTH and cortisol. If the adenohypophysis–adrenal cortex axis is normal, dexamethasone inhibits ACTH and cortisol secretion by negative feedback.

c. **Treatment** is with surgery or **spironolactone,** which is an aldosterone receptor antagonist and, therefore, an effective antihypertensive and diuretic agent.

2. **Cushing syndrome**
   a. **Cause.** Elevated levels of **cortisol (hypercortisolism)** commonly are caused by an ACTH-secreting adenoma within the adenohypophysis (seen in 70% of cases; known as **Cushing disease**), an adrenal adenoma (25% of cases), or adrenal hyperplasia (5% of cases). Oat cell carcinoma of the lung also may produce ACTH ectopically. However, Cushing syndrome most commonly is caused iatrogenically by corticosteroid drug therapy.
   b. **Clinical findings** include: mild hypertension, osteoporosis with back pain, central obesity, moon facies, purple skin striae, and impaired glucose tolerance.
   c. **Treatment** is with **ketoconazole,** an inhibitor of steroid biosynthesis.

3. **Congenital adrenal hyperplasia (CAH)**
   a. **Cause.** CAH most commonly is caused by mutations in the genes for enzymes involved in adrenocortical steroid biosynthesis (e.g., **21-hydroxylase deficiency, 11β-hydroxylase deficiency**). In 21-hydroxylase deficiency (seen in 90% of cases), virtually no synthesis of aldosterone or cortisol occurs. As a result, inter-

mediates are funneled into androgen biosynthesis, and androgen levels are elevated as a result.

b. **Clinical findings.** The elevated levels of androgens lead to **virilization of a female fetus** that can range from mild clitoral enlargement to complete labioscrotal fusion with a phalloid organ. Increased urinary levels of 17-ketosteroids are found. Because cortisol cannot be synthesized, negative feedback to the adenohypophysis does not occur, and ACTH continues to stimulate the adrenal cortex, resulting in **adrenal hyperplasia.**

c. **Treatment.** Depending on the severity of the condition, treatment may include surgical reconstruction and steroid replacement.

4. **Primary adrenal insufficiency (Addison disease)**

a. **Cause.** Primary adrenal insufficiency commonly is caused by autoimmune destruction of the adrenal cortex. Other causes include adrenal tuberculosis, fungal infection, and adrenal hemorrhage.

b. **Clinical findings** include: fatigue, anorexia, nausea, weight loss, hypoglycemia, hypotension, and hyperpigmentation of the skin as a result of increased secretion of melanocyte-stimulating hormone.

c. **Treatment** is steroid replacement therapy.

5. **Secondary adrenal insufficiency**

a. **Cause.** Secondary adrenal insufficiency is caused by a disorder of the hypothalamus or adenohypophysis that decreases ACTH secretion. The most common cause is iatrogenic suppression of ACTH as a side effect of corticosteroid drug therapy.

b. **Clinical findings** are very similar to those of Addison disease, except that there is no hyperpigmentation of the skin.

c. **Treatment** is steroid replacement therapy.

III. ADRENAL MEDULLA

A. General features. The adrenal medulla contains chromaffin cells, which are modified postganglionic sympathetic neurons that are derived embryologically from neural crest cells. Preganglionic sympathetic axons (through splanchnic nerves) synapse on chromaffin cells, causing these cells to secrete catecholamines **(90% epinephrine and 10% norepinephrine).**

B. Clinical considerations

1. **Pheochromocytoma** is a relatively rare neoplasm (usually not malignant) of **neural crest origin** that contains both epinephrine and norepinephrine.

a. **Characteristics.** Pheochromocytoma occurs within families, primarily in adults, as part of the **multiple endocrine neoplasia (MEN) type IIa syndrome** (pheochromocytoma, hyperparathyroidism, and medullary carcinoma of the thyroid) or in association with **von Recklinghausen neurofibromatosis**. It usually is found in the region of the adrenal gland, but also is found in extra-adrenal sites (e.g., near the aortic bifurcation called the **organ of Zuckerkandl**).

b. **Clinical findings.** It is associated with persistent or paroxysmal hypertension, anxiety, tremor, profuse sweating, pallor, and chest and abdominal pain.

c. **Diagnosis.** Increased urinary levels of vanillylmandelic acid metanephrine, inability to suppress catecholamines with clonidine, and hyperglycemia are common laboratory findings.

d. **Treatment** consists of surgery or **phenoxybenzamine** (an α-adrenergic antagonist).

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IV. RADIOLOG

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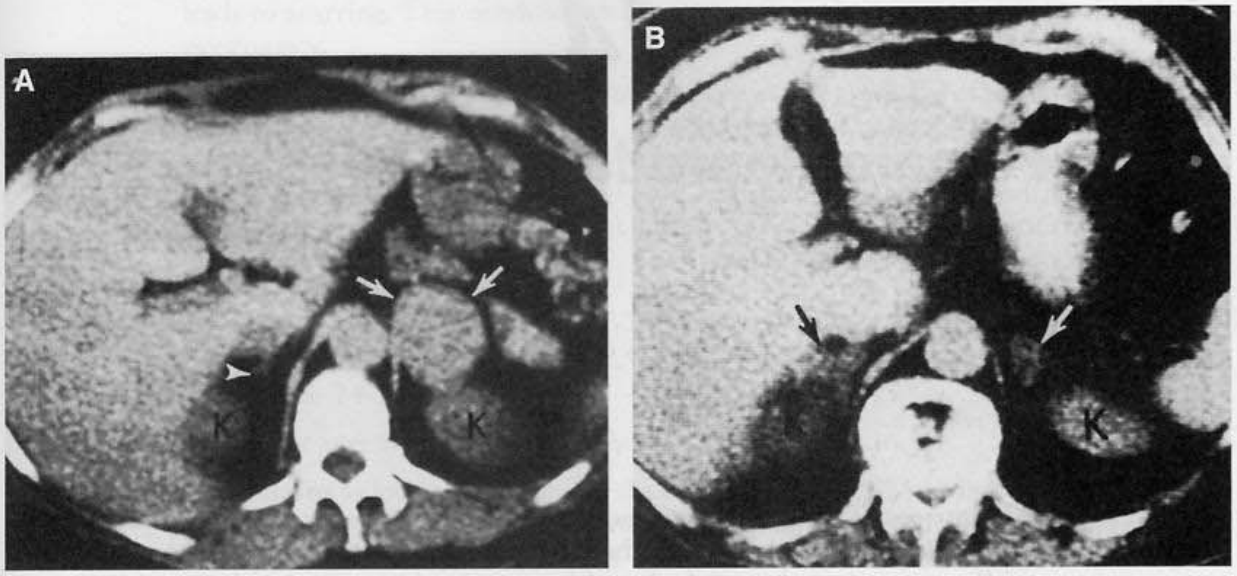


Figure 13-1. (*A*) CT scan of a patient with Cushing syndrome caused by an adrenal adenoma. A large mass (*arrows*) is seen in the left adrenal gland, posterior to the pancreas and anterior to the kidney (*K*). The normal right adrenal gland is shown (*arrowhead*). An adrenal adenoma usually occurs unilaterally, whereas adrenal hyperplasia occurs bilaterally. (*B*) CT scan of a patient with Cushing syndrome caused by adrenal hyperplasia. Both adrenal glands (*arrows*) are enlarged, but they retain their normal anatomic shapes. The normal appearance of the adrenal glands, except for the increased size, may confound the diagnosis. In some cases of adrenal hyperplasia, the adrenal glands show bilateral nodularity. [Reprinted with permission from Weyman PJ, Glazer HS: Adrenals. In Lee JKT, Sagel SS, Stanley RS (eds): *Computed Body Tomography.* New York, Raven Press, 1983.]

2. **Neuroblastoma** is an extracranial neoplasm that contains primitive neuroblasts of **neural crest origin**.
   a. **Characteristics.** Neuroblastoma is the most common solid tumor in children and may metastasize to the bone marrow, liver, and orbit. It is found in extra-adrenal sites, usually along the sympathetic chain ganglia (60%) or within the adrenal medulla (40%).
   b. **Clinical findings.** Neuroblastoma is associated with **opsoclonus,** which is characterized by rapid, irregular, horizontal and vertical movements of the eye ("dancing eyes").
   c. **Diagnosis.** A neuroblastoma contains small cells arranged in **Homer-Wright pseudorosettes**. Increased urinary levels of vanillylmandelic acid and metanephrine are found.
   d. **Treatment** includes surgical excision, radiation, and chemotherapy.

IV. RADIOLOGY

A. Computed tomography (CT) scan of a patient with Cushing syndrome caused by an adrenal adenoma **(Figure 13-1A)**

B. CT scan of a patient with Cushing syndrome caused by adrenal hyperplasia **(Figure 13-1B)**

14

Female Reproductive System

I. OVARIES

A. General features. The ovaries are almond-shaped structures located **posterior** to the broad ligament. They are attached to the lateral pelvic wall by the **suspensory ligament of the ovary** (a region of the broad ligament), which contains the ovarian artery, vein, and nerve. The surface of the ovaries is not covered by peritoneum; they are covered by a simple cuboidal epithelium called the **germinal epithelium**. The arterial supply is from the abdominal aorta via the **ovarian arteries**. Venous drainage is to the **right ovarian vein,** which empties into the inferior vena cava, and the **left ovarian vein,** which empties into the left renal vein. **Right-sided hydronephrosis** in a female may indicate thrombosis of the right ovarian vein that is constricting the ureter, because the right ovarian vein crosses the ureter to enter the inferior vena cava. Ovarian pain often is referred down the inner thigh through the obturator nerve.

B. Clinical considerations

1. **Ovarian cancer.** The most common type is an **epithelial tumor,** which is a malignant transformation of the germinal epithelium that covers the ovary. The main lymphatic drainage of the ovary is to the deep **para-aortic lymph nodes** near the renal artery. The incidence of ovarian cancer is increased in women with **hereditary nonpolyposis colorectal cancer (HNPCC; Lynch syndrome II)**. Ovarian cancer is associated with mutations of the **p53 tumor suppressor gene**. The tumor markers **CEA** and **CA-125** are useful in diagnosis. A palpable ovary or adnexal mass usually suggests an ovarian neoplasm rather than an ovarian cyst.
2. **Ovarian cysts.** A **functional cyst** is a physiologically and hormonally active cyst that has not yet involuted. There are three types: **follicular cyst, corpus luteum cyst**, and **theca lutein cyst** (caused by elevated levels of **β-human chorionic gonadotropin**). Clinical findings include: sudden, extreme pelvic pain, especially in an adolescent girl. Functional cysts usually resolve spontaneously.

II. UTERINE (FALLOPIAN) TUBES

A. General features. The uterine tube has four divisions: the **infundibulum,** which opens into the peritoneal cavity; the **ampulla,** which is the site of fertilization; the **isthmus;** and the **intramural** section, which opens into the uterine cavity. The uterine tubes are supported by the **mesosalpinx,** which is a region of the broad ligament.

B. Clinical considerations

1. **Salpingitis** probably is the most common cause of female infertility. It is a bacterial infection (most commonly gonococcal) of the uterine tube, with inflammation that

leads to scarring. This condition predisposes affected women to an **ectopic tubal pregnancy.**

2. **Ectopic tubal pregnancy** most often occurs in the **ampulla** of the uterine tube. Risk factors include: salpingitis (see II B 1), pelvic inflammatory disease, pelvic surgery, and exposure to diethylstilbestrol in utero. Clinical findings include: sudden onset of abdominal pain, which may be confused with appendicitis in a young woman; last menses 60 or more days ago; positive result on human chorionic gonadotropin test; and intraperitoneal blood seen on culdocentesis.

III. UTERUS (Figure 14-1)

A. Regions. The uterus is divided into four regions.

1. The **fundus** is located superior to the cornua and contributes largely to the upper segment of the uterus during pregnancy. At term, the fundus may extend as high as the xiphoid process (vertebral level T9).
2. The **cornu** is located near the entry of the uterine tubes.
3. The **body** of the uterus is located between the cornu and the cervix. The **isthmus,** which is part of the body of the uterus, is the dividing line between the body of the uterus and the cervix. The isthmus is the preferred site for a surgical incision during cesarean delivery.
4. The **cervix** is located inferior to the body of the uterus. It protrudes into the vagina. It contains the **internal os, cervical canal**, and **external os.** In a nulliparous woman, the external os is round. In a parous woman, it is transverse.

B. Support. The uterus is supported by the following structures:

1. **Pelvic diaphragm (levator ani muscles)**
2. **Urogenital diaphragm**
3. **Urinary bladder**
4. **Round ligament of the uterus,** which is a remnant of the gubernaculum in the embryo
5. **Transverse cervical ligament (cardinal ligament of Mackenrodt),** which extends laterally from the cervix to the side wall of the pelvis. It is located at the base of the broad ligament and contains the **uterine artery,** which is a branch of the internal iliac artery.
6. **Uterosacral ligament,** which extends posteriorly from the cervix to the sacrum and is responsible for bracing the uterus in its normal **anteverted** position
7. **Pubocervical ligament,** which extends anteriorly from the cervix to the pubic symphysis and helps to prevent a **cystocele** (herniation of the urinary bladder into the anterior wall of the vagina)
8. **Broad ligament,** a double fold of parietal peritoneum that extends laterally from the uterus to the side wall of the pelvis
   a. The broad ligament is divided into four **regions**: the **mesosalpinx,** which supports the uterine tubes; the **mesovarium,** which supports the ovary; the **mesometrium,** which supports the uterus; and the **suspensory ligament of the ovary.**

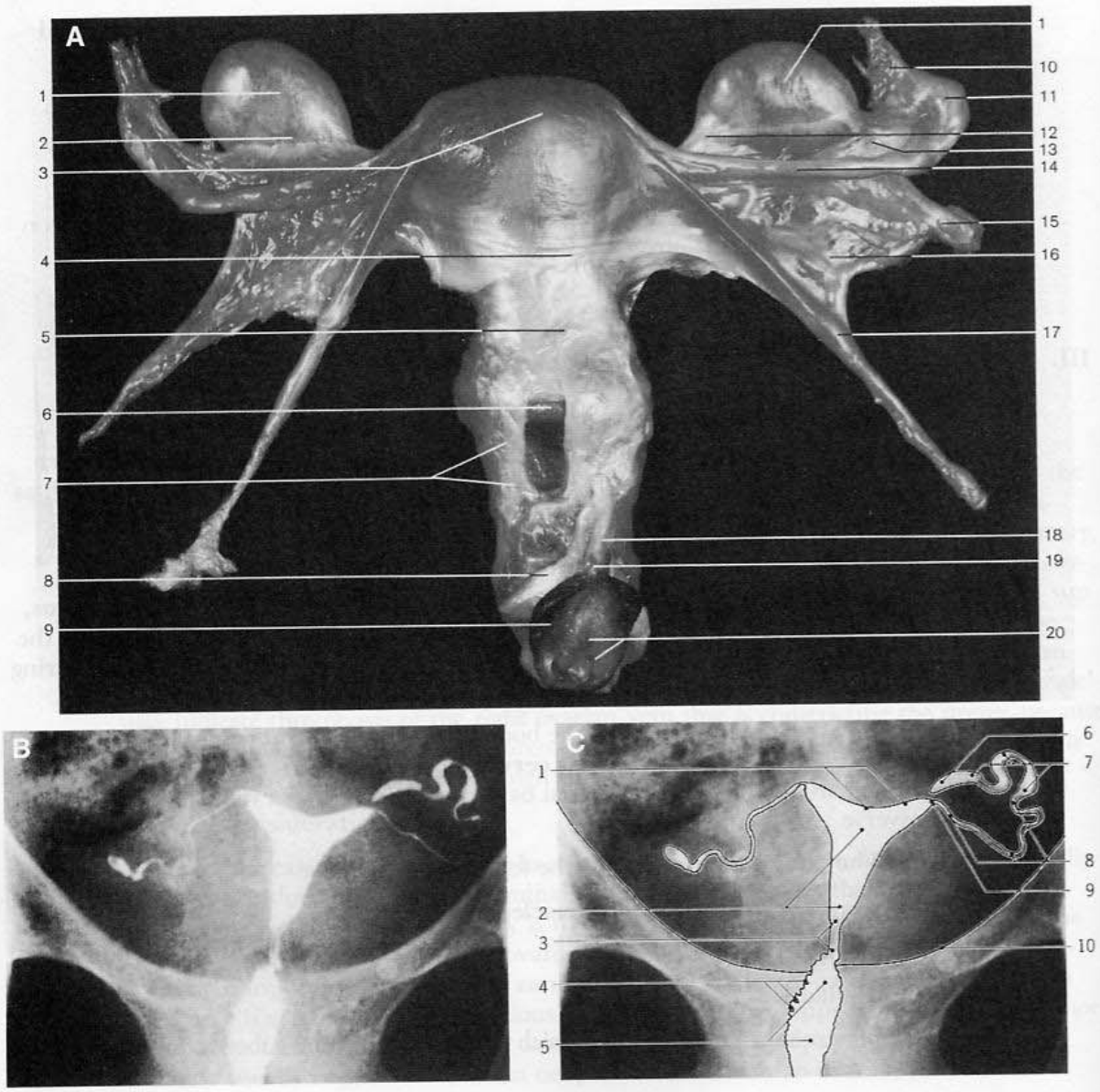


Figure 14-1. (*A*) Anterior view of the female genital organs, with the anterior wall of the vagina opened to show the cervix. *1* = ovary; *2* = mesovarium; *3* = fundus of the uterus; *4* = vesicouterine pouch; *5* = cervix; *6* = vaginal part of the cervix; *7* = vagina; *8* = crus of the clitoris; *9* = labium minus; *10* = infundibulum of the uterine tube; *11* = ampulla of the uterine tube; *12* = ovarian ligament of the uterus; *13* = mesosalpinx; *14* = uterine tube; *15* = suspensory ligament of the ovary (caudally displaced); *16* = broad ligament; *17* = round ligament of the uterus; *18* = corpus cavernosum of the clitoris; *19* = glans of the clitoris; *20* = hymen (vaginal orifice). (*B*) Anteroposterior radiograph of the female genital tract (hysterosalpingography). *1* = fundus of the uterus; *2* = uterine cavity; *3* = isthmus of the uterus; *4* = folds of the cervix; *5* = cervical canal (dilated and stretched); *6* = infundibulum of the uterine tube; *7* = ampulla of the uterine tube; *8* = isthmus of the uterine tube; *9* = opening of the uterine tube; *10* = pecten of the pubis. (*A* reprinted with permission from Rohen JW, Yokochi C, Lütjen-Drecoll E: *Color Atlas of Anatomy,* 4th ed. Baltimore, Williams & Wilkins, 1998, p 336; *B* reprinted with permission from Fleckenstein P, Tranum-Jensen J: *Anatomy in Diagnostic Imaging.* Philadelphia, WB Saunders, 1993, p 291.)

b. The broad ligament contains the following structures: the **ovarian artery, vein, and nerves;** the **uterine tubes;** the **ovarian ligament of the uterus,** which is a remnant of the gubernaculum in the embryo; the **round ligament of the uterus**, which is a remnant of the gubernaculum in the embryo; the **epoophoron,** which is a remnant of the mesonephric tubules in the embryo; the **paroophoron,** which is a remnant of the mesonephric tubules in the embryo; the **Gartner duct,** which is a remnant of the mesonephric duct in the embryo; the **ureter,** which lies at the base of the broad ligament posterior and inferior to the uterine artery (during hysterectomy, the ureters inadvertently may be ligated along with the uterine artery because of their close anatomic relation); and the **uterine artery, vein, and nerves,** which lie at the base of the broad ligament within the transverse cervical ligament.

C. Position of the uterus. The uterus usually is in an anteflexed and anteverted position, which places it in a nearly horizontal position, lying on the superior wall of the urinary bladder. **Anteflexed** refers to the anterior bend of the uterus at the angle between the cervix and the body of the uterus. **Anteverted** refers to the anterior bend of the uterus at the angle between the cervix and the vagina.

D. Clinical considerations

1. **Cervical carcinoma** is the most common gynecologic malignancy. It may spread to the side wall of the pelvis, where the ureters may become obstructed, leading to hydronephrosis. The most common site of lymph node spread (i.e., sentinel nodes) is to the **obturator lymph nodes**.

2. **Uterine fibrinoid (leiomyoma)** is a common benign neoplasm that results from a proliferation of smooth muscle cells of the uterus; these smooth muscle cells may become calcified. Fibrinomas may be located within the myometrium of the uterus (intramural); beneath the endometrium (submucosa), where they may grow into the uterine cavity; or beneath the serosa (subserosal), where they may grow into the peritoneal cavity. They may cause infertility if they block the uterine tube or prevent implantation of the conceptus. They may be palpated as irregular, nodular masses that protrude against the anterior abdominal wall.

IV. VAGINA

A. General features. The vagina extends from the cervix to the vestibule. It is the longest part of the birth canal. The degree to which it can distend during childbirth is limited by the ischial spines and sacrospinous ligaments. It forms a recess around the cervix called the **fornix**. The fornix is divided into three regions:

1. The **anterior fornix** is located anterior to the cervix. It is related to the vesicouterine pouch. On digital examination, the urinary bladder is palpable through the anterior fornix.

2. The **lateral fornices** are located lateral to the cervix.

3. The **posterior fornix** is located posterior to the cervix. On digital examination, the rectum, sacral promontory (vertebral body S1), and coccyx are palpable through the posterior fornix. It is a site for culdocentesis and is related to the rectouterine pouch of Douglas.

B. Clinical considerations

1. In **culdocentesis,** a needle is passed through the posterior fornix into the rectouterine pouch of the peritoneal cavity to obtain a fluid sample for analysis or to collect

oocytes for in vitro fertilization. This procedure provides diagnostic information for many gynecologic conditions (e.g., pelvic inflammatory disease, ectopic tubal pregnancy).

2. **Cystocele** is herniation of the urinary bladder into the anterior wall of the vagina.
3. **Rectocele** is herniation of the rectum into the posterior wall of the vagina.

V. EXTERNAL GENITALIA (Figure 14-2)

A. The **labia majora** are two folds of hairy skin with underlying fat pads.

B. The **labia minora** are two folds of hairless skin located medial to the labia majora. They enclose the vestibule of the vagina. Each labium minus is continuous anteriorly with the **prepuce of the clitoris** and the **frenulum of the clitoris** and posteriorly with the **fourchette,** which connects the labia minora with the **vaginal introitus (entry).**

C. The **vestibule of the vagina** is the space between the labia minora. It contains the **urethral orifice;** the **paraurethral glands (glands of Skene);** the **vaginal introitus,** which is incompletely covered by the **hymen;** the **greater vestibular glands of Bartholin;** and the **lesser vestibular glands.**

D. The **clitoris** is homologous with the penis, but it has no corpus spongiosum and does not transmit the urethra. The **body of the clitoris** is formed by two **corpora caver-**

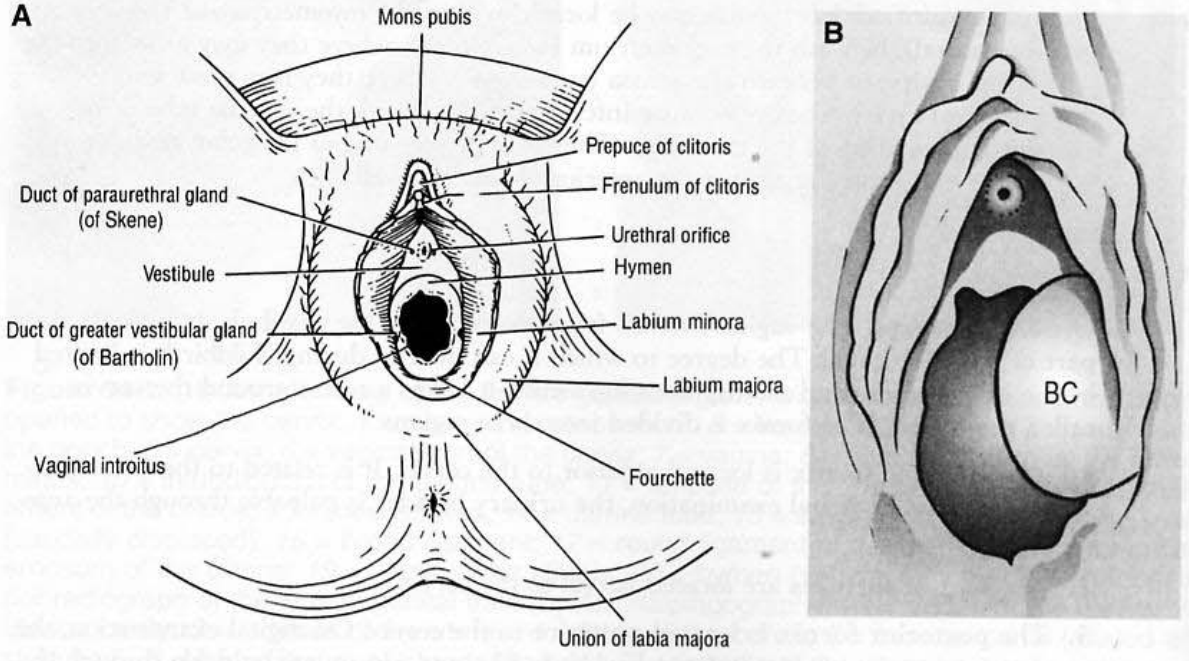


Figure 14-2. (*A*) The female genitalia. (*B*) Diagram of a Bartholin cyst (*BC*) on the left side of the vestibule of the vagina. This cyst is caused by an obstruction of the duct from the greater vestibular glands (of Bartholin). (*A* adapted with permission from Snell RS: *Clinical Anatomy for Medical Students,* 5th ed. Boston, Little Brown, 1995, p 364; *B* adapted with permission from Callahan TL, Caughey AB, Heffner LJ: *Blueprints in Obstetrics & Gynecology.* Malden, MA, Blackwell, 1998, p 103.)

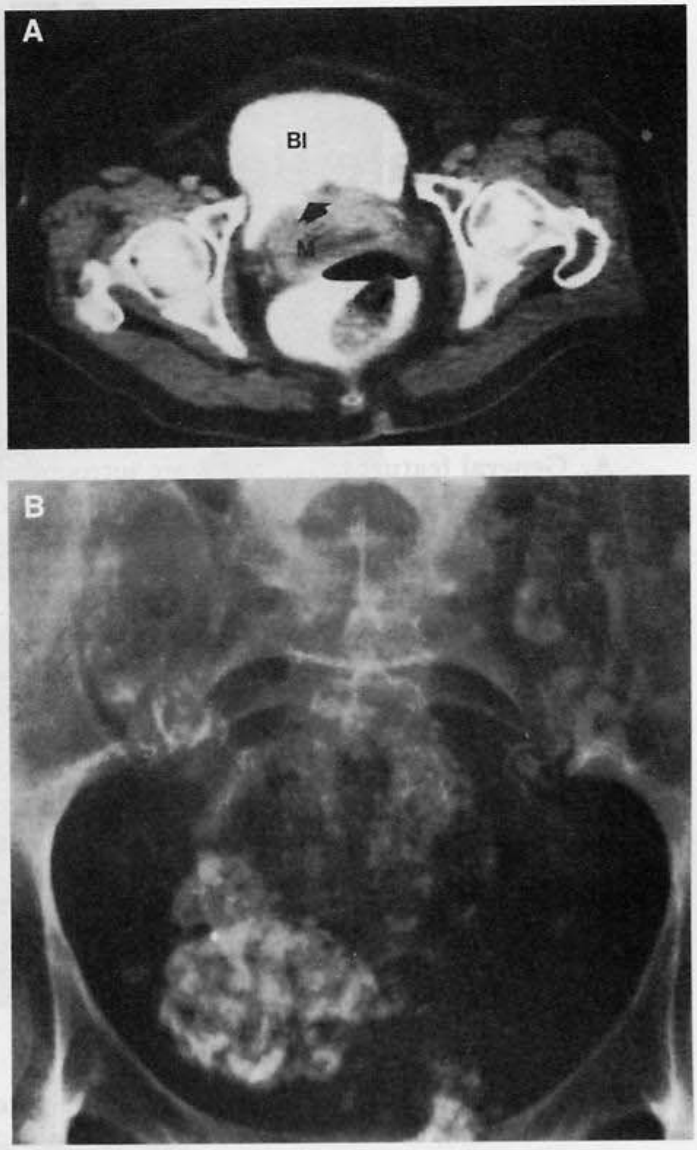


Figure 14-3. (*A*) CT scan showing invasive cervical carcinoma. Note that the posterior margin of the contrast-filled urinary bladder (*Bl*) is compressed because of the tumor mass (*M*) of the cervical carcinoma. (*B*) Radiograph of a calcified uterine fibrinoid (leiomyoma). Fibrinoids appear as nodules with a whorled pattern and often are calcified. A very large fibrinoid may occupy the entire pelvic cavity or may even extend into the abdomen. [*A* reprinted with permission from Gross BH, Callen PW: Ultrasound in the uterus. In Callen PW (ed): *Ultrasonography in Obstetrics and Gynecology.* Philadelphia, WB Saunders, 1983; *B* reprinted with permission from Eisenberg RL: *Gastrointestinal Radiology: A Pattern Approach.* Philadelphia, JB Lippincott, 1983.]

nosa, which are continuous with the crura. The **glans of the clitoris** is formed by the fusion of the **vestibular bulbs.**

VI. RADIOLOGY

A. CT scan showing invasive cervical carcinoma **(Figure 14-3A)**

B. Radiograph showing a calcified uterine fibrinoid (leiomyoma) **[Figure 14-3B]**

15

Male Reproductive System

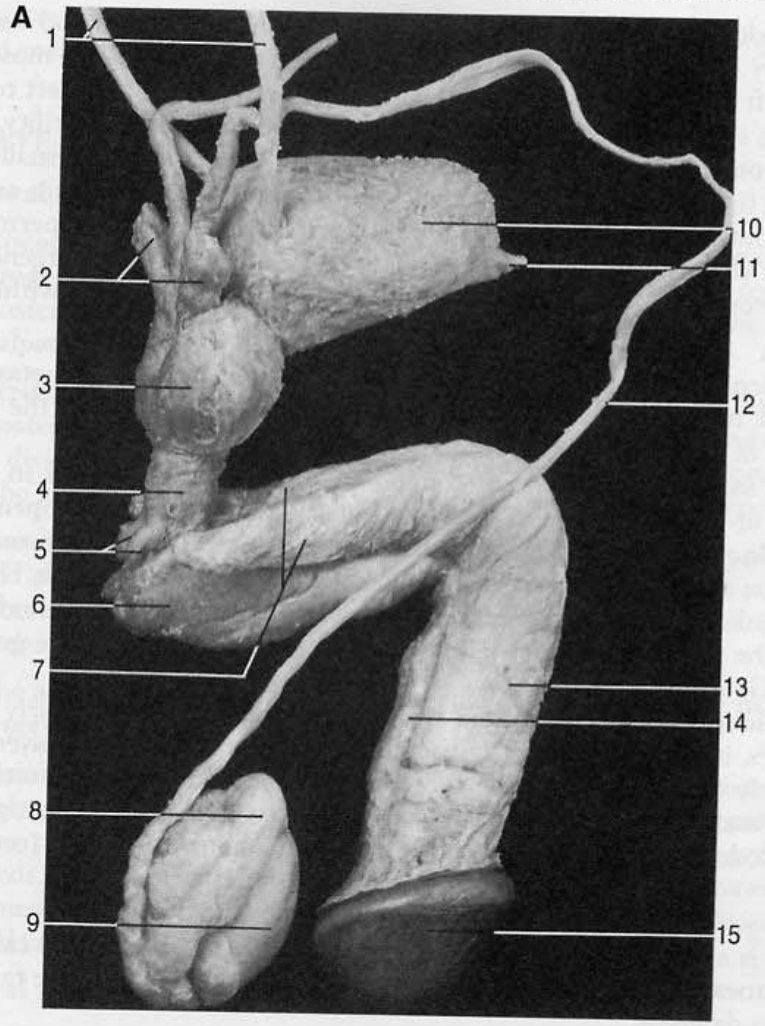
I. TESTES (Figure 15-1)

A. General features. The testes are surrounded by a thick connective tissue layer, the **tunica albuginea.** They are further surrounded incompletely–medially, anteriorly, and laterally, but not posteriorly–by a sac of peritoneum called the **tunica vaginalis.** The testes contain the **seminiferous tubules, straight tubules, rete testes,** and **efferent ductules.** Arterial blood is supplied from the abdominal aorta via the **testicular arteries.** A rich collateral arterial blood supply is provided from the internal iliac artery via the **artery of the ductus deferens,** the inferior epigastric artery via the **cremasteric artery,** and the femoral artery via the **external pudendal artery.** The collateral circulation is sufficient to permit ligation of the testicular artery during surgery. Venous drainage is to the **right testicular vein,** which empties into the inferior vena cava, and the **left testicular vein,** which empties into the left renal vein. The testicular veins are formed by the union of the veins of the **pampiniform plexus.** A **left-sided testicular varicocele** may indicate occlusion of the left testicular vein or the left renal vein by a malignant tumor of the kidney. Lymphatic drainage of the testes is to **deep lumbar nodes** near the renal hilus; knowledge of this route aids in evaluating the spread of testicular cancer. Lymphatic drainage of the scrotum is to **superficial inguinal nodes.**

B. Clinical considerations

1. **Disorders**
   - **a. Cryptorchidism** results when the testes begin to descend along the *normal* pathway, but do not reach the scrotum. In contrast, an **ectopic testis** descends along an *abnormal* pathway. In cryptorchidism, the undescended testis usually is found within the **inguinal canal** or the **abdominal cavity near the deep inguinal ring.** Bilateral cryptorchidism results in **sterility** because the testes require the cooler temperature of the scrotal sac for spermatogenesis. Cryptorchidism is associated with an increased incidence of cancer and torsion.
   - **b. Hydrocele of the testes** occurs when a small patency of the processus vaginalis remains, allowing peritoneal fluid to flow into the tunica vaginalis surrounding the testes.

