

4

Abdomen

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 - Intussusception
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- Anatomy modules 10 through 17
- Embryology modules 65 and 66

Conceptual overview 255

General description 255

Functions 256

- Houses and protects major viscera 256
- Breathing 258
- Changes in intraabdominal pressure 258

Component parts 259

- Wall 259
- Abdominal cavity 260
- Inferior thoracic aperture 262
- Diaphragm 262
- Pelvic inlet 263

Relationship to other regions 263

- Thorax 263
- Pelvis 263
- Lower limb 264

Key features 265

- Arrangement of abdominal viscera in the adult 265
- Skin and muscles of the anterior and lateral abdominal wall and thoracic intercostal nerves 268
- The groin is a weak area in the anterior abdominal wall 269
- Vertebral level L1 271
- The gastrointestinal system and its derivatives are supplied by three major arteries 271
- Venous shunts from left to right 273
- All venous drainage from the gastrointestinal system passes through the liver 274
- Abdominal viscera are supplied by a large prevertebral plexus 276

Regional anatomy 277

Surface topography 277

- Four-quadrant pattern 277
- Nine-region pattern 278

Abdominal wall 280

- Superficial fascia 280
- Anterolateral muscles 282
- Extraperitoneal fascia 288
- Peritoneum 288
- Innervation 289
- Arterial supply and venous drainage 291
- Lymphatic drainage 292

Groin 292

- Inguinal canal 294
- Inguinal hernias 299

Abdominal viscera 303

- Peritoneum 303
- Peritoneal cavity 304
- Organs 310
- Arterial supply 343
- Venous drainage 354
- Lymphatics 358
- Innervation 358

Posterior abdominal region 366

- Posterior abdominal wall 367
- Viscera 373

Vasculature 387

Lymphatic system 392

Nervous system in the posterior abdominal region 394

Sympathetic trunks and splanchnic nerves 394

Surface anatomy 402

Abdomen surface anatomy 402

Defining the surface projection of the abdomen 402

How to find the superficial inguinal ring 403

How to determine lumbar vertebral levels 404

Visualizing structures at the L1 vertebral level 405

Visualizing the position of major blood vessels 406

Using abdominal quadrants to locate major viscera 407

Defining surface regions to which pain from the gut is referred 408

Where to find the kidneys 409

Where to find the spleen 409

Clinical cases 410

Conceptual overview

GENERAL DESCRIPTION

The abdomen is a roughly cylindrical chamber extending from the inferior margin of the thorax to the superior margin of the pelvis and the lower limb (Fig. 4.1A).

The **inferior thoracic aperture** forms the superior opening to the abdomen, and is closed by the diaphragm. Inferiorly, the deep abdominal wall is continuous with the

pelvic wall at the **pelvic inlet**. Superficially, the inferior limit of the abdominal wall is the superior margin of the lower limb.

The chamber enclosed by the abdominal wall contains a single large **peritoneal cavity**, which freely communicates with the pelvic cavity.

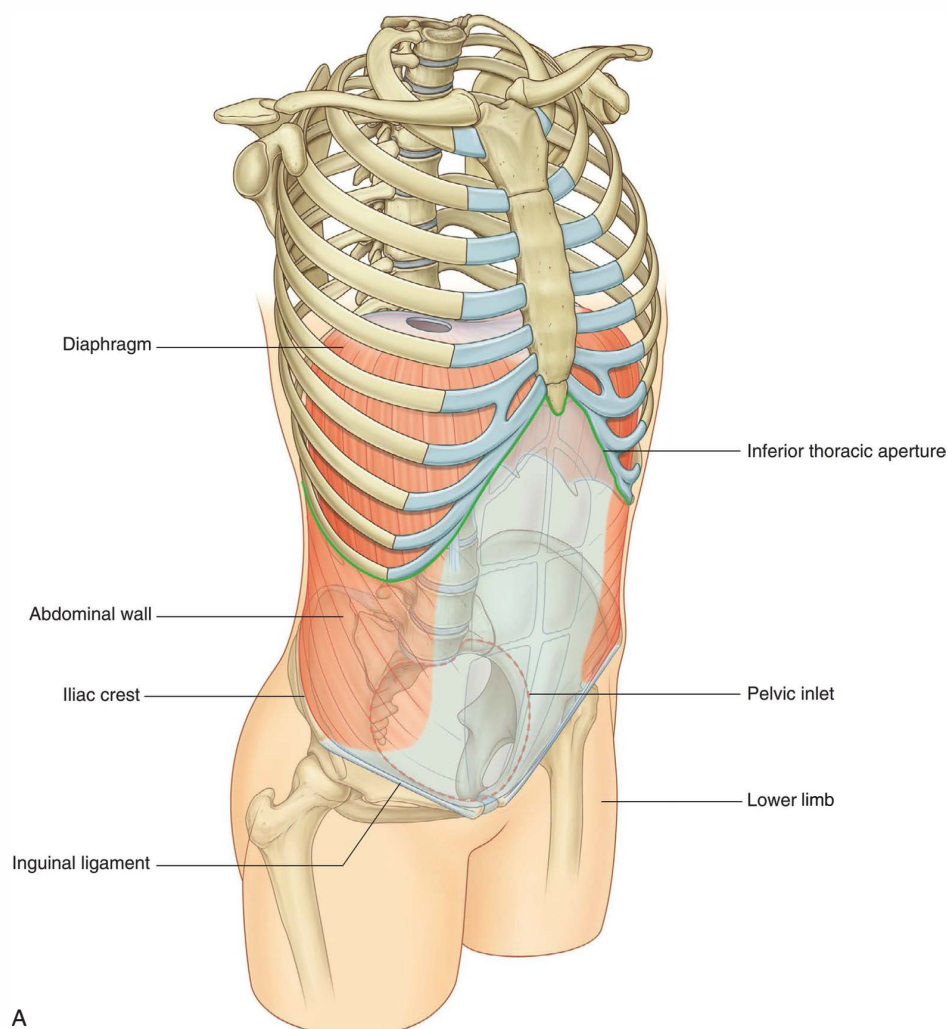
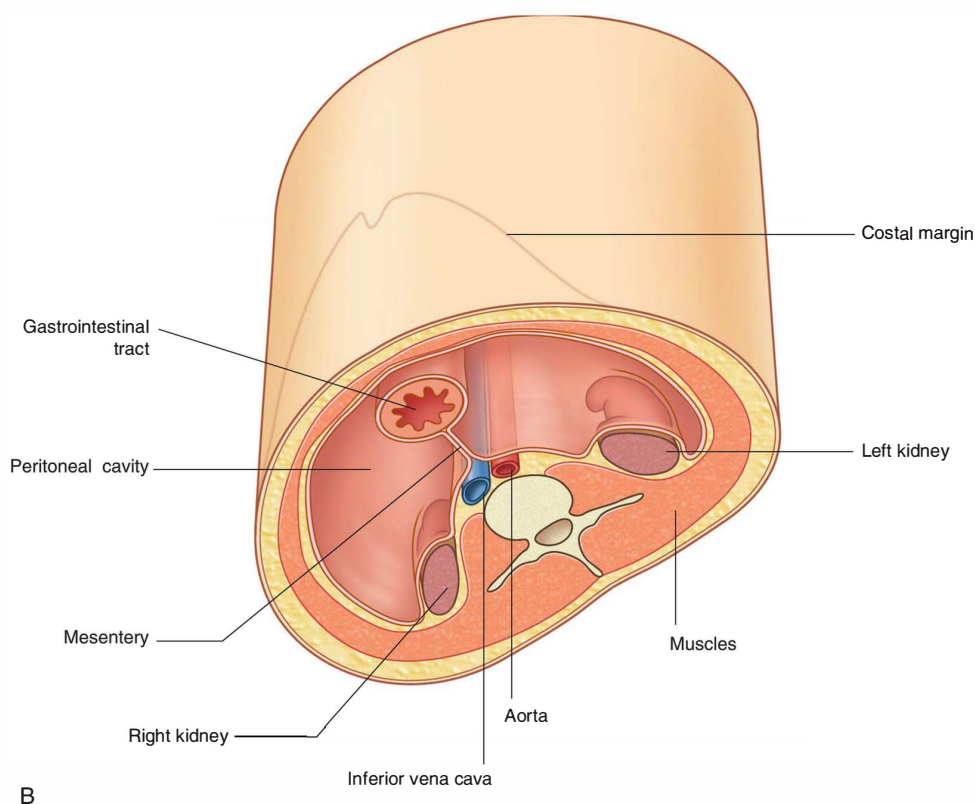


Fig. 4.1 Abdomen. A. Boundaries.



Abdomen



B

Fig. 4.1, cont'd B. Arrangement of abdominal contents. Inferior view.

Abdominal viscera are either suspended in the peritoneal cavity by mesenteries or positioned between the cavity and the musculoskeletal wall ([Fig. 4.1B](#)).

Abdominal viscera include:

- major elements of the gastrointestinal system—the caudal end of the esophagus, stomach, small and large intestines, liver, pancreas, and gallbladder;
- the spleen;
- components of the urinary system—kidneys and ureters;
- the suprarenal glands; and
- major neurovascular structures.

FUNCTIONS

Houses and protects major viscera

The abdomen houses major elements of the gastrointestinal system ([Fig. 4.2](#)), the spleen, and parts of the urinary system.

Much of the liver, gallbladder, stomach, and spleen and parts of the colon are under the domes of the diaphragm, which project superiorly above the costal margin of the thoracic wall, and as a result these abdominal viscera are protected by the thoracic wall. The superior poles of the kidneys are deep to the lower ribs.

Viscera not under the domes of the diaphragm are supported and protected predominantly by the muscular walls of the abdomen.

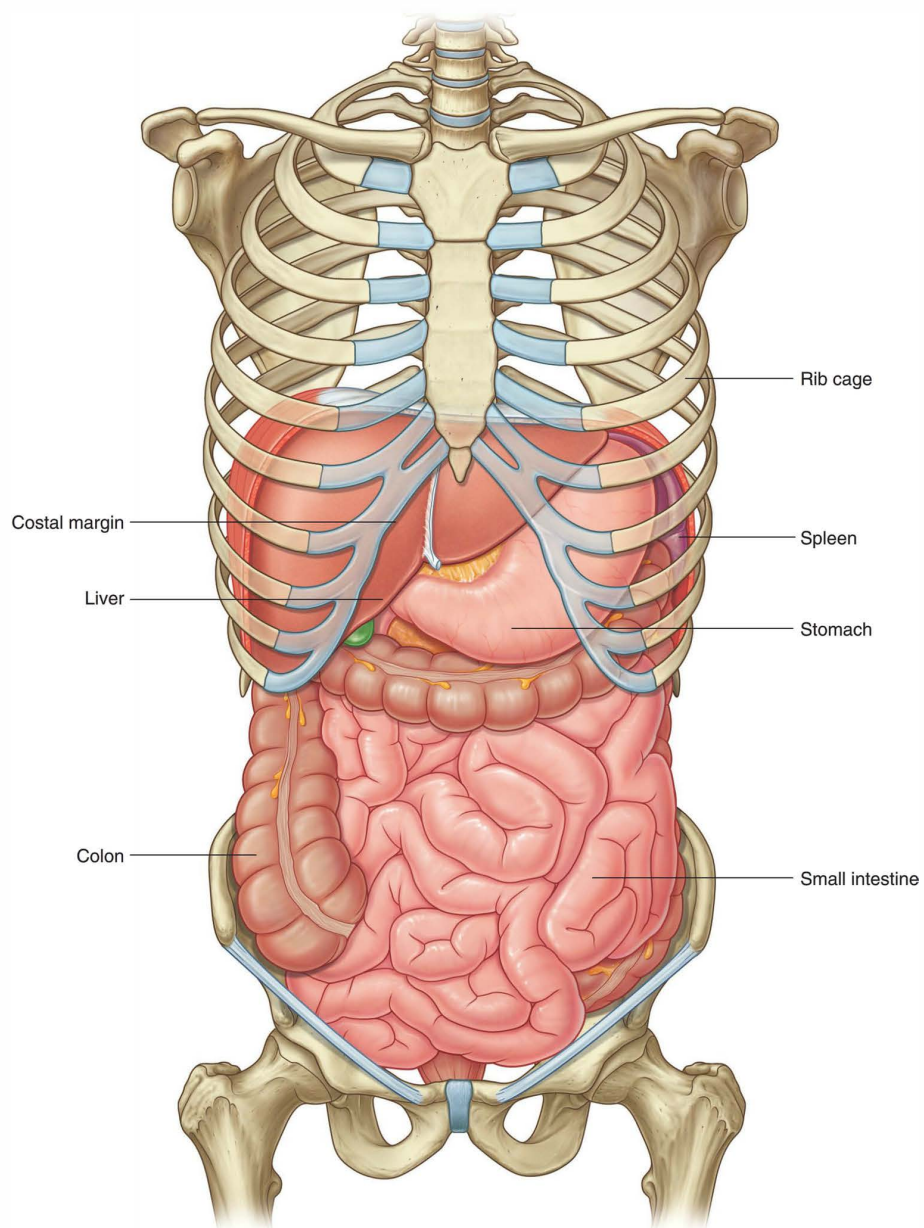


Fig. 4.2 The abdomen contains and protects the abdominal viscera.



Abdomen

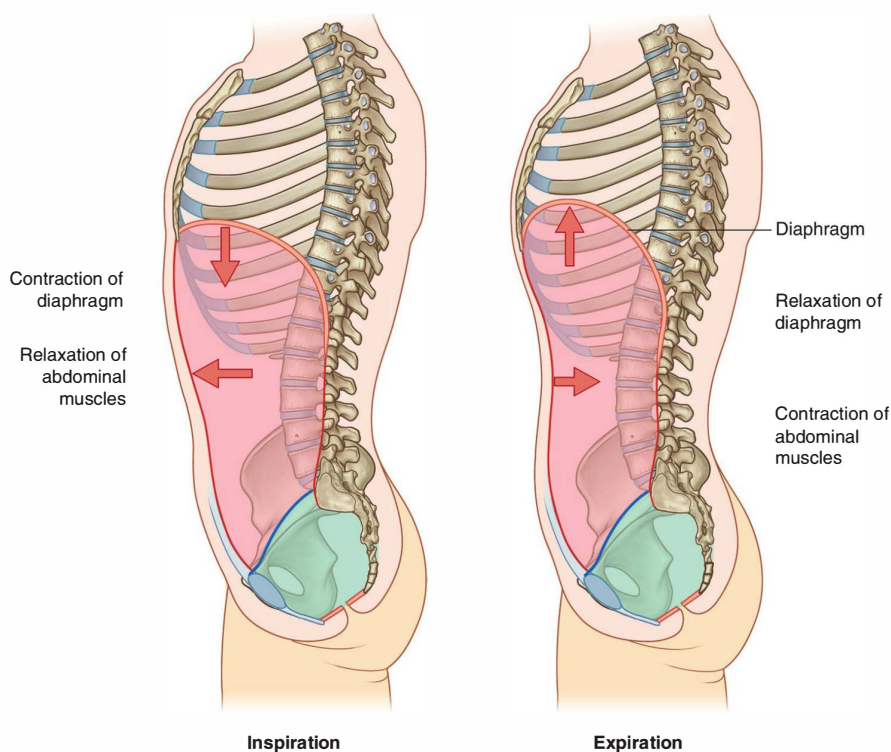


Fig. 4.3 The abdomen assists in breathing.

Breathing

One of the most important roles of the abdominal wall is to assist in breathing:

- It relaxes during inspiration to accommodate expansion of the thoracic cavity and the inferior displacement of abdominal viscera during contraction of the diaphragm (Fig. 4.3).
- During expiration, it contracts to assist in elevating the domes of the diaphragm, thus reducing thoracic volume.

Material can be expelled from the airway by forced expiration using the abdominal muscles, as in coughing or sneezing.

Changes in intraabdominal pressure

Contraction of abdominal wall muscles can dramatically increase intraabdominal pressure when the diaphragm is

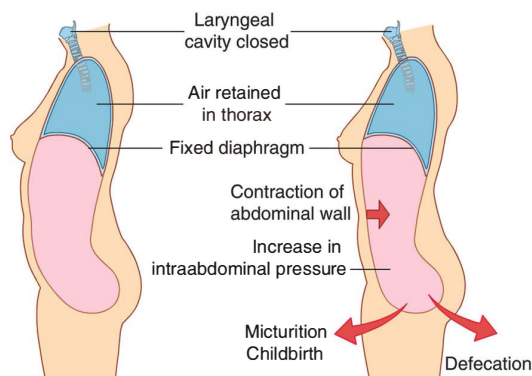


Fig. 4.4 Increasing intraabdominal pressure to assist in micturition, defecation, and childbirth.

in a fixed position (Fig. 4.4). Air is retained in the lungs by closing valves in the larynx in the neck. Increased intraabdominal pressure assists in voiding the contents of the bladder and rectum and in giving birth.

COMPONENT PARTS

Wall

The abdominal wall consists partly of bone but mainly of muscle (Fig. 4.5). The skeletal elements of the wall (Fig. 4.5A) are:

- the five lumbar vertebrae and their intervening intervertebral discs,
- the superior expanded parts of the pelvic bones, and
- bony components of the inferior thoracic wall, including the costal margin, rib XII, the end of rib XI, and the xiphoid process.

Muscles make up the rest of the abdominal wall (Fig. 4.5B):

- Lateral to the vertebral column, the quadratus lumborum, psoas major, and iliacus muscles reinforce the posterior aspect of the wall. The distal ends of the psoas major and iliacus muscles pass into the thigh and are major flexors of the hip joint.
- Lateral parts of the abdominal wall are predominantly formed by three layers of muscles, which are similar in orientation to the intercostal muscles of the thorax—transversus abdominis, internal oblique, and external oblique.

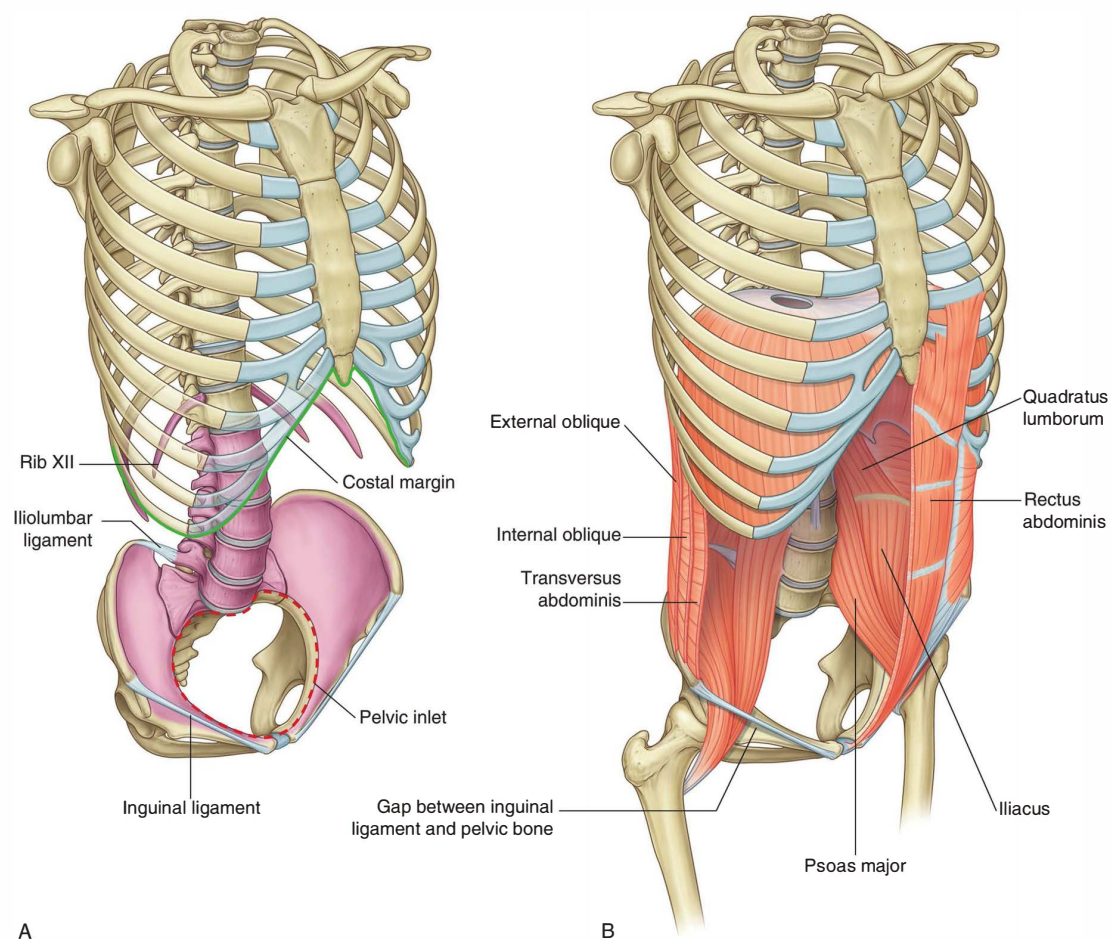


Fig. 4.5 Abdominal wall. A. Skeletal elements. B. Muscles.



Abdomen

- Anteriorly, a segmented muscle (the rectus abdominis) on each side spans the distance between the inferior thoracic wall and the pelvis.

Structural continuity between posterior, lateral, and anterior parts of the abdominal wall is provided by thick fascia posteriorly and by flat tendinous sheets (aponeuroses) derived from muscles of the lateral wall. A fascial layer of varying thickness separates the abdominal wall from the peritoneum, which lines the abdominal cavity.

Abdominal cavity

The general organization of the abdominal cavity is one in which a central gut tube (gastrointestinal system) is suspended from the posterior abdominal wall and partly from the anterior abdominal wall by thin sheets of tissue (**mesenteries**; Fig. 4.6):

- a ventral (anterior) mesentery for proximal regions of the gut tube;
- a dorsal (posterior) mesentery along the entire length of the system.

Different parts of these two mesenteries are named according to the organs they suspend or with which they are associated.

Major viscera, such as the kidneys, that are not suspended in the abdominal cavity by mesenteries are associated with the abdominal wall.

The abdominal cavity is lined by **peritoneum**, which consists of an epithelial-like single layer of cells (the **mesothelium**) together with a supportive layer of connective tissue. Peritoneum is similar to the pleura and serous pericardium in the thorax.

The peritoneum reflects off the abdominal wall to become a component of the mesenteries that suspend the viscera.

- Parietal peritoneum** lines the abdominal wall.
- Visceral peritoneum** covers suspended organs.

Normally, elements of the gastrointestinal tract and its derivatives completely fill the abdominal cavity, making the peritoneal cavity a potential space, and visceral peritoneum on organs and parietal peritoneum on the adjacent abdominal wall slide freely against one another.

Abdominal viscera are either intraperitoneal or retroperitoneal:

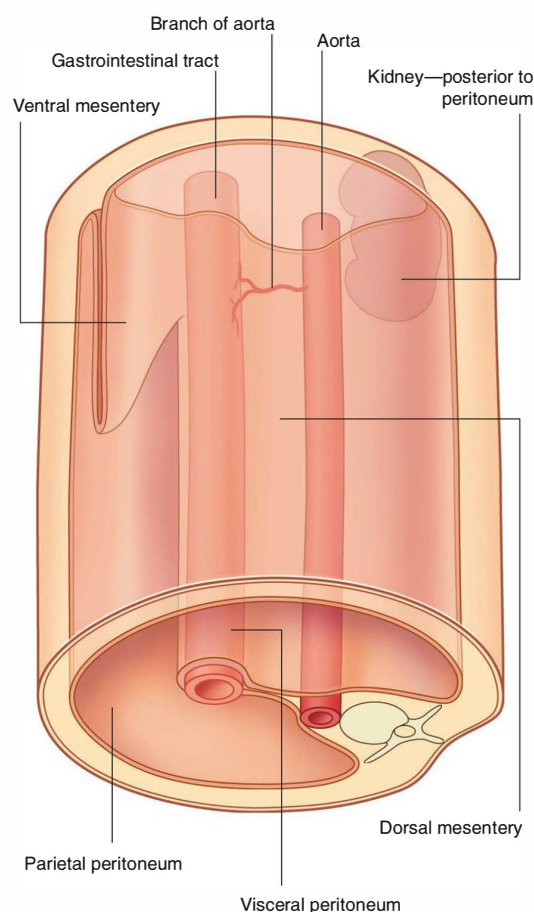


Fig. 4.6 The gut tube is suspended by mesenteries.

- Intraperitoneal** structures, such as elements of the gastrointestinal system, are suspended from the abdominal wall by mesenteries;
- Structures that are not suspended in the abdominal cavity by a mesentery and that lie between the parietal peritoneum and abdominal wall are **retroperitoneal** in position.

Retroperitoneal structures include the kidneys and ureters, which develop in the region between the peritoneum and the abdominal wall and remain in this position in the adult.

During development, some organs, such as parts of the small and large intestines, are suspended initially in the abdominal cavity by a mesentery, and later become retroperitoneal secondarily by fusing with the abdominal wall (Fig. 4.7).