Figure 15-1. (*A*) The male reproductive system. Note the pathway followed by sperm: seminiferous tubules → straight tubules → rete testes → efferent ductules → epididymis → ductus deferens → ejaculatory duct → prostatic urethra → membranous urethra → penile urethra. *1* = ureter; *2* = seminal vesicle; *3* = prostate gland; *4* = membranous urethra (with urogenital diaphragm); *5* = bulbourethral (Cowper) glands; *6* = bulb of the penis; *7* = left and right crura of the penis; *8* = epididymis; *9* = testes; *10* = urinary bladder; *11* = apex of the urinary bladder; *12* = ductus deferens; *13* = corpus cavernosum; *14* = corpus spongiosum; *15* = glans penis. (*B*) Cross-section of the penis. (*A* reprinted with permission from Rohen JW, Yokochi C, Lütjen-Drecoll E: *Color Atlas of Anatomy,* 4th ed. Baltimore, Williams & Wilkins, 1998, p 316; *B* adapted with permission from Chung KW: *BRS Gross Anatomy*, 2nd ed. Baltimore, Williams & Wilkins, 1991.) ▶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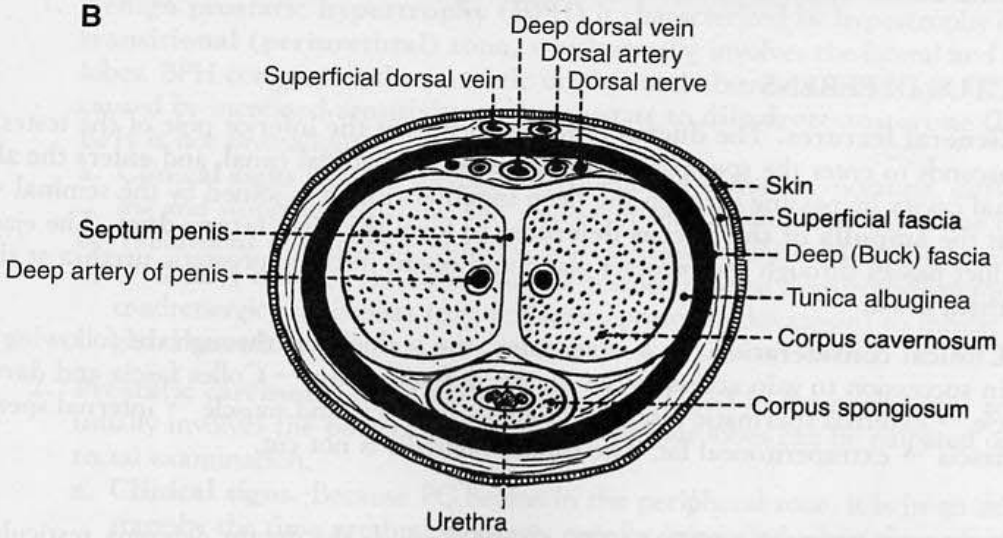

B
Deep dorsal vein
Dorsal artery
Superficial dorsal vein
Dorsal nerve
Skin
Superficial fascia
Septum penis
Deep (Buck) fascia
Deep artery of penis
Tunica albuginea
Corpus cavernosum
Corpus spongiosum
Urethra

c. **Varicocele** is abnormal dilation of the pampiniform plexus and testicular vein. It usually causes a palpable "bag of worms" scrotal swelling. It is most common on the left side (90%), where it is caused by compression of the left testicular vein by the sigmoid colon. Varicocele often is associated with infertility.

d. **Torsion** is rotation of the testes around the spermatic cord, usually toward the penis (i.e., medially). The incidence is increased when the testes are positioned horizontally and the tunica vaginalis is attached high on the spermatic cord ("bell clapper deformity"). Testicular torsion is a medical emergency because compression of the testicular vessels causes ischemic necrosis within 6 hours.

2. **Cancers**

a. **Testicular lymphoma** occurs when a malignant lymphoma metastasizes to the testes. It presents as a testicular mass. Testicular lymphoma is the most common form of testicular cancer in men older than 60 years of age.

b. **Yolk sac tumor** is the most common form of testicular cancer in infants and boys up to 3 years of age. It is associated with **elevated α-fetoprotein levels.**

c. **Seminoma** is the most common type of germ cell neoplasm in men 20–40 years of age; about 90% of all testicular cancers arise from germ cells. It causes either a painless testicular mass, usually on the right side, or diffuse nodularity throughout the testis. It is associated with **elevated human chorionic gonadotropin (hCG) levels.**

d. **Testicular teratocarcinoma** is a germ cell neoplasm. In its early histologic stages, it may resemble a blastocyst with three primary germ layers and may be loosely referred to as "male pregnancy." The tumor comprises well-differentiated cells and structures from each of the primary germ layers: colon glandular tissue (endoderm), cartilage (mesoderm), and squamous epithelium (ectoderm).

II. EPIDIDYMIS

EPIDIDYMIS is a highly coiled duct that consists of a **head, body,** and **tail. Sperm maturation and storage** occur in the head and body of the epididymis. The tail is continuous with the ductus deferens.

III. DUCTUS DEFERENS

A. **General features.** The **ductus deferens** begins at the inferior pole of the testes, ascends to enter the spermatic cord, transits the inguinal canal, and enters the abdominal cavity by passing through the deep inguinal ring. It is joined by the seminal vesicle at the **ampulla of the ductus deferens,** to form the **ejaculatory duct.** The ejaculatory duct passes through the prostate gland and opens into the prostatic urethra at the **urethral crest.**

B. **Clinical consideration.** In a **vasectomy,** the scalpel cuts through the following layers in succession to gain access to the ductus deferens: skin → Colles fascia and dartos muscle → external spermatic fascia → cremasteric fascia and muscle → internal spermatic fascia → extraperitoneal fat. The tunica vaginalis is not cut.

IV. CONTENTS OF THE SPERMATIC CORD

CONTENTS OF THE SPERMATIC CORD include the ductus deferens, testicular artery, artery of the ductus deferens, cremasteric artery, pampiniform venous plexus, sympathetic and parasympathetic nerves, genitofemoral nerve, and lymphatics.

V. SEMINAL VESICLE

SEMINAL VESICLE produces seminal fluid, which contains **fructose** and **choline.** In forensic medicine, the presence of fructose, which is not produced elsewhere in the body, is

used to determine whether sexual assault has occurred. Detection of choline crystals is the preferred method of determining the presence of sperm.

VI. PROSTATE GLAND

A. General features

1. **Location.** The prostate gland lies between the base of the urinary bladder and the urogenital diaphragm. The anterior surface is related to the retropubic space; the posterior surface is related to the seminal vesicles and rectum. The prostate gland is palpated easily during a digital rectal examination.
2. **Structure.** The prostate gland has five lobes: **right and left lateral, right and left posterior,** and **middle**. The prostate gland is a collection of tubulo-alveolar glands and is divided into three zones: **peripheral**, **central**, and **transitional (periurethral).** The lumen of the glands normally contain deposits called **corpora amylacea.**
3. **Prostatic fluid** contains citric acid, acid phosphatase, prostaglandins, fibrinogen, and prostate-specific antigen (PSA), which is a serine protease that liquefies semen after ejaculation. Serum levels of **acid phosphatase** and **PSA** are used as diagnostic tools to detect prostatic carcinoma.
4. The **arterial supply** is from the internal iliac artery via the **inferior vesical artery.**
5. **Venous drainage** follows two pathways. One pathway is: **prostatic venous plexus → internal iliac veins → inferior vena cava (IVC).** This pathway may explain how prostatic cancer metastasizes to the heart and lungs. Venous drainage also proceeds as: **prostatic venous plexus → vertebral venous plexus → cranial dural sinuses.** This pathway may explain how prostatic cancer metastasizes to the vertebral column and brain.

B. Clinical considerations

1. **Benign prostatic hypertrophy (BPH)** is characterized by hypertrophy of the **transitional (periurethral) zone,** which usually involves the lateral and middle lobes. BPH compresses the prostatic urethra and obstructs urine flow. BPH may be caused by increased sensitivity of the prostate to **dihydrotestosterone (DHT).** BPH is not premalignant.
   a. **Clinical signs** include: increased frequency of urination, nocturia, difficulty starting and stopping urination, and a sense of incomplete emptying of the bladder.
   b. **Treatment** may include: surgery, 5α-reductase inhibitors [e.g., finasteride (Proscar)] to block the conversion of testosterone to dihydrotestosterone, or α-adrenergic antagonists (e.g., terazosin, prazosin, doxazosin) to inhibit prostate gland secretion.
2. **Prostatic carcinoma (PC)** most commonly is found in the **peripheral zone,** which usually involves the posterior lobes. The posterior lobes can be palpated on digital rectal examination.
   a. **Clinical signs.** Because PC begins in the peripheral zone, it is in an advanced stage by the time urethral blockage, usually discovered when the patient complains of difficulty in urination, occurs. **Prostatic intraepithelial neoplasia** often is associated with PC. Serum **PSA levels** are diagnostic. Metastasis to bone (e.g., lumbar vertebrae, pelvis) is common.
   b. **Treatment** may include: surgery or radiation; leuprolide (Lupron), which is a gonadotropin releasing hormone (GnRH) agonist that inhibits the release of follicle-stimulating hormone (FSH) and luteinizing hormone (LH) when administered in a

continuous fashion, thereby inhibiting secretion of testosterone; and cyproterone (Androcur) or flutamide (Eulexin), which are androgen receptor antagonists.

VII. EXTERNAL GENITALIA

A. The **scrotum** is an outpouching of the lower abdominal wall whereby layers of the abdominal wall continue into the scrotal area to cover the spermatic cord and testes (see Chapter 6 IV).

B. Penis

1. **General features**
   a. **Structure.** The penis consists of three columns of erectile tissue–one **corpus spongiosum** and two **corpora cavernosa**–bound together by the **tunica albuginea.** It is supported by the **suspensory ligament,** which arises from the linea alba and inserts into the deep fascia (of Buck).
   b. The **arterial supply** is from the internal pudendal artery via the **deep artery of the penis,** which is involved in penile erection, and the **dorsal artery of the penis.**
   c. Venous drainage is to the **deep dorsal vein of the penis** → prostatic venous plexus → internal iliac vein → IVC. Venous drainage is to the **superficial dorsal vein of the penis** → external pudendal vein → great saphenous vein → femoral vein → external iliac vein → IVC.
   d. The penis is innervated by the pudendal nerve via the **dorsal nerve of the penis.**
2. The **corpus spongiosum** begins as the **bulb of the penis** and ends as the glans penis. It is ventrally situated in the penis and transmits the urethra.
3. The **corpora cavernosa** begin as the **crura of the penis** and end proximal to the glans. They are situated dorsally in the penis.
4. **Clinical considerations**
   a. **Hypospadias** occurs when the urethral folds do not fuse completely. As a result, the external urethral orifice opens onto the ventral surface of the penis. It usually is associated with a poorly developed penis that curves ventrally **(chordee).**
   b. **Epispadias** occurs when the external urethral orifice opens onto the dorsal surface of the penis. It usually is associated with exstrophy of the bladder.

VIII. RADIOLOGY

A. **Benign prostatic hypertrophy (Figure 15-2A)**

B. **Prostatic carcinoma with metastasis to bone (Figure 15-2B, C)**

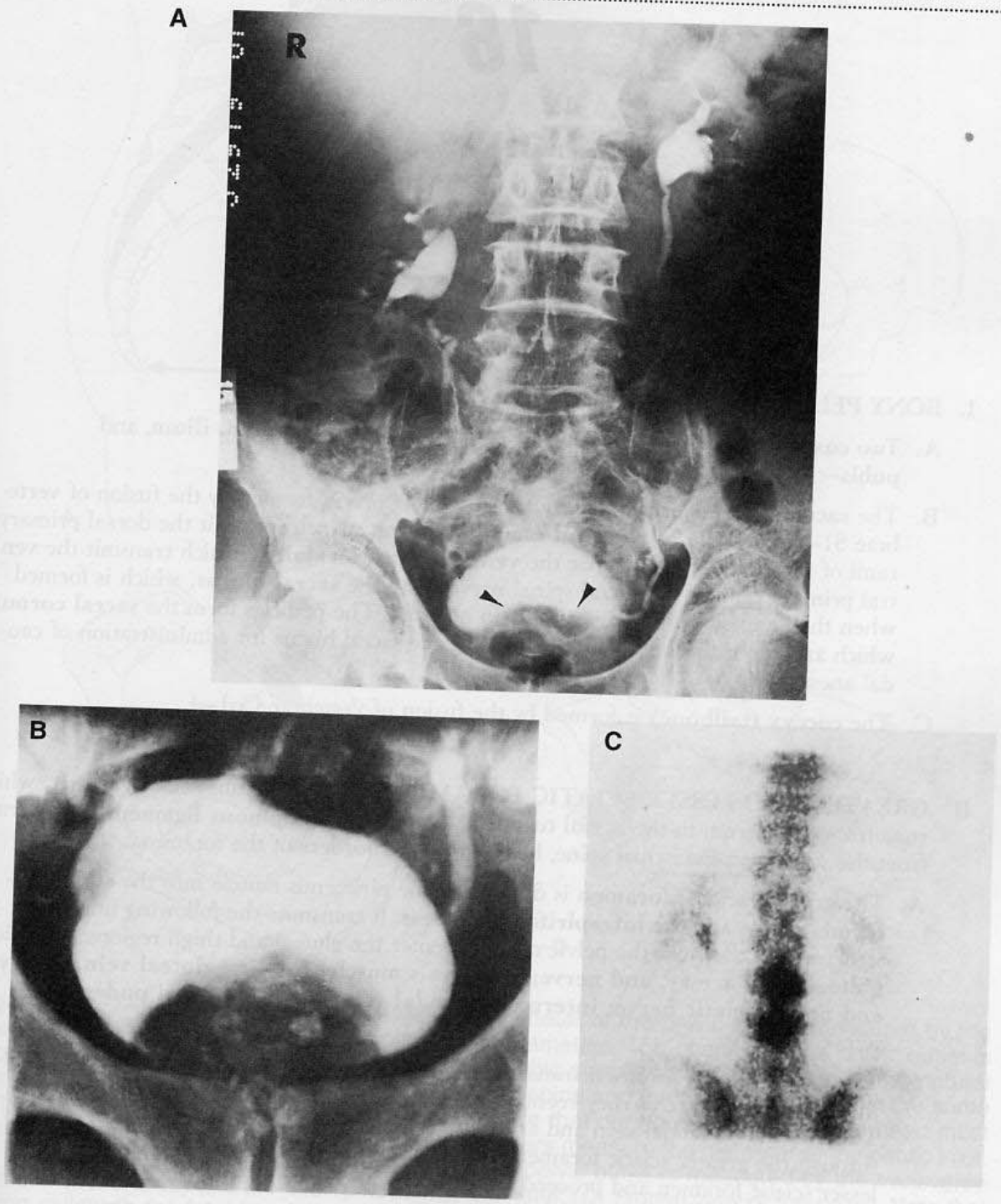


Figure 15-2. (*A*) IVP (intravenous pyelogram) of benign prostatic hypertrophy. Note the elevation of the base of the bladder by a smooth half-moon filling defect (*arrowheads*). This elevation causes a deformity in the pathway of the ureter such that the ureters end in a hook ("fish-hook" phenomenon, seen in the left ureter). (*B*) IVP of prostatic carcinoma showing elevation of the base of the bladder by an irregular filling defect. (*C*) Radionuclide bone scan showing increased tracer uptake in vertebrae L3 and L4, indicating metastatic spread of prostatic carcinoma. (*A* reprinted with permission from Rosenbaum HD, Hildner JH: *Basic Clinical Diagnostic Radiology.* Baltimore, University Park Press, 1984, p 294; *B* reprinted with permission from Eisenberg RL: *Diagnostic Imaging in Surgery.* New York, McGraw-Hill, 1987, p 565; *C* reprinted with permission from Jarrell BE, Carabasi RA: *NMS Surgery,* 3rd ed. Baltimore, Williams & Wilkins, 1996, p 460.)

16

Pelvis

I. **BONY PELVIS** consists of the following bones:

A. Two **coxal (hip) bones,** each consisting of three parts—**ischium, ilium**, and **pubis**—that join at the **acetabulum** of the hip joint.

B. The **sacrum** is the posterior portion of the bony pelvis, formed by the fusion of vertebrae S1–5. It contains the **dorsal sacral foramina,** which transmit the dorsal primary rami of the sacral spinal nerves; the **ventral sacral foramina,** which transmit the ventral primary rami of the sacral spinal nerves; and the **sacral hiatus,** which is formed when the laminae of the S5 vertebra do not fuse. The pedicles form the **sacral cornua,** which are important landmarks in locating the sacral hiatus for administration of caudal anesthesia.

C. The **coccyx (tailbone)** is formed by the fusion of vertebrae Co1–4.

II. **GREATER AND LESSER SCIATIC FORAMINA.** The **sacrotuberous ligament,** which runs from the sacrum to the ischial tuberosity, and the **sacrospinous ligament,** which runs from the sacrum to the ischial spine, help define the borders of the foramina.

A. The **greater sciatic foramen** is divided by the piriformis muscle into the **suprapiriformis recess** and the **infrapiriformis recess**. It transmits the following important structures as they exit the pelvic cavity to enter the gluteal and thigh regions: **superior gluteal vein, artery, and nerve; piriformis muscle; inferior gluteal vein, artery, and nerve; sciatic nerve; internal pudendal vein and artery;** and **pudendal nerve.**

B. The **lesser sciatic foramen** transmits the **internal pudendal vein and artery** and the **pudendal nerve** as they reenter the pelvic cavity and proceed to the perineum. The internal pudendal vein and artery and the pudendal nerve exit the pelvic cavity through the greater sciatic foramen and then reenter the pelvic cavity through the lesser sciatic foramen and proceed to the perineum.

III. **PELVIC INLET (Figure 16-1)**

A. **General features.** The pelvic inlet is defined by the **sacral promontory** (vertebra S1) and the **linea terminalis**. The linea terminalis includes the **pubic crest,** the **iliopectineal line**, and the **arcuate line**. The pelvic inlet divides the pelvic cavity into two parts: the **major (false) pelvis,** which lies above the pelvic inlet between the iliac crests and is part of the abdominal cavity; and the **minor (true) pelvis,** which lies below the pelvic inlet and extends to the pelvic outlet.

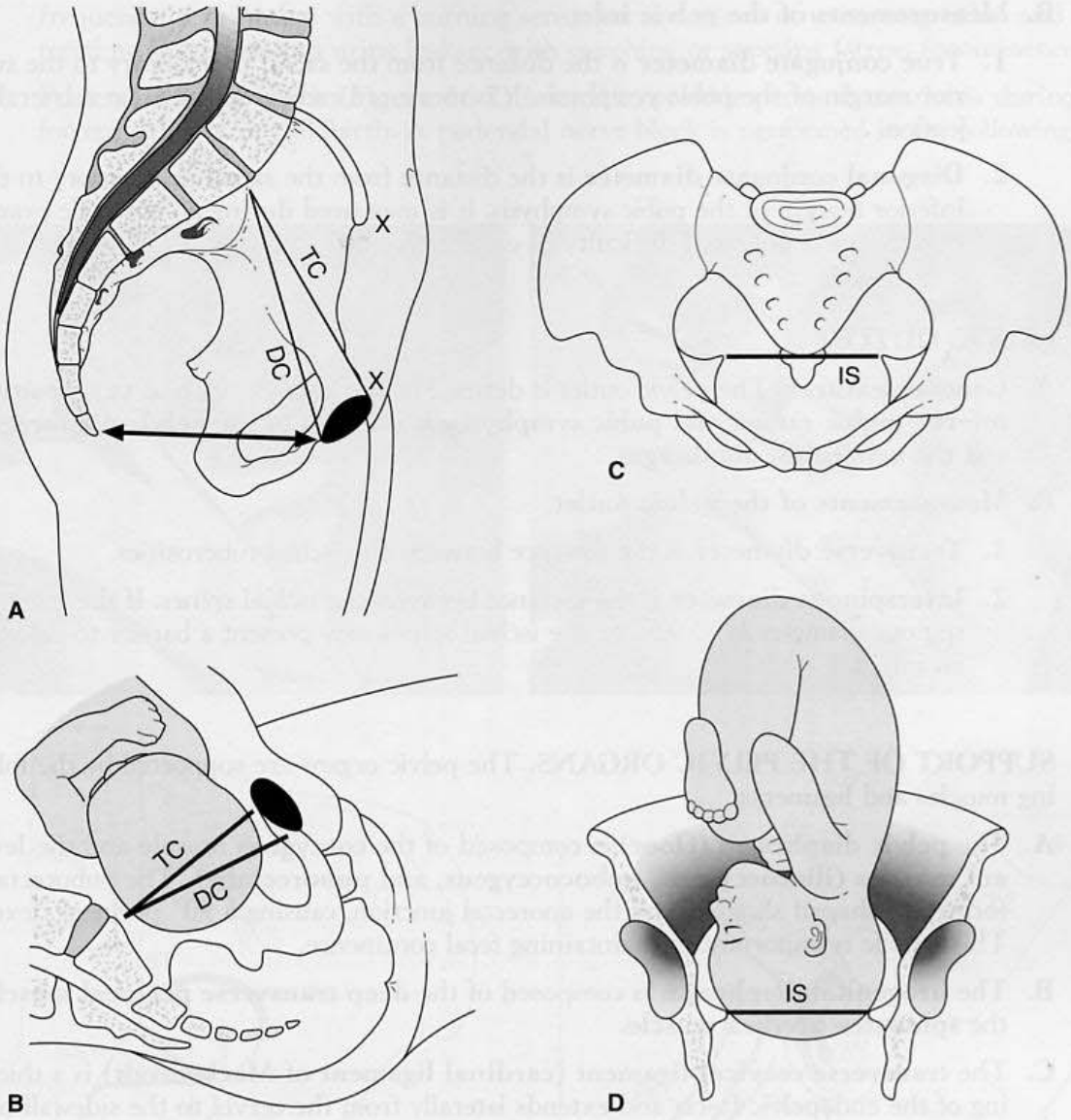


Figure 16-1. (*A*) Lateral view of the pelvis. The diameter of the pelvic inlet is measured by the true conjugate (*TC*) and diagonal conjugate (*DC*) diameters. The opening of the pelvic outlet is shown (*line with arrowheads*) extending from the pubic symphysis to the coccyx. In the natural position of the bony pelvis, the anterior superior iliac spine and the pubic tubercle lie in the same vertical plane (*X*). (*B*) Lateral view of the pelvis. Note that during childbirth the fetal head must pass through the pelvic inlet. The TC and DC diameters measure the diameter of the pelvic inlet. (*C*) Superior view of the pelvis. The diameter of the pelvic outlet is measured by the transverse diameter (not shown) and the interspinous (*IS*) diameter. (*D*) Frontal view of the pelvis. Note that during childbirth the fetal head must pass through the pelvic outlet. The IS diameter measures the diameter of the pelvic outlet. The TC, DC, and IS diameters are important during childbirth, because the fetus must travel through the birth canal, which consists of the pelvic inlet → minor pelvis → cervix → vagina → pelvic outlet. (*A* adapted with permission from Rohen JW, Yokochi C, Lütjen-Drecoll E: *Color Atlas of Anatomy,* 4th ed. Baltimore, Williams & Wilkins, 1998, p 414; *B* and *D* adapted with permission from Callahan TL, Caughey AB, Heffner LJ: *Blueprints in Obstetrics and Gynecology*. Malden, MA, Blackwell Science, 1998, p 18; *C* adapted with permission from Mathers LH, Chase RA, Dolph J, et al: *Clinical Anatomy Principles.* St. Louis, Mosby-Year Book, 1995.)

B. Measurements of the pelvic inlet

1. **True conjugate diameter** is the distance from the sacral promontory to the superior margin of the pubic symphysis. It is measured radiographically on a lateral projection.
2. **Diagonal conjugate diameter** is the distance from the sacral promontory to the inferior margin of the pubic symphysis. It is measured during an obstetric examination to assess potential difficulty in childbirth.

IV. PELVIC OUTLET

A. General features. The pelvic outlet is defined by the **coccyx, ischial tuberosities, inferior pubic ramus**, and **pubic symphysis**. It is closed by the **pelvic diaphragm** and the **urogenital diaphragm**.

B. Measurements of the pelvic outlet

1. **Transverse diameter** is the distance between the ischial tuberosities.
2. **Interspinous diameter** is the distance between the ischial spines. If the interspinous diameter is < 9.5 cm, the ischial spines may present a barrier to delivery of an infant.

V. SUPPORT OF THE PELVIC ORGANS.

The pelvic organs are supported by the following muscles and ligaments:

A. The **pelvic diaphragm (floor)** is composed of the **coccygeus muscle** and the **levator ani muscles (iliococcygeus, pubococcygeus,** and **puborectalis).** The puborectalis forms a U-shaped sling around the anorectal junction, causing a 90° perineal flexure. This muscle is important in maintaining fecal continence.

B. The **urogenital diaphragm** is composed of the **deep transverse perineal muscle** and the **sphincter urethra muscle.**

C. The **transverse cervical ligament (cardinal ligament of Mackenrodt)** is a thickening of the endopelvic fascia and extends laterally from the cervix to the sidewall of the pelvis.

D. The **uterosacral ligament** is a thickening of the endopelvic fascia and extends posteriorly from the cervix to the sacrum.

E. The **pubocervical ligament** is a thickening of the endopelvic fascia and extends anteriorly from the cervix to the pubic symphysis.

VI. CLINICAL CONSIDERATIONS

A. Pelvic relaxation is the weakening or loss of support of the pelvic organs because of damage to the pelvic diaphragm, urogenital diaphragm, transverse cervical ligament, uterosacral ligament, or pubocervical ligament. It may result in **cystocele** (prolapse of the urinary bladder into the anterior vaginal wall), **rectocele** (prolapse of the rectum into the posterior vaginal wall), or **uterine prolapse** (prolapse of the uterus into the vaginal vault). Pelvic relaxation may result from multiple childbirths; birth trauma; increased intraabdominal pressure because of obesity, heavy lifting, or chronic cough; or menopausal loss of muscle tone. Clinical signs include: a heavy sensation in the lower abdomen that is exacerbated by heavy lifting or prolonged standing; increased

frequency of urination with a burning sensation as a result of urine stagnation and bacterial proliferation; and urine leakage with coughing or sneezing (stress incontinence).

B. Pudendal nerve block (Figure 16-2) is used to provide perineal anesthesia during forceps delivery in childbirth. A pudendal nerve block is performed in the following

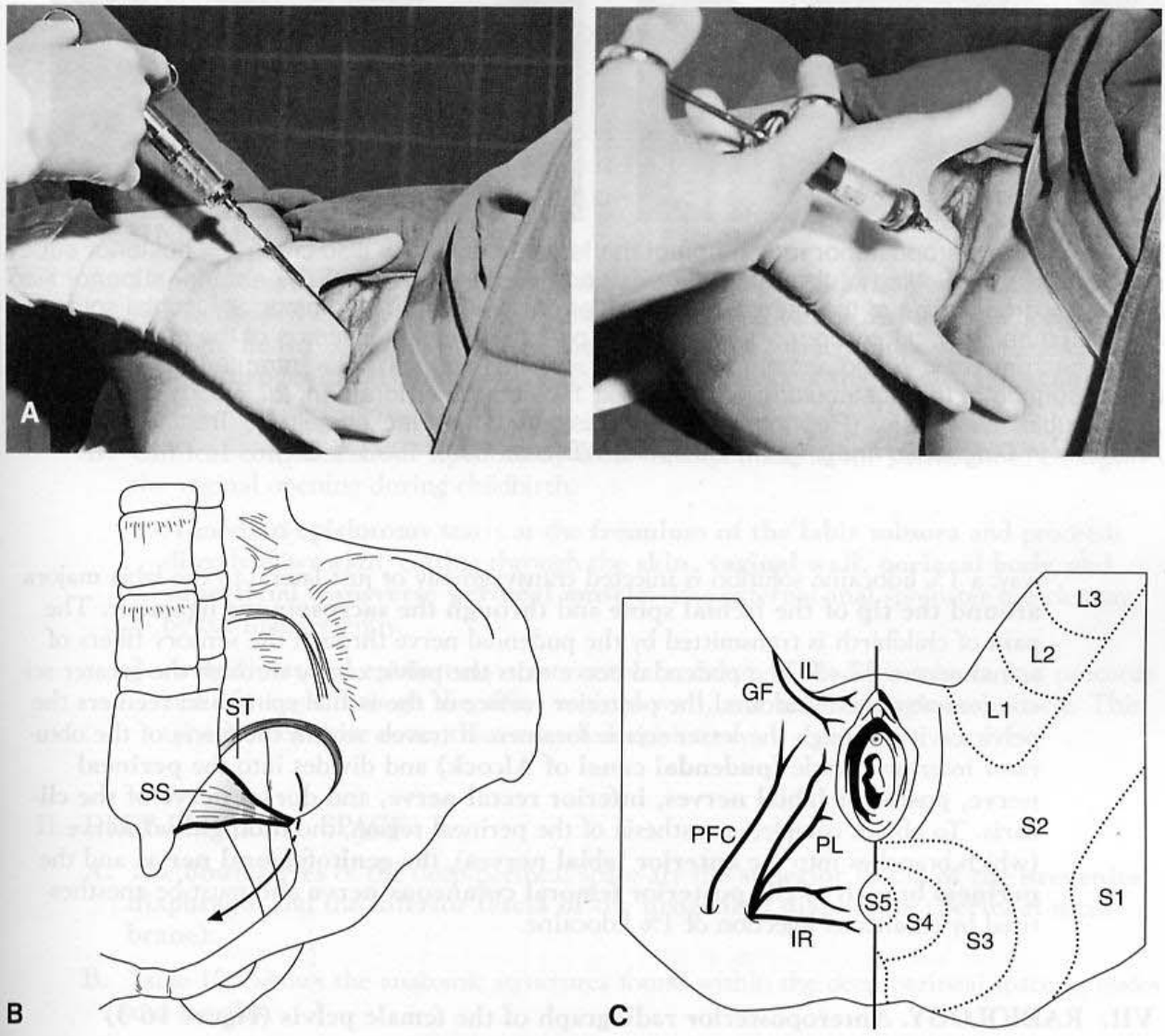


Figure 16-2. (*A*) Administration of a pudendal nerve block transvaginally and lateral to the labia majora. The ischial spine (not shown) is a good anatomic landmark. (*B*) The path of the pudendal nerve (*curved arrow*) as it passes out of the pelvic cavity through the greater sciatic foramen (posterior to the ischial spine) and returns to the pelvic cavity through the lesser sciatic foramen as it proceeds to the perineum. *SS* = sacrospinous ligament; *ST* = sacrotuberous ligament. (*C*) The perineum in the lithotomy position. The posterior labial (*PL*) and inferior rectal (*IR*) nerves are terminal branches of the pudendal nerve. In addition, the ilioinguinal nerve (*IL*), genitofemoral nerve (*GF*), and perineal branch of the posterior femoral cutaneous nerve (*PFC*), which also must be anesthetized by cutaneous injection of 1% lidocaine to obtain complete anesthesia of the perineal region, are shown. Labels L1, L2, L3, S2, S3, S4, and S5 indicate the dermatomes of the perineal region. (*A* reprinted with permission from Scott DB: *Techniques of Regional Anaesthesia.* East Norwalk, CT, Appleton & Lange, 1989, p 159; *B* and *C* adapted from Olson TR: *A.D.A.M. Student Atlas of Anatomy.* Baltimore, Williams & Wilkins, 1996, p 169.

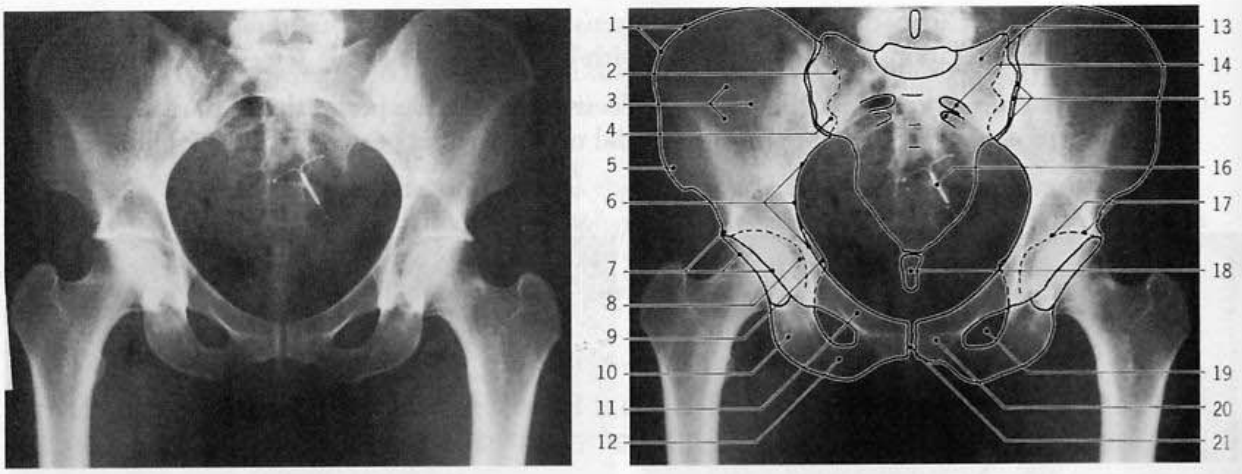


Figure 16-3. Anteroposterior radiograph of the female pelvis. *1* = iliac crest; *2* = posterior superior iliac spine; *3* = wing of the ilium; *4* = posterior inferior iliac spine; *5* = anterior superior iliac spine; *6* = arcuate line of the ilium; *7* = acetabular rim; *8* = acetabular fossa; *9* = ischial spine; *10* = ischial tuberosity; *11* = superior ramus of the pubis; *12* = inferior ramus of the pubis; *13* = ala of the sacrum; *14* = pelvic sacral foramina; *15* = sacroiliac joint; *16* = intrauterine device; *17* = lunate surface of the acetabulum; *18* = coccyx; *19* = obturator foramen; *20* = body of the pubis; *21* = pubic symphysis. (Reprinted with permission from Fleckenstein P, Tranum-Jensen J: *Anatomy in Diagnostic Imaging.* Philadelphia, WB Saunders, 1993, p 80.)

way: a 1% lidocaine solution is injected transvaginally or just lateral to the labia majora **around the tip of the ischial spine** and **through the sacrospinous ligament.** The pain of childbirth is transmitted by the pudendal nerve through the sensory fibers of spinal nerves **S2–5**. The pudendal nerve exits the pelvic cavity through the greater sciatic foramen, travels around the posterior surface of the ischial spine, and reenters the pelvic cavity through the lesser sciatic foramen. It travels within the fascia of the obturator internus muscle **(pudendal canal of Alcock)** and divides into the **perineal nerve, posterior labial nerves, inferior rectal nerve,** and **dorsal nerve of the clitoris.** To obtain complete anesthesia of the perineal region, the **ilioinguinal nerve** (which branches into the **anterior labial nerves**), the **genitofemoral nerve**, and the **perineal branch of the posterior femoral cutaneous nerve** also must be anesthetized by cutaneous injection of 1% lidocaine.

VII. RADIOLOGY. Anteroposterior radiograph of the female pelvis (Figure 16-3)

17

Perineum

I. PERINEUM (Figure 17-1)

A. General features. The **perineum** is the part of the pelvic outlet that is located inferior to the pelvic diaphragm. It is diamond-shaped and can be divided by a line passing through the ischial tuberosities into the **anal triangle,** which contains the anal canal, and the **urogenital triangle,** which contains the outlets of the urinary and genital organs.

B. Clinical consideration. Episiotomy is an incision made in the perineum to enlarge the vaginal opening during childbirth.

1. A **median episiotomy** starts at the **frenulum of the labia minora** and proceeds directly downward, cutting through the **skin, vaginal wall, perineal body**, and **superficial transverse perineal muscle.** The external anal sphincter muscle may be cut inadvertently.

2. A **mediolateral episiotomy** starts at the frenulum of the labia minora and proceeds at a 45° angle through the **skin, vaginal wall,** and **bulbospongiosus muscle**. This type creates more room than a median episiotomy.

II. DEEP PERINEAL SPACE

A. The **boundaries** of the deep perineal space are the **superior fascia of the urogenital diaphragm** and the **inferior fascia of the urogenital diaphragm (perineal membrane).**

B. Table 17-1 shows the anatomic structures found within the deep perineal space in males and females.

III. SUPERFICIAL PERINEAL SPACE

A. The **boundaries** of the superficial perineal space are the **inferior fascia of the urogenital diaphragm (perineal membrane)** and the **superficial perineal fascia,** which is continuous with **Colles fascia.**

B. Table 17-2 shows the anatomic structures found within the superficial perineal space in males and females.

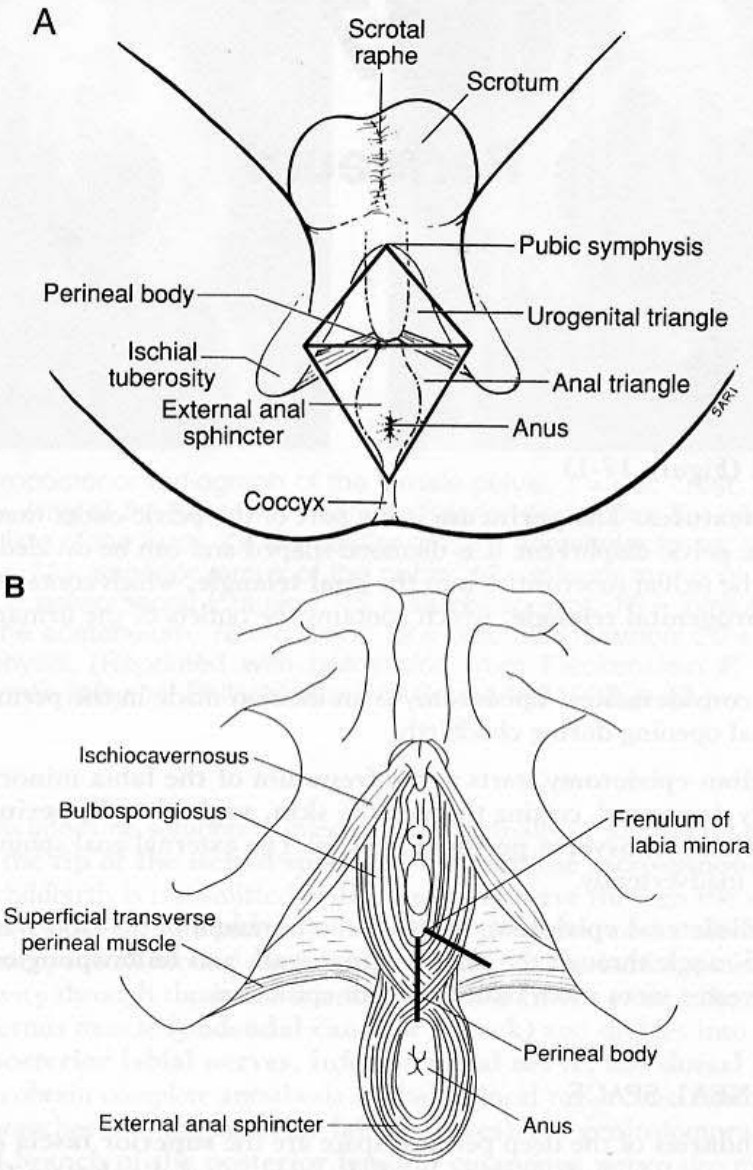


Figure 17-1. (*A*) The male perineum, showing the diamond shape, extending from the pubic symphysis to the coccyx. A transverse line joining the anterior ends of the ischial tuberosities divides the perineum into two unequal triangles, the urogenital triangle anteriorly and the anal triangle posteriorly. The midpoint of the transverse line indicates the site of the perineal body (central perineal tendon). (*B*) The female perineum in the lithotomy position, with incision lines shown for median and mediolateral episiotomies. (*A* reprinted with permission from Moore KL: *Clinically Oriented Anatomy,* 3rd ed. Baltimore, Williams & Wilkins, 1992, p 297; B adapted with permission from Moore KL, Dalley AF II: *Clinically Oriented Anatomy*, 4th ed. Baltimore, Lippincott Williams & Wilkins, 1999, p.389.)

Table 17-1.
Structures Within the Deep Perineal Space

Male	Female
Membranous urethra	Urethra Vagina
Urogenital diaphragm Deep transverse perineal muscle Sphincter urethrae muscle	Urogenital diaphragm Deep transverse perineal muscle Sphincter urethrae muscle
Branches of the internal pudendal artery Artery of the penis	Branches of the internal pudendal artery Artery of the clitoris
Branches of the pudendal nerve Dorsal nerve of the penis	Branches of the pudendal nerve Dorsal nerve of the clitoris
Bulbourethral glands (Cowper glands)	No glands

Table 17-2.
Structures Within the Superficial Perineal Space

Male	Female
Penile (spongy) urethra	Urethra Vestibule of the vagina
Bulbospongiosus muscle Ischiocavernosus muscle Superficial transverse perineal muscle	Bulbospongiosus muscle Ischiocavernosus muscle Superficial transverse perineal muscle
Branches of the internal pudendal artery Perineal artery → posterior scrotal arteries Dorsal artery of the penis Deep artery of the penis	Branches of the internal pudendal artery Perineal artery → posterior labial arteries Dorsal artery of the clitoris Deep artery of the clitoris
Branches of the pudendal nerve Perineal nerve → posterior scrotal nerves Dorsal nerve of the penis	Branches of the pudendal nerve Perineal nerve → posterior labial nerves Dorsal nerve of the clitoris
Bulb of the penis Crura of the penis	Vestibular bulb Crura of the clitoris
Perineal body	Perineal body
Duct of the bulbourethral gland	Greater vestibular glands (Bartholin glands)

18

Upper Limb

I. ARTERIAL SUPPLY (Figure 18-1)

A. The **subclavian artery** extends from the **arch of the aorta** to the **lateral border of the first rib**. It has the following branches:

1. **Internal thoracic artery,** which is continuous with the **superior epigastric artery,** which anastomoses with the **inferior epigastric artery** (a branch of the external iliac artery). This pathway provides a route of collateral circulation if the abdominal aorta is blocked (e.g., postductal coarctation of the aorta).
2. **Vertebral artery**
3. **Thyrocervical trunk,** which has three branches:
   a. **Suprascapular artery,** which participates in collateral circulation around the shoulder
   b. **Transverse cervical artery,** which participates in collateral circulation around the shoulder
   c. **Inferior thyroid artery** (see Chapter 20 IV A 1)

B. The **axillary artery** is a continuation of the subclavian artery. It extends from the **lateral border of the first rib** to the **inferior border of the teres major muscle.** The tendon of the pectoralis minor muscle crosses the axillary artery anteriorly. The axillary artery gives off the following branches:

1. **Thoracoacromial artery**
2. **Lateral thoracic artery**
3. **Anterior humeral circumflex artery**
4. **Posterior humeral circumflex artery**
5. **Subscapular artery,** which gives off the **circumflex scapular artery**

C. The **brachial artery** is a continuation of the axillary artery. It extends from the **lateral border of the teres major muscle** to the **cubital fossa**. The brachial artery has the following branches:

1. **Deep brachial artery.** A midshaft fracture of the humerus may damage the **deep brachial artery and radial nerve** as they travel together on the posterior aspect of the humerus in the radial groove.
2. **Radial artery**
3. **Ulnar artery**

D. **Superficial palmar arch**

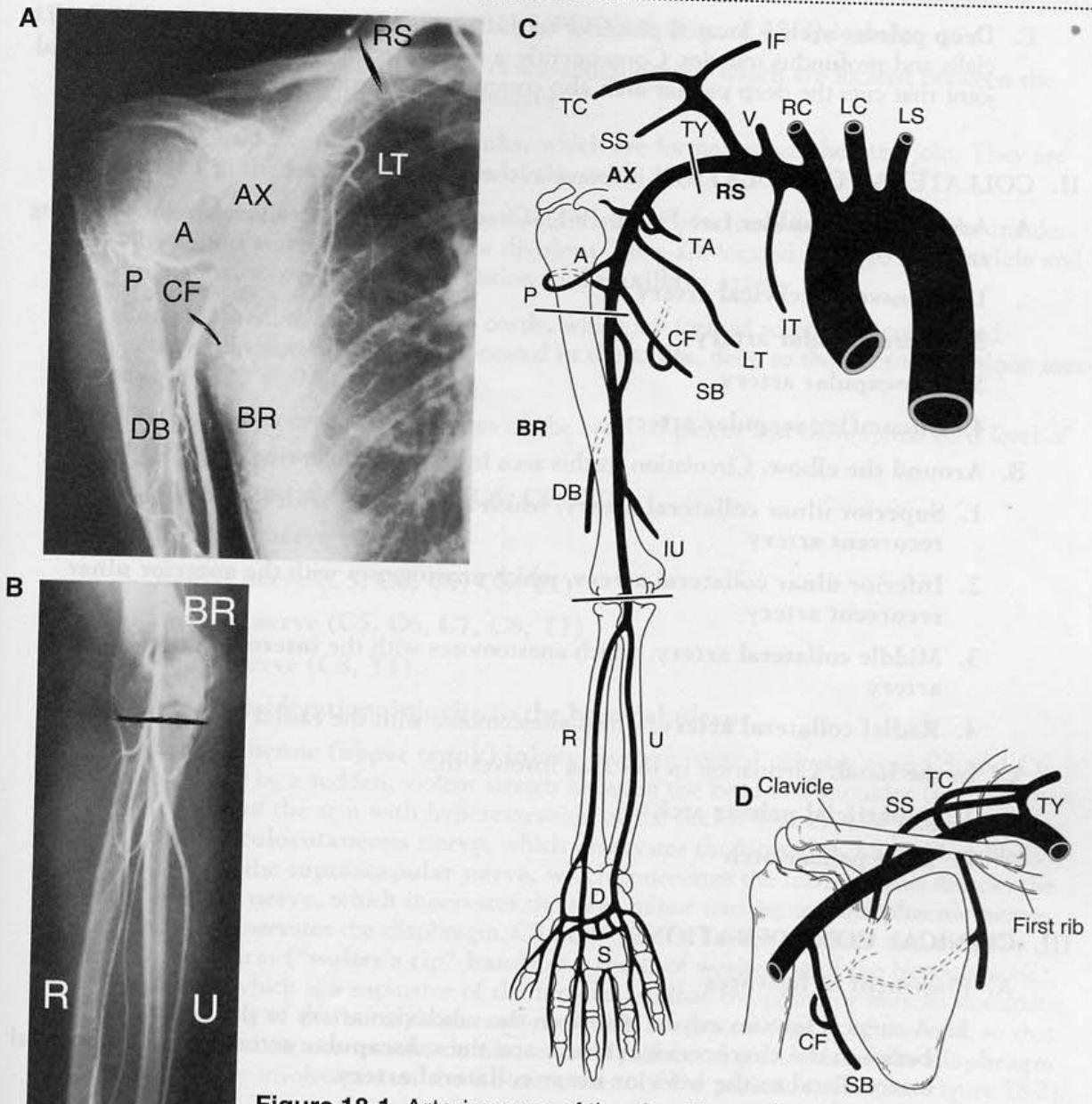


Figure 18-1. Arteriograms of the shoulder region (*A*) and forearm (*B*). (*C*) Arterial supply of the upper limb. (*D*) Collateral circulation around the shoulder. *The lines* from proximal to distal indicate the lateral border of the first rib, the inferior border of the teres major muscle, and the cubital fossa. It is important to be able to identify an artery on an arteriogram and to know which nerve runs with that artery. *A* = anterior circumflex humeral artery; *AX* = axillary artery; *BR* = brachial artery; *CF* = circumflex scapular artery; *D* = deep palmar arch; *DB* = deep brachial artery (runs with the radial nerve); *IF* = inferior thyroid artery; *IT* = internal thoracic artery; *IU* = inferior ulnar collateral artery; *LC* = left common carotid artery; *LS* = left subclavian artery; *LT* = lateral thoracic artery (runs with the long thoracic nerve); *P* = posterior circumflex humeral artery (runs with the axillary nerve); *R* = radial artery; *RC* = right common carotid artery; *RS* = right subclavian artery; *S* = superficial palmar arch; *SB* = subscapular artery; *SS* = suprascapular artery; *TA* = thoracoacromial artery; *TC* = transverse cervical artery; *TY* = thyrocervical trunk; *U* = ulnar artery (runs with the ulnar nerve); *V* = vertebral artery. (*A* and *B* reprinted with permission from Fleckenstein P, Tranum-Jensen J: *Anatomy in Diagnostic Imaging*. Philadelphia, WB Saunders, 1993, pp 76, 77.)

E. **Deep palmar arch** is located posterior to the tendons of the flexor digitorum superficialis and profundus muscles. Consequently, a deep laceration at the metacarpal–carpal joint that cuts the deep palmar arch also compromises flexion of the fingers.

II. COLLATERAL CIRCULATION is found in the following regions:

A. **Around the shoulder** (see Figure 18-1). Circulation in this area involves the following arteries:

1. **Transverse cervical artery**
2. **Suprascapular artery**
3. **Subscapular artery**
4. **Circumflex scapular artery**

B. **Around the elbow.** Circulation in this area involves the following arteries:

1. **Superior ulnar collateral artery,** which anastomoses with the **posterior ulnar recurrent artery**
2. **Inferior ulnar collateral artery,** which anastomoses with the **anterior ulnar recurrent artery**
3. **Middle collateral artery,** which anastomoses with the **interosseous recurrent artery**
4. **Radial collateral artery,** which anastomoses with the **radial recurrent artery**

C. **In the hand.** Circulation in this area involves the:

1. **Superficial palmar arch**
2. **Deep palmar arch**

III. CLINICAL CONSIDERATIONS

A. **Placement of ligatures**

1. A surgical ligature may be placed on the subclavian artery or the axillary artery **between the thyrocervical trunk** and the **subscapular artery,** or on the brachial artery **distal to the inferior ulnar collateral artery.**
2. A surgical ligature may not be placed on the axillary artery **just distal to the subscapular artery.**

B. The **radial artery** and the **cephalic vein** are the vessels most commonly used for **access during long-term hemodialysis.**

C. **Percutaneous arterial catheterization** uses the brachial artery if the femoral artery approach is unavailable. The **left brachial artery** is preferred because approaching from the left side allows access to the descending aorta without crossing the right brachiocephalic trunk and left common carotid arteries, thereby reducing the risk of stroke.

IV. COMPONENTS OF THE BRACHIAL PLEXUS (Figure 18-2) include:

A. Ventral primary rami C5–T1 of the spinal nerves, which are located between the **anterior** and **middle scalene muscles**

B. Upper, middle, and lower trunks, which are formed when the rami join. They are located in the **posterior triangle of the neck.**

C. Three anterior and three posterior divisions, which are formed when the trunks divide into anterior and posterior divisions. They are located **deep to the clavicle** and are named according to their relation to the **axillary artery**.

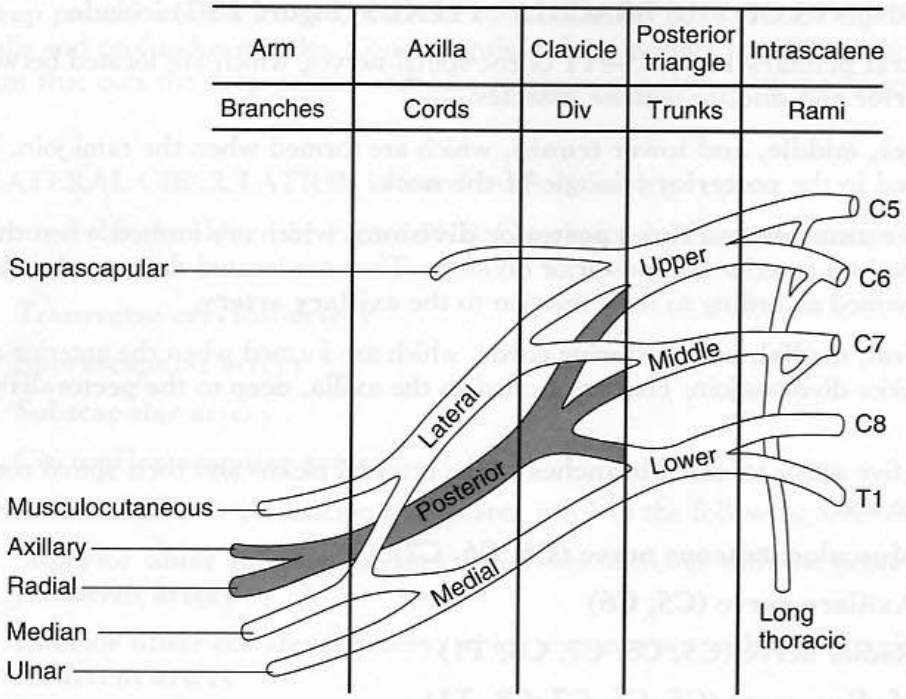
D. Lateral, medial, and posterior cords, which are formed when the anterior and posterior divisions join. They are located **in the axilla, deep to the pectoralis minor muscle.**

E. The five major terminal **branches** of the brachial plexus and their spinal cord level of origin are:

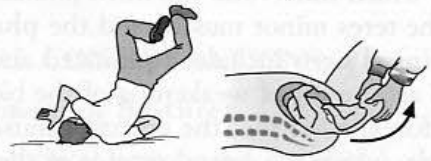
1. **Musculocutaneous nerve (C5, C6, C7)**
2. **Axillary nerve (C5, C6)**
3. **Radial nerve (C5, C6, C7, C8, T1)**
4. **Median nerve (C5, C6, C7, C8, T1)**
5. **Ulnar nerve (C8, T1)**

F. Clinical consideration: injuries to the brachial plexus

1. **Erb-Duchenne (upper trunk) injury** involves ventral primary rami **C5 and C6**. It is caused by a sudden, violent stretch between the head and shoulder (i.e., adduction traction of the arm with hyperextension of the neck). This type of injury damages the **musculocutaneous nerve,** which innervates the biceps brachii and brachialis muscles; the **suprascapular nerve,** which innervates the infraspinatus muscle; the **axillary nerve,** which innervates the teres minor muscle; and the **phrenic nerve,** which innervates the diaphragm. Clinical signs include: a pronated and medially rotated arm **("waiter's tip" hand)** as a result of weakening of the biceps brachii muscle, which is a supinator of the forearm, so that the pronator muscles dominate; weakening of the infraspinous muscle, which is a lateral rotator of the arm, so that the medial rotator muscles dominate; and **ipsilateral paralysis of the diaphragm** caused by involvement of the C5 component of the phrenic nerve (see Figure 18-2).
2. **Klumpke (lower trunk) injury** involves ventral primary rami **C8 and T1**. It is caused by a sudden upward pull of the arm (i.e., abduction injury). This type of injury damages the **median and ulnar nerves,** both of which innervate muscles of the forearm and hand, and the **sympathetic component of spinal nerve T1.** Clinical signs include: **loss of function of the wrist and hand** and **Horner syndrome,** which causes **miosis** (constriction of the pupil due to paralysis of the dilator pupillae muscle), **ptosis** (drooping of the eyelid due to paralysis of the superior tarsal muscle), and **hemianhydrosis** (loss of sweating on one side) (see Figure 18-2).



Injury	Description of injury	Nerves damaged	Clinical sign
Erb-Duchenne (C5 and C6, upper trunk)	Violent stretch between the head and shoulder (i.e., adduction traction of the arm and hyper-extension of the neck)	Musculocutaneous Suprascapular Axillary Phrenic	Pronated and medially rotated arm ("waiter's tip" hand) Ipsilateral paralysis of diaphragm
Klumpke (C8 and T1, lower trunk)	Sudden upward pull of the arm (i.e., abduction injury)	Median Ulnar Sympathetics of T1 spinal nerve	Loss of function of the wrist and hand Horner syndrome



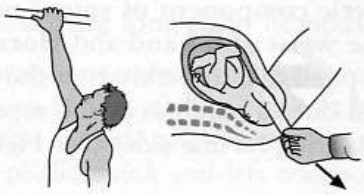


Figure 18-2. (*A*) The rami, trunks, divisions (*Div*), cords, and five major terminal branches of the brachial plexus, along with their anatomic positions. (*B*) Erb-Duchenne and Klumpke injuries to the brachial plexus. (*A* adapted with permission from April EW: *NMS Clinical Anatomy,* 3rd ed. Baltimore, Williams & Wilkins, 1997.)

V. NERVE LESIONS (Table 18-1)

A. Long thoracic nerve injury

1. The long thoracic nerve may be injured by a stab wound or in the course of removal of lymph nodes during a mastectomy.
2. Paralysis of the serratus anterior muscle occurs so that abduction of the arm past the horizontal position is compromised. In addition, the arm cannot be used to push with.
3. To test the function of the serratus anterior muscle clinically, the patient is asked to face a wall and push against it with both arms. If the nerve is injured, the corresponding medial border and inferior angle of the scapula become prominent **(winging of the scapula).**

B. Axillary nerve injury

1. The axillary nerve may be injured by a fracture of the surgical neck of the humerus or by anterior dislocation of the shoulder joint.
2. Paralysis of the deltoid muscle occurs so that abduction of the arm to the horizontal position is compromised.
3. Paralysis of the teres minor muscle also occurs so that lateral rotation of the arm is weakened.
4. Sensory loss occurs on the lateral side of the upper arm.
5. To test the function of the deltoid muscle clinically, the patient's arm is abducted to the horizontal position, and the patient is asked to maintain that position against a downward pull.