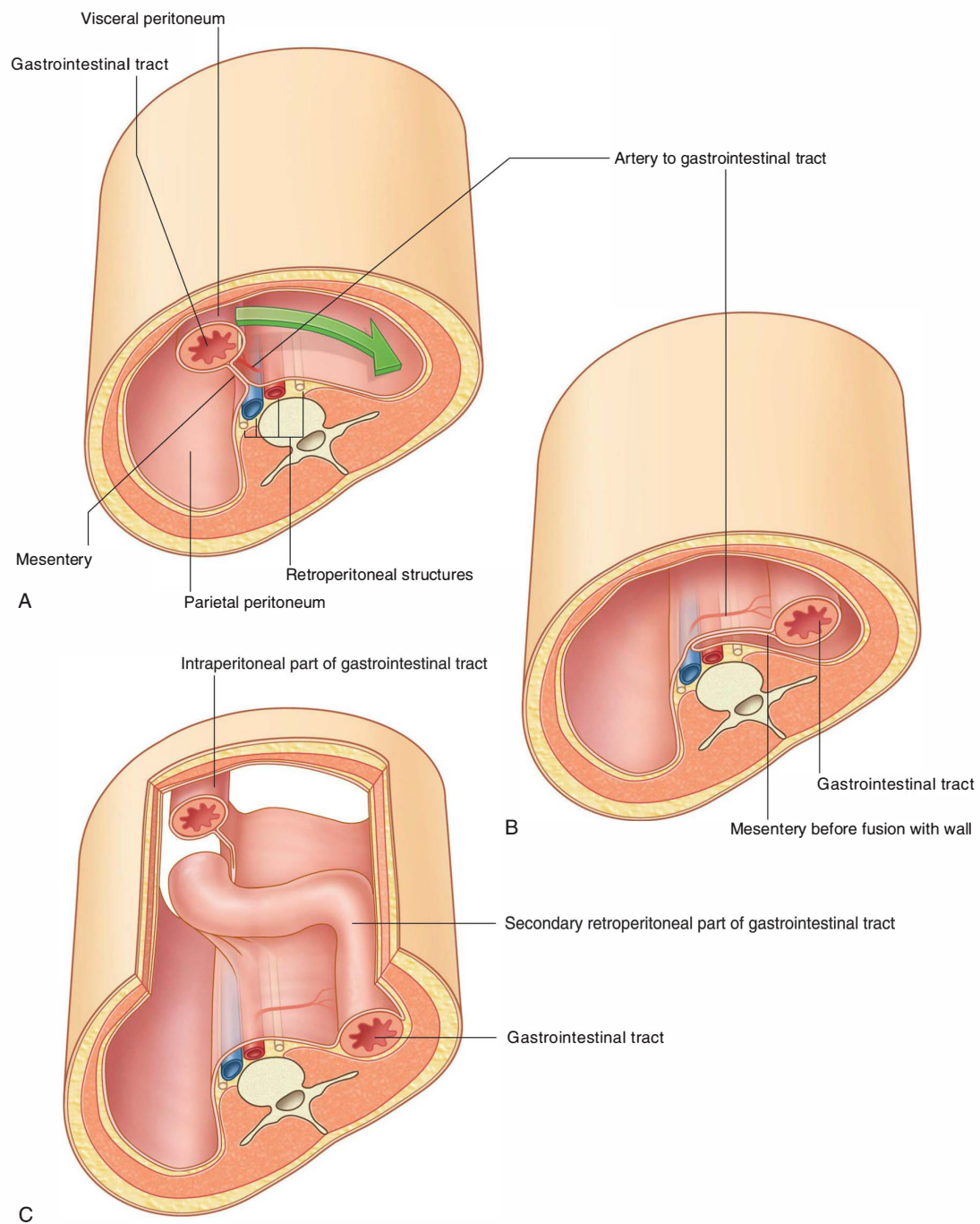


Fig. 4.7 A series showing the progression (A to C) from an intraperitoneal organ to a secondarily retroperitoneal organ.



Abdomen

Large vessels, nerves, and lymphatics are associated with the posterior abdominal wall along the median axis of the body in the region where, during development, the peritoneum reflects off the wall as the dorsal mesentery, which supports the developing gut tube. As a consequence, branches of the neurovascular structures that pass to parts of the gastrointestinal system are unpaired, originate from the anterior aspects of their parent structures, and travel in mesenteries or pass retroperitoneally in areas where the mesenteries secondarily fuse to the wall.

Generally, vessels, nerves, and lymphatics to the abdominal wall and to organs that originate as retroperitoneal structures branch laterally from the central neurovascular structures and are usually paired, one on each side.

Inferior thoracic aperture

The superior aperture of the abdomen is the inferior thoracic aperture, which is closed by the diaphragm (see

pp. 126-127). The margin of the inferior thoracic aperture consists of vertebra TXII, rib XII, the distal end of rib XI, the costal margin, and the xiphoid process of the sternum.

Diaphragm

The musculotendinous diaphragm separates the abdomen from the thorax.

The diaphragm attaches to the margin of the inferior thoracic aperture, but the attachment is complex posteriorly and extends into the lumbar area of the vertebral column (Fig. 4.8). On each side, a muscular extension (crus) firmly anchors the diaphragm to the anterolateral surface of the vertebral column as far down as vertebra LIII on the right and vertebra LII on the left.

Because the costal margin is not complete posteriorly, the diaphragm is anchored to arch-shaped (arcuate) ligaments, which span the distance between available bony points and the intervening soft tissues:

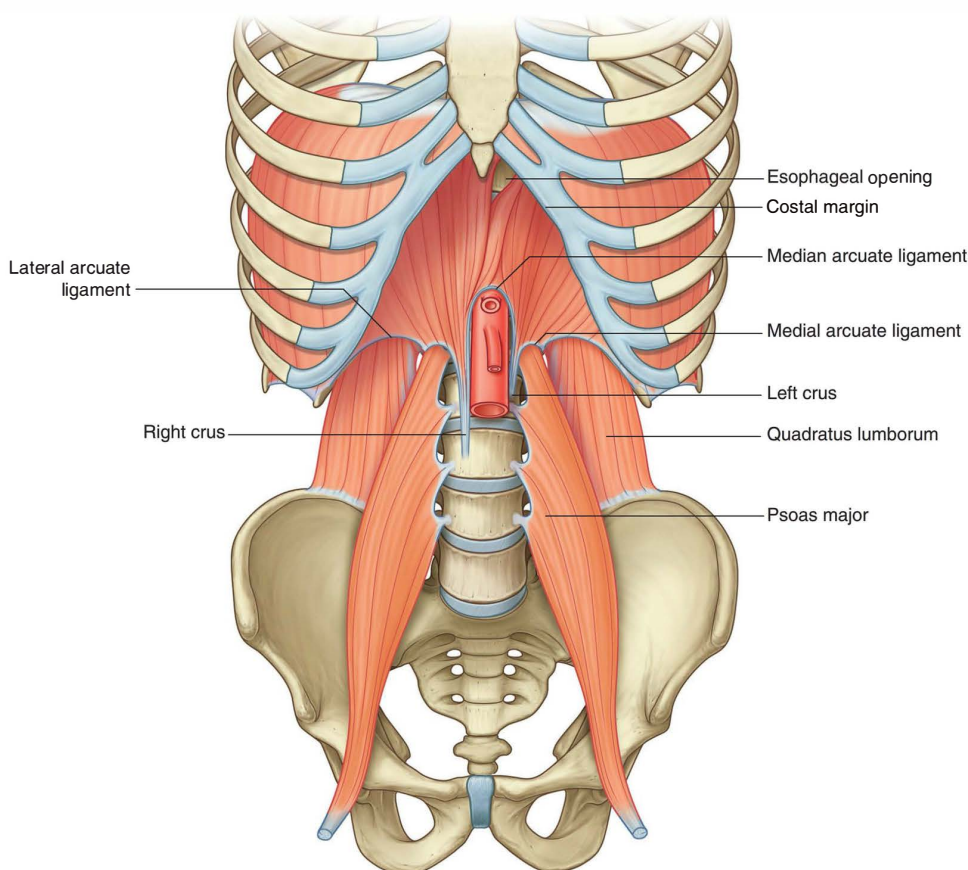


Fig. 4.8 Inferior thoracic aperture and the diaphragm.

- **Medial and lateral arcuate ligaments** cross muscles of the posterior abdominal wall and attach to vertebrae, the transverse processes of vertebra L1 and rib XII, respectively.
- A **median arcuate ligament** crosses the aorta and is continuous with the crus on each side.

The posterior attachment of the diaphragm extends much farther inferiorly than the anterior attachment. Consequently, the diaphragm is an important component of the posterior abdominal wall, to which a number of viscera are related.

Pelvic inlet

The abdominal wall is continuous with the pelvic wall at the pelvic inlet, and the abdominal cavity is continuous with the pelvic cavity.

The circular margin of the pelvic inlet is formed entirely by bone:

- posteriorly by the sacrum,
- anteriorly by the pubic symphysis, and
- laterally, on each side, by a distinct bony rim on the pelvic bone (Fig. 4.9).

Because of the way in which the sacrum and attached pelvic bones are angled posteriorly on the vertebral column, the pelvic cavity is not oriented in the same vertical plane as the abdominal cavity. Instead, the pelvic cavity projects posteriorly, and the inlet opens anteriorly and somewhat superiorly (Fig. 4.10).

RELATIONSHIP TO OTHER REGIONS

Thorax

The abdomen is separated from the thorax by the diaphragm. Structures pass between the two regions through or posterior to the diaphragm (see Fig. 4.8).

Pelvis

The pelvic inlet opens directly into the abdomen and structures pass between the abdomen and pelvis through it.

The peritoneum lining the abdominal cavity is continuous with the peritoneum in the pelvis. Consequently, the

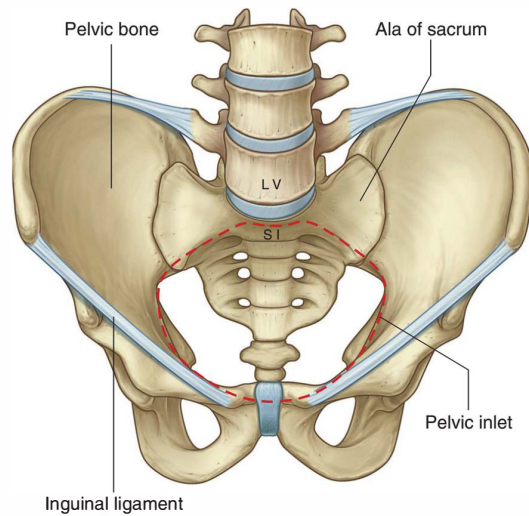


Fig. 4.9 Pelvic inlet.

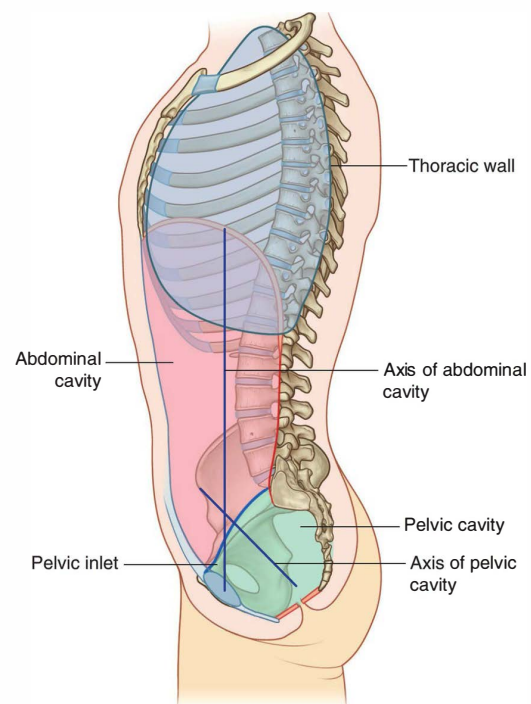


Fig. 4.10 Orientation of abdominal and pelvic cavities.



Abdomen

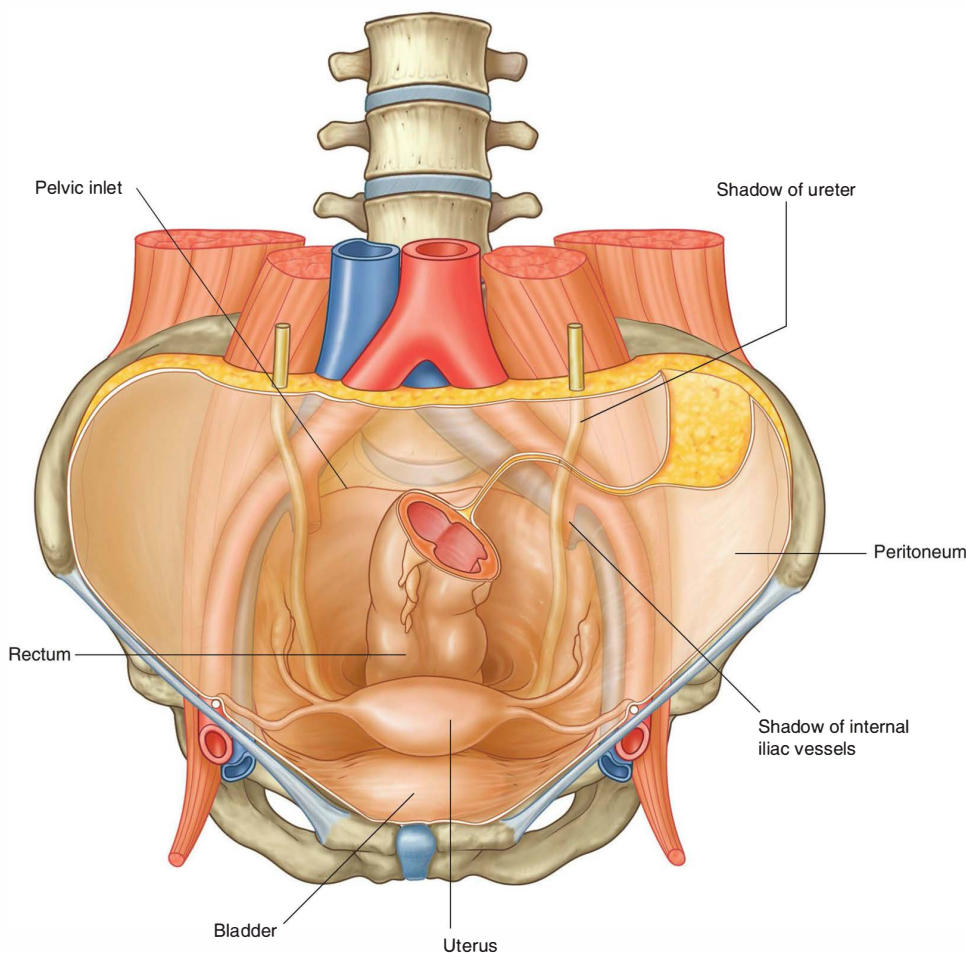


Fig. 4.11 The abdominal cavity is continuous with the pelvic cavity.

abdominal cavity is entirely continuous with the pelvic cavity (Fig. 4.11). Infections in one region can therefore freely spread into the other.

The bladder expands superiorly from the pelvic cavity into the abdominal cavity and, during pregnancy, the uterus expands freely superiorly out of the pelvic cavity into the abdominal cavity.

Lower limb

The abdomen communicates directly with the thigh through an aperture formed anteriorly between the inferior margin of the abdominal wall (marked by the inguinal

ligament) and the pelvic bone (Fig. 4.12). Structures that pass through this aperture are:

- the major artery and vein of the lower limb;
- the femoral nerve, which innervates the quadriceps femoris muscle, which extends the knee;
- lymphatics; and
- the distal ends of psoas major and iliacus muscles, which flex the thigh at the hip joint.

As vessels pass inferior to the inguinal ligament, their names change—the external iliac artery and vein of the abdomen become the femoral artery and vein of the thigh.

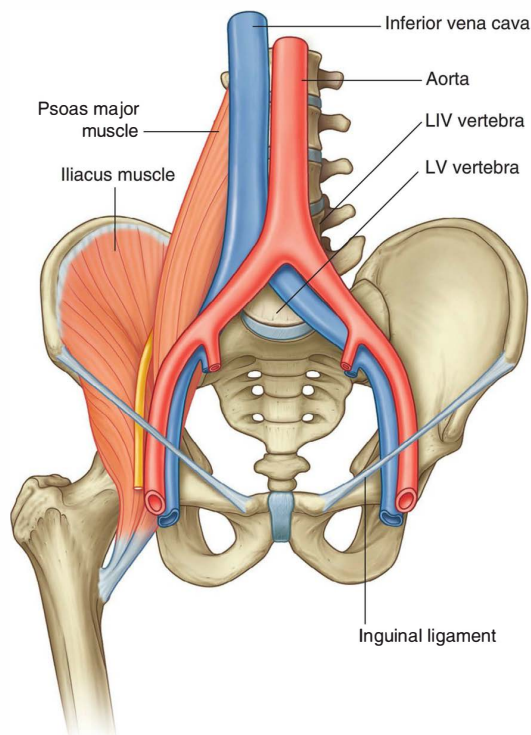


Fig. 4.12 Structures passing between the abdomen and thigh.

KEY FEATURES

Arrangement of abdominal viscera in the adult

A basic knowledge of the development of the gastrointestinal tract is needed to understand the arrangement of viscera and mesenteries in the abdomen (Fig. 4.13).

The early gastrointestinal tract is oriented longitudinally in the body cavity and is suspended from surrounding walls by a large dorsal mesentery and a much smaller ventral mesentery.

Superiorly, the dorsal and ventral mesenteries are anchored to the diaphragm.

The primitive gut tube consists of the foregut, the midgut, and the hindgut. Massive longitudinal growth of the gut tube, rotation of selected parts of the tube, and secondary fusion of some viscera and their associated mesenteries to the body wall participate in generating the adult arrangement of abdominal organs.

Development of the foregut

In abdominal regions, the **foregut** gives rise to the distal end of the esophagus, the stomach, and the proximal part of the duodenum. The foregut is the only part of the gut

tube suspended from the wall by both the ventral and dorsal mesenteries.

A diverticulum from the anterior aspect of the foregut grows into the ventral mesentery, giving rise to the liver and gallbladder, and, ultimately, to the ventral part of the pancreas.

The dorsal part of the pancreas develops from an outgrowth of the foregut into the dorsal mesentery. The spleen develops in the dorsal mesentery in the region between the body wall and presumptive stomach.

In the foregut, the developing stomach rotates clockwise and the associated dorsal mesentery, containing the spleen, moves to the left and greatly expands. During this process, part of the mesentery becomes associated with, and secondarily fuses with, the left side of the body wall.

At the same time, the duodenum, together with its dorsal mesentery and an appreciable part of the pancreas, swings to the right and fuses to the body wall.

Secondary fusion of the duodenum to the body wall, massive growth of the liver in the ventral mesentery, and fusion of the superior surface of the liver to the diaphragm restrict the opening to the space enclosed by the ballooned dorsal mesentery associated with the stomach. This restricted opening is the **omental foramen (epiploic foramen)**.

The part of the abdominal cavity enclosed by the expanded dorsal mesentery, and posterior to the stomach, is the **omental bursa (lesser sac)**. Access, through the omental foramen, to this space from the rest of the peritoneal cavity (**greater sac**) is inferior to the free edge of the ventral mesentery.

Part of the dorsal mesentery that initially forms part of the lesser sac greatly enlarges in an inferior direction, and the two opposing surfaces of the mesentery fuse to form an apron-like structure (the **greater omentum**). The greater omentum is suspended from the greater curvature of the stomach, lies over other viscera in the abdominal cavity, and is the first structure observed when the abdominal cavity is opened anteriorly.

Development of the midgut

The midgut develops into the distal part of the duodenum and the jejunum, ileum, ascending colon, and proximal two-thirds of the transverse colon. A small yolk sac projects anteriorly from the developing midgut into the umbilicus.

Rapid growth of the gastrointestinal system results in a loop of the midgut herniating out of the abdominal cavity and into the umbilical cord. As the body grows in size and the connection with the yolk sac is lost, the midgut returns to the abdominal cavity. While this process is occurring, the two limbs of the midgut loop rotate counterclockwise



Abdomen

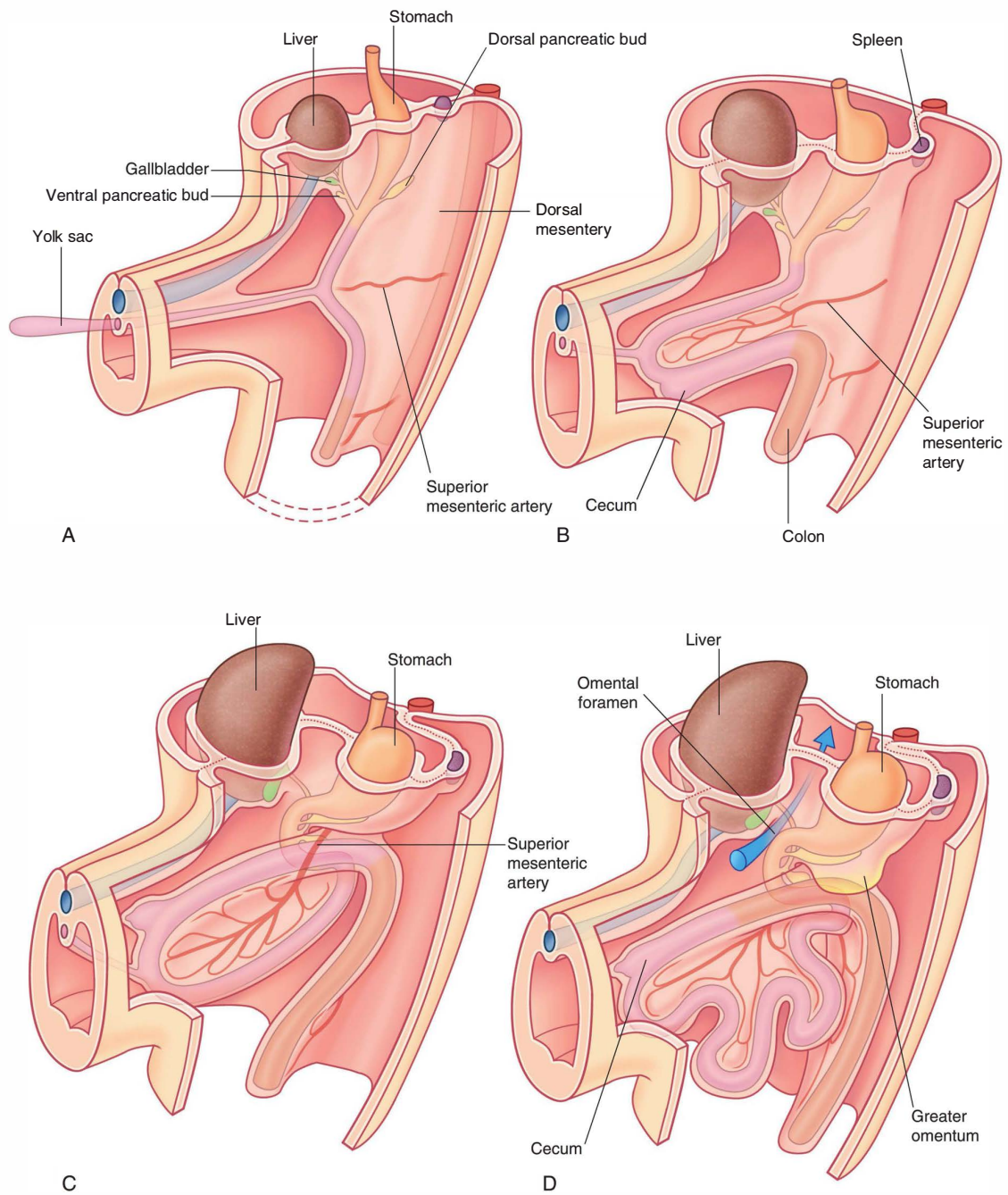


Fig. 4.13 A series (A to H) showing the development of the gut and mesenteries.