C. Radial nerve injury

1. The radial nerve may be injured as a result of a midshaft fracture of the humerus, use of a badly fitted crutch, or falling asleep with the arm draped over a chair.
2. Paralysis of the muscles in the extensor compartment of the forearm occurs so that extension of the wrist and digits is lost, and supination is compromised. Extension of the forearm is preserved, however, because innervation to the triceps muscle usually is intact.
3. Sensory loss occurs on the posterior arm, posterior forearm, and lateral aspect of the dorsum of the hand.
4. Clinically, the hand is flexed at the wrist and lies flaccid **(wrist drop).**

D. Median nerve injury at the elbow or axilla

1. The median nerve may be injured as a result of a supracondylar fracture of the humerus.
2. Paralysis of the muscles in the flexor compartment of the arm occurs so that flexion of the wrist is weakened, and the hand deviates to the ulnar side on flexion. In addition, flexion of the index and middle fingers at the distal (DIP) and proximal (PIP) interphalangeal joints is lost, and pronation is lost.
3. Paralysis of lumbrical muscles 1 and 2 occurs so that flexion of the index and middle fingers at the metacarpophalangeal (MP) joint is lost.

Table 18-1. Nerve Lesions

Nerve	Injury	Impairments	Clinical Features
Long thoracic	Stab wound Mastectomy	Abduction of arm past horizontal is compromised	Test: Pushing against a wall causes winging of scapula
Axillary	Surgical neck fracture of humerus Anterior dislocation of shoulder joint	Abduction of arm to horizontal is compromised Sensory loss on lateral upper arm	Test: Arm is abducted to horizontal position and patient asked to hold position against a pull
Radial	Midshaft fracture of humerus Badly fitted crutch Arm draped over a chair	Extension of wrist and digits is lost Supination is compromised Sensory loss on posterior arm and forearm, and dorsum of hand	Wrist drop 
Median at elbow	Supracondylar fracture of humerus	Flexion of wrist is weakened Hand deviates to ulnar side when flexed Flexion of index and middle fingers at DIP, PIP, and MP joints is lost Abduction, opposition, and flexion of thumb are lost. Sensory loss on palmar and dorsal aspects of index, middle, and half of ring finger and palmar aspect of thumb	Ape hand Benediction hand 
Median at wrist	Slashing of wrist Carpal tunnel syndrome	Flexion of index and middle fingers at MP joint is weakened Abduction and opposition of thumb are lost Sensory loss same as at elbow	Test: Patient makes an "O" with thumb and index finger
Ulnar at elbow	Fracture of medial epicondyle of humerus	Hand deviates to radial side when flexed Flexion of ring and little fingers at DIP and MP joints is lost Extension of ring and little fingers at DIP and PIP joints is lost Adduction and abduction of fingers are lost Adduction of thumb is lost Movement of little finger is lost Sensory loss on palmar and dorsal aspects of half of ring and little finger	Claw hand  Test: Patient holds a paper between middle and ring fingers
Ulnar nerve at wrist	Slashing of wrist	Flexion of ring and little fingers at MP joint is lost Extension of ring and little fingers at DIP and PIP joints is lost Adduction and abduction of fingers are lost Adduction of thumb is lost Movement of little finger is lost Sensory loss same as at elbow	

4. Paralysis of the abductor pollicis brevis, opponens pollicis, and flexor pollicis brevis muscles occurs so that abduction, opposition, and flexion of the thumb are lost.
5. Sensory loss occurs on the palmar and dorsal aspects of the index finger, middle finger, and half of the ring finger, and on the palmar aspect of the thumb.
6. Clinically, the thenar eminence is flattened **(ape hand),** and when the patient is asked to make a fist, the index and middle fingers remain straight while the ring and little fingers flex **(benediction hand).**
7. To test the motor integrity of the median nerve, the patient is asked to maintain an "O" with the thumb and index finger while the physician attempts to pass a probe between them. This procedure tests the function of the opponens pollicis muscle.

E. Median nerve injury at the wrist

1. The median nerve may be injured by slashing of the wrist (e.g., suicide attempt) or by carpal tunnel syndrome.
2. The muscles in the flexor compartment of the arm are not paralyzed.
3. Paralysis of lumbrical muscles 1 and 2 occurs so that flexion of the index and middle fingers at the MP joint is weakened.
4. Paralysis of the abductor pollicis brevis, opponens pollicis, and flexor pollicis brevis muscles occurs so that abduction and opposition of the thumb are lost. Flexion of the thumb is maintained because the flexor pollicis longus muscle is spared.
5. Sensory loss occurs on the palmar and dorsal aspects of the index finger, middle finger, and half of the ring finger, and on the palmar aspect of the thumb.
6. Clinically, the thenar eminence is flattened **(ape hand).**

F. Ulnar nerve injury at the elbow or axilla

1. The ulnar nerve may be injured as a result of a fracture of the medial epicondyle of the humerus.
2. Paralysis of the flexor carpi ulnaris muscle occurs so that the hand deviates radially when flexed.
3. Paralysis of the medial part of the flexor digitorum profundus muscle occurs so that flexion of the ring and little fingers at the DIP joint is lost.
4. Paralysis of lumbrical muscles 3 and 4 occurs so that flexion of the ring and little fingers at the MP joint is lost and extension of the ring and little fingers at the DIP and PIP joints is lost.
5. Paralysis of the palmar and dorsal interosseous muscles occurs so that abduction and adduction of the fingers are lost. Flexion of the fingers at the MP joint is lost, and extension of the fingers at the DIP and PIP joints is lost.
6. Paralysis of the adductor pollicis muscle occurs so that adduction of the thumb is lost.
7. Paralysis of the abductor digiti minimi, flexor digiti minimi, and opponens digiti minimi muscles occurs so that all movement of the little finger is lost.
8. Sensory loss occurs on the palmar and dorsal aspects of half of the ring finger and the little finger.
9. Clinically a mild **clawhand** is observed.
10. To test the motor integrity of the ulnar nerve, the patient holds a piece of paper between the middle finger and ring finger as the physician attempts to remove it. This tests the function of the interosseous muscles.

G. Ulnar nerve injury at the wrist

1. The ulnar nerve may be injured by slashing of the wrist (e.g., suicide attempt).
2. This type of injury does not cause paralysis of the flexor carpi ulnaris muscle or the medial part of the flexor digitorum profundus muscle.
3. Paralysis of lumbrical muscles 3 and 4 occurs so that flexion of the ring and little fingers at the MP joint is lost. Extension of the ring and little fingers at the DIP and PIP joints is lost.
4. Paralysis of the palmar and dorsal interosseous muscles occurs so that abduction and adduction of the fingers are lost. Flexion of the fingers at the MP joint is lost. Extension of the fingers at the DIP and PIP joints is lost.
5. Paralysis of the adductor pollicis muscle occurs so that adduction of the thumb is lost.
6. Paralysis of the abductor digiti minimi, flexor digiti minimi, and opponens digiti minimi muscles occurs so that movement of the little finger is lost. Extension of the fingers at DIP and PIP joints is lost
7. Sensory loss occurs on the palmar and dorsal aspects of half of the ring finger and the little finger.
8. Clinically, a severe **clawhand** is observed because of the unopposed action of the flexor digitorum profundus.

VI. SHOULDER REGION (Figure 18-3)

A. Glenohumeral joint

1. **General features.** The glenohumeral joint is the articulation of the head of the humerus with the glenoid fossa of the scapula. It has two prominent bursae: the **subacromial bursa,** which separates the tendon of the supraspinatus muscle from the deltoid muscle, and the **subscapular bursa,** which separates the scapular fossa from the tendon of the subscapularis muscle. The **rotator cuff,** along with the **tendon of the long head of the biceps brachii muscle**, contributes to the stability of the glenohumeral joint by holding the head of the humerus against the glenoid surface of the scapula. The rotator cuff is formed by the tendons of the following muscles, represented by the acronym SITS:
   a. **Subscapular muscle,** which is innervated by the subscapularis nerve
   b. **Infraspinous muscle,** which is innervated by the suprascapular nerve
   c. **Teres minor muscle,** which is innervated by the axillary nerve
   d. **Supraspinous muscle,** which is innervated by the suprascapular nerve
2. **Clinical considerations**
   a. **Rotator cuff injury. Rotator cuff tendinitis** most commonly involves the **tendon of the supraspinous muscle** and the **subacromial bursa.** It commonly occurs in middle-aged men and causes pain on lifting the arm above the head. **Acute rotator cuff tear** causes acute onset of pain and inability to lift the arm above the head after the injury. In most cases, the **tendon of the supraspinous muscle** is torn.
   b. **Anterior or inferior dislocation of the humerus** is the most common type of shoulder dislocation. The head of the humerus lies anterior and inferior to the **coracoid process** of the scapula and may damage the **axillary nerve** or **axillary artery.** Dislocation occurs because of the shallowness of the glenoid fossa. Clinical signs include: loss of the normal round contour of the shoulder, a palpa-

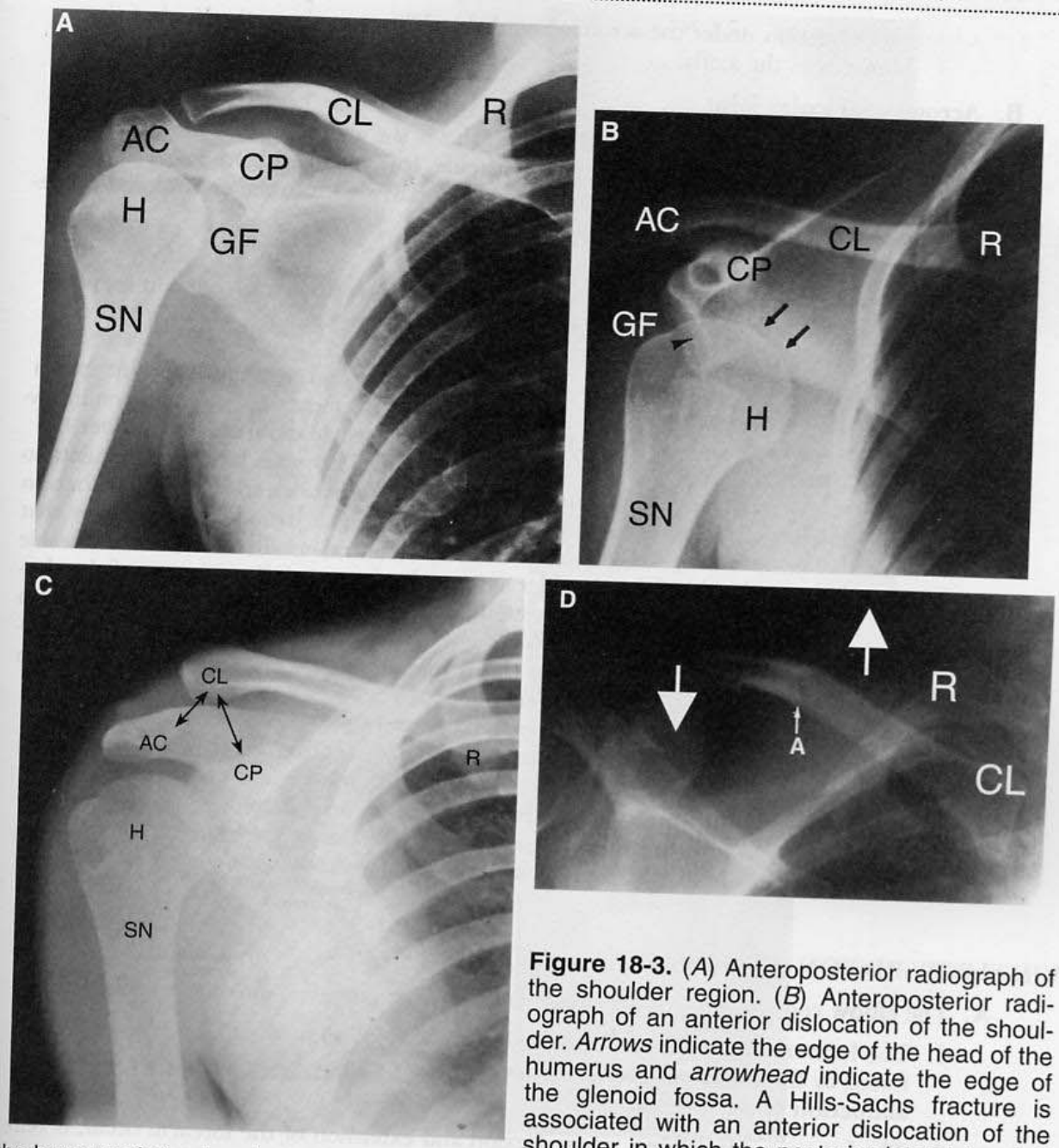


Figure 18-3. (*A*) Anteroposterior radiograph of the shoulder region. (*B*) Anteroposterior radiograph of an anterior dislocation of the shoulder. *Arrows* indicate the edge of the head of the humerus and *arrowhead* indicate the edge of the glenoid fossa. A Hills-Sachs fracture is associated with an anterior dislocation of the shoulder in which the posterior lateral head of the humerus is fractured as a result of contact with the rim of the glenoid fossa. (*C*) Anteroposterior radiograph of a separated shoulder. *Arrows* indicate the coracoclavicular space (*CP* ↔ *CL*) and acromioclavicular space (*AC* ↔ *CL*). (*D*) Anteroposterior radiograph of a fracture located in the middle third of the clavicle (*arrow A*). Note the upward displacement of the proximal fragment (↑) and downward displacement of the distal fragment (↓). *AC* = acromion; *CL* = clavicle; *CP* = coracoid process; *GF* = glenoid fossa; *H* = head of the humerus; *R* = first rib; *SN* = surgical neck of the humerus. (*A* adapted with permission from Fleckenstein P, Tranum-Jensen J: *Anatomy in Diagnostic Imaging.* Philadelphia, WB Saunders, 1993, p 58; *B* adapted with permission from Rosenbaum HD, Hildner JH: *Basic Clinical Diagnostic Radiology.* Baltimore, University Park Press, 1984, p 46; *C* adapted with permission from Slaby F, Jacobs ER: *Radiographic Anatomy.* Media, PA, Harwal, 1990, p 204; *D* adapted with permission from Levy RC, Hawkins H, Barsan WG: *Radiology in Emergency Medicine.* St. Louis, CV Mosby, 1986, p 113.)

ble depression under the acromion, and the ability to palpate the head of the humerus in the axilla.

B. Acromioclavicular joint

1. **General features.** The acromioclavicular joint is the articulation of the lateral end of the clavicle with the acromion of the scapula. It is stabilized by the **coracoacromial ligament, coracoclavicular ligament** (subdivided into the **conoid** and **trapezoid**), and **acromioclavicular ligament.**

2. **Clinical considerations**
   a. **Acromioclavicular subluxation (shoulder separation)** is a common injury that is caused by a downward blow at the tip of the shoulder. There are three grades of shoulder separation:
      (1) **Grade I (minor sprain).** No ligament tearing and no abnormal joint spaces
      (2) **Grade II.** Tearing of the acromioclavicular ligament so that the acromioclavicular space is 50% wider than in the uninjured (contralateral) shoulder
      (3) **Grade III.** Tearing of the coracoclavicular and acromioclavicular ligaments so that the coracoclavicular and acromioclavicular spaces are 50% wider than in the normal contralateral shoulder. Clinical signs include: injured arm that hangs noticeably lower than the normal (contralateral) arm and a noticeable bulge at the tip of the shoulder as a result of upward displacement of the clavicle. Depressing and then releasing the lateral end of the clavicle causes a rebound ("piano key sign"). A radiograph taken with the patient holding a 10-pound weight on the injured side shows marked separation of the acromion from the clavicle in grade II and III separations.
   b. **Fracture of the clavicle** occurs most commonly at the middle third of the clavicle. This type of fracture causes upward displacement of the proximal fragment as a result of the pull of the sternocleidomastoid muscle and downward displacement of the distal fragment as a result of gravity and the pull of the deltoid muscle. The subclavian artery and vein and the divisions of the brachial plexus that are located deep to the clavicle may be at increased risk for injury.

VII. ELBOW REGION (Figure 18-4)

A. The **elbow** consists of three articulations among the humerus, ulnar, and radial bones:

1. The **humeroulnar joint,** where flexion and extension of the forearm occur, is reinforced by the **ulnar collateral ligament.** A tear of this ligament permits abnormal **abduction** of the forearm.

2. The **humeroradial joint,** where flexion and extension of the forearm occur, is reinforced by the **radial collateral ligament.** A tear of this ligament permits abnormal **adduction** of the forearm.

3. The **radioulnar joint,** where pronation and supination of the forearm occur, is reinforced by the **annular ligament.**

B. Clinical considerations

1. **Nursemaid elbow** is a severe distal traction of the radius (e.g., caused by a parent yanking a child's arm). It can cause **subluxation of the head of the radius** from its encirclement by the **annular ligament.** Reduction involves applying direct pressure posteriorly on the head of the radius while simultaneously supinating and extending the forearm. This manipulation effectively "screws" the head of the radius

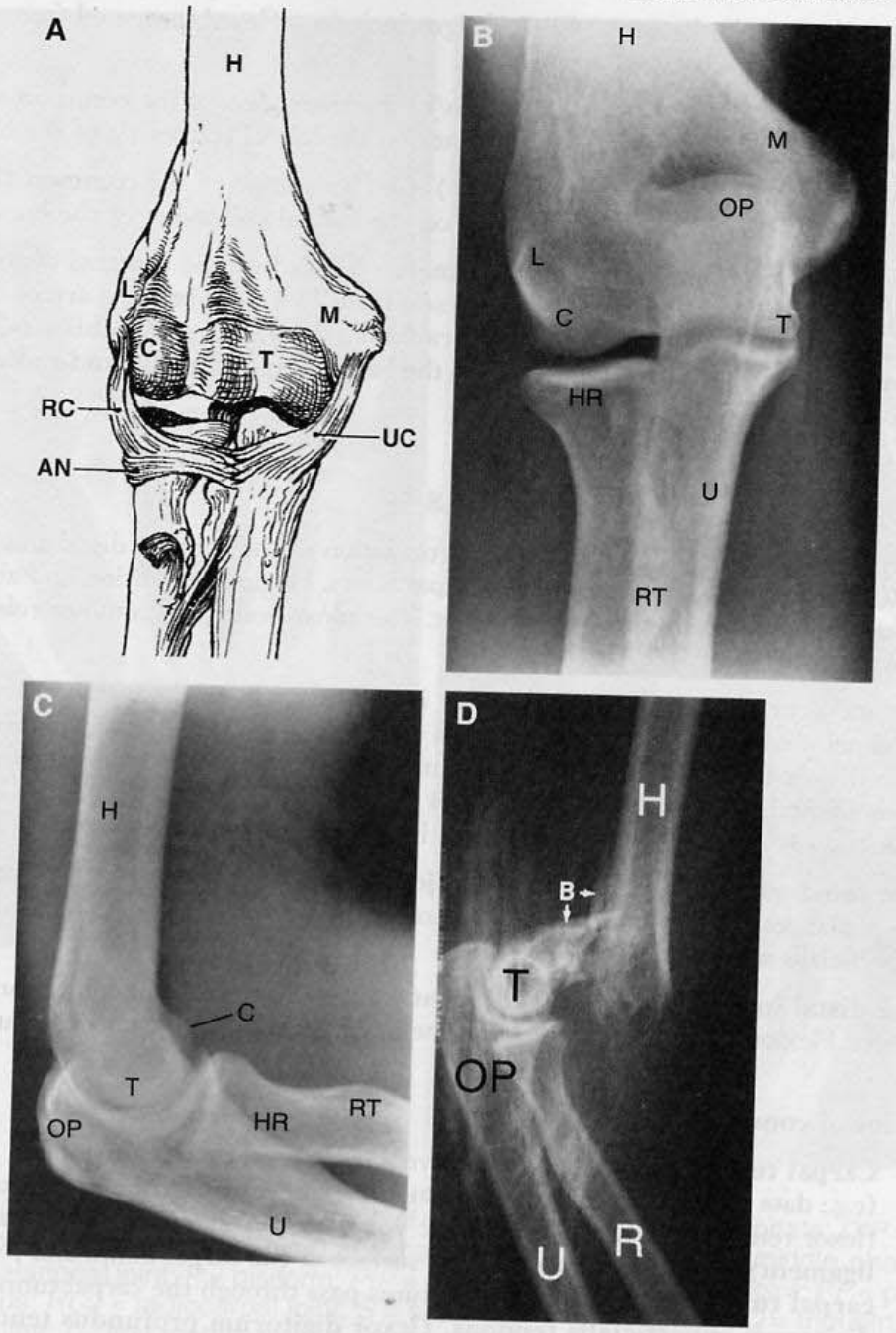


Figure 18-4. (*A*) The elbow region. Note the location of the ligaments that support the elbow joint. Anteroposterior (*B*) and lateral (*C*) radiographs of the right elbow joint. (*D*) Lateral radiograph of a supracondylar fracture (*B arrows*) of the humerus. Displacement of the humerus jeopardizes the contents of the cubital fossa, specifically, the median nerve and brachial artery. *AN* = annular ligament; *C* = capitulum; *H* = humerus; *HR* = head of the radius; *L* = lateral epicondyle; *M* = medial epicondyle; *OP* = olecranon process; *R* = radius; *RC* = radial collateral ligament; *RT* = radial tuberosity; *T* = trochlea; *U* = ulna; *UC* = ulnar collateral ligament. (*A* adapted with permission from April EW: *Anatomy*, 3rd ed. Baltimore, Williams & Wilkins, 1997, p 74; *B* and *C* adapted with permission from Slaby F, Jacobs ER: *Radiographic Anatomy.* Media, PA, Harwal, 1990, pp 10, 12; *D* adapted with permission from Levy RC, Hawkins H, Barsan WG: *Radiology in Emergency Medicine.* St. Louis, CV Mosby, 1986, p 341.)

into the annular ligament. Clinical signs include: a flexed, pronated forearm held close to the body.

2. **Lateral epicondylitis (tennis elbow)** is inflammation of the **common extensor tendon** of the wrist where it originates on the lateral epicondyle of the humerus.
3. **Medial epicondylitis (golfer elbow)** is inflammation of the **common flexor tendon** of the wrist where it originates on the medial epicondyle of the humerus.
4. **Supracondylar fracture of the humerus** jeopardizes the contents of the cubital fossa, specifically the median nerve (see Table 18-1) and brachial artery. The cubital fossa contains the **median nerve, brachial artery, biceps brachii tendon, median cubital vein** (superficial to the bicipital aponeurosis), and **radial nerve** (deep to the brachioradialis muscle).

VIII. WRIST AND HAND REGION (Figure 18-5)

A. The **wrist (radiocarpal) joint** is the articulation of the concave distal end of the radius with the scaphoid and lunate carpal bones. Flexion/extension and abduction/adduction of the hand occur at the wrist. The ulnar bone plays a minor role at this joint.

B. The **metacarpophalangeal (MP) joint** is located between the metacarpals and the proximal phalanx. Flexion at this joint is accomplished by the flexor digitorum superficialis, flexor digitorum profundus, and lumbrical muscles. **Ad**duction at this joint is accomplished by the **p**almar interosseous muscles (hence, the acronym PAD), and **ab**duction is accomplished by the **d**orsal interosseous muscles (DAB).

C. The **proximal interphalangeal (PIP) joint** is located between the proximal and middle phalanges. Flexion at this joint is accomplished primarily by the flexor digitorum superficialis muscle.

D. The **distal interphalangeal (DIP) joint** is located between the middle and distal phalanges. Flexion at this joint is accomplished primarily by the flexor digitorum profundus muscle.

E. Clinical considerations

1. **Carpal tunnel syndrome** is tendosynovitis caused by repetitive hand movements (e.g., data entry) that compress the **median nerve** within the carpal tunnel. The flexor retinaculum (composed of the **volar carpal ligament** and **transverse carpal ligament**) is attached to the palmar surface of the carpal bones and forms the **carpal tunnel.** The following structures pass through the carpal tunnel: the **flexor digitorum superficialis tendons, flexor digitorum profundus tendons, flexor pollicis longus tendon,** and the **median nerve.** No arteries pass through this tunnel. Clinical signs include: sensory loss on the palmar and dorsal aspects of the index finger, middle finger, and half of the ring finger, and on the palmar aspect of the thumb; flattening of the thenar eminence (ape hand); a tingling sensation produced by tapping the palmaris longus tendon (Tinel test); and the ability to elicit symptoms by forced flexion of the wrist and to alleviate them by extension of the wrist (Phalen test).
2. **Slashing of the wrist ("suicide cuts").** A deep laceration on the radial side of the wrist may cut the **radial artery, median nerve, flexor carpi radialis tendon,**

Figure 18-5. (*A*) Posteroanterior radiograph of the hand and wrist. *C* = capitate; *DIP* = distal interphalangeal joint; *DP* = distal phalanx; *H* = hamate; *L* = lunate; *MP* = middle phalanx; *MPJ* = metacarpophalangeal joint; *P* = pisiform; *PIP* = proximal interphalangeal joint; *PP* = proximal phalanx; *R* = radius; *RCJ* = radiocarpal joint; *S* = scaphoid; *T* = trapezoid; *TQ* = triquetrum; *TZ* = trapezium; *U* = ulna; *I* = first metacarpal; *II* = second metacarpal; *III* = third metacarpal; *IV* = fourth metacarpal; *V* = fifth metacarpal. (*B*) Radiograph of a scaphoid fracture (*arrows*). The proximal part of the scaphoid is susceptible to osteonecrosis. (*C*) Lateral radiograph of a Colles fracture (*arrow A*). The distal fragment of the radius (*DR*) is displaced posteriorly (*arrow*) in the "dinner fork" deformity. (*D*) Radiograph of the hand shows a boxer fracture (*arrows*) at the head of the fifth metacarpal (*V*). The location of a "gamekeeper thumb," in which the ulnar collateral ligament of the metacarpophalangeal joint of the thumb becomes disrupted (*dotted line*), is shown. (*A* adapted with permission from Slaby F, Jacobs ER: *Radiographic Anatomy.* Media, PA, Harwal, 1990, p 22; *B* reprinted and *D* adapted with permission from Rosenbaum HD, Hildner JH: *Basic Clinical Diagnostic Radiology,* Baltimore, University Park Press, 1984, p 41; *C* adapted with permission from Levy RC, Hawkins H, Barsan WG: *Radiology in Emergency Medicine.* St. Louis, CV Mosby, 1986, p 353.)

and **palmaris longus tendon.** A deep laceration on the ulnar side of the wrist may cut the **ulnar artery, ulnar nerve,** and **flexor carpi ulnaris tendon.**

3. **Fracture of the scaphoid** (see Figure 18-5B). The scaphoid is the most commonly fractured carpal bone. It articulates with the distal end of the radius at the radiocarpal joint. Fracture of the scaphoid is associated with **osteonecrosis** of the scaphoid bone (proximal fragment) because the blood supply flows from distal to proximal. Clinical signs include: tenderness in the "**anatomic snuffbox**" (formed by the extensor pollicis longus, extensor pollicis brevis, and abductor pollicis longus tendons), because the scaphoid lies in the floor of the snuffbox. A radiograph may appear normal for several weeks until bone resorption occurs.
4. **Colles fracture** is posterior displacement of the distal portion of the radius ("dinner fork" deformity) [see Figure 18-5C]. Typically, it occurs when a person falls on an outstretched hand with the wrist extended, and it often is accompanied by a fracture of the ulnar styloid process.
5. **Boxer fracture** is a fracture at the head of the fifth metacarpal (little finger) [see Figure 18-5D]. It occurs when a closed fist is used to hit a hard or inflexible object. Clinical signs include: pain on the ulnar side of the hand, depression of the head of the fifth metacarpal, and pain elicited by attempts to flex the little finger.
6. **Gamekeeper thumb** is a disruption of the ulnar collateral ligament of the MP joint of the thumb. It commonly occurs when a skier's thumb becomes entangled with the ski pole during a fall. It often is associated with an avulsion fracture at the base of the proximal phalanx of the thumb (see Figure 18-5D).
7. **Volkmann ischemic contracture** causes contraction of the muscles of the forearm. It is often associated with a supracondylar fracture of the humerus in which the brachial artery goes into spasm, reducing blood flow. It also may be caused by a cast that is too tight or by compartment syndrome (see Chapter 19 I F 4), in which muscles are subjected to increased pressure because of edema or hemorrhage.
8. **Dupuytren contracture** is thickening and contracture of the palmar aponeurosis that causes progressive flexion of the fingers. It usually is more pronounced in the ring and little fingers. It is highly correlated with coronary artery disease, possibly because of vasospasm caused by sympathetic innervation of the vasculature within the T1 component of the ulnar nerve.

IX. CROSS-SECTIONAL ANATOMY OF THE RIGHT ARM AND FOREARM (Figure 18-6)

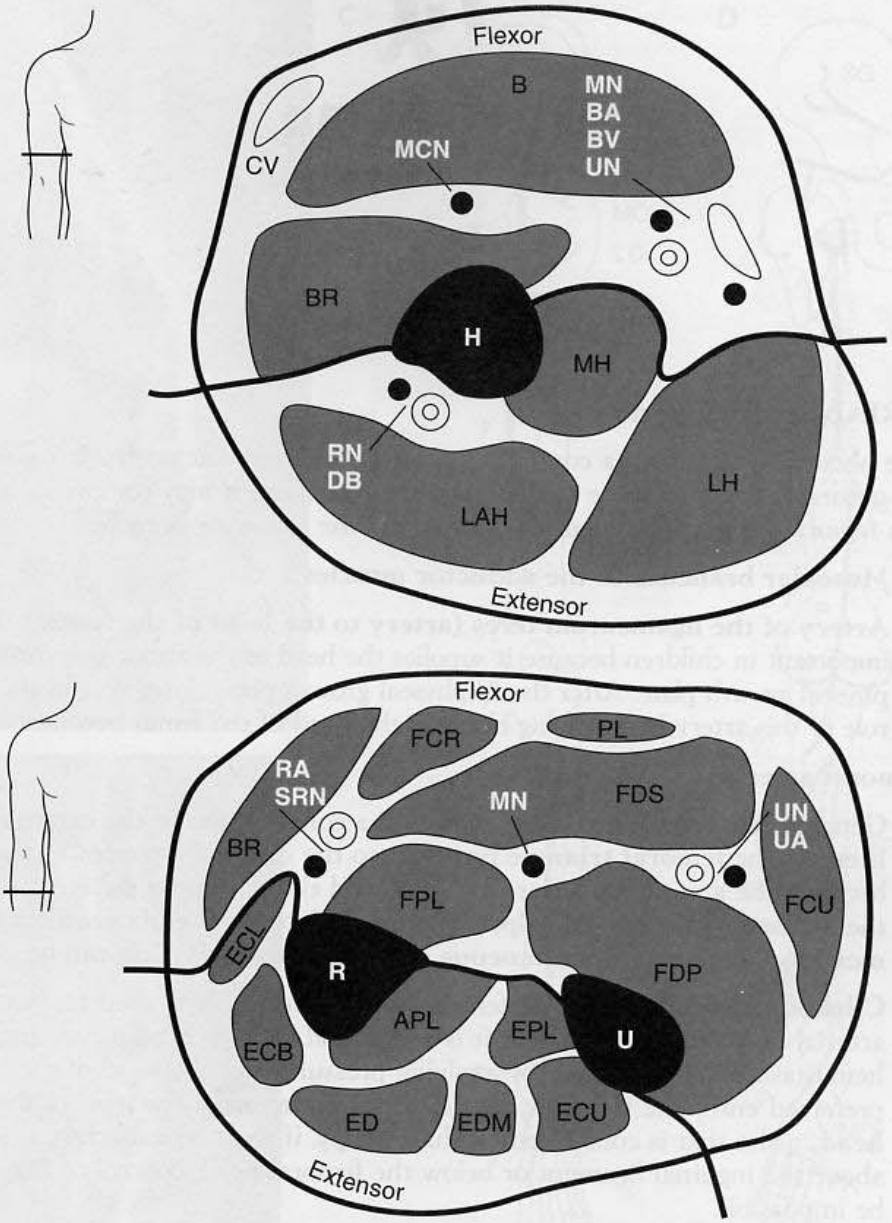


Figure 18-6. (*A*) Cross-section through the right brachium (arm). The *horizontal line* divides the flexor (anterior) compartment from the extensor (posterior) compartment. The radial nerve (*RN*) travels with the deep brachial artery (*DB*) within the extensor compartment. The median nerve (*MN*) travels with the brachial artery (*BA*). The ulnar nerve (*UN*) is seen near the basilic vein (*BV*). *B* = biceps brachii; *BR* = brachioradialis; *CV* = cephalic vein; *H* = humerus; *LAH* = lateral head of the triceps; *LH* = long head of the triceps; *MCN* = musculocutaneous nerve; *MH* = medial head of the triceps. (*B*) Cross-section through the right antebrachium (forearm). The *horizontal line* divides the flexor (anterior) compartment from the extensor (posterior) compartment. Note the location of the ulnar artery (*UA*), ulnar nerve (*UN*), median nerve (*MN*), radial artery (*RA*), and superficial branch of the radial nerve (*SRN*) within the flexor compartment. *APL* = abductor pollicis longus; *BR* = brachioradialis; *ECB* = extensor carpi radialis brevis; *ECL* = extensor carpi radialis longus; *ECU* = extensor carpi ulnaris; *ED* = extensor digitorum; *EDM* = extensor digiti minimi; *EPL* = extensor pollicis longus; *FCR* = flexor carpi radialis; *FCU* = flexor carpi ulnaris; *FDP* = flexor digitorum profundus; *FDS* = flexor digitorum superficialis; *FPL* = flexor pollicis longus; *PL* = palmaris longus; *R* = radius; *U* = ulna. (Adapted with permission from Barrett CP, Poliakoff SJ, Holder LE, et al: *Primer of Sectional Anatomy with MRI and CT Correlation,* 2nd ed. Baltimore, Williams & Wilkins, 1994.)

19

Lower Limb

I. ARTERIAL SUPPLY (Figure 19-1)

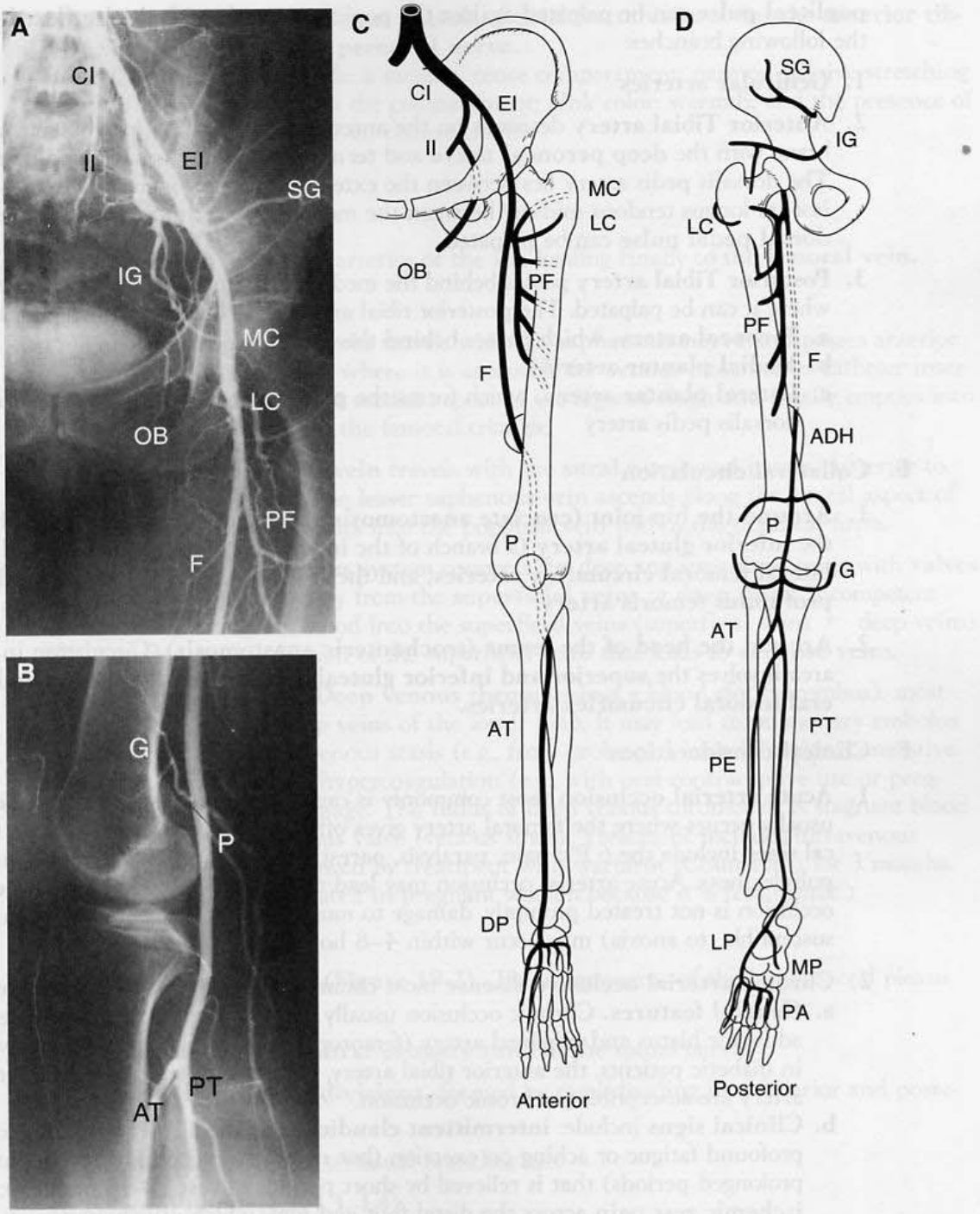
A. The **obturator artery** is a continuation of the internal iliac artery. It passes through the obturator foramen close to the femoral ring, where it may complicate surgical repair of a femoral hernia. The obturator artery has the following branches:

1. **Muscular branches to the adductor muscles**
2. **Artery of the ligamentum teres (artery to the head of the femur).** This artery is important in children because it supplies the head of the femur **proximal** to the epiphyseal growth plate. After the epiphyseal growth plate closes (i.e., in the adult), the role of this artery in supplying blood to the head of the femur becomes insignificant.

B. **Femoral artery**

1. **General features.** The femoral artery is a continuation of the external iliac artery. It enters the **femoral triangle** posterior to the inguinal ligament and midway between the anterior superior iliac spine and the symphysis pubis. At this location, the **femoral pulse** can be palpated, arterial blood can be obtained for **blood gas measurements**, and **percutaneous arterial catheterization** can be performed.
2. **Clinical consideration.** The femoral artery commonly is used for percutaneous arterial catheterization because it is superficial and easily palpated, and because hemostasis can be achieved by applying pressure over the head of the femur. The preferred entry site is **below the inguinal ligament** at the level of the **midfemoral head,** a site that is confirmed by fluoroscopy. If the femoral artery is punctured above the inguinal ligament or below the femoral head, control of hemostasis may be impossible.
3. The femoral artery gives off the **profunda femoris artery.**

Figure 19-1. (*A*) Anteroposterior arteriogram of the hip region. (*B*) Lateral arteriogram of the knee region. Anterior (*C*) and posterior (*D*) views of the arterial supply of the lower limb. It is important to be able to identify an artery on an arteriogram and to state which nerve runs with that artery. *ADH* = adductor hiatus within the adductor magnus muscle; *AT* = anterior tibial artery (runs with the deep peroneal nerve); *CI* = common iliac artery; *DP* = dorsalis pedis artery; *EI* = external iliac artery; *F* = femoral artery (runs with the femoral nerve); *G* = superior genicular arteries; *IG* = inferior gluteal artery (runs with the inferior gluteal nerve); *II* = internal iliac artery; *LC* = lateral femoral circumflex artery; *LP* = lateral plantar artery; *MC* = medial femoral circumflex artery; *MP* = medial plantar artery; *OB* = obturator artery (runs with the obturator nerve); *P* = popliteal artery (runs with the sciatic nerve, where it branches into the tibial nerve and common peroneal nerve); *PA* = plantar arch; *PE* = peroneal artery; *PF* = profunda femoris artery; *PT* = posterior tibial artery (runs with the tibial nerve); *SG* = superior gluteal artery (runs with the superior gluteal nerve). (*A* and *B* adapted with permission from Fleckenstein P, Tranum-Jensen J: *Anatomy in Diagnostic Imaging.* Philadelphia, WB Saunders, 1993, p 109.)



C. The **profunda femoris artery** branches into the:

1. **Four perforating arteries**
2. **Medial circumflex artery,** which provides the main blood supply to the head and neck of the femur in adults
3. **Lateral circumflex artery**

D. The **popliteal artery** is a continuation of the femoral artery at the **adductor hiatus** in the adductor magnus muscle. It extends through the popliteal fossa, where the

popliteal pulse can be palpated against the popliteus muscle with the leg flexed. It has the following branches:

1. **Genicular arteries**
2. **Anterior Tibial artery** descends on the anterior surface of the interosseous membrane with the **deep peroneal nerve** and terminates as the **dorsalis pedis artery.** The dorsalis pedis artery lies between the extensor hallucis longus and extensor digitorum longus tendons midway between the medial and lateral malleolus where the **dorsal pedal pulse** can be palpated.
3. **Posterior Tibial artery** passes behind the medial malleolus with the **tibial nerve** where it can be palpated. The posterior tibial artery gives off the following branches:
   a. **Peroneal artery,** which passes behind the lateral malleolus
   b. **Medial plantar artery**
   c. **Lateral plantar artery,** which forms the **plantar arch,** which connects to the dorsalis pedis artery

E. Collateral circulation

1. **Around the hip joint (cruciate anastomosis).** Circulation in this area involves the **inferior gluteal artery** (a branch of the internal iliac artery), the **medial and lateral femoral circumflex arteries,** and the **first perforating branch of the profundus femoris artery.**
2. **Around the head of the femur (trochanteric anastomosis).** Circulation in this area involves the **superior and inferior gluteal arteries** and the **medial and lateral femoral circumflex arteries.**

F. Clinical considerations

1. **Acute arterial occlusion** most commonly is caused by **embolism** or **thrombosis.** It usually occurs where the femoral artery gives off the profunda femoris artery. Clinical signs include the 6 P's: pain, paralysis, paresthesia, pallor, poikilothermia, and pulselessness. Acute arterial occlusion may lead to loss of the lower limb. If the occlusion is not treated promptly, damage to muscle and nerve (both of which are susceptible to anoxia) may occur within 4–8 hours.
2. **Chronic arterial occlusive disease** most commonly is caused by **atherosclerosis.**
   a. **General features.** Chronic occlusion usually involves the femoral artery near the adductor hiatus and popliteal artery (femoropopliteal in 50% of cases). However, in diabetic patients, the anterior tibial artery, posterior tibial artery, and peroneal artery are susceptible to chronic occlusion.
   b. **Clinical signs** include: **intermittent claudication,** the key feature of which is profound fatigue or aching on exertion (but never after sitting or standing for prolonged periods) that is relieved by short periods of rest (5–10 minutes); **ischemic rest pain** across the distal foot and toes, which usually occurs at night and awakens the patient. The pain is exacerbated by elevation and relieved by keeping the limb in a dependent position (e.g., sleeping with the leg over the side of the bed).
3. **Compartment syndrome** is an increase in the interstitial fluid pressure ($\geq$ 30 mm Hg) within an osseofascial compartment. This increased pressure compromises microcirculation (ischemia) and leads to muscle and nerve damage.
   a. **General features.** Compartment syndrome most often occurs in the anterior compartment of the thigh as a result of crush injuries (e.g., in a car accident) involving the **femoral artery** and **femoral nerve.** It also occurs in the anterior

compartment of the leg as a result of tibial fractures involving the **anterior tibial artery** and **deep peroneal nerve.**

b. **Clinical signs** include: a swollen, tense compartment; pain on passive stretching of the tendons within the compartment; pink color; warmth; and the presence of a pulse over the involved compartment.

II. VENOUS DRAINAGE

A. The **deep veins** follow the arteries of the leg, leading finally to the **femoral vein.**

B. **Superficial veins**

1. The **great saphenous vein** travels with the **saphenous nerve** and passes anterior to the medial malleolus, where it is accessible for venous puncture or catheter insertion. It ascends along the medial aspect of the leg and thigh and finally empties into the femoral vein within the femoral triangle.

2. The **lesser saphenous vein** travels with the **sural nerve** and passes posterior to the lateral malleolus. The lesser saphenous vein ascends along the lateral aspect of the leg and finally empties into the popliteal vein within the popliteal fossa.

C. The **communicating venous system** connects the deep and superficial veins with **valves** that allow flow of blood only from the **superficial veins → deep veins.** Incompetent valves allow backflow of blood into the superficial veins (superficial veins ← deep veins). This backflow causes dilation of the superficial veins that leads to **varicose veins.**

D. **Clinical consideration. Deep venous thrombosis** is a blood clot (thrombus), most commonly within the deep veins of the lower limb. It may lead to pulmonary embolus and usually is caused by venous stasis (e.g., from prolonged immobilization, congestive heart failure, or obesity), hypercoagulation (e.g., with oral contraceptive use or pregnancy), or endothelial damage. The nidus of deep venous thrombosis is stagnant blood behind the cusp of a venous valve (venous sinus). Treatment includes intravenous heparin for 5–7 days followed by treatment with warfarin (Coumadin) for 3 months. (Coumadin is contraindicated in pregnant women because it is teratogenic.)

III. LUMBOSACRAL PLEXUS (Figure 19-2). The components of the lumbosacral plexus include:

A. The **L1–5 and S1–4 ventral primary rami** of the spinal nerves

B. **Anterior and posterior divisions,** formed by rami dividing into anterior and posterior divisions

C. **Branches.** The six major terminal branches are:

1. **Femoral nerve (L2, L3, L4)**
2. **Obturator nerve (L2, L3, L4)**
3. **Superior gluteal nerve (L4, L5, S1)**
4. **Inferior gluteal nerve (L5, S1, S2)**
5. **Common peroneal nerve (L4, L5, S1, S2),** which divides into the **superficial** and **deep peroneal nerves**
6. **Tibial nerve (L4, L5, S1, S2, S3),** which combines with the common peroneal nerve to make up the **sciatic nerve**

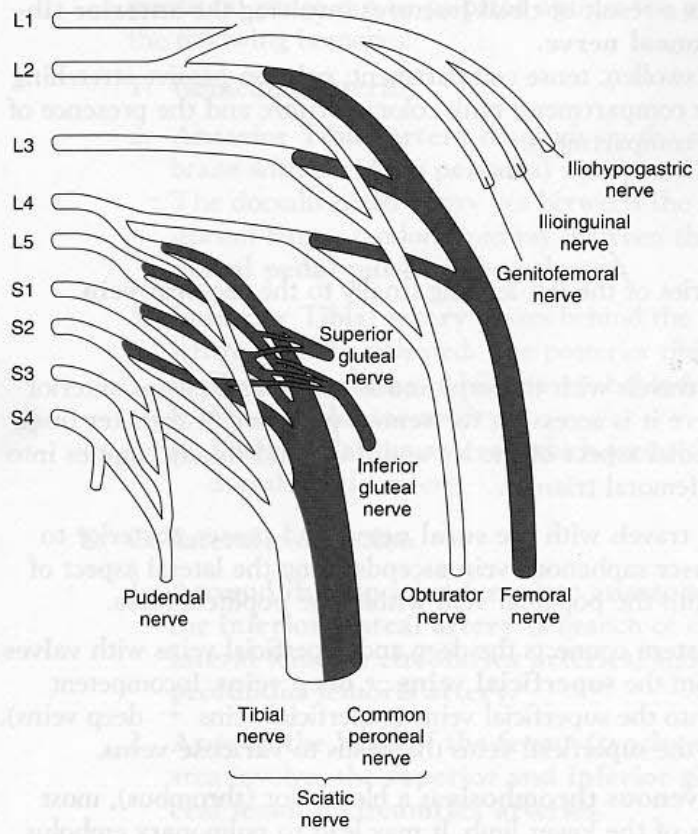


Figure 19-2. The lumbosacral plexus. The rami, divisions, and six major terminal branches are shown. The posterior divisions and branches are shown in black. The pudendal nerve is also shown which was discussed previously. (See Chapter 16 II A and VI B, Figure 16-2, and Table 17-2.)

D. Clinical considerations. Herniation of intervertebral disks is the most common injury that affects the lumbosacral plexus (see Chapter 1 I D 15 and Table 1-2).

IV. NERVE LESIONS (Table 19-1)

A. Femoral nerve injury

1. The femoral nerve may be injured by trauma at the femoral triangle or pelvic fracture.
2. Paralysis of the iliacus and sartorius muscles occurs so that flexion of the thigh is weakened.
3. Paralysis of the quadriceps femoris muscles occurs so that extension of the leg is lost (i.e., loss of knee-jerk reflex).
4. Sensory loss occurs on the anterior aspect of the thigh and the medial aspect of the leg.

B. Obturator nerve injury

1. The obturator nerve may be injured as a result of anterior dislocation of the hip or during radical retropubic prostatectomy.
2. Paralysis of a portion of the adductor magnus, adductor longus, and adductor brevis muscles occurs so that adduction of the thigh is lost.
3. Sensory loss occurs on the medial aspect of the thigh.

Table 19-1.
Nerve Lesions

Nerve	Cause of Injury	Impairments	Clinical Features
Femoral	Trauma at femoral triangle Pelvic fracture	Flexion of thigh is weakened Extension of leg is lost Sensory loss on anterior thigh and medial leg	Loss of knee jerk reflex Anesthesia on anterior thigh
Obturator	Anterior hip dislocation Radical retropubic prostatectomy	Adduction of thigh is lost Sensory loss on medial thigh	
Superior gluteal	Surgery in area Posterior hip dislocation Poliomyelitis	Gluteus medius and minimus function is lost Ability to pull pelvis down and abduction of thigh are lost	Gluteus medius limp, or waddling gait Positive Trendelenburg sign Contralateral 
Inferior gluteal	Surgery in area Posterior hip dislocation	Gluteus maximus function is lost Ability to rise from a seated position, climb stairs, or jump is lost	Leaning backward at heel strike 
Common peroneal	Blow to lateral aspect of leg Fracture of neck of fibula	Eversion of foot is lost Dorsiflexion of foot is lost Extension of toes is lost Sensory loss on anterolateral leg and dorsum of the foot	Plantar flexion (foot drop) and inversion of foot Inability to stand on heels Walks with a foot slap 
Tibial at popliteal fossa	Trauma at popliteal fossa	Inversion of foot is lost Plantar flexion of foot is lost Flexion of toes is lost Sensory loss on sole of foot	Dorsiflexion and eversion of foot Inability to stand on toes

C. Superior gluteal nerve injury

1. The superior gluteal nerve may be injured during surgery, posterior dislocation of the hip, or poliomyelitis.
2. Paralysis of the gluteus medius and gluteus minimus muscles occurs so that the ability to pull the pelvis down and abduction of the thigh are lost.
3. Clinically, this condition is called **"gluteus medius limp"** or **"waddling gait."** The patient demonstrates a **positive Trendelenburg sign,** which is tested as follows. The patient stands with his or her back to the examiner and alternately raises each foot off the ground. If the superior gluteal nerve on the *left* side is injured, the *right* pelvis falls downward when the patient raises the right foot off the ground. Note that it is the side *contralateral* to the nerve injury that is affected. A Trendelenburg sign also can be observed in a patient with a hip dislocation or fracture of the neck of the femur.

D. Inferior gluteal nerve injury

1. The inferior gluteal nerve may be injured during surgery or posterior dislocation of the hip.
2. Paralysis of the gluteus maximus muscle occurs so that the ability to rise from a seated position, to climb stairs, or to jump is lost.
3. Clinically, the patient is able to walk. However, the patient leans the body trunk backward at heel strike to compensate for the loss of gluteus maximus function.

E. Common peroneal nerve injury

1. The common peroneal nerve may be injured as the result of a blow to the lateral aspect of the leg or fracture of the neck of the fibula. This is a very common type of injury.
2. Paralysis of the peroneus longus and peroneus brevis muscles (innervated by the superficial peroneal nerve) occurs so that eversion of the foot is lost.
3. Paralysis of the tibialis anterior muscle (innervated by the deep peroneal nerve) occurs so that dorsiflexion of the foot is lost.
4. Paralysis of the extensor digitorum longus and extensor hallucis longus muscles (innervated by the deep peroneal nerve) occurs so that extension of the toes is lost.
5. Sensory loss occurs on the anterolateral aspect of the leg and dorsum of the foot.
6. Clinically, the patient presents with the **foot plantar flexed ("foot drop")** and **inverted**. Because of the loss of dorsiflexion, the **patient cannot stand on his or her heels.** The patient has a high-stepping gait in which the foot is raised higher than normal so that the toes do not hit the ground. In addition, the foot is brought down suddenly, which produces a "slapping" sound **(foot slap).**

F. Tibial nerve injury at the popliteal fossa

1. The tibial nerve may be injured as a result of trauma at the popliteal fossa.
2. Paralysis of the tibialis posterior muscle occurs so that inversion of the foot is weakened.
3. Paralysis of the gastrocnemius, soleus, and plantaris muscles occurs so that plantar flexion of the foot is lost.
4. Paralysis of the flexor digitorum longus and flexor hallucis longus muscles occurs so that flexion of the toes is lost.
5. Sensory loss occurs on the sole of the foot.

6. Clinically, the patient presents with the **foot dorsiflexed** and **everted**. Because of the loss of plantar flexion, the **patient cannot stand on his or her toes.**

V. HIP AND GLUTEAL REGION (Figure 19-3). The **piriformis muscle** is the landmark of the gluteal region. The superior gluteal vessels and nerve emerge superior to the piriform muscle; the inferior gluteal vessels and nerve emerge inferior to it. Gluteal intramuscular injections can be safely made in the **superolateral portion** of the buttock.

A. The **hip joint** is the articulation of the head of the femur with the lunate surface of the acetabulum and the acetabular labrum. It is supported by the following ligaments:

1. The **iliofemoral ligament (Y ligament of Bigelow)** is the largest ligament and reinforces the hip joint anteriorly.
2. The **pubofemoral ligament** reinforces the hip joint inferiorly.
3. The **ischiofemoral ligament** is the thinnest ligament and reinforces the hip joint posteriorly.
4. The **ligamentum teres** plays a minor role in the stability of the hip joint, but carries the **artery to the head of the femur**.

B. The hip joint is related to the **femoral triangle,** which contains the following structures (listed medially → laterally):

1. The **femoral canal** (the most medial structure), which contains lymphatics and lymph nodes
2. The **femoral vein.** The **great saphenous vein** joins the femoral vein within the femoral triangle, just below and lateral to the pubic tubercle. A great saphenous vein cutdown can be performed at this site.
3. The **femoral artery**
4. The **femoral nerve** (the most lateral structure)

C. Clinical considerations

1. **Femoral neck fracture** most commonly occurs just distal to the femoral head (subcapital location) in elderly women who have osteoporosis. As a result, the lower limb is **externally rotated** and **shorter** than the uninjured limb. Avascular necrosis of the femoral head may occur if the medial and lateral circumflex arteries are compromised.
2. **Posterior dislocation of the hip joint** most commonly occurs due to severe trauma (e.g., car accident in which the flexed knee hits the dashboard). In a posterior dislocation, the head of the femur lies posterior to the iliofemoral ligament; the acetabulum may be fractured as well. As a result, the lower limb is **internally rotated, adducted**, and is **shorter** than the uninjured limb. Avascular necrosis of the femoral head may occur if the medial and lateral circumflex arteries are compromised. The **sciatic nerve** also may be damaged.
3. **Anterior dislocation of the hip joint** accounts for the remainder of hip dislocations. In an anterior dislocation, the head of the femur lies anterior to the iliofemoral ligament. As a result, the lower limb is **externally rotated** and **abducted**. The **femoral artery** may be damaged so that the lower limb may become cyanotic.
4. **Legg-Perthes disease** is characterized by idiopathic avascular necrosis of the head of the femur. This necrosis may occur when the medial and lateral circumflex arteries gradually replace the artery to the head of the femur as the main blood supply to this area. It most commonly affects Caucasian boys and causes unilateral hip pain,

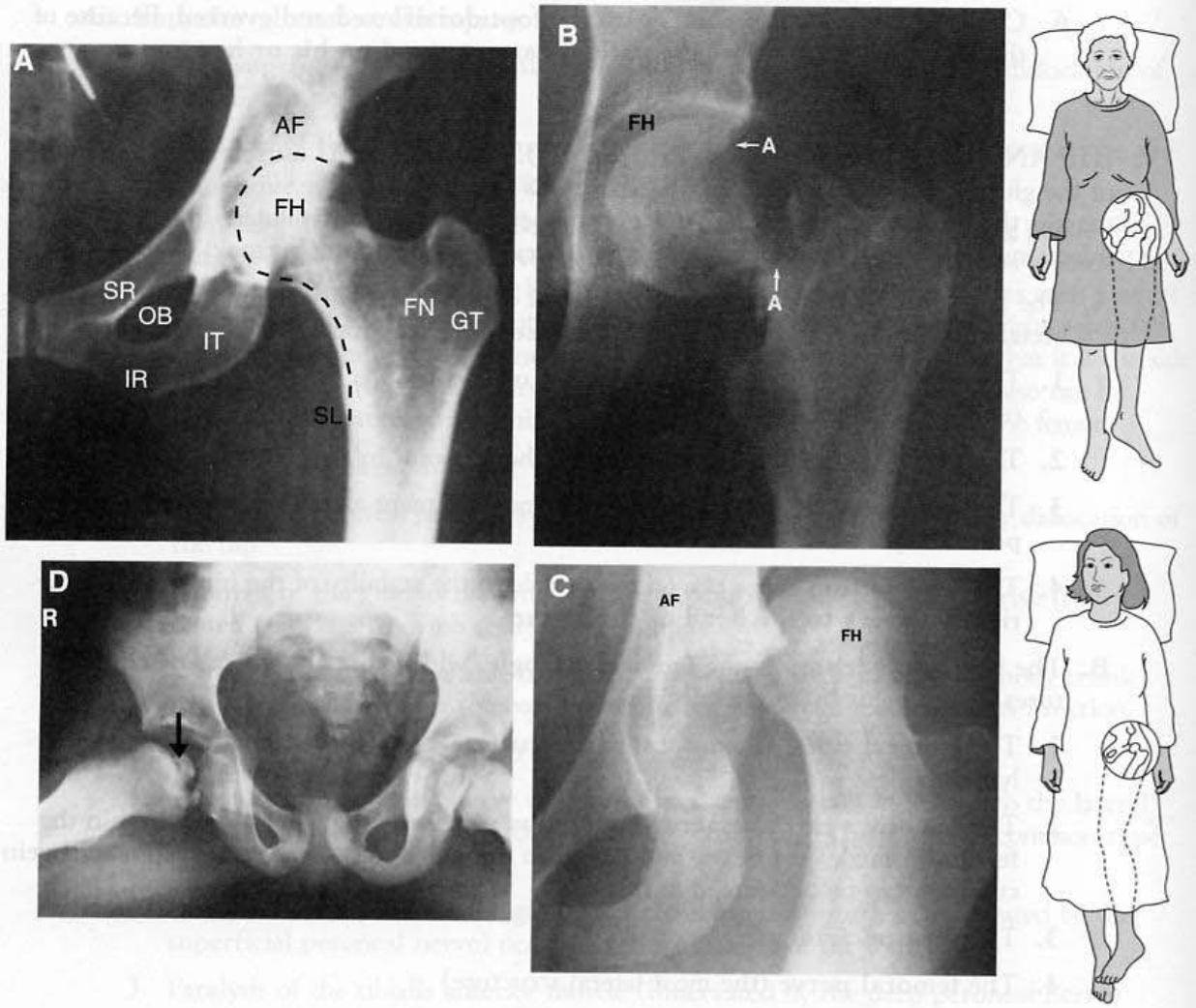


Figure 19-3. (*A*) Anteroposterior radiograph of the hip region. *AF* = acetabular fossa (*curved dotted line*); *FH* = femoral head; *FN* = femoral neck; *GT* = greater trochanter; *IR* = inferior ramus of the pubis; *IT* = ischial tuberosity; *OB* = obturator foramen; *SL* = Shenton line (a radiology term that describes a curved line drawn along the medial border of the femur and the superior border of the obturator foramen); *SR* = superior ramus of the pubis. (*B*) Anteroposterior radiograph of a femoral neck fracture (subcapital). In this type of fracture, seen most commonly in elderly women with osteoporosis, the lower limb is externally rotated and is shorter than the uninjured limb. *A* = oblique fracture line; *FH* = femoral head. (*C*) Anteroposterior radiograph of a posteriorly dislocated hip. This type of dislocation occurs most commonly in people who are involved in car accidents. The lower limb is internally rotated, adducted, and is shorter than the uninjured limb. *AF* = acetabular fossa; *FH* = dislocated femoral head. (*D*) Anteroposterior radiograph of an 8-year-old boy with Legg-Perthes disease. This patient had a limp and pain in the right hip. The femoral head on the right side (*arrow*) is almost completely absent, except for two bone fragments. The femoral head on the left side is normal. (*A* adapted with permission from Fleckenstein P, Tranum-Jensen J: *Anatomy in Diagnostic Imaging.* Philadelphia, WB Saunders, 1993, p 80; *B* and *C* adapted with permission from Levy RC, Hawkins H, Barsan WG: *Radiology in Emergency Medicine.* St. Louis, CV Mosby, 1986, pp 403, 405; *D* adapted with permission from Rosenbaum HD, Hildner JH: *Basic Clinical Diagnostic Radiology.* Baltimore, University Park Press, 1984, p 69.)

slight external rotation, and a limp. This disease has three major phases: **initial, degenerative**, and **regenerative.**

VI. KNEE REGION (Figure 19-4)

A. The **knee (femorotibial) joint** is the articulation of the medial and lateral condyles of the femur with the medial and lateral condyles of the tibia. It is supported by the following ligaments:

1. The **patellar ligament,** which is struck to elicit the knee-jerk reflex. This reflex is blocked by damage to the femoral nerve, which supplies the quadriceps muscle, or by damage to spinal cord segments L2–4.
2. The **medial (tibial) collateral ligament** extends from the medial epicondyle of the femur to the shaft of the tibia. This ligament prevents **abduction** at the knee joint; tearing causes abnormal passive abduction of the extended leg.
3. The **lateral (fibular) collateral ligament** extends from the lateral epicondyle of the femur to the head of the fibula. This ligament prevents **adduction** at the knee joint; tearing causes abnormal passive adduction of the extended leg.
4. The **anterior cruciate ligament** extends from the anterior aspect of the tibia to the lateral condyle of the femur. This ligament prevents anterior movement of the tibia in reference to the femur. A torn anterior cruciate ligament causes abnormal passive anterior displacement of the tibia **(anterior drawer sign). Hyperextension injury** at the knee joint stretches the anterior cruciate ligament.
5. The **posterior cruciate ligament** extends from the posterior aspect of the tibia to the medial condyle of the femur. This ligament prevents posterior movement of the tibia in reference to the femur. A torn posterior cruciate ligament causes abnormal passive posterior displacement of the tibia **(posterior drawer sign). Hyperflexion injury** at the knee joint stretches the posterior cruciate ligament.