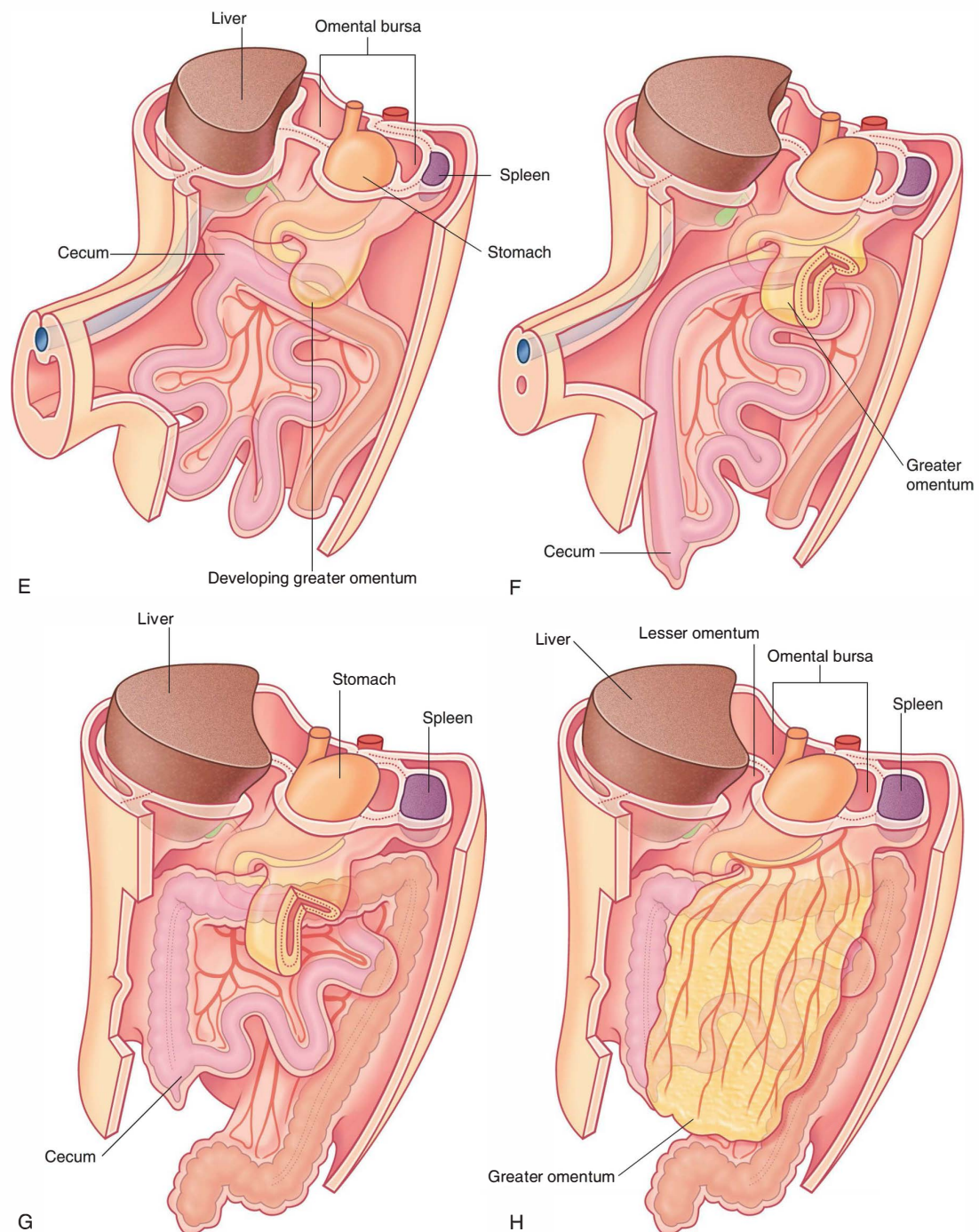


Fig. 4.13, cont'd



Abdomen

around their combined central axis, and the part of the loop that becomes the cecum descends into the inferior right aspect of the cavity. The superior mesenteric artery, which supplies the midgut, is at the center of the axis of rotation.

The cecum remains intraperitoneal, the ascending colon fuses with the body wall becoming secondarily retroperitoneal, and the transverse colon remains suspended by its dorsal mesentery (transverse mesocolon). The greater omentum hangs over the transverse colon and the mesocolon and usually fuses with these structures.

Development of the hindgut

The distal one-third of the transverse colon, descending colon, sigmoid colon, and superior part of the rectum develop from the hindgut.

Proximal parts of the hindgut swing to the left and become the descending colon and sigmoid colon. The descending colon and its dorsal mesentery fuse to the body wall, while the sigmoid colon remains intraperitoneal. The sigmoid colon passes through the pelvic inlet and is continuous with the rectum at the level of vertebra SIII.

Skin and muscles of the anterior and lateral abdominal wall and thoracic intercostal nerves

The anterior rami of thoracic spinal nerves T7 to T12 follow the inferior slope of the lateral parts of the ribs and cross the costal margin to enter the abdominal wall (Fig. 4.14). Intercostal nerves T7 to T11 supply skin and muscle of the abdominal wall, as does the subcostal nerve T12. In addition, T5 and T6 supply upper parts of the external oblique muscle of the abdominal wall; T6 also supplies cutaneous innervation to skin over the xiphoid.

Skin and muscle in the inguinal and suprapubic regions of the abdominal wall are innervated by L1 and not by thoracic nerves.

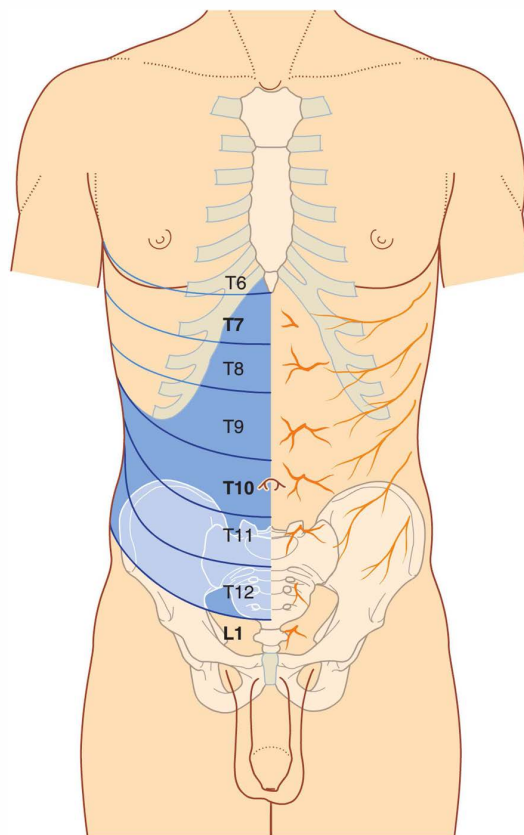


Fig. 4.14 Innervation of the anterior abdominal wall.

Dermatomes of the anterior abdominal wall are indicated in Figure 4.14. In the midline, skin over the infrasternal angle is T6 and that around the umbilicus is T10. L1 innervates skin in the inguinal and suprapubic regions.

Muscles of the abdominal wall are innervated segmentally in patterns that generally reflect the patterns of the overlying dermatomes.

The groin is a weak area in the anterior abdominal wall

During development, the gonads in both sexes descend from their sites of origin on the posterior abdominal wall into the pelvic cavity in women and the developing scrotum in men (Fig. 4.15).

Before descent, a cord of tissue (the **gubernaculum**) passes through the anterior abdominal wall and connects the inferior pole of each gonad with primordia of the scrotum in men and the labia majora in women (labioscrotal swellings).

A tubular extension (the **processus vaginalis**) of the peritoneal cavity and the accompanying muscular layers of the anterior abdominal wall project along the gubernaculum on each side into the labioscrotal swellings.

In men, the testis, together with its neurovascular structures and its efferent duct (the ductus deferens) descends into the scrotum along a path, initially defined by the gubernaculum, between the processus vaginalis and the accompanying coverings derived from the abdominal wall.

All that remains of the gubernaculum is a connective tissue remnant that attaches the caudal pole of the testis to the scrotum.

The **inguinal canal** is the passage through the anterior abdominal wall created by the processus vaginalis. The **spermatic cord** is the tubular extension of the layers of the abdominal wall into the scrotum that contains all structures passing between the testis and the abdomen.

The distal sac-like terminal end of the spermatic cord on each side contains the testis, associated structures, and the now isolated part of the peritoneal cavity (the cavity of the tunica vaginalis).

In women, the gonads descend to a position just inside the pelvic cavity and never pass through the anterior abdominal wall. As a result, the only major structure passing through the inguinal canal is a derivative of the gubernaculum (the round ligament of the uterus).

In both men and women, the groin (inguinal region) is a weak area in the abdominal wall (Fig. 4.15) and is the site of inguinal hernias.

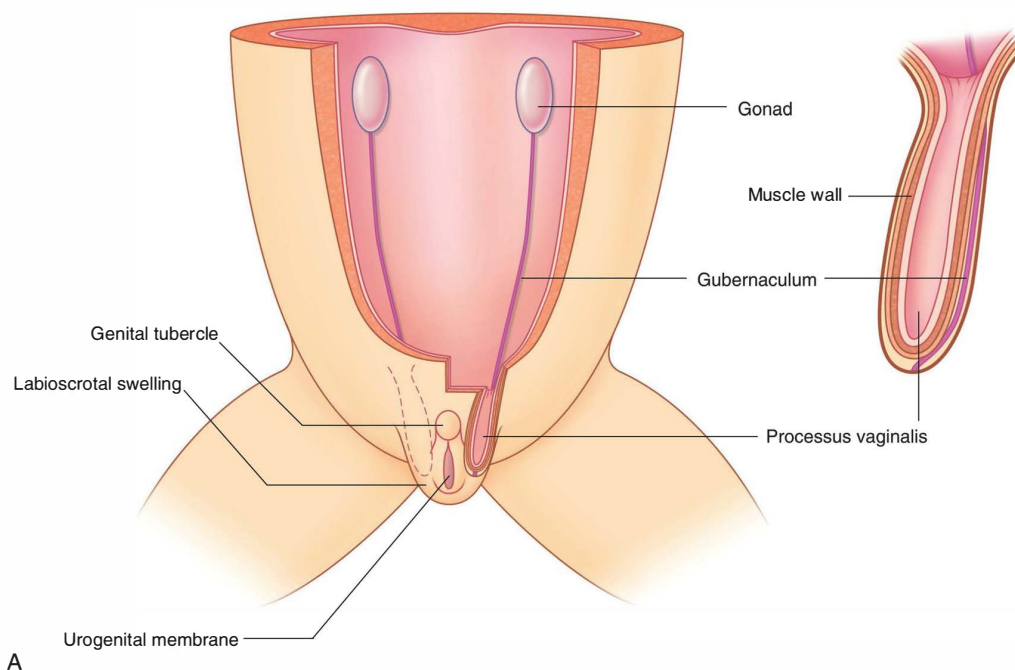


Fig. 4.15 Inguinal region. A. Development.



Abdomen

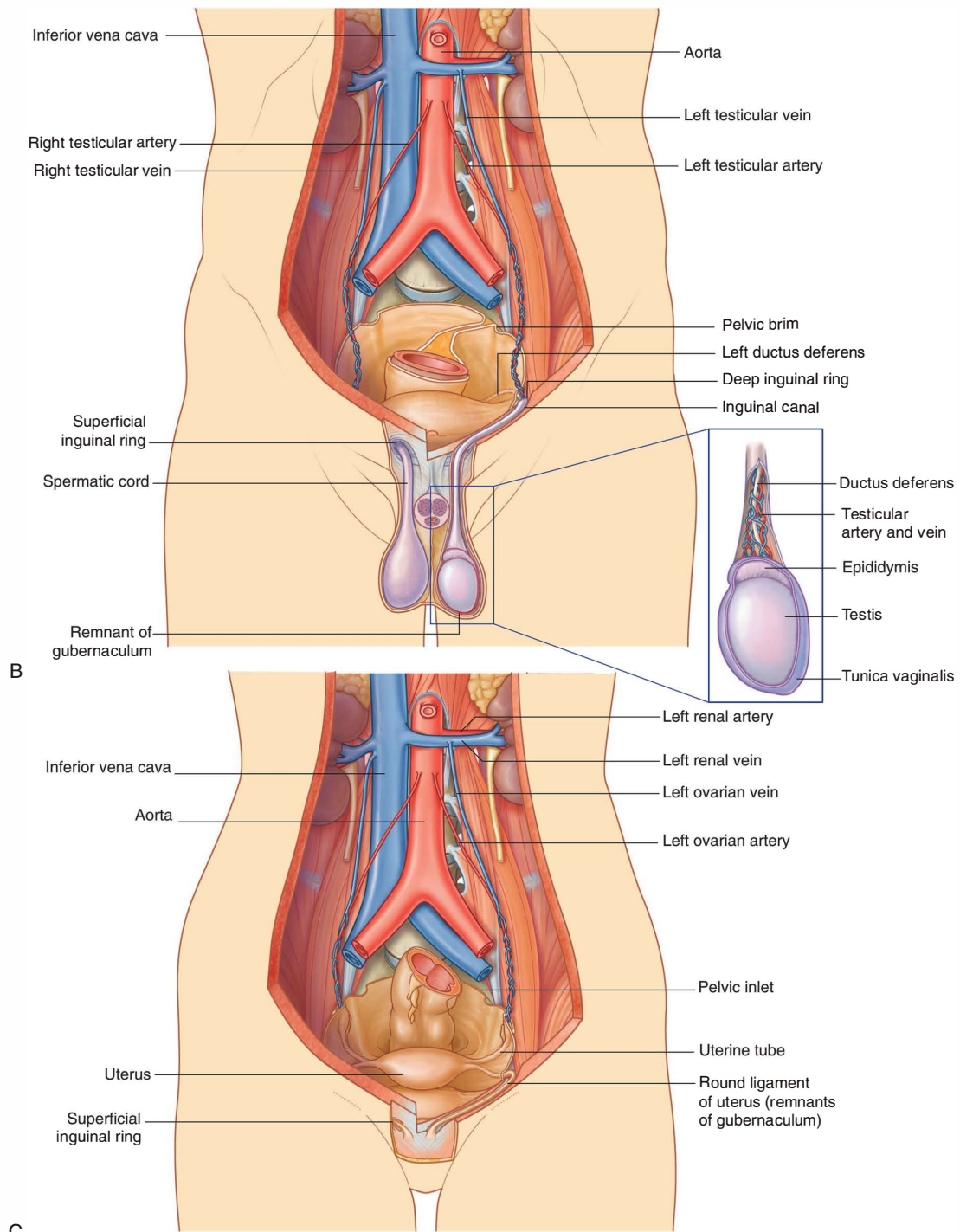


Fig. 4.15, cont'd B. In men. C. In women.

Vertebral level LI

The transpyloric plane is a horizontal plane that transects the body through the lower aspect of vertebra LI (Fig. 4.16). It:

- is about midway between the jugular notch and the pubic symphysis, and crosses the costal margin on each side at roughly the ninth costal cartilage;
- crosses through the opening of the stomach into the duodenum (the pyloric orifice), which is just to the right of the body of LI; the duodenum then makes a characteristic C-shaped loop on the posterior abdominal wall and crosses the midline to open into the jejunum just to the left of the body of vertebra LII, whereas the head of the pancreas is enclosed by the loop of the duodenum, and the body of the pancreas extends across the midline to the left;
- crosses through the body of the pancreas; and
- approximates the position of the hila of the kidneys; though because the left kidney is slightly higher than the right, the transpyloric plane crosses through the inferior aspect of the left hilum and the superior part of the right hilum.

The gastrointestinal system and its derivatives are supplied by three major arteries

Three large unpaired arteries branch from the anterior surface of the abdominal aorta to supply the abdominal part of the gastrointestinal tract and all of the structures (liver, pancreas, and gallbladder) to which this part of the gut gives rise during development (Fig. 4.17). These arteries pass through derivatives of the dorsal and ventral mesenteries to reach the target viscera. These vessels therefore also supply structures such as the spleen and lymph nodes that develop in the mesenteries. These three arteries are:

- the **celiac artery**, which branches from the abdominal aorta at the upper border of vertebra LI and supplies the foregut;

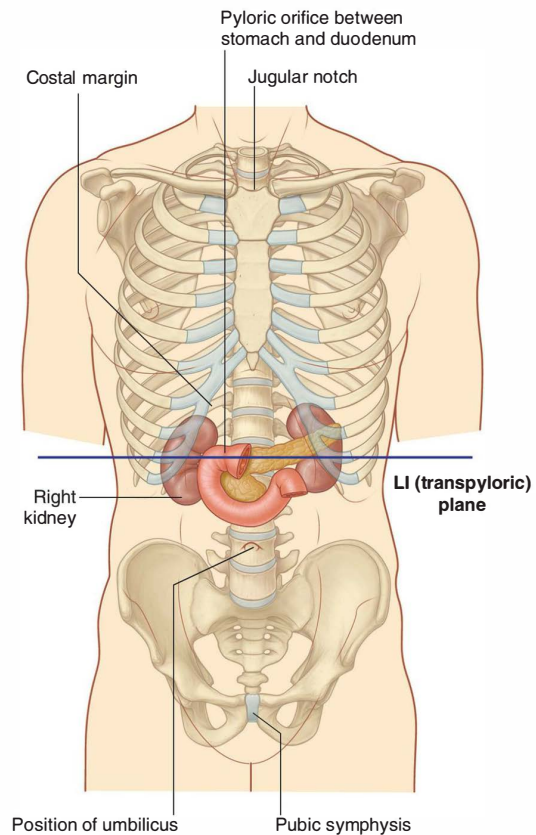


Fig. 4.16 Vertebral level LI.

- the **superior mesenteric artery**, which arises from the abdominal aorta at the lower border of vertebra LI and supplies the midgut; and
- the **inferior mesenteric artery**, which branches from the abdominal aorta at approximately vertebral level LIII and supplies the hindgut.



Abdomen

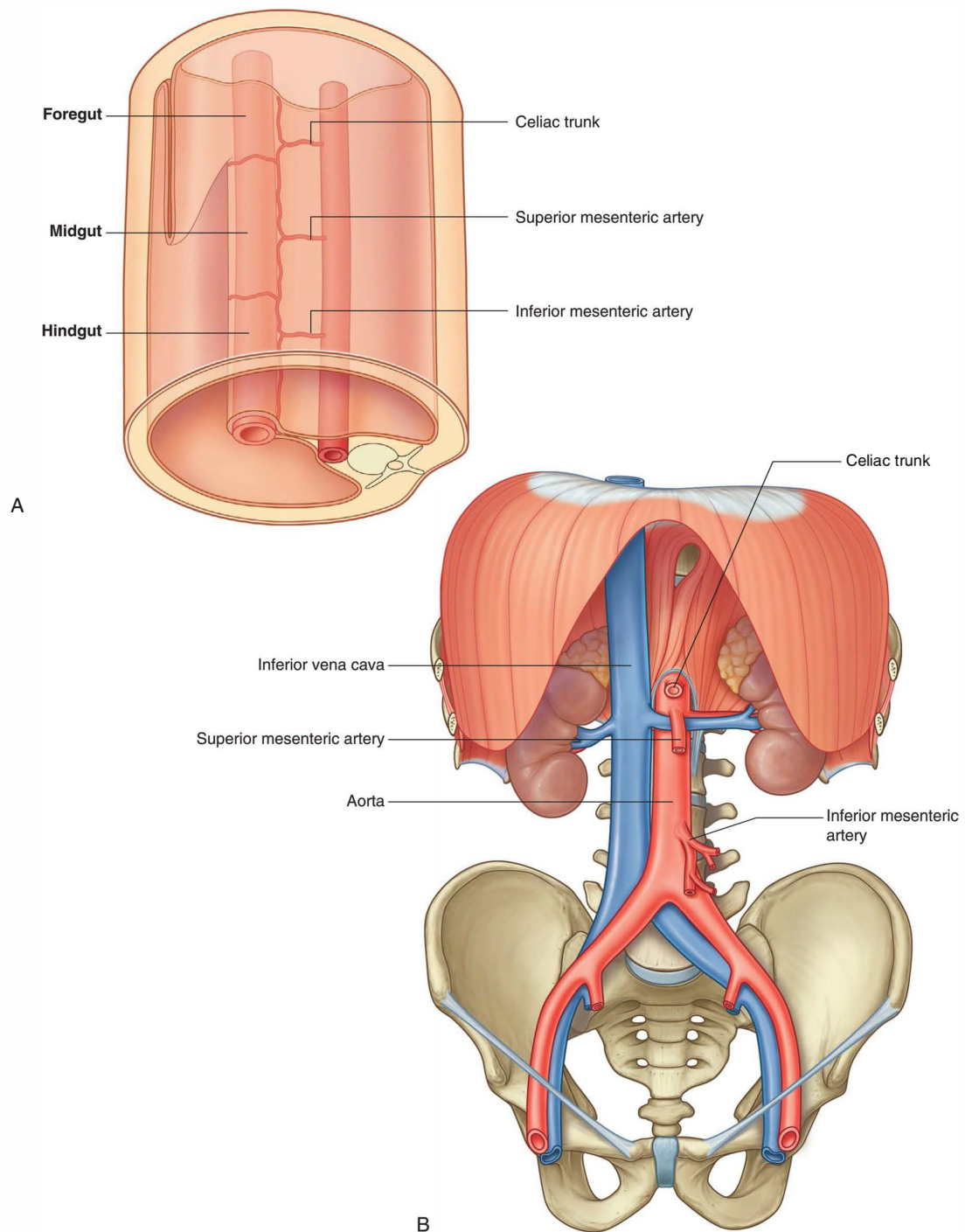


Fig. 4.17 Blood supply of the gut. **A.** Relationship of vessels to the gut and mesenteries. **B.** Anterior view.

Venous shunts from left to right

All blood returning to the heart from regions of the body other than the lungs flows into the right atrium of the heart. The inferior vena cava is the major systemic vein in the abdomen and drains this region together with the pelvis, perineum, and both lower limbs (Fig. 4.18).

The inferior vena cava lies to the right of the vertebral column and penetrates the central tendon of the

diaphragm at approximately vertebral level TVIII. A number of large vessels cross the midline to deliver blood from the left side of the body to the inferior vena cava.

- One of the most significant is the left renal vein, which drains the kidney, suprarenal gland, and gonad on the same side.

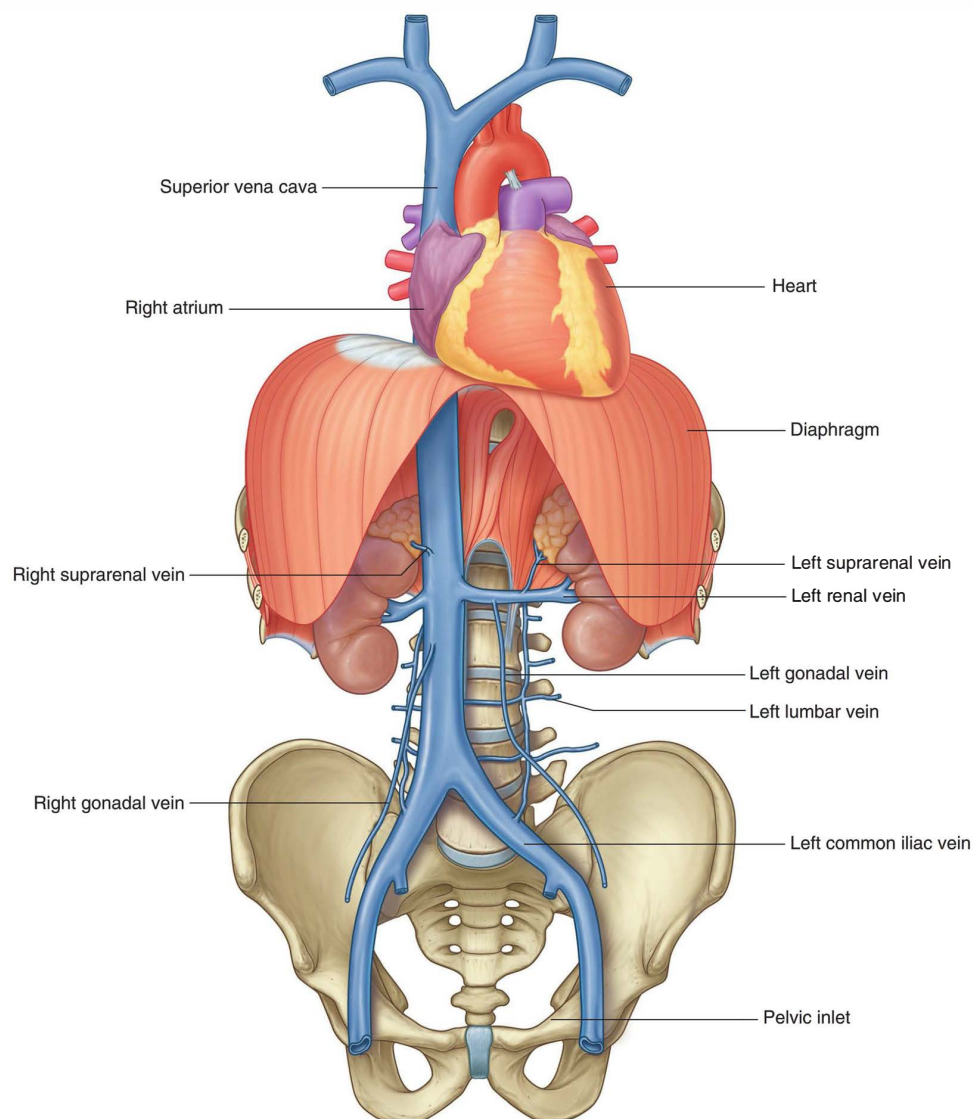


Fig. 4.18 Left-to-right venous shunts.