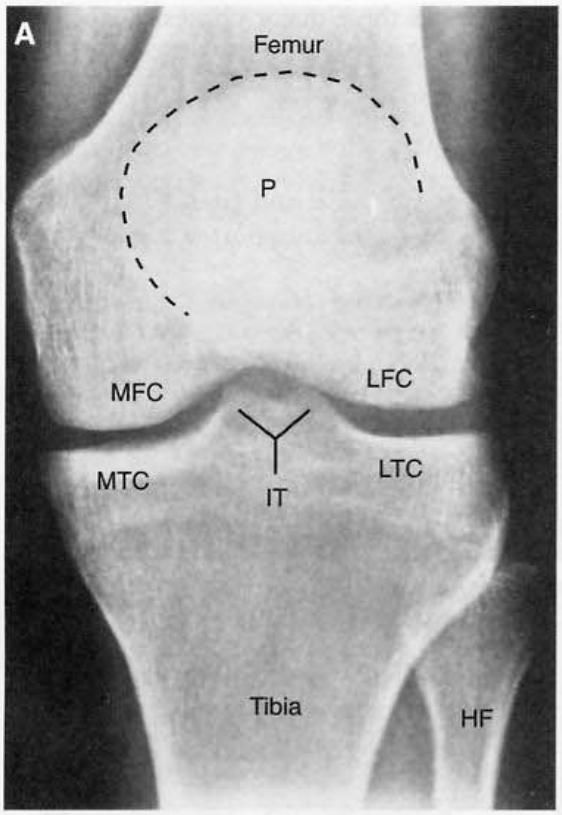
B. The knee joint contains menisci, which include:

1. The **medial meniscus,** a C-shaped fibrocartilage that is attached to the medial collateral ligament. It is easily torn because it is not very mobile.
2. The **lateral meniscus,** an O-shaped fibrocartilage

C. The knee joint is related to the popliteal fossa, which contains the **tibial nerve, common peroneal nerve, popliteal artery and vein,** and **small saphenous vein.**

D. Clinical consideration. The **terrible triad of O'Donoghue** is caused by a violent blow on the lateral side of the knee (e.g., football "clipping") that causes abduction and lateral rotation. This injury causes tearing of the following structures:

1. **Anterior cruciate ligament**
2. **Medial collateral ligament** (because of excessive abduction of the knee joint)
3. **Medial meniscus** (as a result of its attachment to the medial collateral ligament)


A
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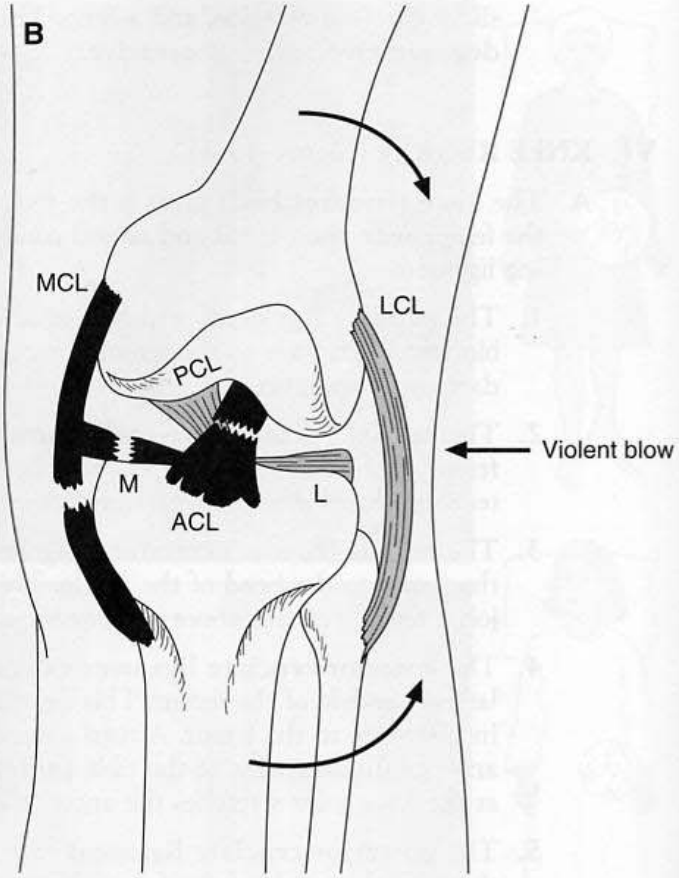
B
MCL
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Violent blow
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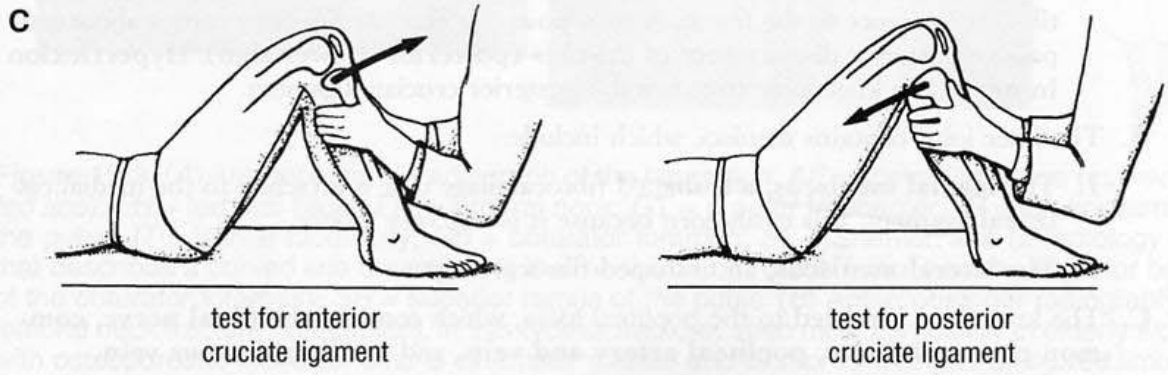
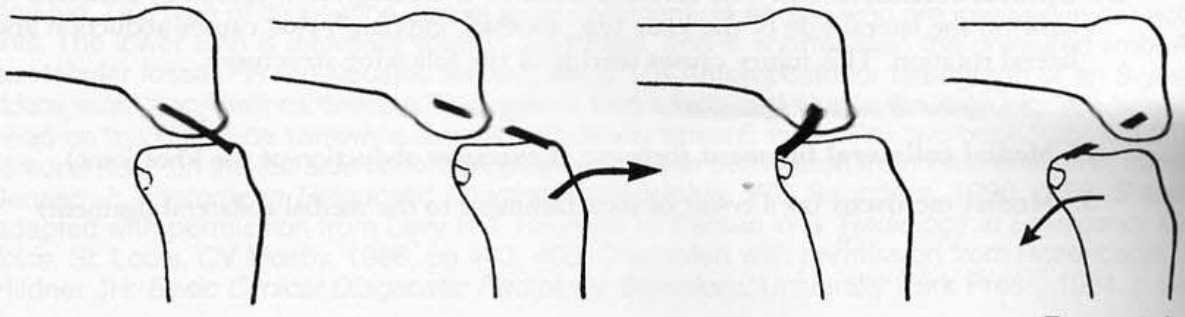

C
test for anterior
cruciate ligament
test for posterior
cruciate ligament


Torn anterior
cruciate ligament
Torn posterior
cruciate ligament

VII. ANKLE AND FOOT REGION (Figure 19-5)

A. The **ankle (talocrural) joint** is the articulation of the inferior surface of the tibia with the trochlea of the talus. **Dorsiflexion** and **plantar flexion** of the foot occur at this joint. The ankle is supported by the following ligaments:

1. The **medial (deltoid) ligament** extends from the medial malleolus of the tibia to the talus, navicular, and calcaneus bones. It consists of the **anterior tibiotalar, posterior tibiotalar, tibionavicular**, and **tibiocalcaneal ligaments.**
2. The **lateral ligament** extends from the lateral malleolus of the fibula to the talus and calcaneus bones. This ligament consists of the **anterior talofibular, posterior talofibular, and calcaneofibular ligaments.**

B. The ankle (talocrural) joint contains the **medial malleolus,** which is related to the following structures:

1. The medial malleolus is related anteriorly to the **saphenous nerve** and **great saphenous vein** (an excellent location for a great saphenous vein cutdown).
2. The medial malleolus is related posteriorly to the **flexor hallucis longus, flexor digitorum longus,** and **tibial posterior tendons; posterior tibial artery;** and **tibial nerve.**

C. The **subtalar joint** is the articulation of the talus and the calcaneus. **Inversion** and **eversion** of the foot occur at this joint.

D. The **transverse tarsal (Chopart) joint** actually is two joints: the **talonavicular joint** and the **calcaneocuboid joint. Inversion** and **eversion** of the foot also occur at this joint.

E. The **tarsometatarsal (Lisfranc) joint** is the articulation of the tarsal bones with the metatarsals.

F. Clinical considerations (Figure 19-6)

1. **Inversion injury** is the most common ankle injury. It occurs when the foot is forcibly **inverted** and results in the following injuries:
   - **a.** Stretch or tear of the lateral ligament, most commonly the **anterior talofibular ligament**
   - **b. Fracture of the fibula**
   - **c. Avulsion of the tuberosity of the fifth metatarsal (Jones fracture),** where the **peroneus brevis muscle** attaches.

◀ **Figure 19-4.** (*A*) Anteroposterior radiograph of the left knee. *HF* = head of fibula; *IT* = intercondylar tubercles; *LFC* = lateral femoral condyle; *LTC* = lateral tibial condyle; *MFC* = medial femoral condyle; *MTC* = medial tibial condyle; *P* = patella (*dotted line* indicates border). (*B*) "Terrible triad of O'Donoghue" injury to the left knee caused by a violent blow to the lateral side of the knee (e.g., football "clipping"). The *curved arrows* indicate the direction of movement at the knee joint (abduction and lateral rotation). The anterior cruciate ligament (*ACL*), medial meniscus (*M*), and medial collateral ligament (*MCL*) are torn. Other structures of the knee are uninjured. *L* = lateral meniscus; *LCL* = lateral collateral ligament; *PCL* = posterior cruciate ligament. (*C*) Clinical tests for a torn anterior cruciate ligament (anterior drawer sign) and a torn posterior cruciate ligament (posterior drawer sign). (*A* adapted with permission from Slaby F, Jacobs ER: *Radiographic Anatomy.* Media, PA, Harwal, 1990, p 53; *C* adapted with permission from Snell RS: *Clinical Anatomy for Medical Students,* 5th ed. Boston, Little, Brown, 1995, p 620.)

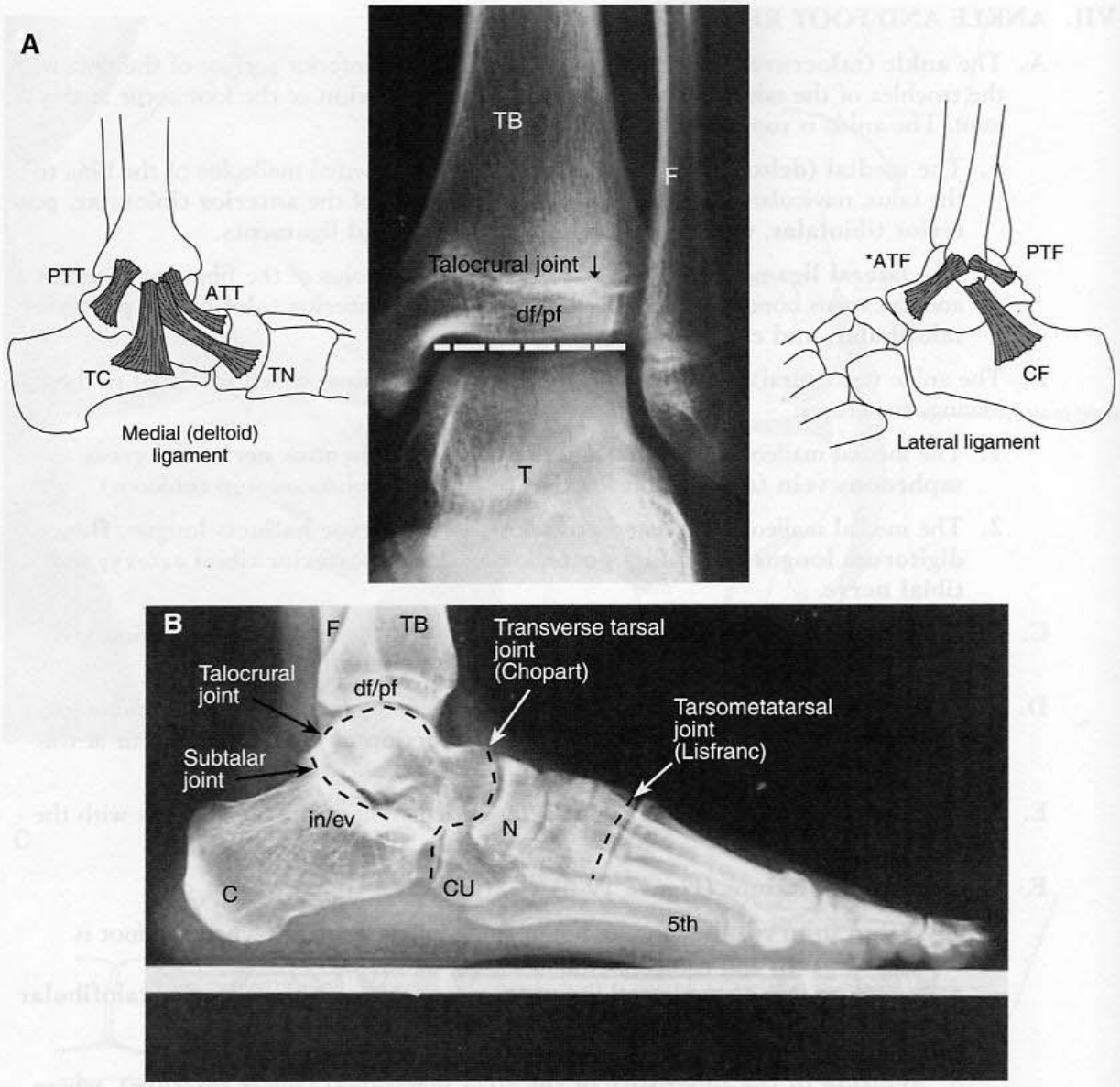


Figure 19-5. (*A*) Anteroposterior radiograph of the left ankle. The *dotted line* indicates the talocrural joint, where dorsiflexion and plantar flexion (*df/pf*) occur. The diagrams show the components of the medial (deltoid) and lateral ligaments that provide support for the talocrural joint. *ATF* = anterior talofibular ligament (*indicates most commonly injured in an ankle sprain); *ATT* = anterior tibiotalar ligament; *CF* = calcaneofibular ligament; *F* = fibula; *PTF* = posterior talofibular ligament; *PTT* = posterior tibiotalar ligament; *T* = talus; *TB* = tibia; *TC* = tibiocalcaneal ligament; *TN* = tibionavicular ligament. (*B*) Lateral radiograph of the left ankle shows the talocrural joint, where dorsiflexion and plantar flexion (*df/pf*) occur. The subtalar and transverse tarsal (Chopart) joints, where inversion and eversion (*in/ev*) occur, are shown. The tarsometatarsal (Lisfranc) joint is shown as well. *C* = calcaneus; *CU* = cuboid; *F* = fibula; *N* = navicular; *T* = talus; *TB* = tibia; *5th* = fifth metatarsal (little toe). (*A* adapted with permission from Keats TE, Smith TH: *An Atlas of Normal Developmental Roentgen Anatomy,* 2nd ed. Chicago, Year Book Medical Publishers, 1988, p 572; *B* adapted with permission from Slaby F, Jacobs ER: *Radiographic Anatomy.* Media, PA, Harwal, 1990, p 76.)

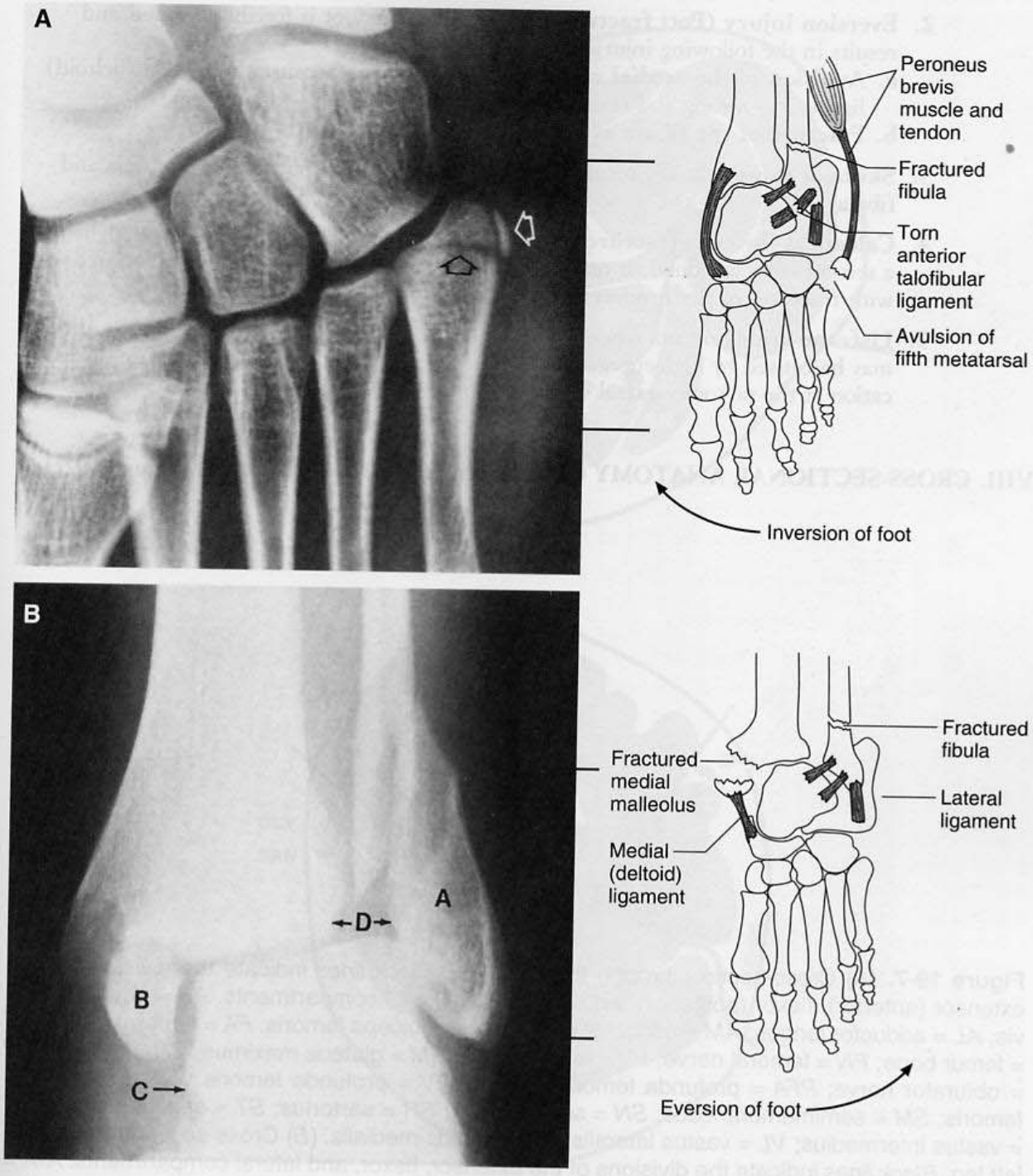
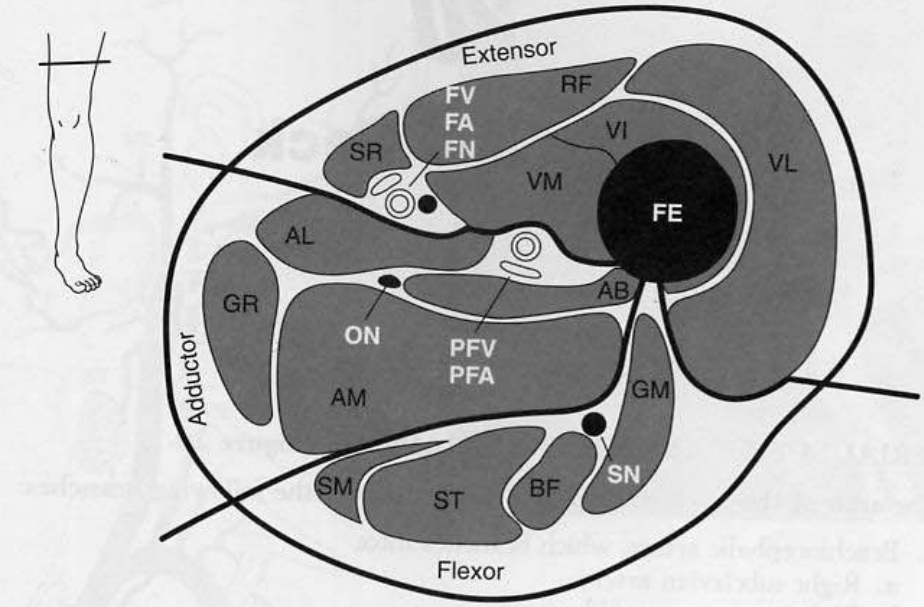


Figure 19-6. (*A*) Anteroposterior radiograph and diagram of an inversion injury of the left ankle. The radiograph shows avulsion of the fifth metatarsal (*black arrow*) caused by the pull of the tendon of the peroneus brevis muscle. The epiphyseal growth plate is oriented vertically (*white arrow*). In addition, in an inversion injury, the anterior talofibular ligament usually is torn and the fibula is fractured. (*B*) Anteroposterior radiograph and diagram of an eversion injury of the left ankle. The radiograph shows fracture of the fibula (*A*), avulsion of the medial malleolus (*B*), lateral movement of the talus (*C*), and a widened interosseous space (*D*). (*A* reprinted with permission from Eisenberg RL: *Diagnostic Imaging in Surgery.* New York, McGraw-Hill, 1987, p 743; *B* reprinted with permission from Levy RC, Hawkins H, Barsan WG: *Radiology in Emergency Medicine.* St. Louis, CV Mosby, 1986, p 427.)

2. **Eversion injury (Pott fracture)** occurs when the foot is forcibly **everted** and results in the following injuries:
   a. **Avulsion of the medial malleolus,** which occurs because the medial (deltoid) ligament is strong and resists tearing
   b. **Fracture of the fibula** as a result of lateral movement of the talus
3. **Ski boot injury** usually results in fracture of the distal portions of the tibia and fibula.
4. **Calcaneal (lover's) fracture** occurs when a person jumps from a great height (e.g., a second story window). It usually involves the **subtalar joint** and is associated with fractures of the **lumbar vertebrae** and the **neck of the femur.**
5. **Lisfranc injury** occurs when a bicyclist's foot is caught in the pedal clips. It also may be caused by high-energy trauma (e.g., car accident). It causes fracture or dislocation at the tarsometatarsal (Lisfranc) joint.

VIII. CROSS-SECTIONAL ANATOMY OF THE LEFT THIGH AND LEG (Figure 19-7)

Figure 19-7. (*A*) Cross-section through the left thigh. *Black lines* indicate the divisions of the extensor (anterior), flexor (posterior), and adductor (medial) compartments. *AB* = adductor brevis; *AL* = adductor longus; *AM* = adductor magnus; *BF* = biceps femoris; *FA* = femoral artery; *FE* = femur bone; *FN* = femoral nerve; *FV* = femoral vein; *GM* = gluteus maximus; *GR* = gracilis; *ON* = obturator nerve; *PFA* = profunda femoris artery; *PFV* = profunda femoris vein; *RF* = rectus femoris; *SM* = semimembranosus; *SN* = sciatic nerve; *SR* = sartorius; *ST* = semitendinosus; *VI* = vastus intermedius; *VL* = vastus lateralis; *VM* = vastus medialis. (*B*) Cross-section through the left leg. *Black lines* indicate the divisions of the extensor, flexor, and lateral compartments. *ATA* = anterior tibial artery; *ATV* = anterior tibial vein; *DPN* = deep peroneal nerve; *EDL* = extensor digitorum longus; *EHL* = extensor hallucis longus; *F* = fibula; *FDL* = flexor digitorum longus; *FHL* = flexor hallucis longus; *GSV* = great saphenous vein; *PA* = peroneal artery; *PB* = peroneus brevis; *PL* = peroneus longus; *PTA* = posterior tibial artery; *PTV* = posterior tibial vein; *PV* = peroneal vein; *S* = soleus; *SAN* = saphenous nerve; *SPN* = superficial peroneal nerve; *TA* = tibialis anterior; *TB* = tibia; *TN* = tibial nerve; *TP* = tibialis posterior. (Adapted with permission from Moore KL: *Clinically Oriented Anatomy,* 3rd ed. Baltimore, Williams & Wilkins, 1992, p 390.)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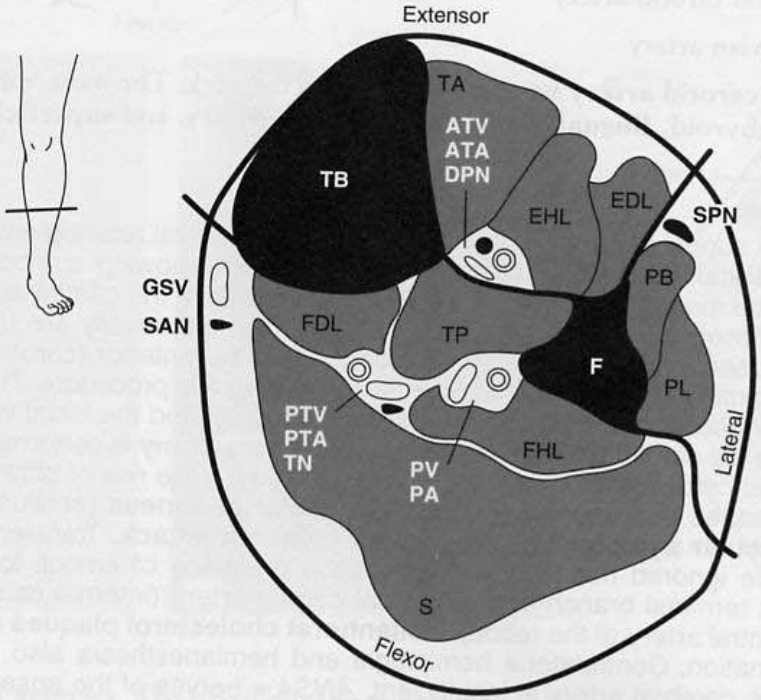
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20

Head and Neck

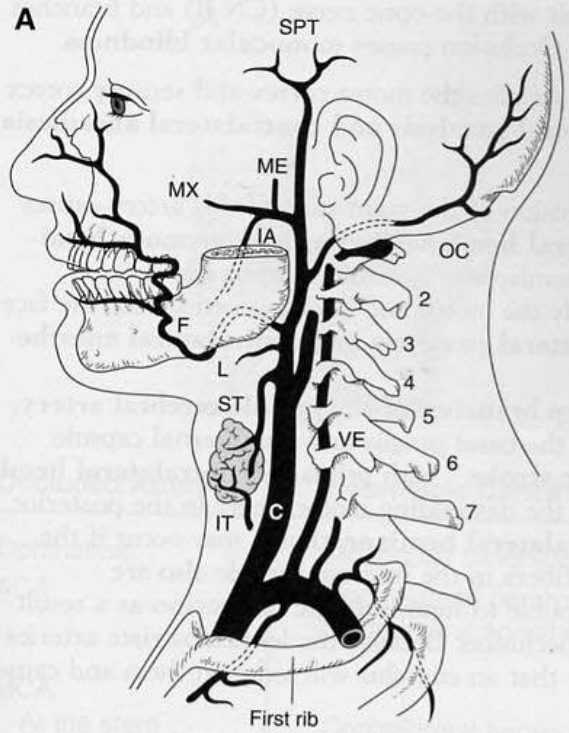
I. ARTERIAL SUPPLY AND VENOUS DRAINAGE (Figure 20-1)

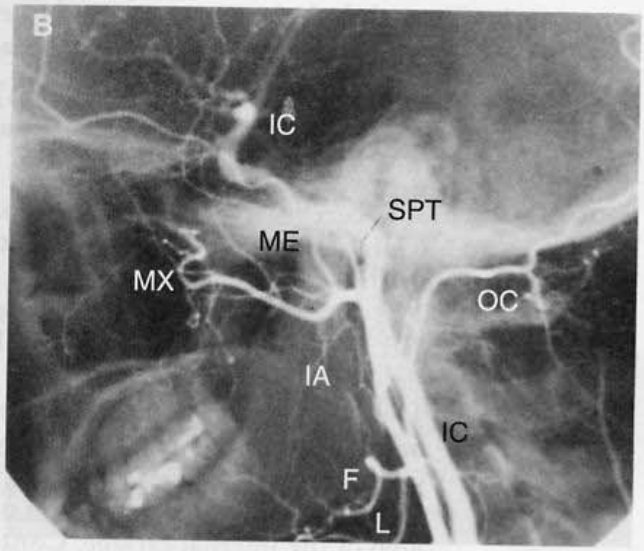
A. The **arch of the aorta** (see Figure 3-7) consists of the following **branches**:

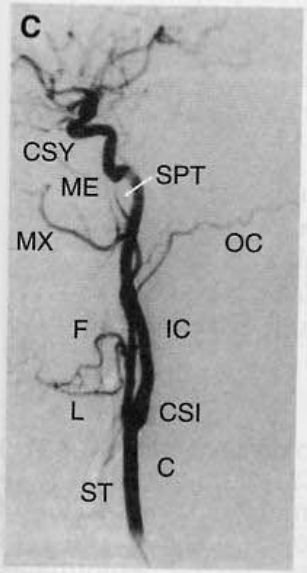
1. Brachiocephalic artery, which branches into:
   - **a.** Right subclavian artery
   - **b.** Right common carotid artery
2. Left common carotid artery
3. Left subclavian artery

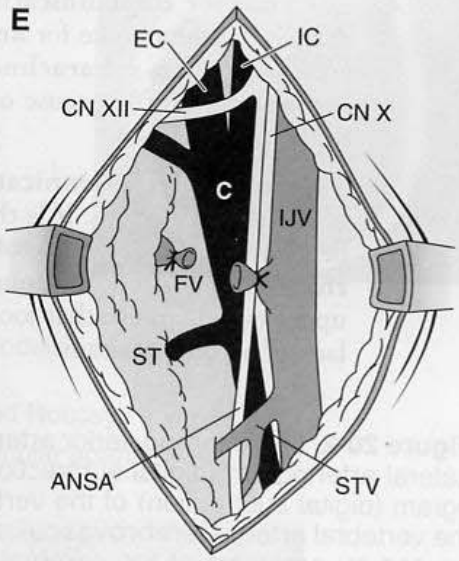
B. The **external carotid artery** has eight branches in the neck. The most important are the **superior thyroid, lingual, facial, occipital, maxillary,** and **superficial tempo-**

Figure 20-1. (*A*) Arterial supply of the head and neck region. (*B*) Lateral arteriogram and (*C*) lateral arteriogram with digital subtraction. (*D*) Lateral arteriogram showing a blocked internal carotid artery (*arrow*). The most common location of atherosclerosis in the carotid artery is at the **bifurcation of the common carotid artery**. Carotid artery plaques usually are ulcerated. (*E*) The surgical exposure used in a carotid endarterectomy within the anterior (carotid) triangle of the neck. Note the anatomic structures that may be at risk during this procedure. The incision is made along the anterior border of the sternocleidomastoid muscle, and the facial vein is ligated and cut to better expose the carotid bifurcation. **Carotid endarterectomy** is performed to remove blockages of the internal carotid artery. This procedure can reduce the risk of stroke in patients who have emboli or plaques that cause **transient monocular blindness (amaurosis fugax),** which is the **classic ocular symptom of a transient ischemic attack.** Transient monocular blindness should not be ignored because it indicates the presence of emboli to the **central artery of the retina**, a terminal branch of the internal carotid artery (internal carotid artery → ophthalmic artery → central artery of the retina). **Hollenhorst cholesterol plaques** are observed during a retinal examination. Contralateral hemiplegia and hemianesthesia also may occur if blood flow to the middle cerebral artery is insufficient. *ANSA* = nerves of the ansa cervicalis; *C* = common carotid artery; *CN X* = vagus nerve; *CN XII* = hypoglossal nerve; *CSI* = carotid sinus; *CSY* = carotid siphon; *EC* = external carotid artery; *F* = facial artery; *FV* = facial vein (cut); *IA* = inferior alveolar artery; *IC* = internal carotid artery; *IJV* = internal jugular vein; *IT* = inferior thyroid artery; *L* = lingual artery; *ME* = middle meningeal artery; *MX* = maxillary artery; *OC* = occipital artery; *SPT* = superficial temporal artery; *ST* = superior thyroid artery; *STV* = superior thyroid vein; *VE* = vertebral artery. (*A* adapted with permission from Moore KL: *Clinically Oriented Anatomy,* 3rd ed. Baltimore, Williams & Wilkins, 1992, p 666; *B* and *C* adapted with permission from Fleckenstein P, Tranum-Jensen J: *Anatomy in Diagnostic Imaging.* Philadelphia, WB Saunders, 1993, p 157; *D* adapted with permission from Freedman M: *Clinical Imaging: An Introduction to the Role of Imaging in Clinical Practice.* New York, Churchill Livingstone, 1988, p 579; *E* adapted with permission from Blackbourne LH, Fleischer KJ: *Advanced Surgical Recall.* Baltimore, Williams & Wilkins, 1997, p 787.)