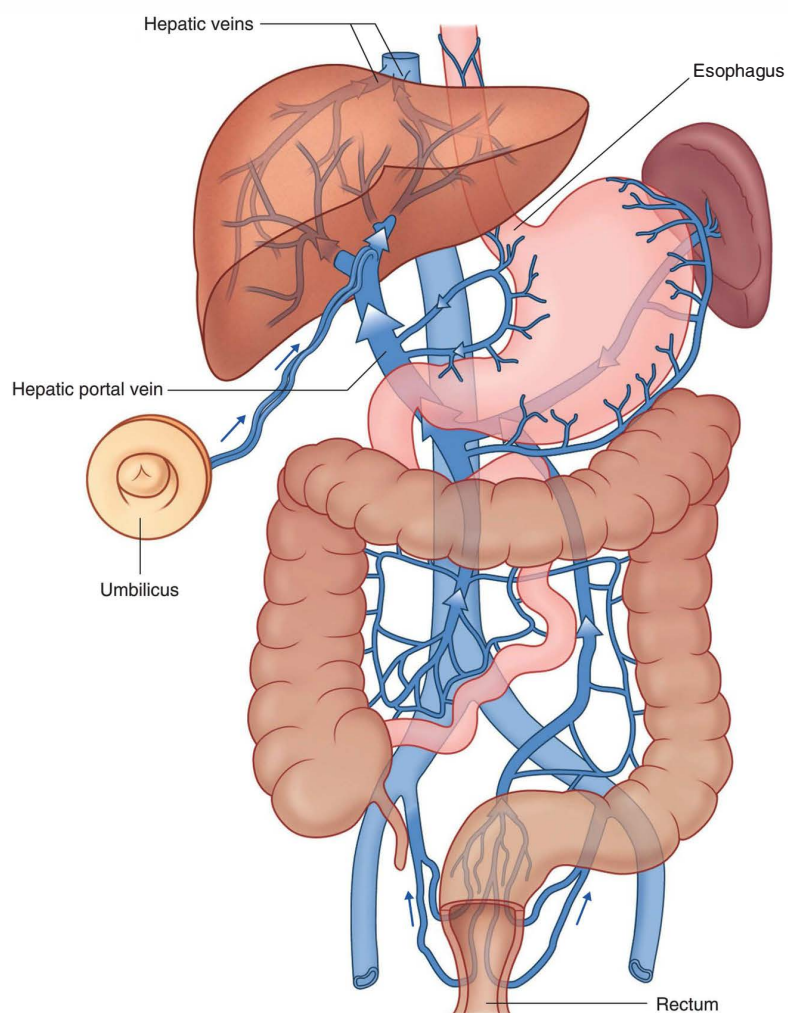


Abdomen

- Another is the left common iliac vein, which crosses the midline at approximately vertebral level LV to join with its partner on the right to form the inferior vena cava. These veins drain the lower limbs, the pelvis, the perineum, and parts of the abdominal wall.
- Other vessels crossing the midline include the left lumbar veins, which drain the back and posterior abdominal wall on the left side.

All venous drainage from the gastrointestinal system passes through the liver

Blood from abdominal parts of the gastrointestinal system and the spleen passes through a second vascular bed, in the liver, before ultimately returning to the heart (Fig. 4.19).



Venous blood from the digestive tract, pancreas, gallbladder, and spleen enters the inferior surface of the liver through the large **hepatic portal vein**. This vein then ramifies like an artery to distribute blood to small endothelial-lined hepatic sinusoids, which form the vascular exchange network of the liver.

After passing through the sinusoids, the blood collects in a number of short **hepatic veins**, which drain into the inferior vena cava just before the inferior vena cava penetrates the diaphragm and enters the right atrium of the heart.

Normally, vascular beds drained by the hepatic portal system interconnect, through small veins, with beds drained by systemic vessels, which ultimately connect directly with either the superior or inferior vena cava.

Portacaval anastomoses

Among the clinically most important regions of overlap between the portal and caval systems are those at each end of the abdominal part of the gastrointestinal system:

- around the inferior end of the esophagus;
- around the inferior part of the rectum.

Small veins that accompany the degenerate umbilical vein (**round ligament of the liver**) establish another important portacaval anastomosis.

The round ligament of the liver connects the umbilicus of the anterior abdominal wall with the left branch of the

portal vein as it enters the liver. The small veins that accompany this ligament form a connection between the portal system and para-umbilical regions of the abdominal wall, which drain into systemic veins.

Other regions where portal and caval systems interconnect include:

- where the liver is in direct contact with the diaphragm (the bare area of the liver);
- where the wall of the gastrointestinal tract is in direct contact with the posterior abdominal wall (retroperitoneal areas of the large and small intestine); and
- the posterior surface of the pancreas (much of the pancreas is secondarily retroperitoneal).

Blockage of the hepatic portal vein or of vascular channels in the liver

Blockage of the hepatic portal vein or of vascular channels in the liver can affect the pattern of venous return from abdominal parts of the gastrointestinal system. Vessels that interconnect the portal and caval systems can become greatly enlarged and tortuous, allowing blood in tributaries of the portal system to bypass the liver, enter the caval system, and thereby return to the heart. Portal hypertension can result in esophageal and rectal varices and in caput medusae in which systemic vessels that radiate from para-umbilical veins enlarge and become visible on the abdominal wall.



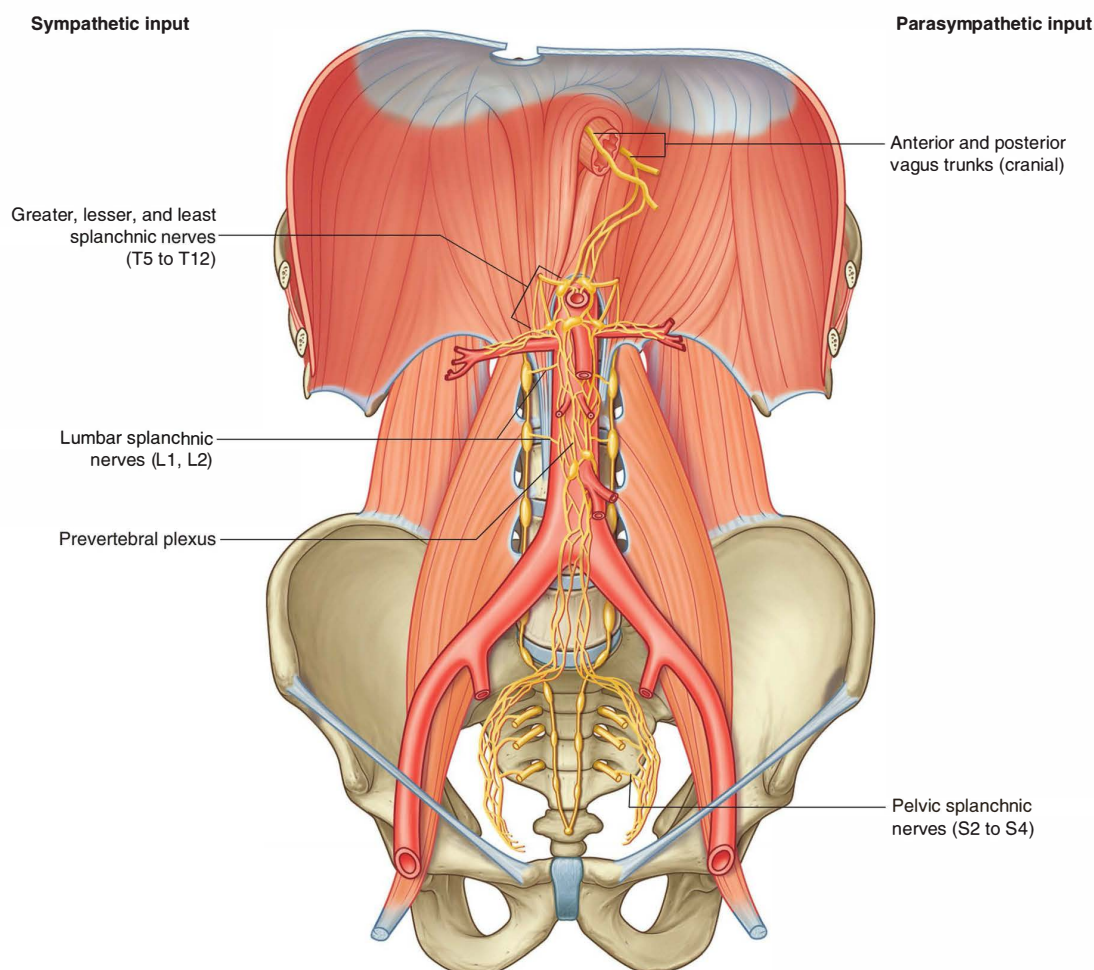
Abdomen

Abdominal viscera are supplied by a large prevertebral plexus

Innervation of the abdominal viscera is derived from a large prevertebral plexus associated mainly with the anterior and lateral surfaces of the aorta (Fig. 4.20). Branches are distributed to target tissues along vessels that originate from the abdominal aorta.

The prevertebral plexus contains sympathetic, parasympathetic, and visceral sensory components:

- Sympathetic components originate from spinal cord levels T5 to L2.
- Parasympathetic components are from the vagus nerve [X] and spinal cord levels S2 to S4.
- Visceral sensory fibers generally parallel the motor pathways.



Regional anatomy

The abdomen is the part of the trunk inferior to the thorax (Fig. 4.21). Its musculomembranous walls surround a large cavity (the **abdominal cavity**), which is bounded superiorly by the diaphragm and inferiorly by the pelvic inlet.

The abdominal cavity may extend superiorly as high as the fourth intercostal space, and is continuous inferiorly with the pelvic cavity. It contains the **peritoneal cavity** and the abdominal viscera.

SURFACE TOPOGRAPHY

Topographical divisions of the abdomen are used to describe the location of abdominal organs and the pain

associated with abdominal problems. The two schemes most often used are:

- a four-quadrant pattern and
- a nine-region pattern.

Four-quadrant pattern

A horizontal transumbilical plane passing through the umbilicus and the intervertebral disc between vertebrae LIII and LIV and intersecting with the vertical median plane divides the abdomen into four quadrants—the right upper, left upper, right lower, and left lower quadrants (Fig. 4.22).

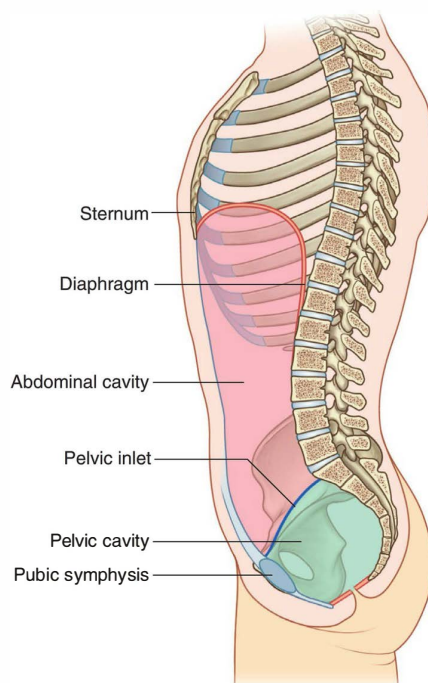


Fig. 4.21 Boundaries of the abdominal cavity.

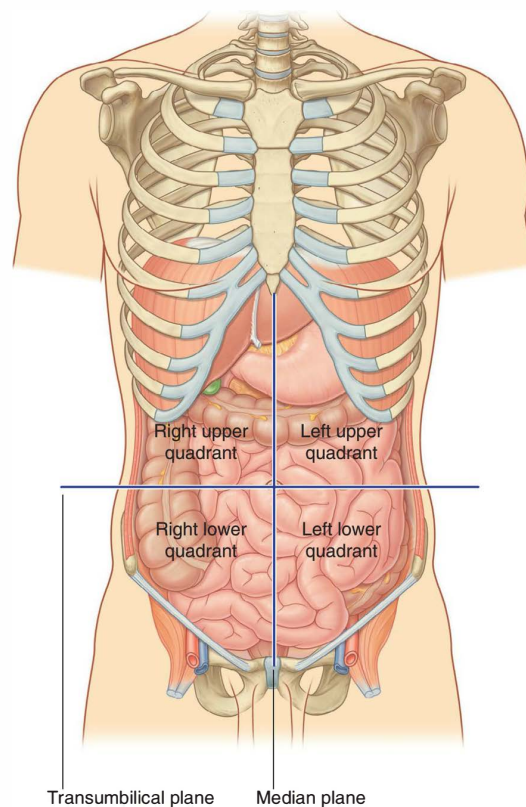


Fig. 4.22 Four-quadrant topographical pattern.



Abdomen

Nine-region pattern

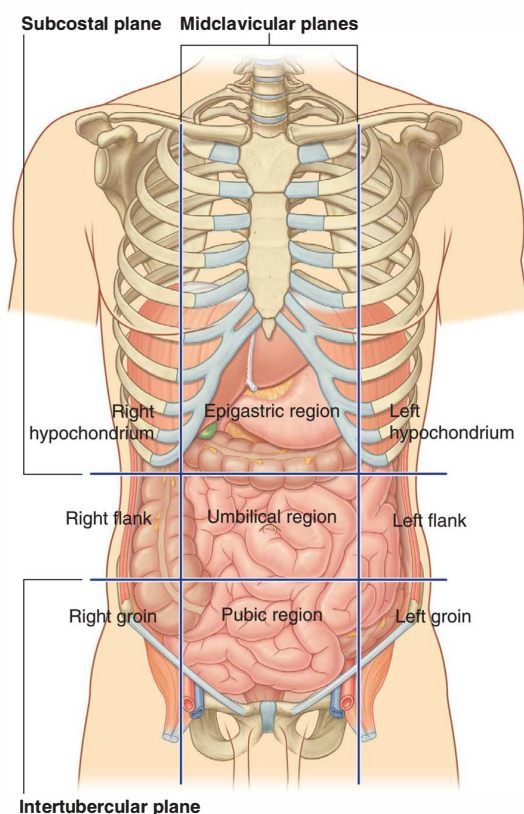
The nine-region pattern is based on two horizontal and two vertical planes (Fig. 4.23).

- The superior horizontal plane (the **subcostal plane**) is immediately inferior to the costal margins, which places it at the lower border of the costal cartilage of rib X and passing posteriorly through the body of vertebra LIII. (Note, however, that sometimes the **transpyloric plane**, halfway between the jugular notch and the symphysis pubis or halfway between the umbilicus and the inferior end of the body of the sternum, passing posteriorly through the lower border of vertebra LI and intersecting with the costal margin at the ends of the ninth costal cartilages, is used instead.)
- The inferior horizontal plane (the **intertubercular plane**) connects the tubercles of the iliac crests, which

are palpable structures 5 cm posterior to the anterior superior iliac spines, and passes through the upper part of the body of vertebra LV.

- The vertical planes pass from the midpoint of the clavicles inferiorly to a point midway between the anterior superior iliac spine and pubic symphysis.

These four planes establish the topographical divisions in the nine-region organization. The following designations are used for each region: superiorly the right hypochondrium, the epigastric region, and the left hypochondrium; inferiorly the right groin (inguinal region), pubic region, and left groin (inguinal region); and in the middle the right flank (lateral region), the umbilical region, and the left flank (lateral region) (Fig. 4.23).



In the clinic

Surgical incisions

Access to the abdomen and its contents is usually obtained through incisions in the anterior abdominal wall. Traditionally, incisions have been placed at and around the region of surgical interest. The size of these incisions was usually large to allow good access and optimal visualization of the abdominal cavity. As anesthesia has developed and muscle-relaxing drugs have become widely used, the abdominal incisions have become smaller.

Currently, the most commonly used large abdominal incision is a central craniocaudal incision from the xiphoid process to the symphysis pubis, which provides wide access to the whole of the abdominal contents and allows an exploratory procedure to be performed (laparotomy).

In the clinic**Laparoscopic surgery**

Laparoscopic surgery, also known as minimally invasive or keyhole surgery, is performed by operating through a series of small incisions no more than 1 to 2 cm in length. As the incisions are much smaller than those used in traditional abdominal surgery, patients experience less postoperative pain and have shorter recovery times. There is also a favorable cosmetic outcome with smaller scars. Several surgical procedures such as appendectomy, cholecystectomy, and hernia repair, as well as numerous orthopaedic, urological, and gynecological procedures, are now commonly performed laparoscopically.

During the operation, a camera known as a laparoscope is used to transmit live, magnified images of the surgical field to a monitor viewed by the surgeon. The camera is inserted into the abdominal cavity through a small incision, called a port-site, usually at the umbilicus. In order to create enough space to operate, the abdominal wall is elevated by inflating the cavity with gas, typically carbon dioxide. Other long, thin surgical instruments are then introduced through additional port-sites, which can be used by the surgeon

to operate. The placement of these port-sites is carefully planned to allow optimal access to the surgical field.

Laparoscopic surgery has been further enhanced with the use of surgical robots. Using these systems the surgeon moves the surgical instruments indirectly by controlling robotic arms, which are inserted into the operating field through small incisions. Robot-assisted surgery is now routinely used worldwide and has helped overcome some of the limitations of laparoscopy by enhancing the surgeon's dexterity. The robotic system is precise, provides the surgeon with a 3D view of the surgical field, and allows improved degree of rotation and manipulation of the surgical instruments. Several procedures such as prostatectomy and cholecystectomy can now be performed with this method.

Laparoendoscopic single-site surgery, also known as single-port laparoscopy, is the most recent advance in laparoscopic surgery. This method uses a single incision, usually umbilical, to introduce a port with several operating channels and can be performed with or without robotic assistance. Benefits include less postoperative pain, a faster recovery time, and an even better cosmetic result than traditional laparoscopic surgery.



Abdomen

ABDOMINAL WALL

The abdominal wall covers a large area. It is bounded superiorly by the xiphoid process and costal margins, posteriorly by the vertebral column, and inferiorly by the upper parts of the pelvic bones. Its layers consist of skin, superficial fascia (subcutaneous tissue), muscles and their associated deep fascias, extraperitoneal fascia, and parietal peritoneum (Fig. 4.24).

Superficial fascia

The superficial fascia of the abdominal wall (subcutaneous tissue of abdomen) is a layer of fatty connective tissue. It is usually a single layer similar to, and continuous with, the superficial fascia throughout other regions of the body. However, in the lower region of the anterior part of the abdominal wall, below the umbilicus, it forms two layers: a superficial fatty layer and a deeper membranous layer.

Superficial layer

The superficial fatty layer of superficial fascia (**Camper's fascia**) contains fat and varies in thickness (Figs. 4.25 and 4.26). It is continuous over the inguinal ligament with the superficial fascia of the thigh and with a similar layer in the perineum.

In men, this superficial layer continues over the penis and, after losing its fat and fusing with the deeper layer of superficial fascia, continues into the scrotum where it forms a specialized fascial layer containing smooth muscle fibers (the **dartos fascia**). In women, this superficial layer retains some fat and is a component of the labia majora.

Deeper layer

The deeper membranous layer of superficial fascia (**Scarpa's fascia**) is thin and membranous, and contains little or no fat (Fig. 4.25). Inferiorly, it continues into the thigh, but just below the inguinal ligament, it fuses with the deep fascia of the thigh (the **fascia lata**; Fig. 4.26). In the midline, it is firmly attached to the linea alba and the symphysis pubis. It continues into the anterior part of the perineum where it is firmly attached to the ischiopubic rami and to the posterior margin of the perineal membrane. Here, it is referred to as the **superficial perineal fascia (Colles' fascia)**.

In men, the deeper membranous layer of superficial fascia blends with the superficial layer as they both pass over the penis, forming the superficial fascia of the penis, before they continue into the scrotum where they form the dartos fascia (Fig. 4.25). Also in men, extensions of the deeper membranous layer of superficial fascia attached to the pubic symphysis pass inferiorly onto the dorsum and

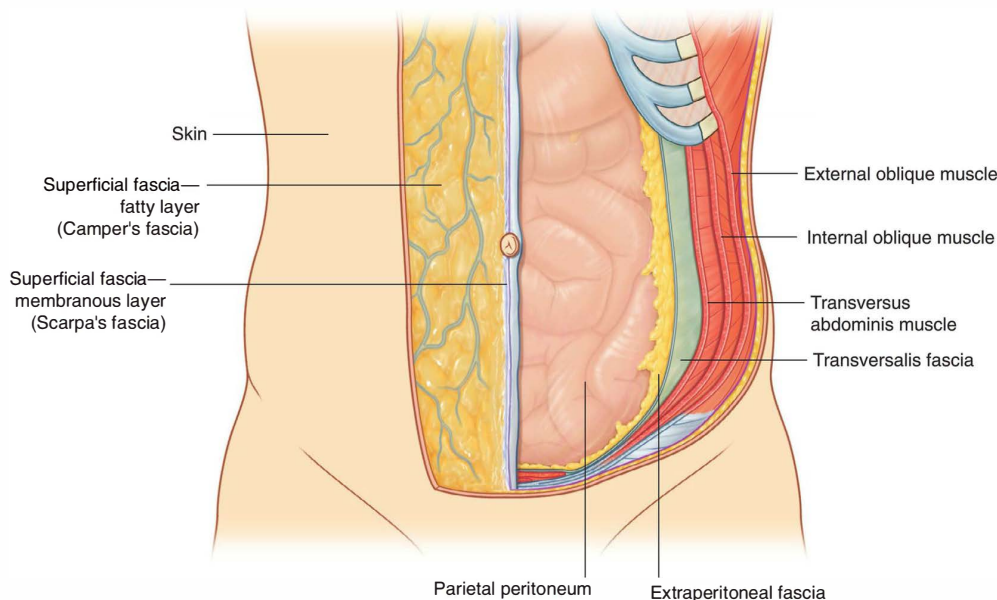


Fig. 4.24 Layers of the abdominal wall.

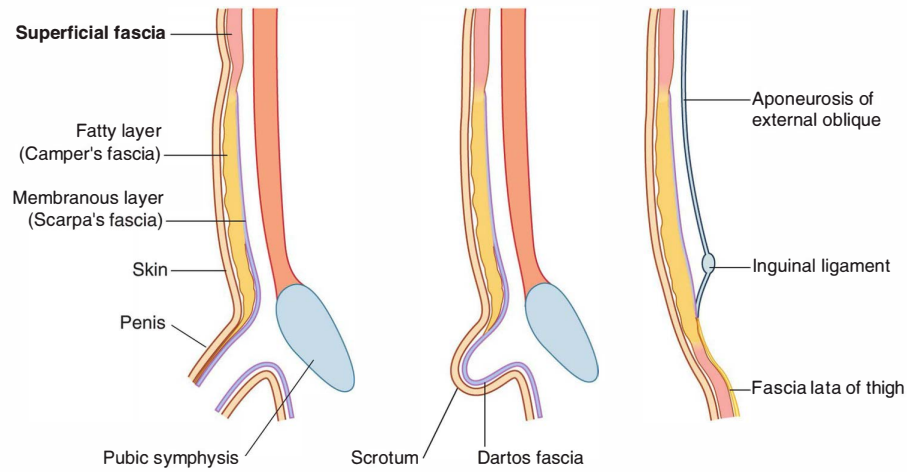


Fig. 4.25 Superficial fascia.

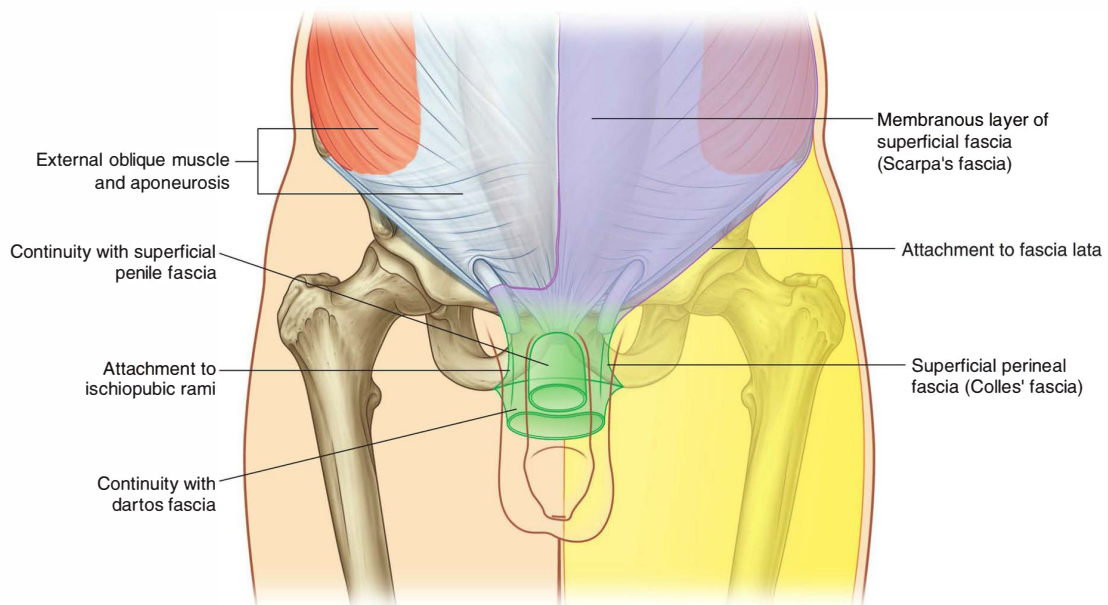


Fig. 4.26 Continuity of membranous layer of superficial fascia into other areas.



Abdomen

sides of the penis to form the **fundiform ligament of penis**. In women, the membranous layer of the superficial fascia continues into the labia majora and the anterior part of the perineum.

Anterolateral muscles

There are five muscles in the anterolateral group of abdominal wall muscles:

- three flat muscles whose fibers begin posterolaterally, pass anteriorly, and are replaced by an aponeurosis as the muscle continues toward the midline—the external oblique, internal oblique, and transversus abdominis muscles;
- two vertical muscles, near the midline, which are enclosed within a tendinous sheath formed by the aponeuroses of the flat muscles—the rectus abdominis and pyramidalis muscles.

Each of these five muscles has specific actions, but together the muscles are critical for the maintenance of

many normal physiological functions. By their positioning, they form a firm, but flexible, wall that keeps the abdominal viscera within the abdominal cavity, protects the viscera from injury, and helps maintain the position of the viscera in the erect posture against the action of gravity.

In addition, contraction of these muscles assists in both quiet and forced expiration by pushing the viscera upward (which helps push the relaxed diaphragm further into the thoracic cavity) and in coughing and vomiting.

All these muscles are also involved in any action that increases intraabdominal pressure, including parturition (childbirth), micturition (urination), and defecation (expulsion of feces from the rectum).

Flat muscles

External oblique

The most superficial of the three flat muscles in the anterolateral group of abdominal wall muscles is the **external oblique**, which is immediately deep to the superficial fascia (Fig. 4.27, Table 4.1). Its laterally placed muscle fibers pass in an inferomedial direction, while its large

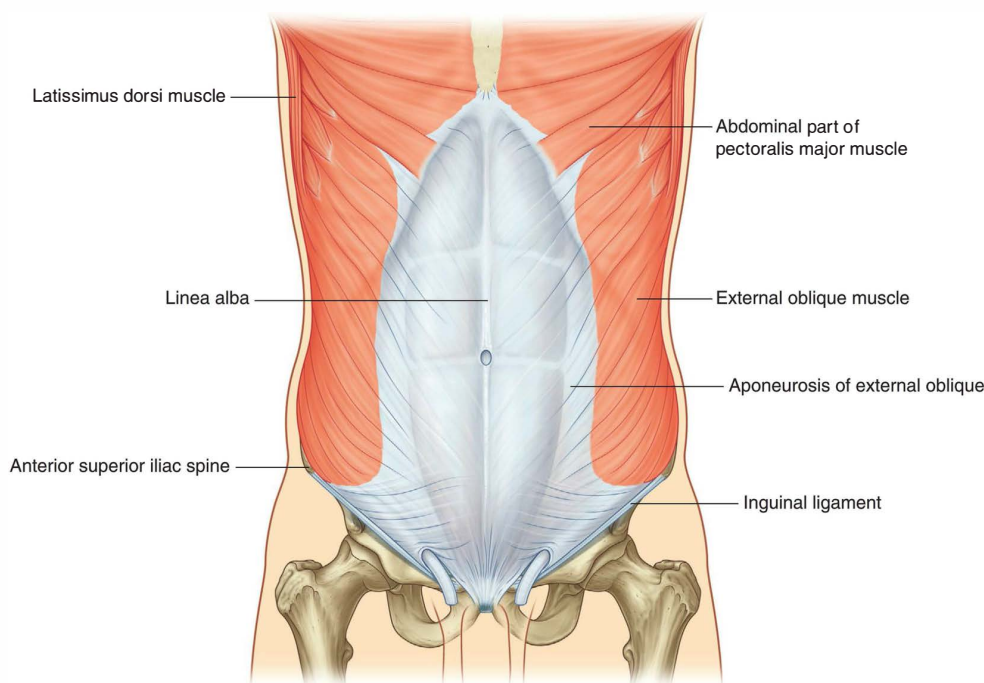


Fig. 4.27 External oblique muscle and its aponeurosis.

aponeurotic component covers the anterior part of the abdominal wall to the midline. Approaching the midline, the aponeuroses are entwined, forming the linea alba, which extends from the xiphoid process to the pubic symphysis.

Associated ligaments

The lower border of the external oblique aponeurosis forms the **inguinal ligament** on each side (Fig. 4.27). This thickened reinforced free edge of the external oblique aponeurosis passes between the anterior superior iliac spine laterally and the pubic tubercle medially (Fig. 4.28). It folds

under itself forming a trough, which plays an important role in the formation of the inguinal canal.

Several other ligaments are also formed from extensions of the fibers at the medial end of the inguinal ligament:

- The **lacunar ligament** is a crescent-shaped extension of fibers at the medial end of the inguinal ligament that pass backward to attach to the **pecten pubis** on the superior ramus of the pubic bone (Figs. 4.28 and 4.29).
- Additional fibers extend from the lacunar ligament along the pecten pubis of the pelvic brim to form the **pectineal (Cooper's) ligament**.

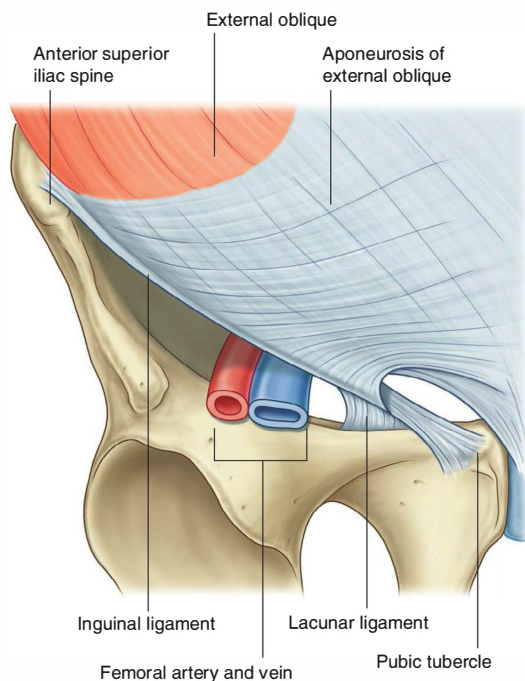


Fig. 4.28 Ligaments formed from the external oblique aponeurosis.

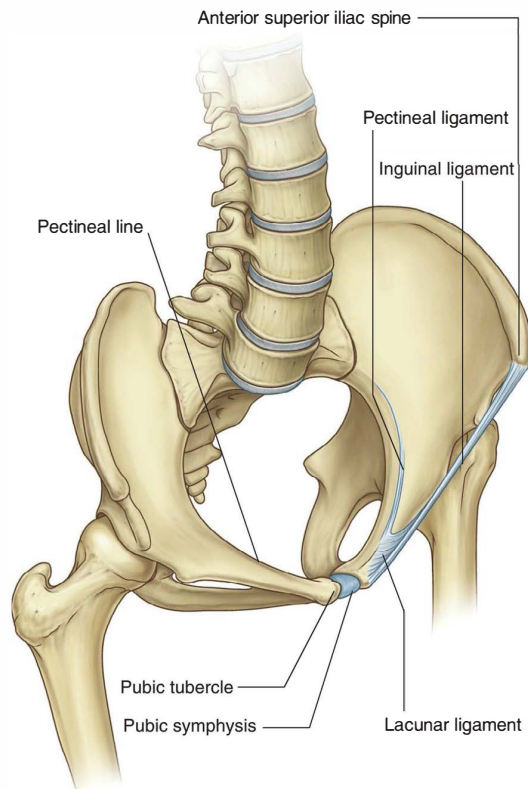


Fig. 4.29 Ligaments of the inguinal region.



Abdomen

Internal oblique

Deep to the external oblique muscle is the **internal oblique** muscle, which is the second of the three flat muscles (Fig. 4.30, Table 4.1). This muscle is smaller and thinner than the external oblique, with most of its muscle fibers passing in a superomedial direction. Its lateral muscular components end anteriorly as an aponeurosis that blends into the linea alba at the midline.

Transversus abdominis

Deep to the internal oblique muscle is the **transversus abdominis** muscle (Fig. 4.31, Table 4.1), so named because of the direction of most of its muscle fibers. It ends in an anterior aponeurosis, which blends with the linea alba at the midline.

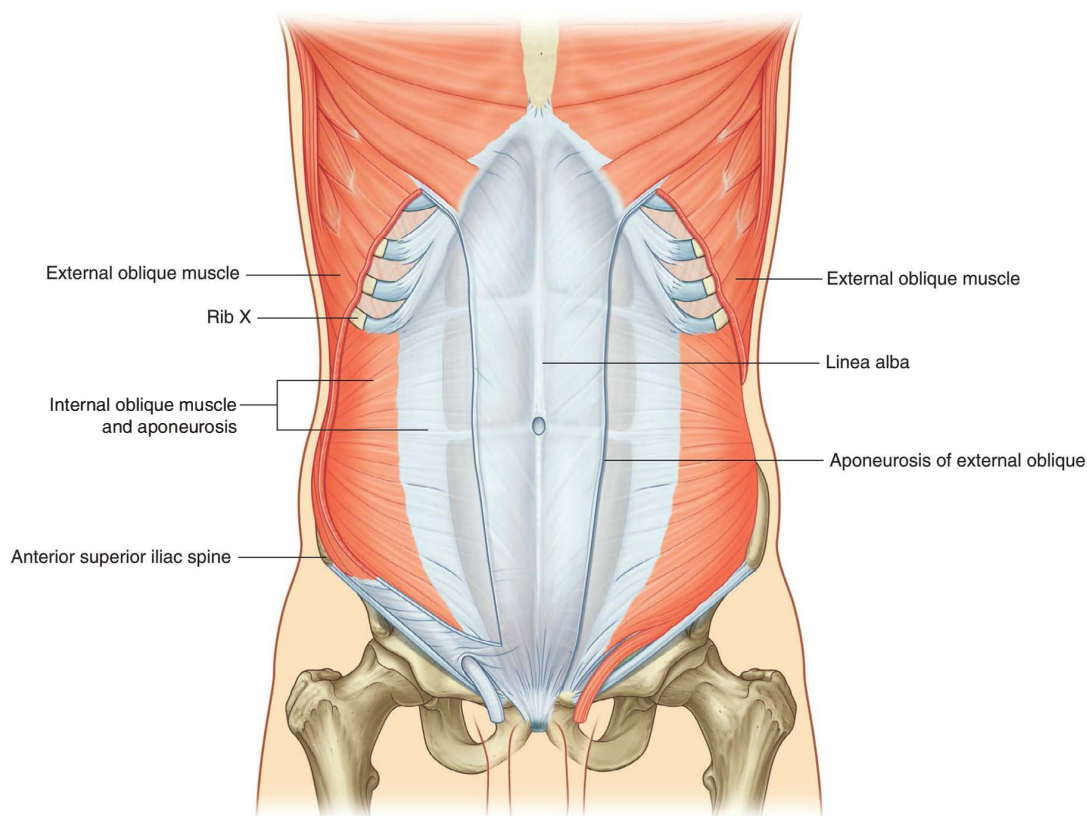


Fig. 4.30 Internal oblique muscle and its aponeurosis.

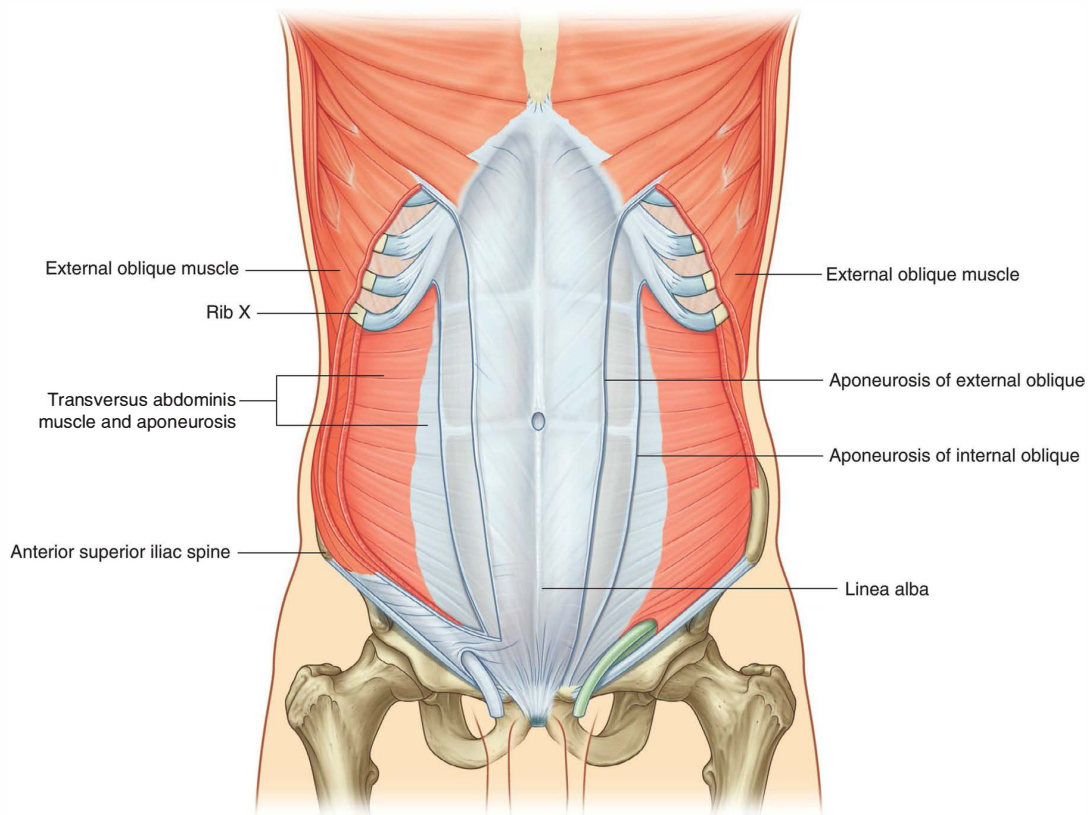


Fig. 4.31 Transversus abdominis muscle and its aponeurosis.

Transversalis fascia

Each of the three flat muscles is covered on its anterior and posterior surfaces by a layer of deep (or investing) fascia. In general, these layers are unremarkable except for the layer deep to the transversus abdominis muscle (the **transversalis fascia**), which is better developed.

The transversalis fascia is a continuous layer of deep fascia that lines the abdominal cavity and continues into the pelvic cavity. It crosses the midline anteriorly, associating with the transversalis fascia of the opposite side, and is continuous with the fascia on the inferior surface of the diaphragm. It is continuous posteriorly with the deep fascia

covering the muscles of the posterior abdominal wall and attaches to the thoracolumbar fascia.

After attaching to the crest of the ilium, the transversalis fascia blends with the fascia covering the muscles associated with the upper regions of the pelvic bones and with similar fascia covering the muscles of the pelvic cavity. At this point, it is referred to as the **parietal pelvic** (or **endopelvic**) fascia.

There is therefore a continuous layer of deep fascia surrounding the abdominal cavity that is thick in some areas, thin in others, attached or free, and participates in the formation of specialized structures.



Abdomen

Vertical muscles

The two vertical muscles in the anterolateral group of abdominal wall muscles are the large rectus abdominis and the small pyramidalis (Fig. 4.32, Table 4.1).

Rectus abdominis

The **rectus abdominis** is a long, flat muscle and extends the length of the anterior abdominal wall. It is a paired muscle, separated in the midline by the linea alba, and it

Table 4.1 Abdominal wall muscles

Muscle	Origin	Insertion	Innervation	Function
External oblique	Muscular slips from the outer surfaces of the lower eight ribs (ribs V to XII)	Lateral lip of iliac crest; aponeurosis ending in midline raphe (linea alba)	Anterior rami of lower six thoracic spinal nerves (T7 to T12)	Compress abdominal contents; both muscles flex trunk; each muscle bends trunk to same side, turning anterior part of abdomen to opposite side
Internal oblique	Thoracolumbar fascia; iliac crest between origins of external and transversus; lateral two-thirds of inguinal ligament	Inferior border of the lower three or four ribs; aponeurosis ending in linea alba; pubic crest and pectineal line	Anterior rami of lower six thoracic spinal nerves (T7 to T12) and L1	Compress abdominal contents; both muscles flex trunk; each muscle bends trunk and turns anterior part of abdomen to same side
Transversus abdominis	Thoracolumbar fascia; medial lip of iliac crest; lateral one-third of inguinal ligament; costal cartilages lower six ribs (ribs VII to XII)	Aponeurosis ending in linea alba; pubic crest and pectineal line	Anterior rami of lower six thoracic spinal nerves (T7 to T12) and L1	Compress abdominal contents
Rectus abdominis	Pubic crest, pubic tubercle, and pubic symphysis	Costal cartilages of ribs V to VII; xiphoid process	Anterior rami of lower seven thoracic spinal nerves (T7 to T12)	Compress abdominal contents; flex vertebral column; tense abdominal wall
Pyramidalis	Front of pubis and pubic symphysis	Into linea alba	Anterior ramus of T12	Tenses the linea alba

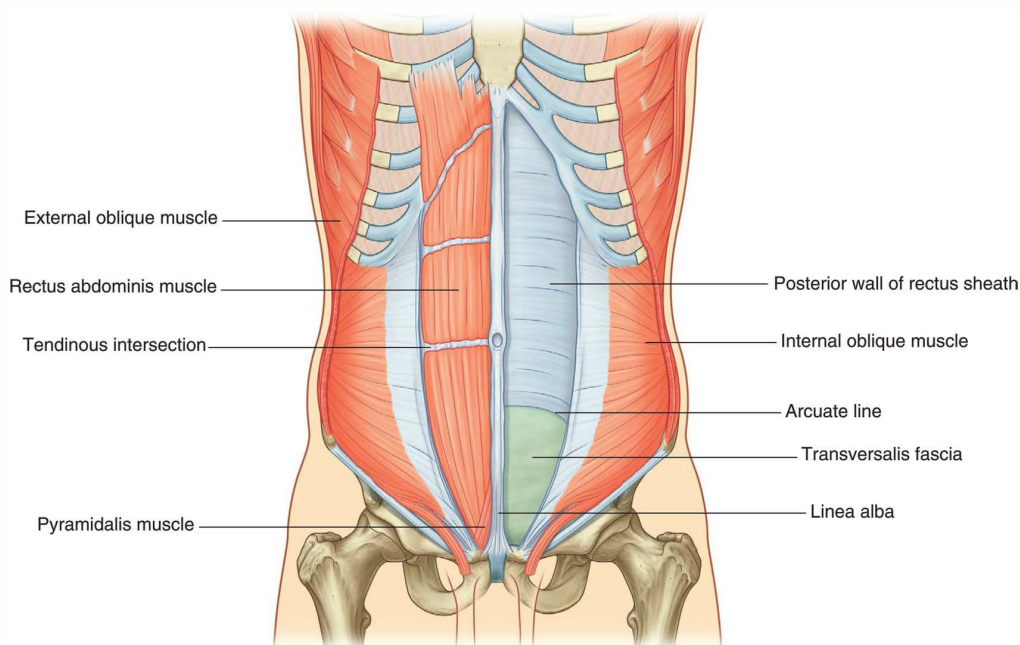


Fig. 4.32 Rectus abdominis and pyramidalis muscles.

widens and thins as it ascends from the pubic symphysis to the costal margin. Along its course, it is intersected by three or four transverse fibrous bands or **tendinous intersections** (Fig. 4.32). These are easily visible on individuals with a well-developed rectus abdominis.

Pyramidalis

The second vertical muscle is the **pyramidalis**. This small, triangular muscle, which may be absent, is anterior to the rectus abdominis and has its base on the pubis, and its apex is attached superiorly and medially to the linea alba (Fig. 4.32).

Rectus sheath

The rectus abdominis and pyramidalis muscles are enclosed in an aponeurotic tendinous sheath (the **rectus sheath**) formed by a unique layering of the aponeuroses of the external and internal oblique, and transversus abdominis muscles (Fig. 4.33).

The rectus sheath completely encloses the upper three-quarters of the rectus abdominis and covers the anterior surface of the lower one-quarter of the muscle. As no sheath covers the posterior surface of the lower quarter of the rectus abdominis muscle, the muscle at this point is in direct contact with the transversalis fascia.

The formation of the rectus sheath surrounding the upper three-quarters of the rectus abdominis muscle has the following pattern:

- The anterior wall consists of the aponeurosis of the external oblique and half of the aponeurosis of the internal oblique, which splits at the lateral margin of the rectus abdominis.
- The posterior wall of the rectus sheath consists of the other half of the aponeurosis of the internal oblique and the aponeurosis of the transversus abdominis.

At a point midway between the umbilicus and the pubic symphysis, corresponding to the beginning of the lower one-quarter of the rectus abdominis muscle, all of the aponeuroses move anterior to the rectus muscle. There is no posterior wall of the rectus sheath and the anterior wall of the sheath consists of the aponeuroses of the external oblique, the internal oblique, and the transversus abdominis muscles. From this point inferiorly, the rectus abdominis muscle is in direct contact with the transversalis fascia. Marking this point of transition is an arch of fibers (the **arcuate line**; see Fig. 4.32).

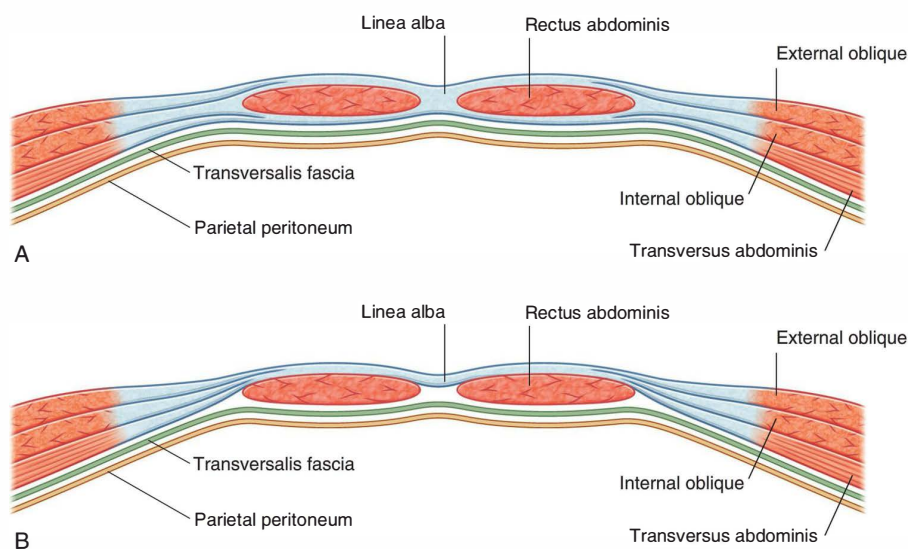


Fig. 4.33 Organization of the rectus sheath. **A.** Transverse section through the upper three-quarters of the rectus sheath. **B.** Transverse section through the lower one-quarter of the rectus sheath.



Abdomen

Extraperitoneal fascia

Deep to the transversalis fascia is a layer of connective tissue, the **extraperitoneal fascia**, which separates the transversalis fascia from the peritoneum (Fig. 4.34). Containing varying amounts of fat, this layer not only lines the abdominal cavity but is also continuous with a similar layer lining the pelvic cavity. It is abundant on the posterior abdominal wall, especially around the kidneys, continues over organs covered by peritoneal reflections, and, as the vasculature is located in this layer, extends into mesenteries with the blood vessels. Viscera in the extraperitoneal fascia are referred to as **retroperitoneal**.

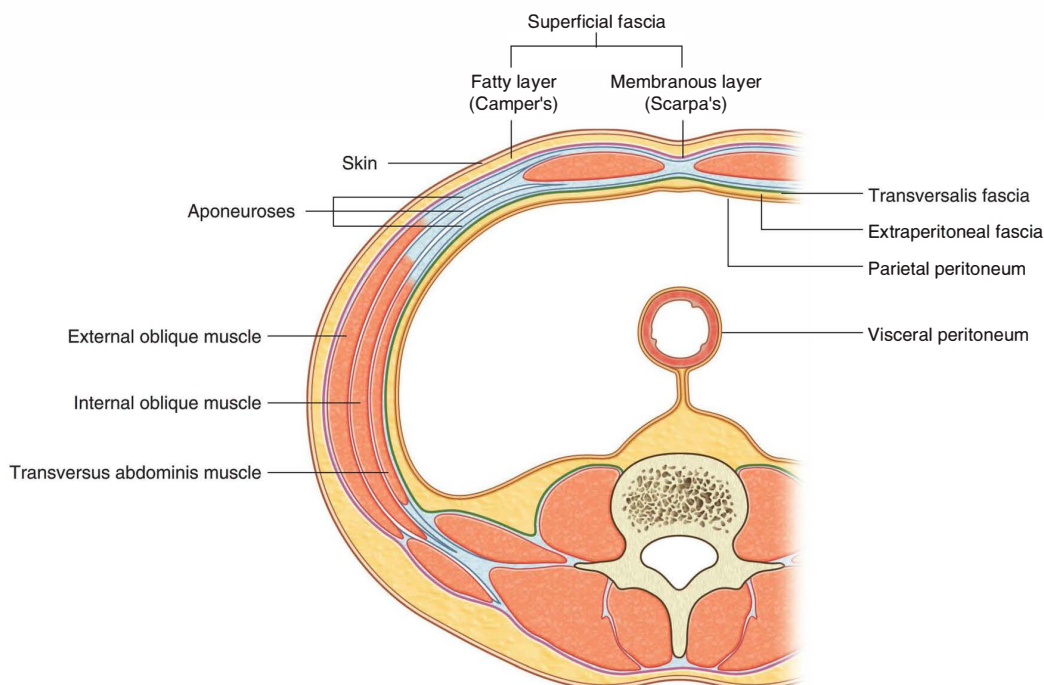
In the description of specific surgical procedures, the terminology used to describe the extraperitoneal fascia is further modified. The fascia toward the anterior side of the body is described as preperitoneal (or, less commonly, pro-peritoneal) and the fascia toward the posterior side of the body has been described as retroperitoneal (Fig. 4.35).

Examples of the use of these terms would be the continuity of fat in the inguinal canal with the preperitoneal fat and a transabdominal preperitoneal laparoscopic repair of an inguinal hernia.

Peritoneum

Deep to the extraperitoneal fascia is the peritoneum (see Figs. 4.6 and 4.7 on pp. 260-261). This thin serous membrane lines the walls of the abdominal cavity and, at various points, reflects onto the abdominal viscera, providing either a complete or a partial covering. The peritoneum lining the walls is the parietal peritoneum; the peritoneum covering the viscera is the visceral peritoneum.

The continuous lining of the abdominal walls by the parietal peritoneum forms a sac. This sac is closed in men but has two openings in women where the uterine tubes provide a passage to the outside. The closed sac in men and the semiclosed sac in women is called the peritoneal cavity.