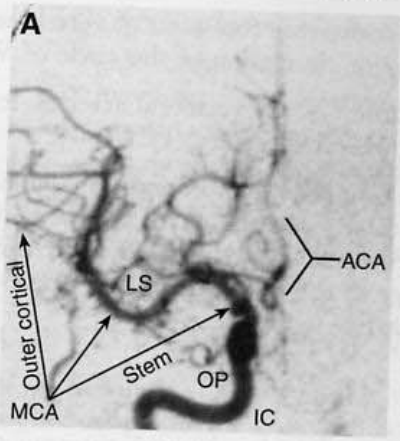
ral arteries. The maxillary artery enters the infratemporal fossa by passing posterior to the neck of the mandible and forms two branches:

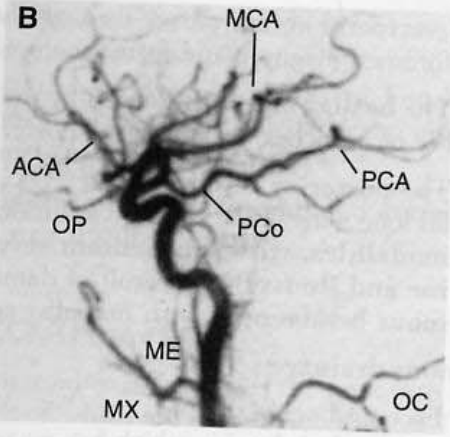
1. The **middle meningeal artery,** which supplies the periosteal **dura mater** in the cranium. Skull fractures in the area of the **pterion** (junction of the parietal, frontal, temporal, and sphenoid bones) may sever the middle meningeal artery, resulting in an **epidural hemorrhage.**
2. **Inferior alveolar artery**

C. The **internal carotid artery (Figure 20-2)** has no branches in the neck and forms the anterior circulation of the circle of Willis. The internal carotid artery has a number of important branches in the head.

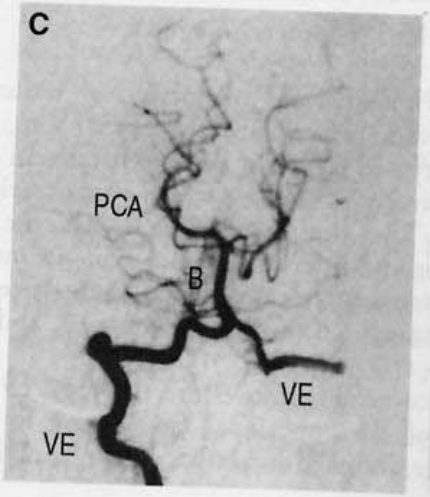
1. The **ophthalmic artery** enters the orbit with the optic nerve (CN II) and branches into the **central artery of the retina.** Occlusion causes **monocular blindness.**
2. The **anterior cerebral artery (ACA)** supplies the motor cortex and sensory cortex for the leg. Occlusion causes **contralateral paralysis and contralateral anesthesia of the leg.**
3. **Middle cerebral artery (MCA).** Occlusion of the main stem of this artery causes **contralateral hemiplegia, contralateral hemianesthesia, homonymous hemianopia (◐◐),** and, if the dominant hemisphere is involved, **aphasia.**
   a. The **outer cortical branches** supply the motor and sensory cortexes for the face and arm. Occlusion causes **contralateral paralysis and contralateral anesthesia of the face and arm.**
   b. The **lenticulostriate arteries (deep branches of the middle cerebral artery, or lateral striate arteries)** supply the basal ganglia and the internal capsule. Occlusion causes **classic "paralytic stroke,"** with primarily **contralateral hemiplegia** as a result of destruction of the descending motor fibers in the posterior limb of the internal capsule. **Contralateral hemianesthesia** may occur if the ascending sensory thalamocortical fibers in the internal capsule also are destroyed. These arteries are susceptible to **hemorrhagic infarction** as a result of hypertension or atherosclerotic occlusion. Because the lenticulostriate arteries branch at right angles, it is unlikely that an embolus will lodge in them and cause an embolic infarction.
4. The **anterior communicating artery** connects the two anterior cerebral arteries. It is the most common site for **aneurysms** (e.g., congenital berry aneurysm). Rupture of an aneurysm causes **subarachnoid hemorrhage** and, possibly, **bitemporal lower quadrantanopia** (◒◒) because of the close proximity of the anterior communicating artery to the optic chiasm.
5. The **posterior communicating artery** connects the anterior and posterior circulation of the circle of Willis. It is the second most common site of **aneurysm** (e.g., congenital berry aneurysm). Rupture of an aneurysm in this area causes **subarachnoid hemorrhage** and, possibly, **oculomotor nerve (CN III) paralysis,** characterized by a droopy upper eyelid, an eye that looks down and out, diplopia, a fixed and dilated pupil, and lack of accommodation.

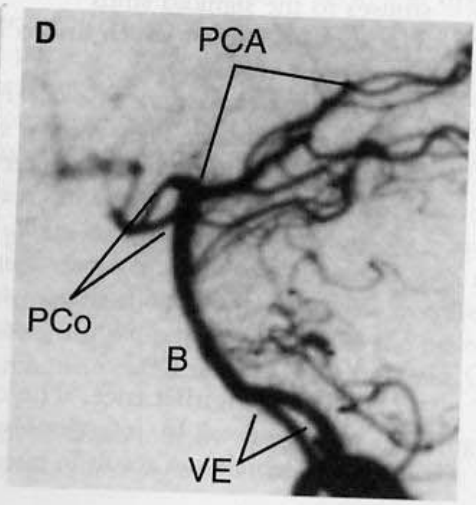
Figure 20-2. (*A*) Anteroposterior arteriogram (digital subtraction) of the internal carotid artery. (*B*) ▶ Lateral arteriogram (digital subtraction) of the internal carotid artery. (*C*) Anteroposterior arteriogram (digital subtraction) of the vertebral artery. (*D*) Lateral arteriogram (digital subtraction) of the vertebral artery. **Cerebrovascular disorders (strokes)** most commonly are cerebral infarcts caused by occlusion of the cerebral vessels by thrombosis or embolism, not by hemorrhage. Strokes are characterized by relatively abrupt onset of a focal neurologic deficit. (*E*) CT scan showing a large stroke in the area of the left middle cerebral artery, with edema and mass effect. No visible hemorrhage is apparent; most strokes are caused by thrombosis or embolism. In a clinical vignette question, first identify the neurologic deficit of stroke mentioned in the question, then match the deficit to the occluded artery (*table*), and finally identify the appropriate artery on the arteriogram. *1* = ischemic brain parenchyma; *2* = midline shift to the right; *3* = right frontal horn of the lateral ventricle; *ACA* = anterior cerebral artery; *B* = basilar artery; *IC* = internal carotid artery; *LS* = lenticulostriate arteries of the middle cerebral artery; *MCA* = middle cerebral artery (stem and outer cortical branches); *ME* = middle meningeal artery; *MX* = maxillary artery; *OC* = occipital artery; *OP* = ophthalmic artery; *PCA* = posterior cerebral artery; *PCo* = posterior communicating artery; *VE* = vertebral artery. (*A-D* adapted with permission from Fleckenstein P, Tranum-Jensen J: *Anatomy in Diagnostic Imaging.* Philadelphia, WB Saunders, 1993, pp 180-183; *E* reprinted with permission from Bhushan V, Le T, Amin C: *First Aid for the USMLE Step 1: A Student to Student Guide.* Stamford, CT, Appleton & Lange, 1999.)





Occluded Artery	Neurologic Deficit of Stroke
Ophthalmic	Monocular blindness (transient)
ACA	Contralateral paralysis and contralateral anesthesia of leg
MCA	
At the stem	Contralateral hemiplegia, contralateral hemianesthesia, homonymous hemianopia, aphasia
Lenticulostriate	Classic "paralytic stroke"
	Contralateral hemiplegia, possible contralateral hemianesthesia
Outer cortical	Contralateral paralysis and anesthesia of face and arm
PCA	Contralateral sensory loss of all modalities with concomitant severe pain (thalamic syndrome of Dejerine and Roussy)
	Homonymous hemianopia with macular sparing





D. The **vertebral artery** passes through the transverse foramina of vertebrae C1–6 and the foramen magnum and forms the posterior circulation of the circle of Willis.

1. The **basilar artery** is formed by the union of the vertebral arteries. It has a number of branches, including the posterior cerebral artery (PCA).
2. The **posterior cerebral artery** (PCA) supplies the midbrain, thalamus, and occipital lobe with visual cortex. Occlusion causes **contralateral sensory loss of all modalities, with concomitant severe pain (i.e., thalamic syndrome of Dejerine and Roussy)** as a result of damage to the thalamus. It also causes **homonymous hemianopia with macular sparing (◐◐)**.

E. Venous drainage

1. **Face and scalp**
   a. The **facial vein,** which has no valves, provides the major venous drainage of the face. It drains into the **internal jugular vein**. The facial vein makes clinically important connections with the **cavernous sinus** via the **superior and inferior ophthalmic veins** and the **pterygoid plexus of veins**. This connection with the cavernous sinus provides a potential route of infection from the superficial face (**"danger zone of the face"**) to the dural venous sinuses within the cranium.
   b. **Diploic veins,** which have no valves, run within the flat bones of the skull.
   c. **Emissary veins**, which have no valves, form an anastomosis between the superficial veins on the outside of the skull and the dural venous sinuses.
2. **Dural venous sinuses**, which have no valves, form between the endosteal dura and the meningeal dura and include the following sinuses:
   a. The **superior sagittal sinus,** which is located along the superior aspect of the falx cerebri. **Arachnoid granulations,** which transmit cerebrospinal fluid from the subarachnoid space to the dural venous sinuses, protrude into its wall.
   b. The **inferior sagittal sinus,** which is located along the inferior aspect (free edge) of the falx cerebri
   c. The **straight sinus,** which is formed by the union of the inferior sagittal sinus and the **great vein of Galen,** which drains venous blood from deep areas of the brain
   d. The **occipital sinus,** which is located in the attached border of the tentorium cerebelli
   e. The **confluence of sinuses,** which is formed by the union of the superior sagittal, straight, and occipital sinuses
   f. The **transverse sinus,** which drains venous blood from the confluence of sinuses to the sigmoid sinus
   g. The **sigmoid sinus,** which drains into the internal jugular vein
   h. **Cavernous sinuses**
      (1) **General features.** The cavernous sinuses are located on either side of the sphenoid bone. They receive venous blood from the facial vein, superior and inferior ophthalmic veins, pterygoid plexus of veins, central vein of the retina, and each other via the intercavernous sinuses, which pass anterior and posterior to the hypophyseal stalk. They drain venous blood into the superior petrosal sinus → transverse sinus and inferior petrosal sinus → internal jugular vein. The cavernous sinuses are anatomically related to the **internal carotid artery** (carotid siphon), postganglionic sympathetic nerves, and **CN III, IV, VI, V_1,** and **V_2.**
      (2) **Clinical significance.** The cavernous sinuses are the most clinically significant sinuses. In infections of the superficial face (see I E 1 a), **thrombophlebitis** can result in poor drainage and enlargement involving CN III, IV,

VI, V_1, and V_2, thereby producing ocular signs. Infections can spread from one side to the other through the intercavernous sinuses. Poor drainage may cause exophthalmus and edema of the eyelids and conjunctiva. Fistulas between the carotid artery and cavernous sinus may cause headache, orbital pain, diplopia, arterialization of the conjunctiva, and ocular bruit.

F. **Clinical consideration. Epidural, subdural, subarachnoid,** and **extracranial hemorrhages** may occur within the head area (Figure 20-3).

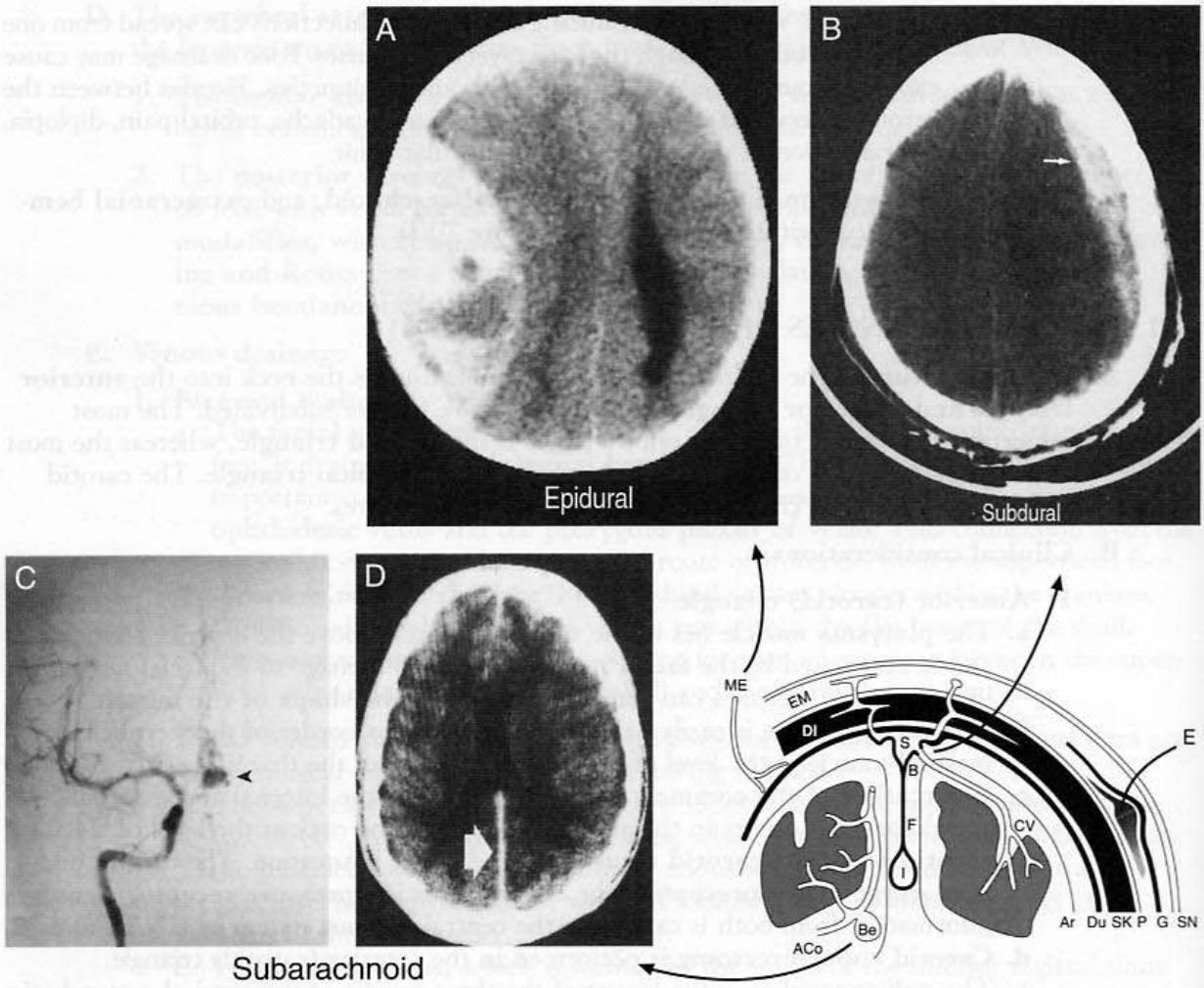
II. CERVICAL TRIANGLES OF THE NECK (Figure 20-4)

A. **General features.** The sternocleidomastoid muscle divides the neck into the **anterior triangle and posterior triangle,** both of which are further subdivided. The most important subdivision of the anterior triangle is the **carotid triangle,** whereas the most important subdivision of the posterior triangle is the **occipital triangle**. The carotid and occipital triangles contain important anatomic structures.

B. **Clinical considerations**

1. **Anterior (carotid) triangle**
   a. The **platysma muscle** lies in the superficial fascia above the anterior triangle and is innervated by the **facial nerve**. Accidental damage to the facial nerve during surgery in this area can cause **distortion of the shape of the mouth.**
   b. The **carotid pulse** is easily palpated at the anterior border of the sternocleidomastoid muscle at the level of the superior border of the thyroid cartilage (C5).
   c. **Bifurcation of the common carotid artery** into the internal and external carotid arteries occurs in the anterior triangle of the neck at the level of C4. The **carotid body** and **carotid sinus** are found at the bifurcation. The carotid body is an **oxygen chemoreceptor;** the carotid sinus is a **pressure receptor.** Sensory information from both is carried to the central nervous system by **CN IX** and **X.**
   d. **Carotid endarterectomy** is performed in the anterior (carotid) triangle.
   e. The stellate ganglion is the lowest of the three ganglia of the cervical sympathetic trunk. The term **stellate ganglion nerve block** is not strictly correct because the anesthetic is injected above the stellate ganglion, with enough anesthetic injected to spread both up and down the cervical sympathetic trunk. The needle is inserted between the trachea medially and between the sternocleidomastoid muscle and the common carotid artery laterally, using the **cricoid cartilage (C6)** and the **transverse process of vertebra C6** as landmarks. A successful block causes **vasodilation** of the blood vessels of the head, neck, and upper limb. It also causes **Horner syndrome,** which causes **miosis** (constriction of the pupil due to paralysis of the dilator pupillae muscle), **ptosis** (drooping of the eyelid due to paralysis of the superior tarsal muscle), and **hemianhydrosis** (loss of sweating on one side). A stellate ganglion nerve block is used in **Raynaud phenomenon** and to relieve vasoconstriction after frostbite or microsurgery of the hand.

2. **Posterior (occipital) triangle**
   a. **Injury to CN XI** within the posterior (occipital) triangle (e.g., from surgery or a penetrating wound) causes paralysis of the **trapezius muscle.** As a result, **abduction of the arm past the horizontal position** is compromised.
   b. **Injury to the trunk of the brachial plexus,** which lies in the posterior (occipital) triangle, results in **Erb-Duchenne** or **Klumpke** syndrome (see Chapter 18 IV F).
   c. **Severe hemorrhage of the upper limb** may be stopped by applying downward and posterior pressure to compress the subclavian artery against the first rib. The



Type of Hemorrhage	Injury	Blood Vessel Affected	Blood in CSF?	Clinical Features
Epidural	Skull fracture near pterion or greater wing of sphenoid Middle cranial fossa A medical emergency	Middle meningeal artery	No	CT scan shows lens-shaped (biconvex) hyperdensity adjacent to bone; arterial blood located between skull and dura Lucid interval for a few hours followed by death ("talk and die syndrome") May cause a transtentorial herniation, which compresses (1) CN III, causing ipsilateral dilated pupil, and (2) cerebral peduncles, causing contralateral hemiparesis

Type of Hemorrhage	Injury	Blood Vessel Affected	Blood in CSF?	Clinical Features
Subdural	Violent shaking of head (e.g., child abuse or car accident); Common in alcoholics and elderly	Superior cerebral veins ("bridging veins")	No	CT scan shows a crescent-shaped hyperdensity that hugs contours of brain; venous blood located between dura and arachnoid Blood accumulates slowly (days to weeks after trauma)
Subarachnoid	Contusion or laceration injury to the brain Berry aneurysm	Cerebral artery Anterior or posterior communicating artery	Yes	CT scan shows hyperdensity in basal cistern, fissures, and sulci; thickening of falx cerebri; arterial blood within subarachnoid space Irritation of meninges causes sudden onset of the "worst headache of my life," stiff neck, nausea, vomiting, and decreased mentation; earlier "herald headaches" may occur
Extracranial	Depressed cranial fracture Normal childbirth	Emissary veins; Branches of superficial temporal and occipital arteries	No	Venous and arterial blood located between galea aponeurotica and skull (subaponeurotic space) Lumpy clot, "black eye"

◀ **Figure 20-3.** (*A*) Epidural, (*B*) Subdural, (*C* and *D*) Subarachnoid, and (*E*) Extracranial hemorrhages. In a clinical vignette question, first identify the clinical features mentioned in the question, then match the features with the appropriate blood vessel and hemorrhage (*table*), and finally identify the correct CT scan. *ACo* = anterior communicating artery (most common site for a berry aneurysm); *Ar* = arachnoid; *B* = bridging vein; *Be* = berry (congenital) aneurysm; *CV* = cerebral vein; *Dl* = diploic vein; *Du* = dura mater; *EM* = emissary vein; *F* = falx cerebri; *G* = galea aponeurotica; *I* = inferior sagittal sinus; *ME* = middle meningeal artery; *P* = periosteum; *S* = superior sagittal sinus; *SK* = skull; *SN* = skin. The *arrow* in *D* shows thickening of the falx cerebri. (*A* and *B* adapted with permission from Levy RC, Hawkins H, Barsan WG: *Radiology in Emergency Medicine.* St. Louis, CV Mosby, 1986, pp 36, 38; *C* reprinted with permission from Freedman M: *Clinical Imaging: An Introduction to the Role of Imaging in Clinical Practice.* New York, Churchill Livingstone, 1988, p 575; and *D* reprinted with permission from Eisenberg RL: *Diagnostic Imaging in Surgery.* New York, McGraw-Hill, 1987, p 608.)

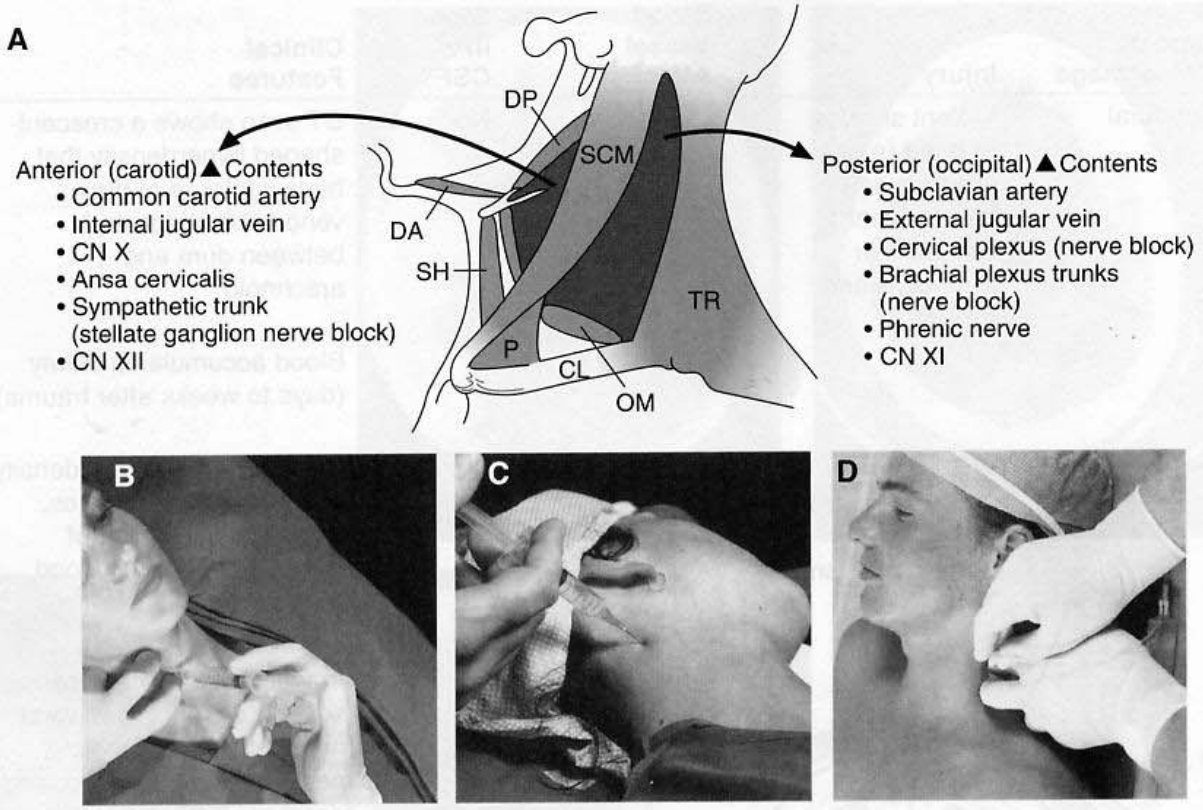


Figure 20-4. (*A*) Lateral aspect of the neck, showing the cervical triangles and their contents. Note that the common carotid artery, internal jugular vein, and CN X all lie within the **carotid sheath**. (*B*) Stellate ganglion, (*C*) cervical plexus, and (*D*) brachial plexus nerve blocks are shown. *CL* = clavicle; *DA* = digastric muscle (anterior belly); *DP* = digastric muscle (posterior belly); *OM* = omohyoid muscle (inferior belly); *P* = platysma; *SCM* = sternocleidomastoid muscle; *SH* = sternohyoid muscle; *TR* = trapezius muscle. (*B, C,* and *D* reprinted with permission from Scott DB: *Techniques of Regional Anaesthesia.* Stamford, CT, Appleton & Lange, 1989, pp 77, 93, 209).

brachial plexus and subclavian artery enter the posterior (occipital) triangle in an area that is bounded anteriorly by the **anterior scalene muscle**, posteriorly by the **middle scalene muscle**, and inferiorly by the **first rib**.

d. Enlarged supraclavicular lymph nodes as a result of upper gastrointestinal or lung cancer may be palpated in the posterior (occipital) triangle.

e. Cervical plexus nerve block is used for superficial surgery on the neck or thyroid gland. The needle is inserted at **vertebral level C3,** along a landmark line that connects the mastoid process to the transverse process of C6.

f. Brachial plexus nerve block. The needle is inserted into the interscalene groove (between the anterior and middle scalene muscles) at **vertebral level C6.** The cricoid cartilage (C6) and sternocleidomastoid muscle are used as landmarks.