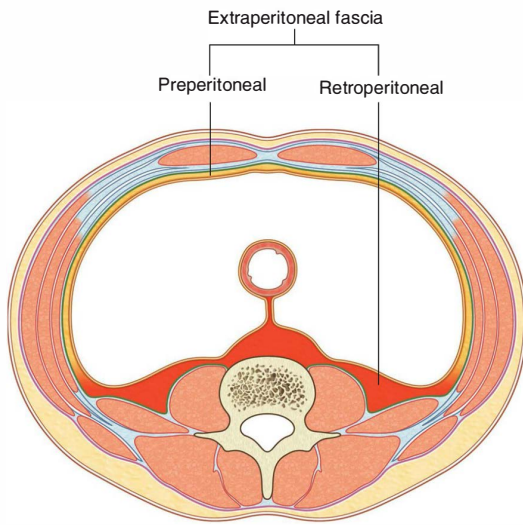


Fig. 4.35 Subdivisions of the extraperitoneal fascia.

Innervation

The skin, muscles, and parietal peritoneum of the anterolateral abdominal wall are supplied by T7 to T12 and L1 spinal nerves. The anterior rami of these spinal nerves pass around the body, from posterior to anterior, in an inferomedial direction (Fig. 4.36). As they proceed, they give off a lateral cutaneous branch and end as an anterior cutaneous branch.

The intercostal nerves (T7 to T11) leave their intercostal spaces, passing deep to the costal cartilages, and continue onto the anterolateral abdominal wall between the internal oblique and transversus abdominis muscles (Fig. 4.37). Reaching the lateral edge of the rectus sheath, they enter the rectus sheath and pass posterior to the lateral aspect of the rectus abdominis muscle. Approaching the midline, an anterior cutaneous branch passes through the rectus abdominis muscle and the anterior wall of the rectus sheath to supply the skin.

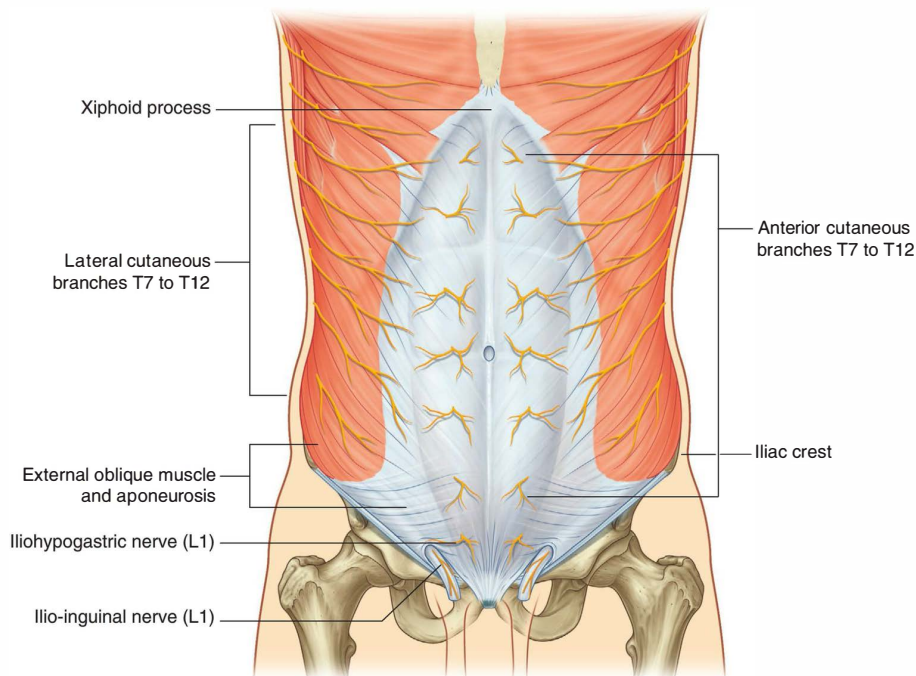


Fig. 4.36 Innervation of the anterolateral abdominal wall.



Abdomen

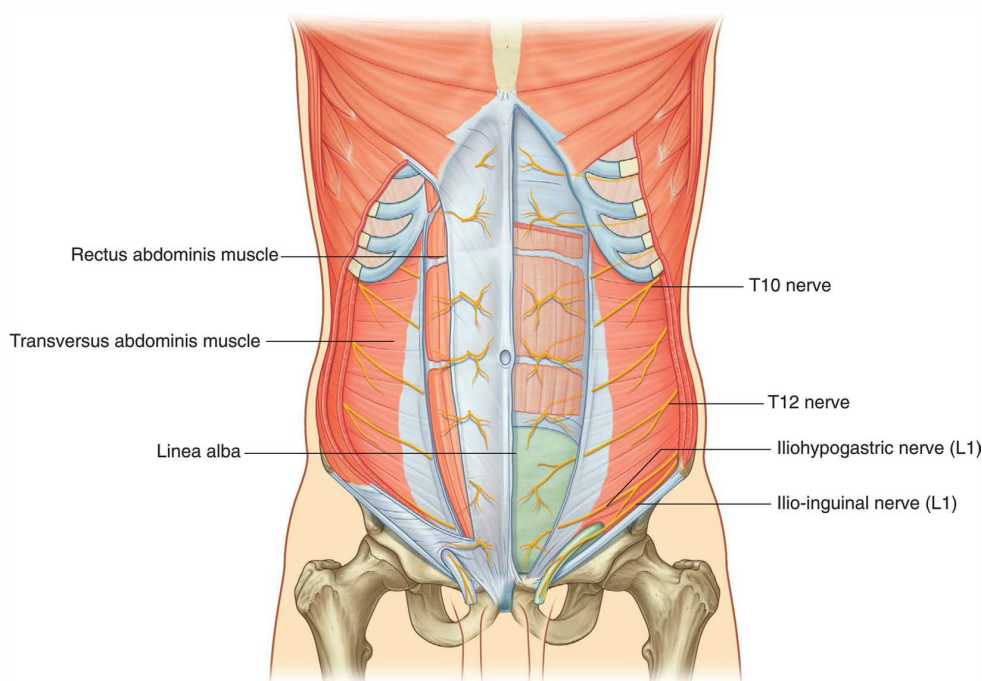


Fig. 4.37 Path taken by the nerves innervating the anterolateral abdominal wall.

Spinal nerve T12 (the **subcostal nerve**) follows a similar course as the intercostals. Branches of L1 (the **iliohypogastric nerve** and **ilio-inguinal nerve**), which originate from the lumbar plexus, follow similar courses initially, but deviate from this pattern near their final destination.

Along their course, nerves T7 to T12 and L1 supply branches to the anterolateral abdominal wall muscles and the underlying parietal peritoneum. All terminate by supplying skin:

- Nerves T7 to T9 supply the skin from the xiphoid process to just above the umbilicus.
- T10 supplies the skin around the umbilicus.
- T11, T12, and L1 supply the skin from just below the umbilicus to, and including, the pubic region (Fig. 4.38).
- Additionally, the ilio-inguinal nerve (a branch of L1) supplies the anterior surface of the scrotum or labia majora, and sends a small cutaneous branch to the thigh.

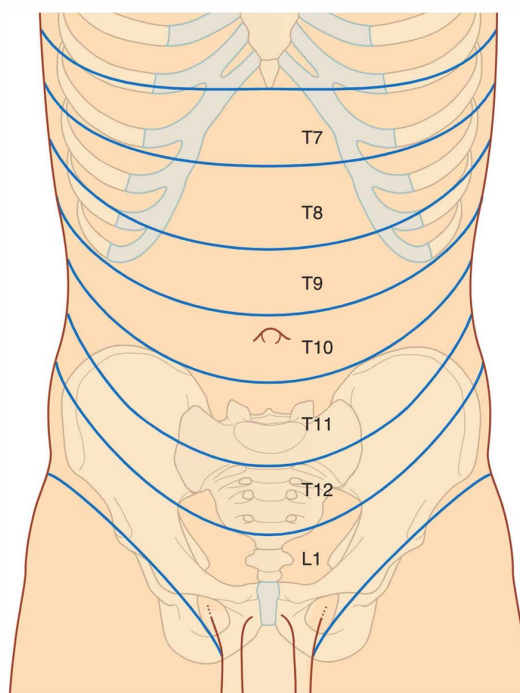


Fig. 4.38 Dermatomes of the anterolateral abdominal wall.

Arterial supply and venous drainage

Numerous blood vessels supply the anterolateral abdominal wall. Superficially:

- the superior part of the wall is supplied by branches from the **musculophrenic artery**, a terminal branch of the **internal thoracic artery**, and
- the inferior part of the wall is supplied by the medially placed **superficial epigastric artery** and the laterally placed **superficial circumflex iliac artery**, both branches of the **femoral artery** (Fig. 4.39).

At a deeper level:

- the superior part of the wall is supplied by the **superior epigastric artery**, a terminal branch of the internal thoracic artery;
- the lateral part of the wall is supplied by branches of the **tenth** and **eleventh intercostal arteries** and the **subcostal artery**; and
- the inferior part of the wall is supplied by the medially placed **inferior epigastric artery** and the laterally placed **deep circumflex iliac artery**, both branches of the **external iliac artery**.

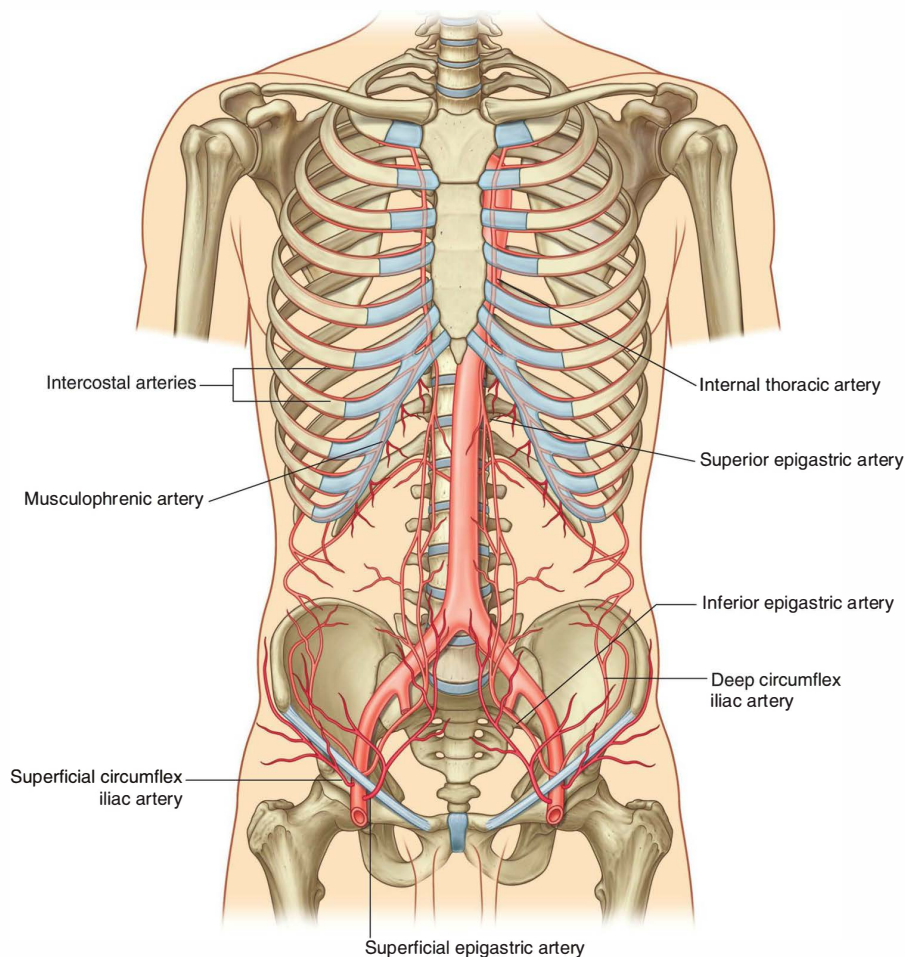


Fig. 4.39 Arterial supply to the anterolateral abdominal wall.



Abdomen

The superior and inferior epigastric arteries both enter the rectus sheath. They are posterior to the rectus abdominis muscle throughout their course, and anastomose with each other (Fig. 4.40).

Veins of similar names follow the arteries and are responsible for venous drainage.

Lymphatic drainage

Lymphatic drainage of the anterolateral abdominal wall follows the basic principles of lymphatic drainage:

- Superficial lymphatics above the umbilicus pass in a superior direction to the **axillary nodes**, while drainage below the umbilicus passes in an inferior direction to the **superficial inguinal nodes**.

- Deep lymphatic drainage follows the deep arteries back to **parasternal nodes** along the internal thoracic artery, lumbar nodes along the abdominal aorta, and external iliac nodes along the external iliac artery.

GROIN

The groin (inguinal region) is the area of junction between the anterior abdominal wall and the thigh. In this area, the abdominal wall is weakened from changes that occur during development and a peritoneal sac or diverticulum, with or without abdominal contents, can therefore protrude through it, creating an inguinal hernia. This type of hernia can occur in both sexes, but it is most common in males.

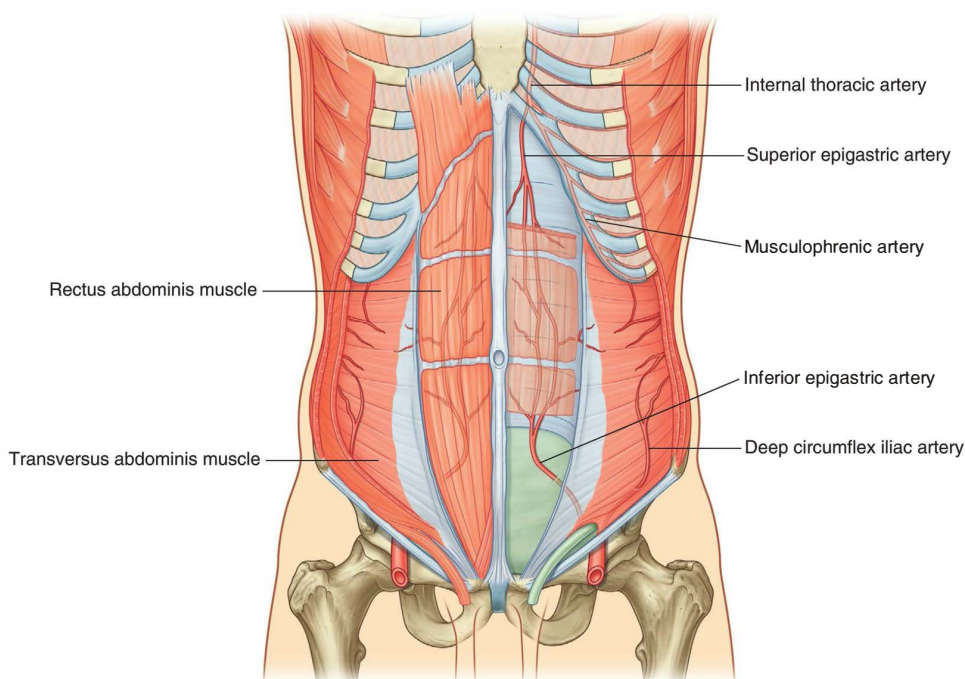


Fig. 4.40 Superior and inferior epigastric arteries.

The inherent weakness in the anterior abdominal wall in the groin is caused by changes that occur during the development of the gonads. Before the descent of the testes and ovaries from their initial position high in the posterior abdominal wall, a peritoneal outpouching (the processus vaginalis) forms (Fig. 4.41), protruding through the various layers of the anterior abdominal wall and acquiring coverings from each:

- The transversalis fascia forms its deepest covering.
- The second covering is formed by the musculature of the internal oblique (a covering from the transversus abdominis muscle is not acquired because the processus vaginalis passes under the arching fibers of this abdominal wall muscle).
- Its most superficial covering is the aponeurosis of the external oblique.

As a result the processus vaginalis is transformed into a tubular structure with multiple coverings from the layers of the anterior abdominal wall. This forms the basic structure of the **inguinal canal**.

The final event in this development is the descent of the testes into the scrotum or of the ovaries into the pelvic cavity. This process depends on the development of the gubernaculum, which extends from the inferior border of the developing gonad to the labioscrotal swellings (Fig. 4.41).

The processus vaginalis is immediately anterior to the gubernaculum within the inguinal canal.

In men, as the testes descend, the testes and their accompanying vessels, ducts, and nerves pass through the inguinal canal and are therefore surrounded by the same fascial layers of the abdominal wall. Testicular descent completes the formation of the spermatic cord in men.

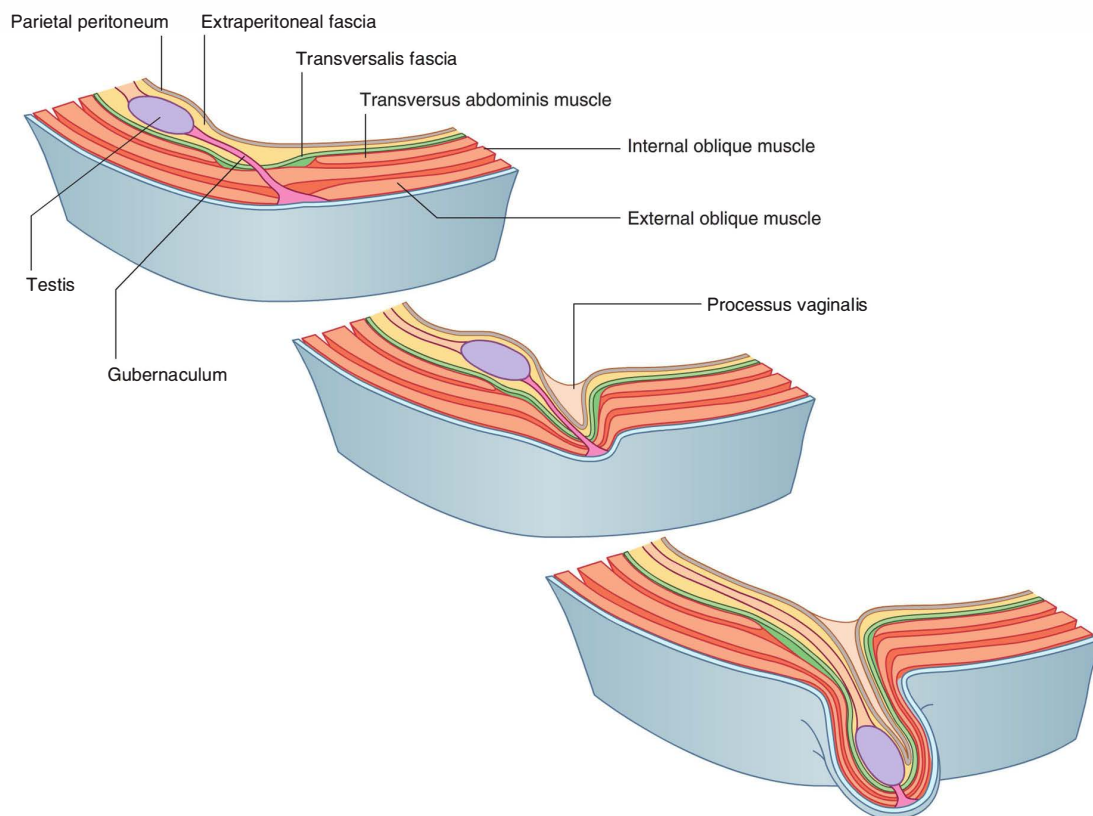


Fig. 4.41 Descent of the testis from week 7 (postfertilization) to birth.



Abdomen

In women, the ovaries descend into the pelvic cavity and become associated with the developing uterus. Therefore, the only remaining structure passing through the inguinal canal is the round ligament of the uterus, which is a remnant of the gubernaculum.

The development sequence is concluded in both sexes when the processus vaginalis obliterates. If this does not occur or is incomplete, a potential weakness exists in the anterior abdominal wall and an inguinal hernia may develop. In males, only proximal regions of the tunica vaginalis obliterate. The distal end expands to enclose most of the testis in the scrotum. In other words, the cavity of the tunica vaginalis in men forms as an extension of the developing peritoneal cavity that becomes separated off during development.

Inguinal canal

The inguinal canal is a slit-like passage that extends in a downward and medial direction, just above and parallel to the lower half of the inguinal ligament. It begins at the

deep inguinal ring and continues for approximately 4 cm, ending at the superficial inguinal ring (Fig. 4.42). The contents of the canal are the genital branch of the genitofemoral nerve, the **spermatic cord** in men, and the round ligament of the uterus in women. Additionally, in both sexes, the ilio-inguinal nerve passes through part of the canal, exiting through the superficial inguinal ring with the other contents.

Deep inguinal ring

The deep (internal) inguinal ring is the beginning of the inguinal canal and is at a point midway between the anterior superior iliac spine and the pubic symphysis (Fig. 4.43). It is just above the inguinal ligament and immediately lateral to the inferior epigastric vessels. Although sometimes referred to as a defect or opening in the transversalis fascia, it is actually the beginning of the tubular evagination of transversalis fascia that forms one of the coverings (the **internal spermatic fascia**) of the spermatic cord in men or the round ligament of the uterus in women.

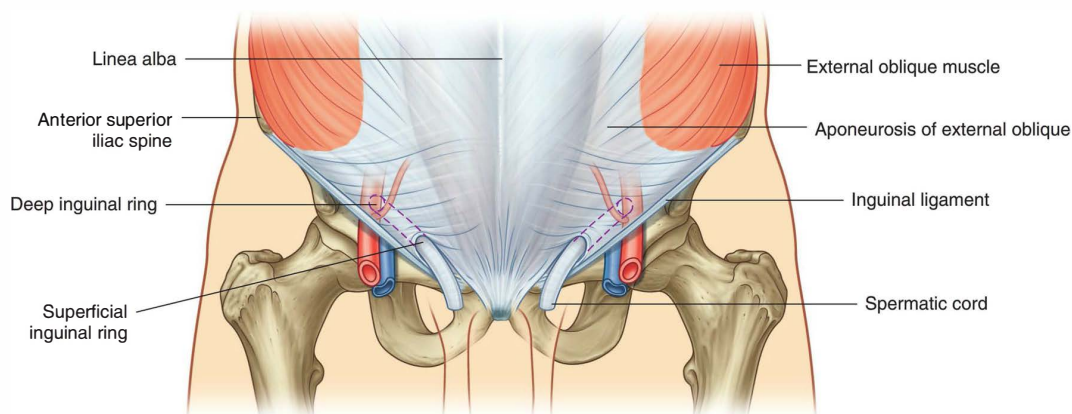


Fig. 4.42 Inguinal canal.

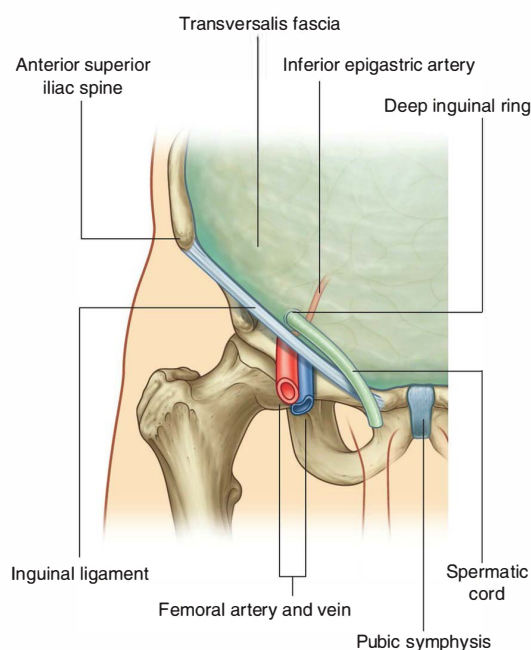


Fig. 4.43 Deep inguinal ring and the transversalis fascia.

Superficial inguinal ring

The superficial (external) inguinal ring is the end of the inguinal canal and is superior to the pubic tubercle (Fig. 4.44). It is a triangular opening in the aponeurosis of the external oblique, with its apex pointing superolaterally and its base formed by the pubic crest. The two remaining sides of the triangle (the **medial crus** and the **lateral crus**) are attached to the pubic symphysis and the pubic tubercle, respectively. At the apex of the triangle the two crura are held together by crossing (intercrural) fibers, which prevent further widening of the superficial ring.

As with the deep inguinal ring, the superficial inguinal ring is actually the beginning of the tubular evagination of the aponeurosis of the external oblique onto the structures traversing the inguinal canal and emerging from the superficial inguinal ring. This continuation of tissue over the spermatic cord is the **external spermatic fascia**.

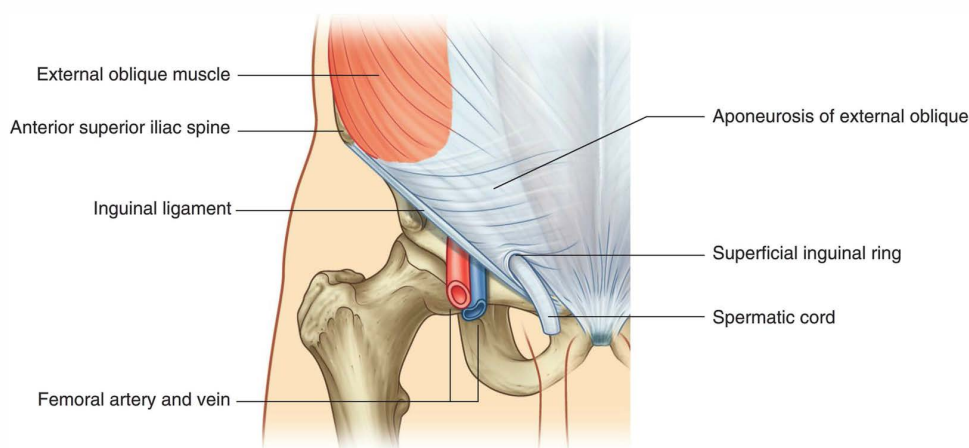


Fig. 4.44 Superficial inguinal ring and the aponeurosis of the external oblique.



Abdomen

Anterior wall

The anterior wall of the inguinal canal is formed along its entire length by the aponeurosis of the external oblique muscle (Fig. 4.44). It is also reinforced laterally by the lower fibers of the internal oblique that originate from the lateral two-thirds of the inguinal ligament (Fig. 4.45). This adds an additional covering over the deep inguinal ring, which is a potential point of weakness in the anterior abdominal wall. Furthermore, as the internal oblique muscle covers the deep inguinal ring, it also contributes a layer (the **cremasteric fascia** containing the **cremasteric muscle**) to the coverings of the structures traversing the inguinal canal.

Posterior wall

The posterior wall of the inguinal canal is formed along its entire length by the transversalis fascia (see Fig. 4.43). It is reinforced along its medial one-third by the **conjoint tendon (inguinal falx; Fig. 4.45)**. This tendon is the combined insertion of the transversus abdominis and internal oblique muscles into the pubic crest and pectineal line.

As with the internal oblique muscle's reinforcement of the area of the deep inguinal ring, the position of the conjoint tendon posterior to the superficial inguinal ring

provides additional support to a potential point of weakness in the anterior abdominal wall.

Roof

The roof (superior wall) of the inguinal canal is formed by the arching fibers of the transversus abdominis and internal oblique muscles (Figs. 4.45 and 4.46). They pass from their lateral points of origin from the inguinal ligament to their common medial attachment as the conjoint tendon.

Floor

The floor (inferior wall) of the inguinal canal is formed by the medial one-half of the inguinal ligament. This rolled-under, free margin of the lowest part of the aponeurosis of the external oblique forms a gutter or trough on which the contents of the inguinal canal are positioned. The lacunar ligament reinforces most of the medial part of the gutter.

Contents

The contents of the inguinal canal are:

- the spermatic cord in men, and
- the round ligament of the uterus and genital branch of the genitofemoral nerve in women.

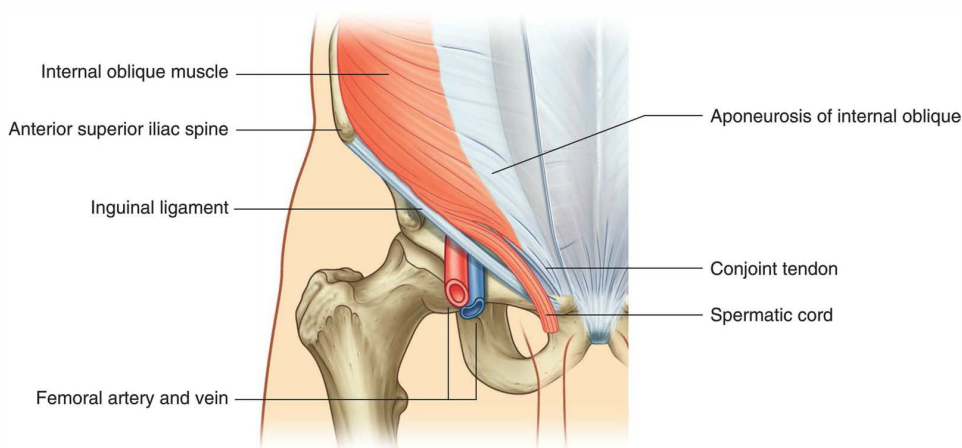


Fig. 4.45 Internal oblique muscle and the inguinal canal.

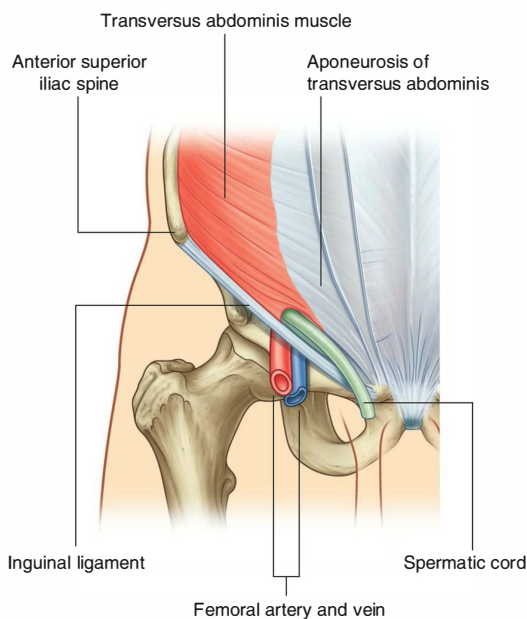


Fig. 4.46 Transversus abdominis muscle and the inguinal canal.

These structures enter the inguinal canal through the deep inguinal ring and exit it through the superficial inguinal ring.

Additionally, the ilio-inguinal nerve (L1) passes through part of the inguinal canal. This nerve is a branch of the lumbar plexus, enters the abdominal wall posteriorly by piercing the internal surface of the transversus abdominis muscle, and continues through the layers of the anterior abdominal wall by piercing the internal oblique muscle. As it continues to pass inferomedially, it enters the inguinal canal. It continues down the canal to exit through the superficial inguinal ring.

Spermatic cord

The spermatic cord begins to form proximally at the deep inguinal ring and consists of structures passing between the abdominopelvic cavities and the testis, and the three fascial coverings that enclose these structures (Fig. 4.47).

The structures in the spermatic cord include:

- the ductus deferens,
- the artery to the ductus deferens (from the inferior vesical artery),

- the testicular artery (from the abdominal aorta),
- the pampiniform plexus of veins (testicular veins),
- the cremasteric artery and vein (small vessels associated with the cremasteric fascia),
- the genital branch of the genitofemoral nerve (innervation to the cremasteric muscle),
- sympathetic and visceral afferent nerve fibers,
- lymphatics, and
- remnants of the processus vaginalis.

These structures enter the deep inguinal ring, proceed down the inguinal canal, and exit from the superficial inguinal ring, having acquired the three fascial coverings during their journey. This collection of structures and fascias continues into the scrotum where the structures connect with the testes and the fascias surround the testes.

Three fascias enclose the contents of the spermatic cord:

- The internal spermatic fascia, which is the deepest layer, arises from the transversalis fascia and is attached to the margins of the deep inguinal ring.
- The cremasteric fascia with the associated cremasteric muscle, which is the middle fascial layer, arises from the internal oblique muscle.
- The external spermatic fascia, which is the most superficial covering of the spermatic cord, arises from the aponeurosis of the external oblique muscle and is attached to the margins of the superficial inguinal ring (Fig. 4.47).

Round ligament of the uterus

The round ligament of the uterus is a cord-like structure that passes from the uterus to the deep inguinal ring where it enters the inguinal canal. It passes down the inguinal canal and exits through the superficial inguinal ring. At this point, it has changed from a cord-like structure to a few strands of tissue, which attach to the connective tissue associated with the labia majora. As it traverses the inguinal canal, it acquires the same coverings as the spermatic cord in men.

The round ligament of the uterus is the long distal part of the original gubernaculum in the fetus that extends from the ovary to the labioscrotal swellings. From its attachment to the uterus, the round ligament of the uterus continues to the ovary as the ligament of the ovary that develops from the short proximal end of the gubernaculum.



Abdomen

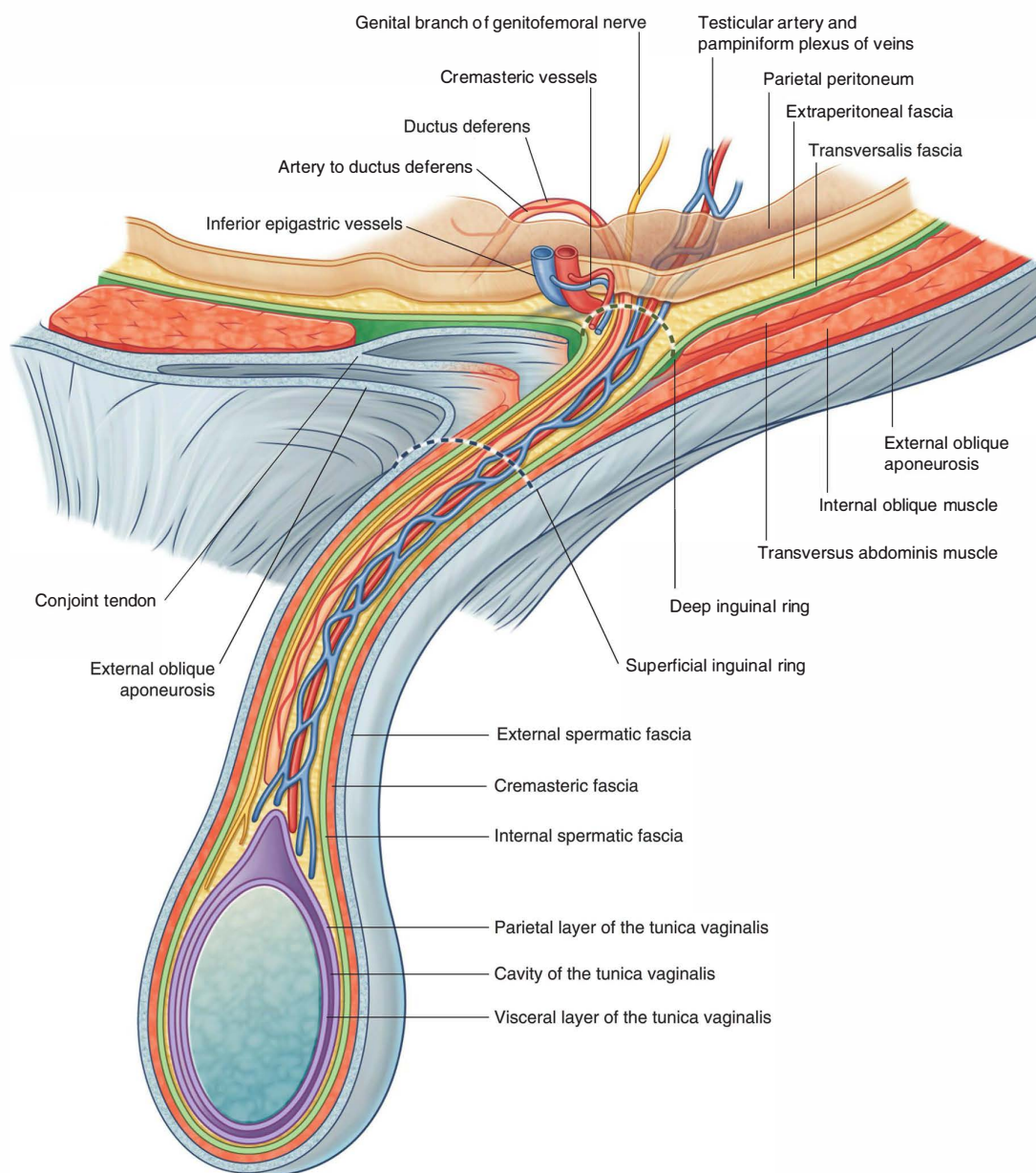


Fig. 4.47 Spermatic cord.

In the clinic**Cremasteric reflex**

In men, the cremaster muscle and cremasteric fascia form the middle or second covering of the spermatic cord. This muscle and its associated fascia are supplied by the genital branch of the genitofemoral nerve (L1/L2). Contraction of this muscle and the resulting elevation of the testis can be stimulated by a reflex arc. Gently touching the skin at and around the anterior aspect of the superior part of the thigh stimulates the sensory fibers in the ilio-inguinal nerve. These sensory fibers enter the spinal cord at level L1. At this level, the sensory fibers stimulate the motor fibers carried in the genital branch of the genitofemoral nerve, which results in contraction of the cremaster muscle and elevation of the testis.

The cremasteric reflex is more active in children, tending to diminish with age. As with many reflexes, it may be absent in certain neurological disorders. Although it can be used for testing spinal cord function at level L1 in men, its clinical use is limited.

Inguinal hernias

An inguinal hernia is the protrusion or passage of a peritoneal sac, with or without abdominal contents, through a weakened part of the abdominal wall in the groin. It occurs because the peritoneal sac enters the inguinal canal either:

- indirectly, through the deep inguinal ring, or
- directly, through the posterior wall of the inguinal canal.

Inguinal hernias are therefore classified as either indirect or direct.

Indirect inguinal hernias

The indirect inguinal hernia is the most common of the two types of inguinal hernia and is much more common in men than in women (Fig. 4.48). It occurs because some

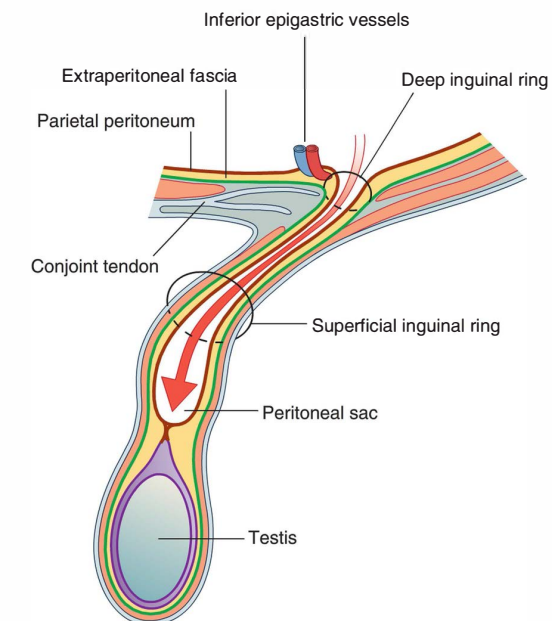


Fig. 4.48 Indirect inguinal hernia.

part, or all, of the embryonic processus vaginalis remains open or patent. It is therefore referred to as being congenital in origin.

The protruding peritoneal sac enters the inguinal canal by passing through the deep inguinal ring, just lateral to the inferior epigastric vessels. The extent of its excursion down the inguinal canal depends on the amount of processus vaginalis that remains patent. If the entire processus vaginalis remains patent, the peritoneal sac may traverse the length of the canal, exit the superficial inguinal ring, and continue into the scrotum in men or the labia majus in women. In this case, the protruding peritoneal sac acquires the same three coverings as those associated with the spermatic cord in men or the round ligament of the uterus in women.



Abdomen

Direct inguinal hernias

A peritoneal sac that enters the medial end of the inguinal canal directly through a weakened posterior wall is a direct inguinal hernia (Fig. 4.49). It is usually described as acquired because it develops when abdominal musculature has been weakened, and is commonly seen in mature men. The bulging occurs medial to the inferior epigastric vessels in the inguinal triangle (Hesselbach's triangle), which is bounded:

- laterally by the inferior epigastric artery,
- medially by the rectus abdominis muscle, and
- inferiorly by the inguinal ligament (Fig. 4.50).

Internally, a thickening of the transversalis fascia (the iliopubic tract) follows the course of the inguinal ligament (Fig. 4.50).

This type of inguinal hernia does not traverse the entire length of the inguinal canal but may exit through the superficial inguinal ring. When this occurs, the peritoneal sac acquires a layer of external spermatic fascia and can extend, like an indirect hernia, into the scrotum.

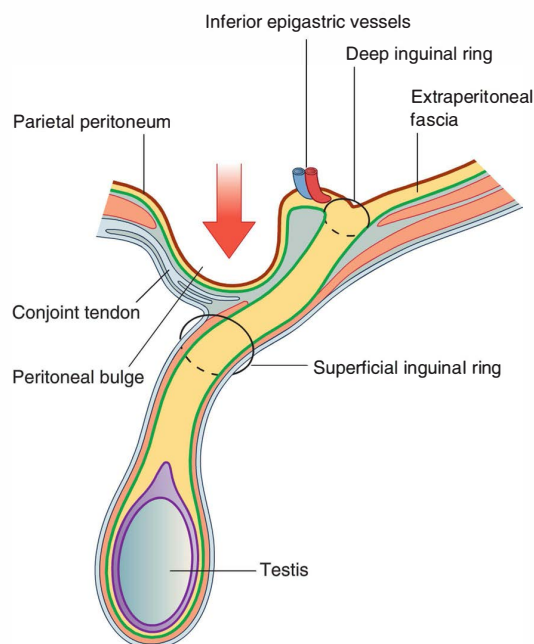
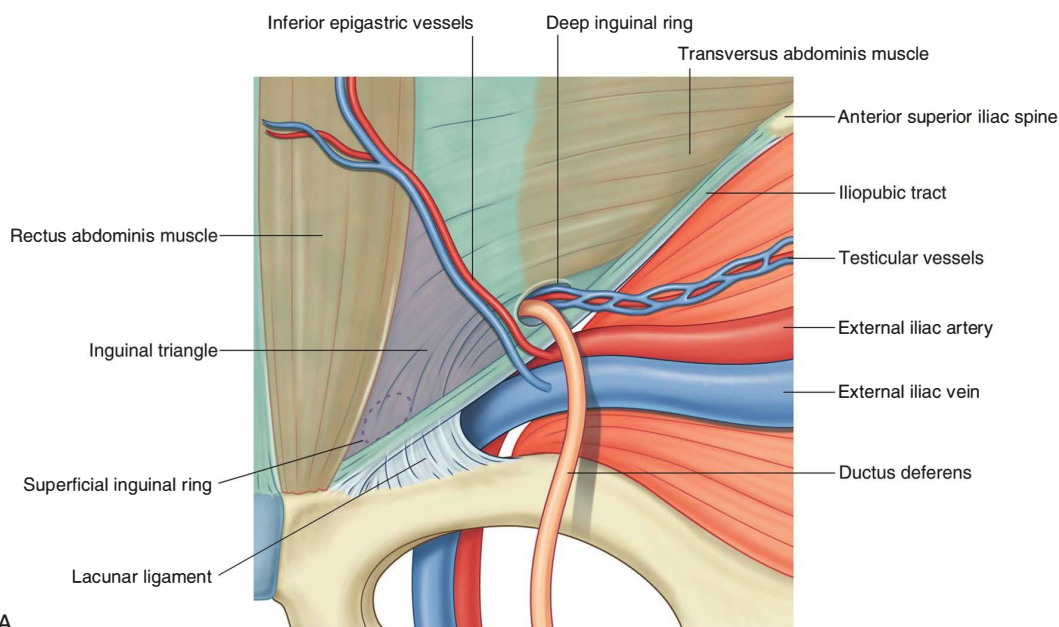


Fig. 4.49 Direct inguinal hernia.



A

Fig. 4.50 Right inguinal triangle. A. Internal view.

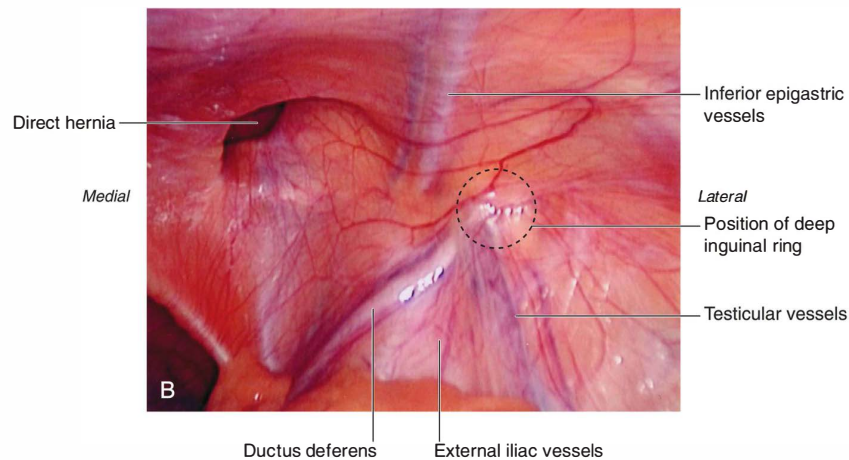


Fig. 4.50, cont'd B. Laparoscopic view showing the parietal peritoneum still covering the area.

In the clinic

Masses around the groin

Around the groin there is a complex confluence of anatomical structures. Careful examination and good anatomical knowledge allows determination of the correct anatomical structure from which the mass arises and therefore the diagnosis. The most common masses in the groin are hernias.

The key to groin examination is determining the position of the inguinal ligament. The inguinal ligament passes between the anterior superior iliac spine laterally and the pubic tubercle medially. Inguinal hernias are above the inguinal ligament and are usually more apparent on standing. A visual assessment of the lump is necessary, bearing in mind the anatomical landmarks of the inguinal ligament.

In men, it is wise to examine the scrotum to check for a lump. If an abnormal mass is present, an inability to feel its upper edge suggests that it may originate from the inguinal canal and might be a hernia. By placing the hand over the lump and asking the patient to cough, the lump bulges outward.

An attempt should be made to reduce the swelling by applying gentle, firm pressure over the lump. If the lump is reducible, the hand should be withdrawn and careful observation will reveal recurrence of the mass.

The position of an abnormal mass in the groin relative to the pubic tubercle is very important, as are the presence of increased temperature and pain, which may represent early signs of strangulation or infection.

As a general rule:

- An inguinal hernia appears through the superficial inguinal ring above the pubic tubercle and crest.

- A femoral hernia (see below) appears through the femoral canal below and lateral to the pubic tubercle.

A hernia is the protrusion of a viscus, in part or in whole, through a normal or abnormal opening. The viscus usually carries a covering of parietal peritoneum, which forms the lining of the hernial sac.

Inguinal hernias

Hernias occur in a variety of regions. The commonest site is the groin of the lower anterior abdominal wall. In some patients, inguinal hernias are present from birth (congenital) and are caused by the persistence of the processus vaginalis and the passage of viscera through the inguinal canal. Acquired hernias occur in older patients and causes include raised intraabdominal pressure (e.g., from repeated coughing associated with lung disease), damage to nerves of the anterior abdominal wall (e.g., from surgical abdominal incisions), and weakening of the walls of the inguinal canal.

One of the potential problems with hernias is that bowel and fat may become stuck within the hernial sac. This can cause appreciable pain and bowel obstruction, necessitating urgent surgery. Another potential risk is **strangulation** of the hernia, in which the blood supply to the bowel is cut off at the neck of the hernial sac, rendering the bowel ischemic and susceptible to perforation.

The hernial sac of an **indirect inguinal hernia** enters the deep inguinal ring and passes through the inguinal canal. If the hernia is large enough, the hernial sac may

(continues)



Abdomen

In the clinic—cont'd

emerge through the superficial inguinal ring. In men, such a hernia may extend into the scrotum (Fig. 4.51).

The hernial sac of a **direct inguinal hernia** pushes forward through the posterior wall of the inguinal canal immediately posterior to the superficial inguinal ring. The hernia protrudes directly forward medial to the inferior epigastric vessels and through the superficial inguinal ring.

The differentiation between an indirect and a direct inguinal hernia is made during surgery when the inferior epigastric vessels are identified at the medial edge of the deep internal ring:

- An indirect hernial sac passes lateral to the inferior epigastric vessels.
- A direct hernia is medial to the inferior epigastric vessels.

Inguinal hernias occur more commonly in men than in women possibly because men have a much larger inguinal canal than women.

Femoral hernias

A **femoral hernia** passes through the femoral canal and into the medial aspect of the anterior thigh. The femoral

canal lies at the medial edge of the femoral sheath, which contains the femoral artery, femoral vein, and lymphatics. The neck of the femoral canal is extremely narrow and is prone to trapping bowel within the sac, so making this type of hernia irreducible and susceptible to bowel strangulation. Femoral hernias are usually acquired, are not congenital, and most commonly occur in middle-aged and elderly populations. In addition, because women generally have wider pelvises than men, they tend to occur more commonly in women.

Sportsmen's groin/sportsmen's hernia

The groin can loosely be defined as the area where the leg meets the trunk near the midline. Here the abdominal muscles of the trunk blend in with the adductor muscles of the thigh, the medial end of the inguinal ligament attaches to the pubic tubercle, the pubic symphysis attaches the two pubic bones together, and the superficial (external) inguinal ring occurs. It also is in and around this region where there is considerable translation of force during most athletic and sporting activities. Pain in the groin or pubic region can be due to numerous causes, which include inflammatory changes at the pubic symphysis, insertional problems of the rectus abdominis/adductor longus, and hernias.

Umbilical hernias

Umbilical hernias are rare. Occasionally, they are congenital and result from failure of the small bowel to return to the abdominal cavity from the umbilical cord during development. After birth, umbilical hernias may result from incomplete closure of the umbilicus (navel). Overall, most of these hernias close in the first year of life, and surgical repair is not generally attempted until later.

Para-umbilical hernias may occur in adults at and around the umbilicus and often have small necks, so requiring surgical treatment.

Incisional hernias

Incisional hernias occur through a defect in a scar of a previous abdominal operation. Usually, the necks of these hernias are wide and do not therefore strangulate the viscera they contain.

Other hernias

A **spigelian hernia** passes upward through the arcuate line into the lateral border at the lower part of the posterior rectus sheath. It may appear as a tender mass on one side of the lower anterior abdominal wall.