III. LARYNX (Figure 20-5)

A. General features. The larynx consists of five major cartilages: the **cricoid, thyroid, epiglottis,** and two **arytenoid** cartilages. The **ventricle** of the larynx is bounded superiorly by the **vestibular folds (false vocal cords)** and inferiorly by the **vocal folds**

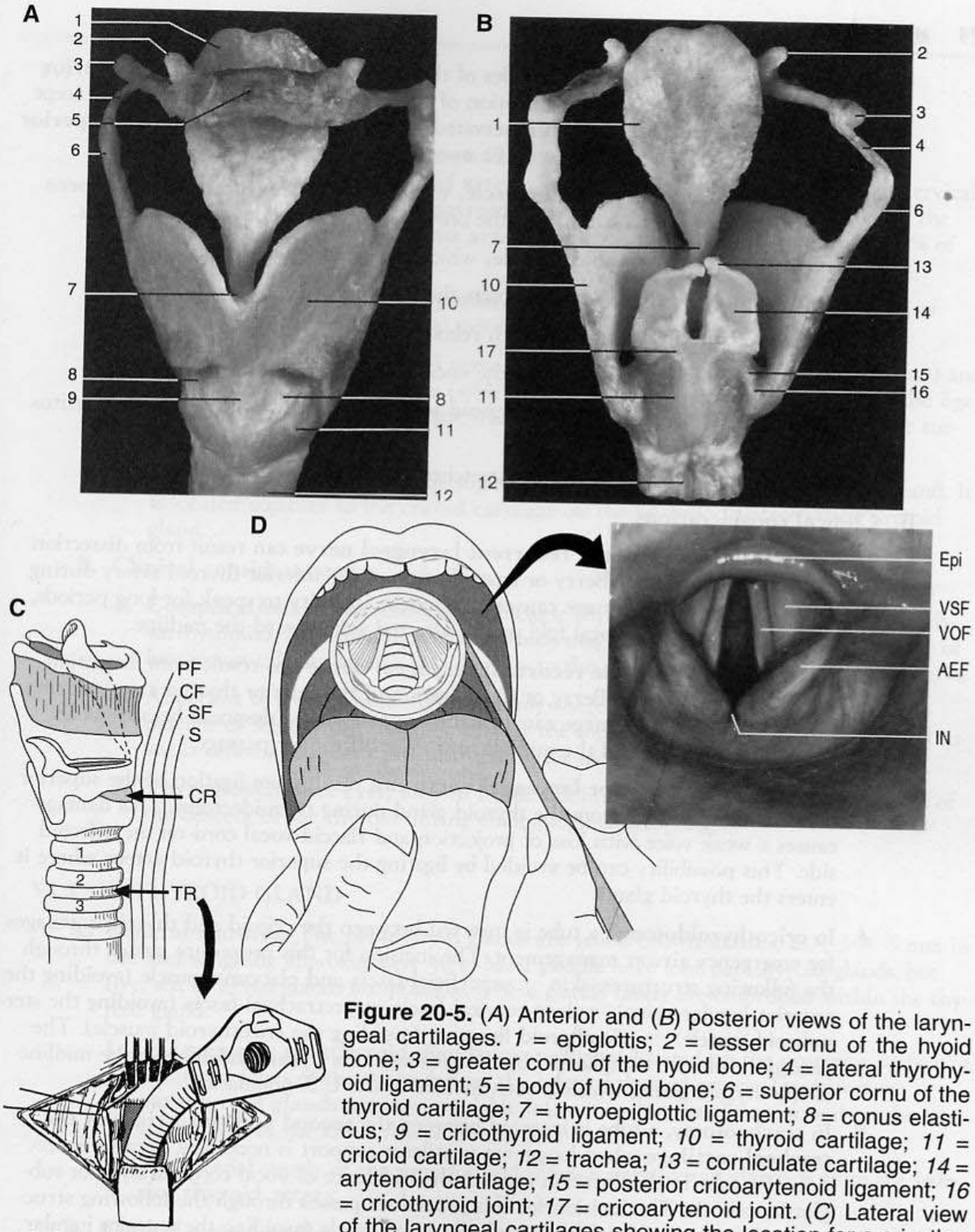


Figure 20-5. (*A*) Anterior and (*B*) posterior views of the laryngeal cartilages. *1* = epiglottis; *2* = lesser cornu of the hyoid bone; *3* = greater cornu of the hyoid bone; *4* = lateral thyrohyoid ligament; *5* = body of hyoid bone; *6* = superior cornu of the thyroid cartilage; *7* = thyroepiglottic ligament; *8* = conus elasticus; *9* = cricothyroid ligament; *10* = thyroid cartilage; *11* = cricoid cartilage; *12* = trachea; *13* = corniculate cartilage; *14* = arytenoid cartilage; *15* = posterior cricoarytenoid ligament; *16* = cricothyroid joint; *17* = cricoarytenoid joint. (*C*) Lateral view of the laryngeal cartilages showing the location for a cricothyroidotomy (*CR*) and a tracheotomy (*TR*). Note the anatomic layers that must be penetrated. *CF* = deep cervical fascia; *PF* = pretracheal fascia; *S* = skin; *SF* = superficial fascia. (*D*) Anatomic structures seen during inspection of the vocal folds with a laryngeal mirror. *AEF* = aryepiglottic fold; *Epi* = epiglottis; *IN* = interarytenoid notch; *VOF* = vocal fold; *VSF* = vestibular fold. (*A, B,* and *D* (*right*) adapted with permission from Rohen JW, Yokochi C, Lütjen-Drecoll E: *Color Atlas of Anatomy*, 4th ed. Baltimore, Williams & Wilkins, 1998, pp 154, 157; *C* (*lower*) adapted with permission from Moore KL: *Clinically Oriented Anatomy,* 3rd ed. Baltimore, Williams & Wilkins, 1992, p 819; *D* (*left*) reprinted with permission from Pegington J: *Clinical Anatomy in Action, vol. 2. The Head and Neck*. Edinburgh, Churchill Livingstone, 1986.)

(true vocal cords). All intrinsic muscles of the larynx are innervated by the **inferior laryngeal nerve of CN X** (a continuation of the **recurrent laryngeal nerve**), except the **cricothyroid muscle,** which is innervated by the **external branch of the superior laryngeal nerve of CN X.** The intrinsic muscles of the larynx include:

1. The **posterior cricoarytenoid muscle,** which **abducts** the vocal folds and opens the airway during respiration. It is the only muscle that abducts the vocal folds.
2. The **lateral cricoarytenoid muscle,** which adducts the vocal folds
3. The **arytenoid muscle,** which adducts the vocal folds
4. The **thyroarytenoid muscle,** which relaxes the vocal folds
5. The **vocalis muscle,** which alters the vocal folds for speaking and singing
6. The **transverse and oblique arytenoid muscles,** which close the laryngeal aditus (sphincter function)
7. The **cricothyroid muscle,** which stretches and tenses the vocal folds

B. Clinical considerations

1. **Unilateral damage to the recurrent laryngeal nerve** can result from dissection around the ligament of Berry or from ligation of the inferior thyroid artery during thyroidectomy. This damage causes hoarseness, inability to speak for long periods, and movement of the vocal fold on the affected side toward the midline.
2. **Bilateral damage to the recurrent laryngeal nerve** can result from dissection around the ligament of Berry or from ligation of the inferior thyroid artery during thyroidectomy. This damage causes acute breathlessness (dyspnea) because both vocal folds move toward the midline and close off the air passage.
3. **Damage to the superior laryngeal nerve can** result from ligation of the superior thyroid artery too far from the thyroid gland during thyroidectomy. This damage causes a weak voice with loss of projection and flaccid vocal cord on the affected side. This possibility can be avoided by ligating the superior thyroid artery where it enters the thyroid gland.
4. In **cricothyroidotomy,** a tube is inserted between the cricoid and thyroid cartilages for emergency airway management. The incision for this procedure passes through the following structures: skin → superficial fascia and platysma muscle (avoiding the anterior jugular veins) → deep cervical fascia → pretracheal fascia (avoiding the sternohyoid muscle) → cricothyroid ligament (avoiding the cricothyroid muscle). The procedure may be complicated by the presence of a **pyramidal lobe** in the midline of the thyroid gland, which is seen in 75% of the U.S. population.
5. In **tracheotomy,** a tube is inserted between the **second and third rings of the tracheal cartilage** when long-term ventilator support is necessary, because insertion of a tube in this location reduces the incidence of vocal cord paralysis or subglottic stenosis. The incision for this procedure passes through the following structures: skin → superficial fascia and platysma muscle (avoiding the anterior jugular veins) → deep cervical fascia → pretracheal fascia → wall between cartilage rings. The following structures are at risk for injury: the **inferior thyroid veins,** which form a plexus anterior to the trachea; the **thyroid ima artery,** which is present in 10% of people and supplies the inferior border of the isthmus of the thyroid gland; and the **thymus gland** in infants. Tracheotomy can be complicated by massive hemorrhage 1-2 weeks after placement of the tube. The hemorrhage is caused by erosion of the **brachiocephalic (innominate) artery.**

IV. THYROID GLAND

A. General features

1. The **arterial supply** of the thyroid gland is from the external carotid artery through the **superior thyroid artery**, from the subclavian artery and thyrocervical trunk through the **inferior thyroid artery,** and sometimes from the arch of the aorta through the **thyroid ima artery,** which is present in approximately 10% of the U.S. population.
2. Venous drainage is to the **superior**, **middle**, and **inferior thyroid veins,** all of which empty into the internal jugular vein.
3. The right recurrent laryngeal nerve (which recurs around the subclavian artery) and left recurrent laryngeal nerve (which recurs around the arch of the aorta at the ligamentum arteriosum) run in the tracheoesophageal groove along the posterior surface of the thyroid gland.
4. The **ligament of Berry** is the superior suspensory ligament of the thyroid gland. It is located adjacent to the cricoid cartilage on the posterior surface of the thyroid gland.

B. Clinical considerations

1. **Complications of thyroidectomy** include thyroid storm (hyperpyrexia and tachyarrhythmia), hypoparathyroidism (which may develop within 24 hours because of low serum calcium levels), and damage to the recurrent or superior laryngeal nerve.
2. **Aberrant thyroid tissue** may occur anywhere along the path of embryologic descent of the thyroid from the base of the tongue (foramen cecum), where this tissue is called a **lingual cyst,** to the superior mediastinum.
3. **Thyroglossal duct cyst,** located in the midline of the neck, is a cystic remnant of the descent of the thyroid during embryologic development.

V. PARATHYROID GLAND

A. General features. The parathyroid glands are yellow-brown masses, 2 × 3 × 5 mm in size and weighing approximately 40 g. Most people have four parathyroid glands, but five, six, or seven glands are possible. These glands rarely are embedded within the thyroid gland.

1. The **superior parathyroid glands** invariably are located on the posterior surface of the upper lobes of the thyroid, near the inferior thyroid artery. The **inferior parathyroid glands** are more variable in location but usually are found on the lateral surface of the lower thyroid lobes.
2. The arterial supply of the superior and inferior parathyroid glands is from the **inferior thyroid artery.**

B. Clinical considerations

1. **Primary hyperparathyroidism** results from autonomous secretion of parathyroid hormone (PTH) caused by glandular hyperplasia, adenoma or, rarely, carcinoma. The **clinical sign** is persistent hypercalcemia. In 90% of cases, surgical removal of the hyperfunctioning glands results in cure.
2. **Injury to the parathyroid glands** most commonly occurs during thyroidectomy as a result of disruption of the blood supply from the inferior thyroid artery.

VI. PAROTID GLAND

A. General features. The parotid gland produces serous saliva that enters the mouth through the **parotid duct of Stenson.** The facial nerve (CN VII) enters the parotid gland after emerging from the stylomastoid foramen. This nerve divides into the temporal, zygomatic, buccal, mandibular, and cervical branches, which innervate the muscles that control facial expression. CN VII has no function in the parotid gland.

1. The **arterial supply** is from branches of the external carotid artery; **venous drainage** is through the retromandibular vein → external jugular vein.
2. The parotid gland is innervated by postganglionic sympathetic neurons from the superior cervical ganglion. These neurons reach the parotid gland with the arteries and stimulate the secretion of thick mucus. This gland also is innervated by preganglionic parasympathetic neurons whose cell bodies are located in the **inferior salivatory nucleus** of the **glossopharyngeal nerve (CN IX).** These neurons travel within the **tympanic nerve** and the **lesser petrosal nerve** to synapse on cell bodies within the **otic ganglion**. Postganglionic parasympathetic neurons leave the otic ganglion and are distributed with the **auriculotemporal nerve** of the trigeminal nerve (CN V) to the parotid gland to stimulate a watery secretion.

B. Clinical considerations

1. **Surgery on the parotid gland** may damage the **auriculotemporal nerve of CN V** and cause loss of sensation in the auriculotemporal area. This nerve also carries postganglionic sympathetic nerve fibers to the sweat glands of the head and postganglionic parasympathetic nerve fibers to the parotid gland for salivation. If this nerve is severed, aberrant regeneration may cause **sweating whenever the person eats (Frey syndrome).**
2. **Bell palsy or surgery on the parotid gland** may cause a lower motor neuron lesion of the facial nerve (CN VII). The lesion causes **ipsilateral paralysis of the upper and lower face**, loss of the corneal reflex (efferent limb), loss of taste from the anterior two-thirds of the tongue, and hyperacusis (increased acuity to sound). Clinical signs include: ipsilateral inability to blink the eye or raise the eyebrow, because of an upper face deficit involving the orbicularis oculi and frontalis muscles, respectively; and ipsilateral inability to seal the lips or smile normally, because of a lower face deficit involving the orbicularis oris muscle. If CN VII is severed, aberrant regeneration may cause **tearing whenever the person eats (crocodile tears syndrome).**
3. **Stroke** within the internal capsule affecting the corticobulbar tract causes an upper motor neuron lesion of the facial nerve (CN VII). This lesion causes **contralateral paralysis of the lower face,** but spares the upper face. Clinical signs include: contralateral inability to seal the lips or smile normally because of a lower face deficit involving the orbicularis oris muscle.

VII. SKULL AND FORAMINA (Figure 20-6)

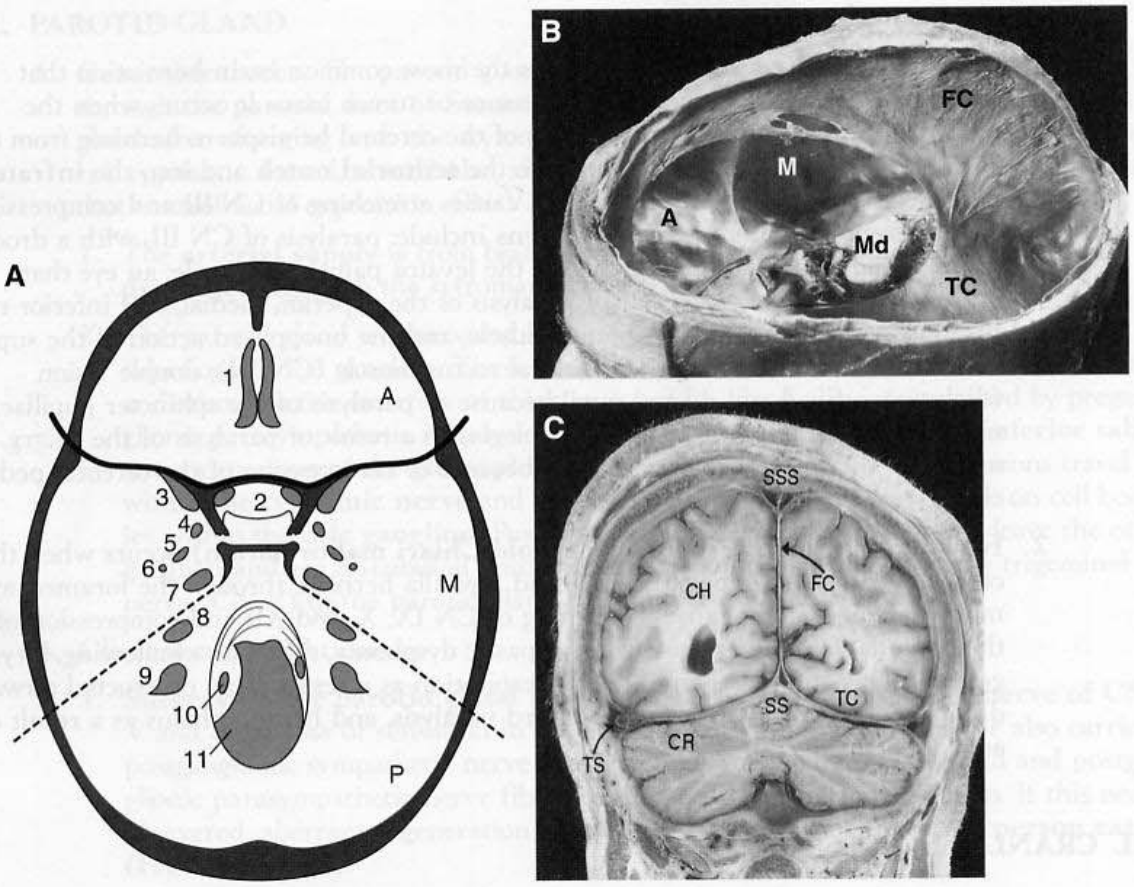
A. General features. Clinical vignette questions about fractures of the skull and other clinical conditions can be approached using knowledge of the structures transmitted through various foramina in the skull. In addition, the **falx cerebri** and **tentorium cerebelli** divide the interior of the skull into compartments. This arrangement becomes clinically important when increased intracranial pressure in one compartment causes the brain to "herniate," or shift to a compartment with lower pressure.

B. Clinical considerations

1. **Transtentorial (uncal) herniation** is the most common brain herniation that results from increased intracranial pressure or tumor mass. It occurs when the parahippocampal gyrus and the uncus of the cerebral hemisphere herniate from the **supratentorial compartment** through the **tentorial notch** and into the **infratentorial compartment.** This herniation causes stretching of CN III and compression of the cerebral peduncles. **Clinical signs** include: paralysis of CN III, with a droopy upper eyelid as a result of paralysis of the levator palpebrae muscle; an eye that looks down and out as a result of paralysis of the superior, medial, and inferior rectus muscles and the inferior oblique muscle, and the unopposed action of the superior oblique muscle (CN IV) and lateral rectus muscle (CN VI); double vision (diplopia); a fixed and dilated pupil because of paralysis of the sphincter pupillae muscle; lack of accommodation (cycloplegia) as a result of paralysis of the ciliary muscle; and contralateral hemiparesis because of compression of the cerebral peduncles.
2. **Foramen magnum herniation (Arnold-Chiari malformation)** occurs when the cerebellar vermis, cerebellar tonsils, and medulla herniate through the foramen magnum. This herniation causes stretching of CN IX, X, and XII and compression of the medulla. **Clinical signs** include: spastic dysphonia, difficulty swallowing, laryngeal stridor (vibrating sound during respiration as a result of an obstructed airway), diminished gag reflex, apnea, vocal cord paralysis, and hydrocephalus as a result of aqueductal stenosis.

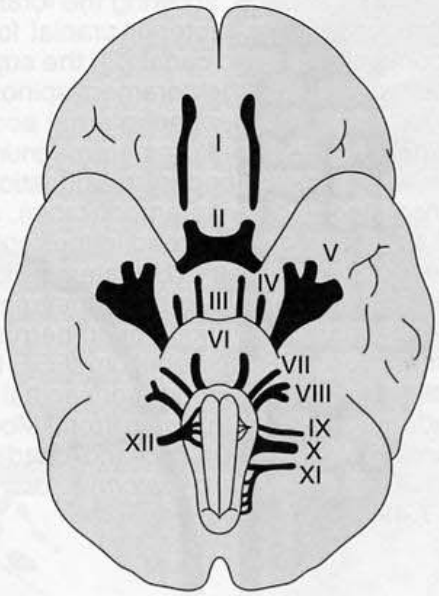
VIII. CRANIAL NERVES (Figure 20-7)

IX. EXTRAOCULAR MUSCLES AND CLINICAL TESTS (Figure 20-8)



Foramen	Structures Transmitted
Anterior cranial fossa	
1. Cribriform plate	CN I Discharge of CSF from the nose (rhinorrhea) occurs as a result of fracture of the cribriform plate and dural tear
Middle cranial fossa	
2. Optic canal	CN II
3. Superior orbital fissure	CN III, IV, V_1, VI
4. Foramen rotundum	CN V_2
5. Foramen ovale	CN V_3, lesser petrosal nerve
6. Foramen spinosum	Middle meningeal artery; epidural hemorrhage occurs as a result of a fracture in this area
7. Foramen lacerum	Empty
Posterior cranial fossa	
8. Internal acoustic meatus	CN VII, VIII Discharge of CSF from the external acoustic meatus (otorrhea) occurs as a result of fracture of the mastoid process and dural tear
9. Jugular foramen	CN IX, X, XI, sigmoid sinus; a mass in the jugular foramen causes difficulty in swallowing (dysphagia) and speaking (dysarthria), paralysis of the uvula, and inability to shrug the shoulders
10. Hypoglossal canal	CN XII
11. Foramen magnum	Medulla of the brain stem, CN XI, vertebral arteries

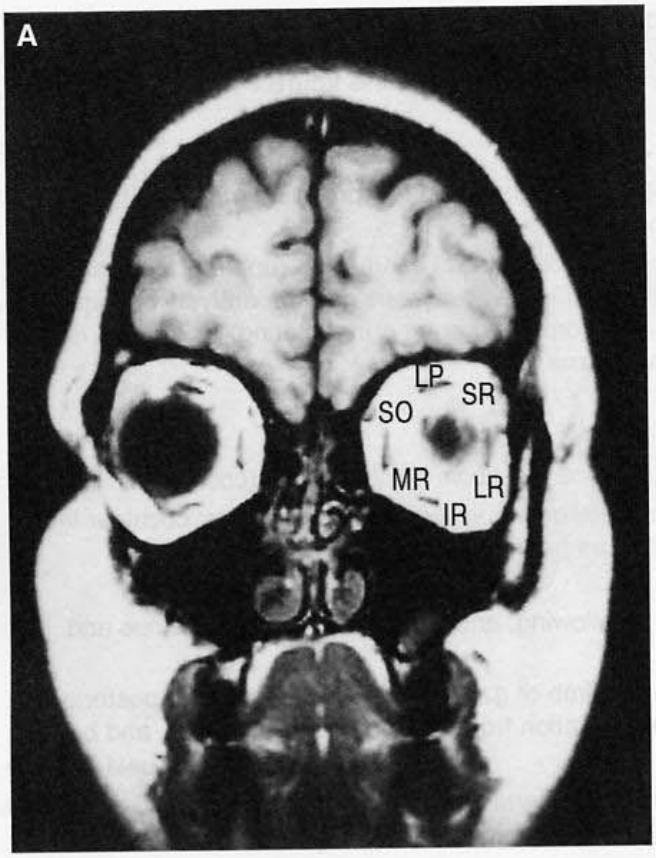
Figure 20-6. (*A*) Base of the skull (interior aspect), showing the foramina within the anterior (*A*), middle (*M*), and posterior (*P*) cranial fossae. The anterior cranial fossa includes the cribriform plate (*1*); the middle cranial fossa contains the optic canal (*2*), the superior orbital fissure (*3*), the foramen rotundum (*4*), the foramen ovale (*5*), the foramen spinosum (*6*), and the foramen lacerum (*7*); and the posterior cranial fossa includes the internal acoustic meatus (*8*), the jugular foramen (*9*), the hypoglossal canal (*10*), and the foramen magnum (*11*). In a clinical vignette question, first identify the clinical features mentioned in the question, then match the features with the appropriate structures transmitted and the foramen (*table*), and finally identify the foramen in the figure. Common clinical situations are indicated in the *table* (e.g., rhinorrhea, epidural hemorrhage, otorrhea, mass in the jugular foramen). (*B*) Lateral and (*C*) frontal views of gross specimens, showing the falx cerebri and tentorium cerebelli. The anatomy of the falx cerebri and tentorium cerebelli is important in understanding various brain herniations (see VII A). *A* = anterior cranial fossa; *CH* = cerebral hemisphere; *CR* = cerebellum; *FC* = falx cerebri; *M* = middle cranial fossa; *Md* = midbrain; *SS* = straight sinus; *SSS* = superior sagittal sinus; *TC* = tentorium cerebelli; *TS* = transverse sinus. (*A* adapted with permission from Moore KL: *Clinically Oriented Anatomy,* 3rd ed. Baltimore, Williams & Wilkins, 1992; *B* and *C* adapted with permission from Gosling JA, Harris PF, Humpherson JR, et al: *Human Anatomy: Color Atlas and Text,* 3rd ed. London, Mosby-Wolfe, 1996, pp 7.48, 7.49.)

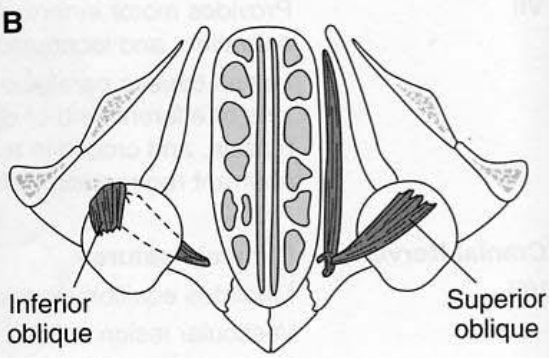


Cranial Nerve	Clinical Features
I	Mediates sense of smell (olfaction).
II	Mediates sense of sight (vision).
III	Lesion [e.g., transtentorial (uncal) herniation] causes a droopy upper eyelid due to paralysis of levator palpebrae muscle. The **eye looks down and out** due to paralysis of superior, medial, and inferior rectus muscles and inferior oblique muscle together with the unopposed action of superior oblique muscle (CN IV) and lateral rectus muscle (CN VI). Double vision (diplopia) occurs when patient looks in direction of the paretic muscle. The **pupil is fixed and dilated** due to paralysis of sphincter pupillae muscle. Accommodation is lost (cycloplegia) due to paralysis of ciliary muscle.
IV	Innervates superior oblique muscle. Lesion causes extortion of eye; vertical diplopia, which increases when looking down (e.g., reading a book); and head tilting to compensate for extorsion.
V	Provides sensory innervation to face and motor innervation to muscles of mastication. Lesion causes hemianesthesia of face, loss of afferent limb of corneal reflex, loss of afferent limb of oculocardiac reflex, paralysis of muscles of mastication, deviation of jaw to injured side, hypoacusis due to paralysis of tensor tympani muscle, and tic douloureux (recurrent, stabbing pain).
VI	Innervates lateral rectus muscle. Lesion causes convergent strabismus, inability to abduct eye, and horizontal diplopia when patient looks toward paretic muscle.

Figure 20-7. The base of the brain, with locations of CN I—XII. In a clinical vignette question, first identify the clinical features mentioned in the question, then match the features with the appropriate cranial nerve, and finally identify the cranial nerve in the figure.

Cranial Nerve	Clinical Features
VII	Provides motor innervation to muscles of facial expression; mediates taste, salivation, and lacrimation. Lesion causes paralysis of muscles of facial expression (upper and lower face), loss of efferent limb of corneal reflex, hyperacusis due to paralysis of stapedius muscle, and crocodile tears syndrome (tearing during eating) as a result of aberrant regeneration after trauma.
VIII	Mediates equilibrium and balance (vestibular) and hearing (cochlear). Vestibular lesion causes disequilibrium, vertigo, and nystagmus; cochlear lesion (e.g., acoustic neuroma) causes hearing loss and tinnitus.
IX	Mediates taste, salivation, swallowing, and input from the carotid sinus and carotid body. Lesion causes loss of afferent limb of gag reflex, loss of taste from posterior third of tongue, and loss of sensation from pharynx, tonsils, fauces, and back of tongue.
X	Mediates speech and swallowing, and innervates viscera in thorax and abdomen. Lesion causes paralysis of pharynx and larynx, deviation of uvula to **opposite side** of injured nerve, loss of efferent limb of the gag reflex, and loss of efferent limb of oculocardiac reflex.
XI	Innervates sternocleidomastoid and trapezius muscles. Lesion causes inability to turn head to **opposite side** of injured nerve and inability to shrug ipsilateral shoulder.
XII	Innervates intrinsic and extrinsic muscles of tongue. Lesion causes deviation of tongue to **same side** of injured nerve.





Muscle	Nerve	Clinical Test* or Function
Levator palpebrae	CN III	Keeps the eye open
Superior rectus	CN III	Patient is asked to look first to the side, then look up
Medial rectus	CN III	Patient is asked to look to the nose (medially)
Inferior rectus	CN III	Patient is asked to look first to the side, then look down
Inferior oblique	CN III	Patient is asked to look first to the nose, then look up: **"up and in" toward the bridge of the nose**
Superior oblique	CN IV	Patient is asked to look first to the nose, then look down: **"down and in" toward the tip of the nose**
Lateral rectus	CN VI	Patient is asked to look to the side (laterally)
Orbicularis oculi	CN VII	Closes the eye; efferent limb of the corneal reflex
Dilator pupillae	Postganglionic sympathetic	Dilates the pupil
Superior tarsal	Postganglionic sympathetic	Keeps the eye open
Sphincter pupillae	Postganglionic parasympathetic	Constricts the pupil
Ciliary muscle	Postganglionic parasympathetic	Performs accommodation

◀ **Figure 20-8.** (*A*) Coronal MRI through the orbit. (*B*) Horizontal (axial) diagram through the orbit showing the unique origin and insertion of the inferior oblique and superior oblique muscles. In a clinical vignette question, first identify the clinical test, then match the clinical test with the appropriate muscle, and finally identify the muscle on the MRI. *IR* = inferior rectus; *LP* = levator palpebrae; *LR* = lateral rectus; *MR* = medial rectus; *SO* = superior oblique; *SR* = superior rectus. (*A* adapted with permission from Fleckenstein P, Tranum-Jensen J: *Anatomy in Diagnostic Imaging*. Philadelphia, WB Saunders, 1993, p 171; *B* adapted with permission from Snell RS: *Clinical Anatomy for Medical Students*, 5th ed. Boston, Little, Brown, 1995, p 718.)

*Because the actions of the superior rectus, inferior rectus, superior oblique, and inferior oblique muscles are complicated, the physician tests eye movements with the eye placed in a position where a single action of the muscle predominates.

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Ronald W. Dudek

SECOND EDITION

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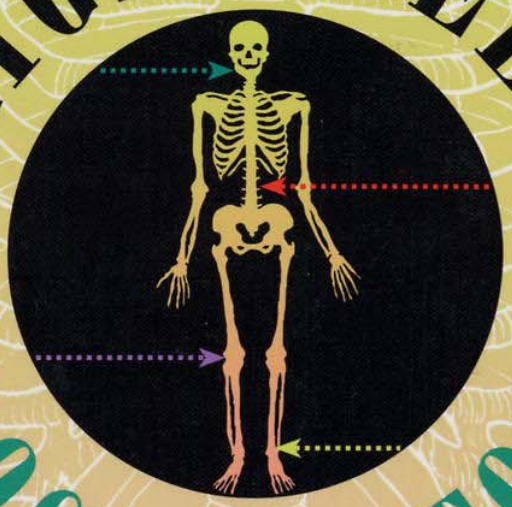

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