Abdominopelvic cavity hernias can also develop in association with the pelvic walls, and sites include the obturator canal, the greater sciatic foramen and above and below the piriformis muscle.

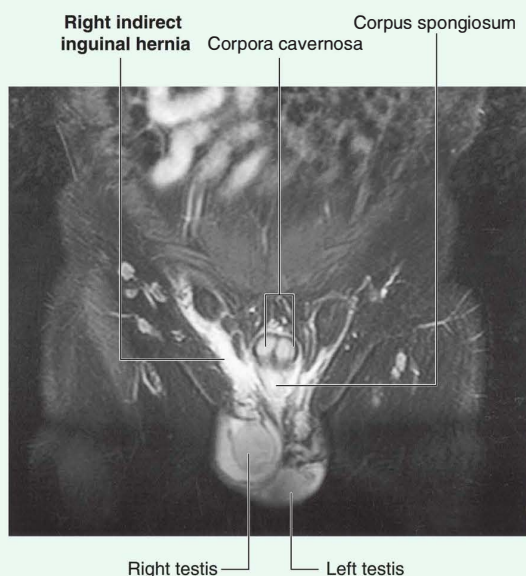


Fig. 4.51 Right indirect inguinal hernia. T2, fat saturated, weighted magnetic resonance image in the coronal plane of a male groin.

ABDOMINAL VISCERA

Peritoneum

A thin membrane (the peritoneum) lines the walls of the abdominal cavity and covers much of the viscera. The parietal peritoneum lines the walls of the cavity and the visceral peritoneum covers the viscera. Between the parietal and visceral layers of peritoneum is a potential space (the peritoneal cavity). Abdominal viscera either are suspended in the peritoneal cavity by folds of peritoneum (**mesenteries**) or are outside the peritoneal cavity. Organs suspended in the cavity are referred to as intraperitoneal (Fig. 4.52); organs outside the peritoneal cavity, with only one surface or part of one surface covered by peritoneum, are retroperitoneal.

Innervation of the peritoneum

The parietal peritoneum associated with the abdominal wall is innervated by somatic afferents carried in branches of the associated spinal nerves and is therefore sensitive to well-localized pain. The visceral peritoneum is innervated by visceral afferents that accompany autonomic nerves (sympathetic and parasympathetic) back to the central nervous system. Activation of these fibers can lead to referred and poorly localized sensations of discomfort, and to reflex visceral motor activity.

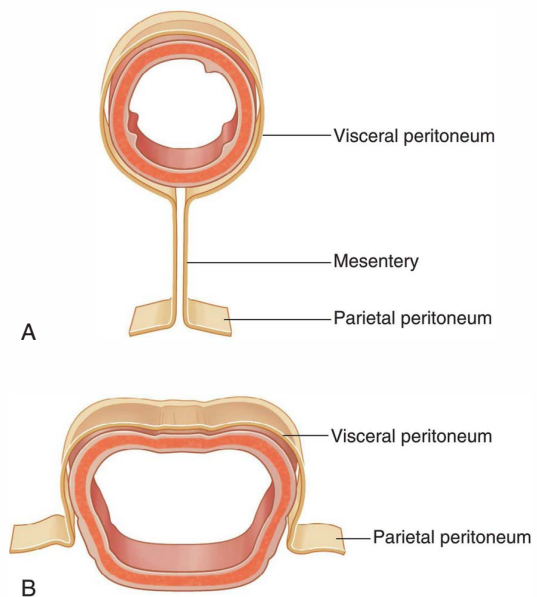


Fig. 4.52 A. Intraperitoneal. B. Retroperitoneal.



Abdomen

Peritoneal cavity

The peritoneal cavity is subdivided into the greater sac and the omental bursa (lesser sac; [Fig. 4.53](#)).

- The greater sac accounts for most of the space in the peritoneal cavity, beginning superiorly at the diaphragm and continuing inferiorly into the pelvic cavity. It is entered once the parietal peritoneum has been penetrated.
- The omental bursa is a smaller subdivision of the peritoneal cavity posterior to the stomach and liver and is

continuous with the greater sac through an opening, the omental (epiploic) foramen ([Fig. 4.54](#)).

Surrounding the omental (epiploic) foramen are numerous structures covered with peritoneum. They include the portal vein, hepatic artery proper, and bile duct anteriorly; the inferior vena cava posteriorly; the caudate lobe of the liver superiorly; and the first part of the duodenum inferiorly.

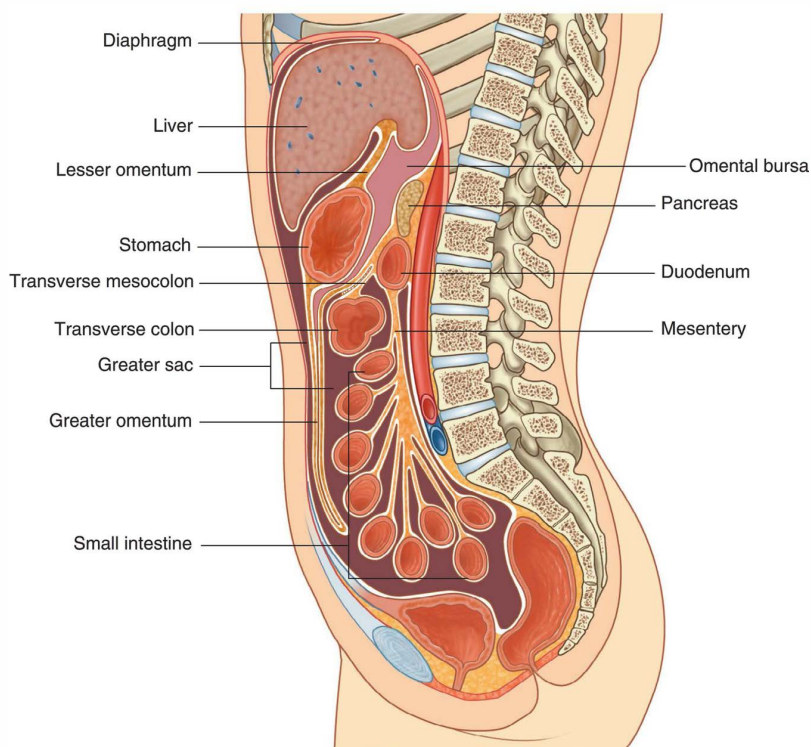


Fig. 4.53 Greater and lesser sacs of the peritoneal cavity.

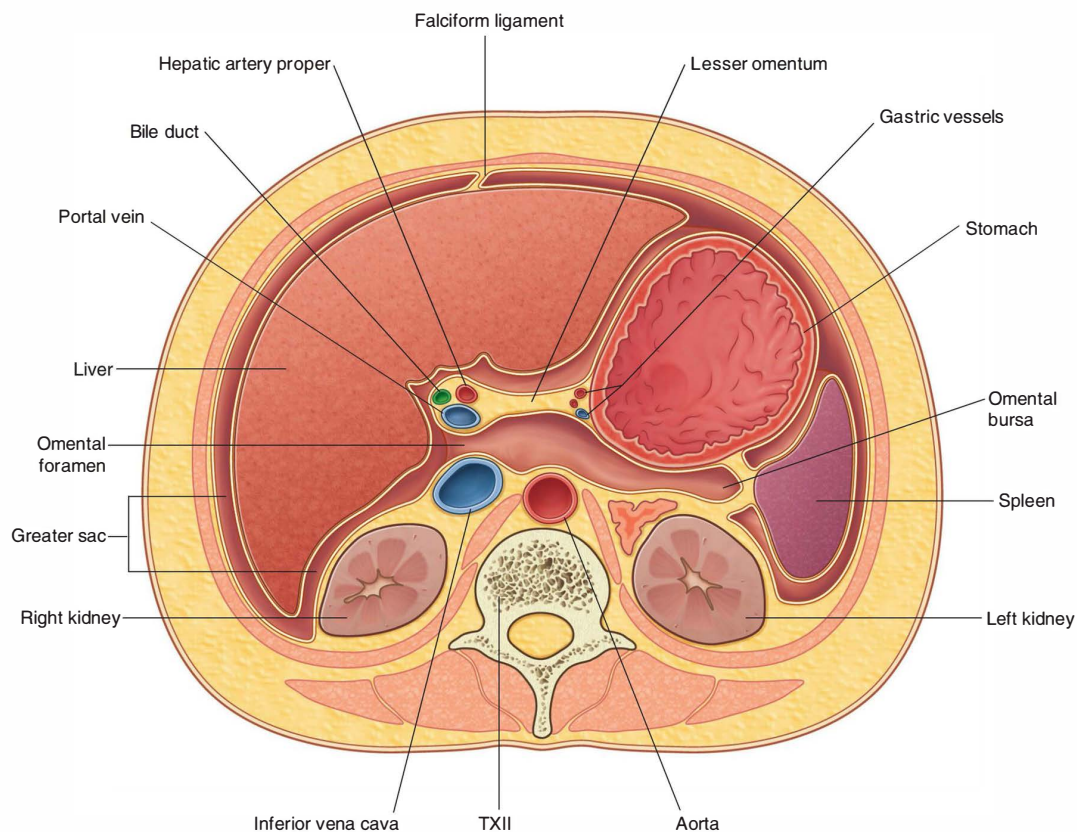


Fig. 4.54 Transverse section illustrating the continuity between the greater and lesser sacs through the omental (epiploic) foramen.

In the clinic

Peritoneum

A small volume of peritoneal fluid within the peritoneal cavity lubricates movement of the viscera suspended in the abdominal cavity.

The peritoneal space has a large surface area, which facilitates the spread of disease through the peritoneal cavity and over the bowel and visceral surfaces. Conversely, this large surface area can be used for administering certain types of treatment and a number of procedures.

Ventriculoperitoneal shunts

Patients with obstructive hydrocephalus (an excessive accumulation of cerebrospinal fluid within the cerebral ventricular system) require continuous drainage of this fluid. This is achieved by placing a fine-bore catheter through the skull into the cerebral ventricles and placing the extracranial part of the tube beneath the scalp and

skin of the chest wall and then passing it through the abdominal wall into the peritoneal cavity. Cerebrospinal fluid drains through the tube into the peritoneal cavity, where it is absorbed.

Dialysis and peritoneal dialysis

People who develop renal failure require dialysis to live. There are two methods.

In the first method (**hemodialysis**), blood is taken from the circulation, dialyzed through a complex artificial membrane, and returned to the body. A high rate of blood flow is required to remove excess body fluid, exchange electrolytes, and remove noxious metabolites. To accomplish this, either an arteriovenous fistula is established surgically (by connecting an artery to a vein, usually in the upper limb, and requiring approximately six weeks to "mature") and is cannulated each time the patient returns for dialysis, or a large-bore cannula is

(continues)



Abdomen

In the clinic—cont'd

placed into the right atrium, through which blood can be aspirated and returned.

In the second method of dialysis, the peritoneum is used as the dialysis membrane. The large surface area of the peritoneal cavity is an ideal dialysis membrane for fluid and electrolyte exchange. To accomplish dialysis, a small tube is inserted through the abdominal wall and dialysis fluid is injected into the peritoneal cavity. Electrolytes and molecules are exchanged across the peritoneum between the fluid and blood. Once dialysis is completed, the fluid is drained.

Peritoneal spread of disease

The large surface area of the peritoneal cavity allows infection and malignant disease to spread easily throughout the abdomen (Fig. 4.55). If malignant cells enter the peritoneal cavity by direct invasion (e.g., from colon or ovarian cancer), spread may be rapid. Similarly, a surgeon excising a malignant tumor and releasing malignant cells into the peritoneal cavity may cause an appreciable worsening of the patient's prognosis. Infection can also spread across the large surface area.

The peritoneal cavity can also act as a barrier to, and container of, disease. Intraabdominal infection therefore tends to remain below the diaphragm rather than spread into other body cavities.

Perforated bowel

A perforated bowel (e.g., caused by a perforated duodenal ulcer) often leads to the release of gas into the peritoneal

cavity. This peritoneal gas can be easily visualized on an erect chest radiograph—gas can be demonstrated in extremely small amounts beneath the diaphragm. A patient with severe abdominal pain and subdiaphragmatic gas needs a laparotomy.

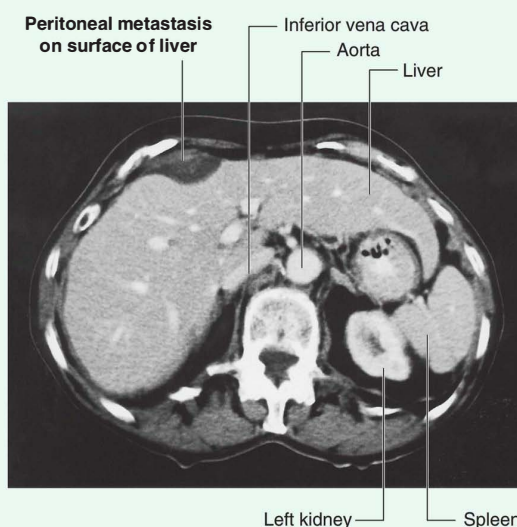


Fig. 4.55 Peritoneal metastasis on the surface of the liver. Computed tomogram in the axial plane of the upper abdomen.

Omenta, mesenteries, and ligaments

Throughout the peritoneal cavity numerous peritoneal folds connect organs to each other or to the abdominal wall. These folds (omenta, mesenteries, and ligaments) develop from the original dorsal and ventral mesenteries, which suspend the developing gastrointestinal tract in the embryonic coelomic cavity. Some contain vessels and nerves supplying the viscera, while others help maintain the proper positioning of the viscera.

Omenta

The omenta consist of two layers of peritoneum, which pass from the stomach and the first part of the duodenum to other viscera. There are two:

- the greater omentum, derived from the dorsal mesentery, and
- the lesser omentum, derived from the ventral mesentery.

Greater omentum

The **greater omentum** is a large, apron-like, peritoneal fold that attaches to the greater curvature of the stomach and the first part of the duodenum (Fig. 4.56). It drapes inferiorly over the transverse colon and the coils of the jejunum and ileum (see Fig. 4.53). Turning posteriorly, it ascends to associate with, and become adherent to, the peritoneum on the superior surface of the transverse colon and the anterior layer of the transverse mesocolon before arriving at the posterior abdominal wall.

Usually a thin membrane, the greater omentum always contains an accumulation of fat, which may become substantial in some individuals. Additionally, there are two arteries and accompanying veins, the **right** and **left gastro-omental vessels**, between this double-layered peritoneal apron just inferior to the greater curvature of the stomach.

Lesser omentum

The other two-layered peritoneal omentum is the **lesser omentum** (Fig. 4.57). It extends from the lesser curvature of the stomach and the first part of the duodenum to the inferior surface of the liver (Figs. 4.53 and 4.57).

A thin membrane continuous with the peritoneal coverings of the anterior and posterior surfaces of the stomach and the first part of the duodenum, the lesser omentum is divided into:

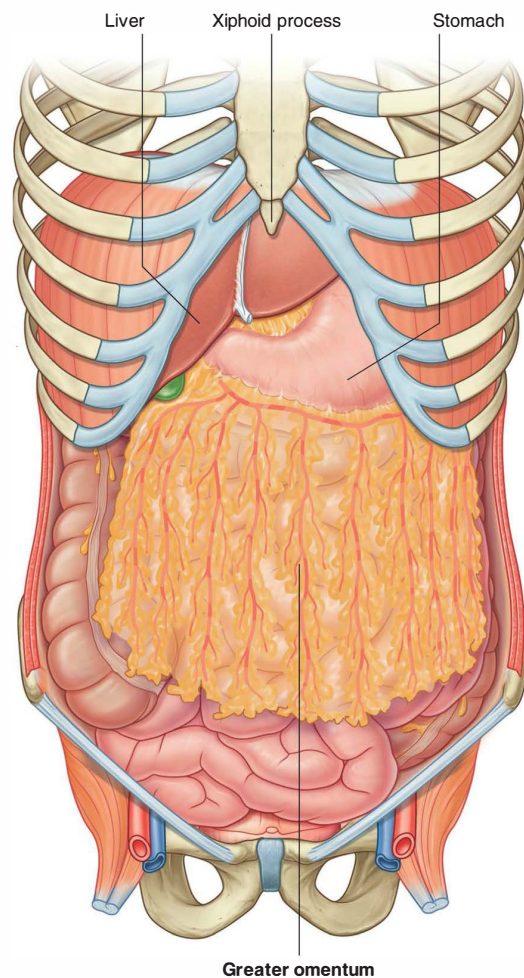


Fig. 4.56 Greater omentum.

- a medial hepatogastric ligament, which passes between the stomach and liver, and
- a lateral hepatoduodenal ligament, which passes between the duodenum and liver.

The hepatoduodenal ligament ends laterally as a free margin and serves as the anterior border of the omental foramen (Fig. 4.54). Enclosed in this free edge are the hepatic artery proper, the bile duct, and the portal vein. Additionally, the right and left gastric vessels are between the layers of the lesser omentum near the lesser curvature of the stomach.



Abdomen

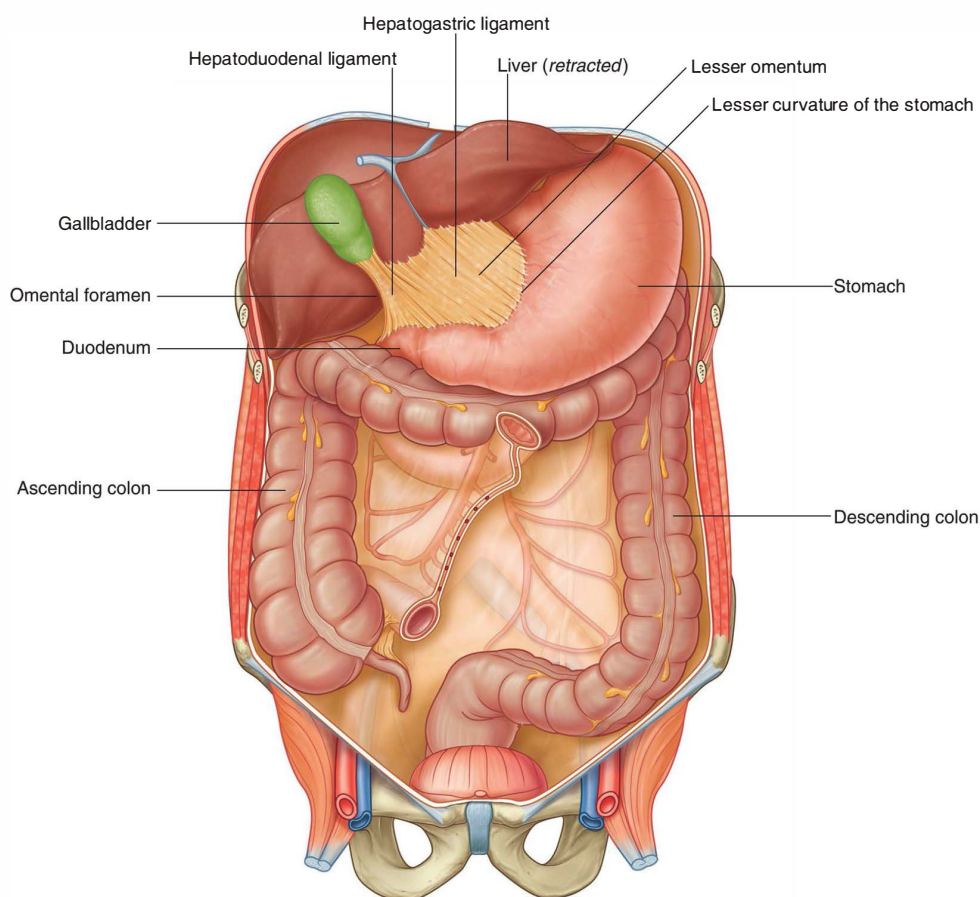


Fig. 4.57 Lesser omentum.

In the clinic

The greater omentum

When a laparotomy is performed and the peritoneal cavity is opened, the first structure usually encountered is the greater omentum. This fatty double-layered vascular membrane hangs like an apron from the greater curvature of the stomach, drapes over the transverse colon, and lies freely suspended within the abdominal cavity. It is often referred to as the "policeman of the abdomen" because of its apparent ability to migrate to any inflamed area and wrap itself around the organ to wall off inflammation. When a part of bowel becomes inflamed, it ceases peristalsis. This aperistaltic area is referred to as a local paralytic ileus. The remaining noninflamed part of the

bowel continues to move and "massages" the greater omentum to the region where there is no peristalsis. The localized inflammatory reaction spreads to the greater omentum, which then adheres to the diseased area of bowel.

The greater omentum is also an important site for metastatic tumor spread. Direct omental spread by a transcoelomic route is common for carcinoma of the ovary. As the metastases develop within the greater omentum, it becomes significantly thickened.

In computed tomography imaging and during laparotomy, the thickened omentum is referred to as an "omental cake."

Mesenteries

Mesenteries are peritoneal folds that attach viscera to the posterior abdominal wall. They allow some movement and provide a conduit for vessels, nerves, and lymphatics to reach the viscera and include:

- the mesentery—associated with parts of the small intestine,
- the transverse mesocolon—associated with the transverse colon, and
- the sigmoid mesocolon—associated with the sigmoid colon.

All of these are derivatives of the dorsal mesentery.

Mesentery

The **mesentery** is a large, fan-shaped, double-layered fold of peritoneum that connects the jejunum and ileum to the posterior abdominal wall (Fig. 4.58). Its superior attachment is at the duodenojejunal junction, just to the left of the upper lumbar part of the vertebral column. It passes obliquely downward and to the right, ending at the ileocecal junction near the upper border of the right sacro-iliac joint. In the fat between the two peritoneal layers of the mesentery are the arteries, veins, nerves, and lymphatics that supply the jejunum and ileum.

Transverse mesocolon

The **transverse mesocolon** is a fold of peritoneum that connects the transverse colon to the posterior abdominal wall (Fig. 4.58). Its two layers of peritoneum leave the posterior abdominal wall across the anterior surface of the head and body of the pancreas and pass outward to surround the transverse colon. Between its layers are the arteries, veins, nerves, and lymphatics related to the transverse colon. The anterior layer of the transverse mesocolon is adherent to the posterior layer of the greater omentum.

Sigmoid mesocolon

The **sigmoid mesocolon** is an inverted, V-shaped peritoneal fold that attaches the sigmoid colon to the abdominal wall (Fig. 4.58). The apex of the V is near the division of the left common iliac artery into its internal and external branches, with the left limb of the descending V along the medial border of the left psoas major muscle and the right limb descending into the pelvis to end at the level of

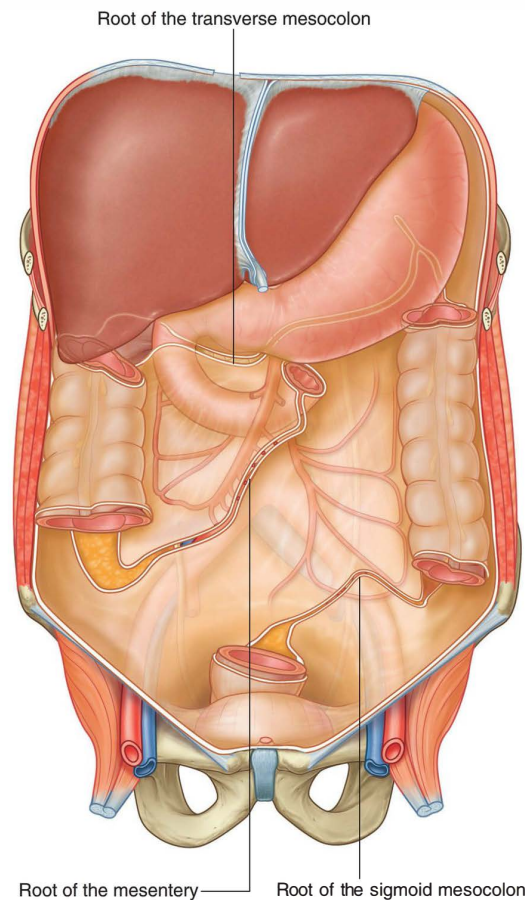


Fig. 4.58 Peritoneal reflections, forming mesenteries, outlined on the posterior abdominal wall.

vertebra SIII. The sigmoid and superior rectal vessels, along with the nerves and lymphatics associated with the sigmoid colon, pass through this peritoneal fold.

Ligaments

Peritoneal ligaments consist of two layers of peritoneum that connect two organs to each other or attach an organ to the body wall, and may form part of an omentum. They are usually named after the structures being connected. For example, the splenorenal ligament connects the left kidney to the spleen and the gastrophrenic ligament connects the stomach to the diaphragm.



Abdomen

Organs

Abdominal esophagus

The abdominal esophagus represents the short distal part of the esophagus located in the abdominal cavity. Emerging through the right crus of the diaphragm, usually at the level of vertebra TX, it passes from the esophageal hiatus to the cardiac orifice of the stomach just left of the midline (Fig. 4.59).

Associated with the esophagus, as it enters the abdominal cavity, are the anterior and posterior vagal trunks:

- The **anterior vagal trunk** consists of several smaller trunks whose fibers mostly come from the left vagus nerve; rotation of the gut during development moves these trunks to the anterior surface of the esophagus.
- Similarly, the **posterior vagal trunk** consists of a single trunk whose fibers mostly come from the right vagus nerve, and rotational changes during development move this trunk to the posterior surface of the esophagus.

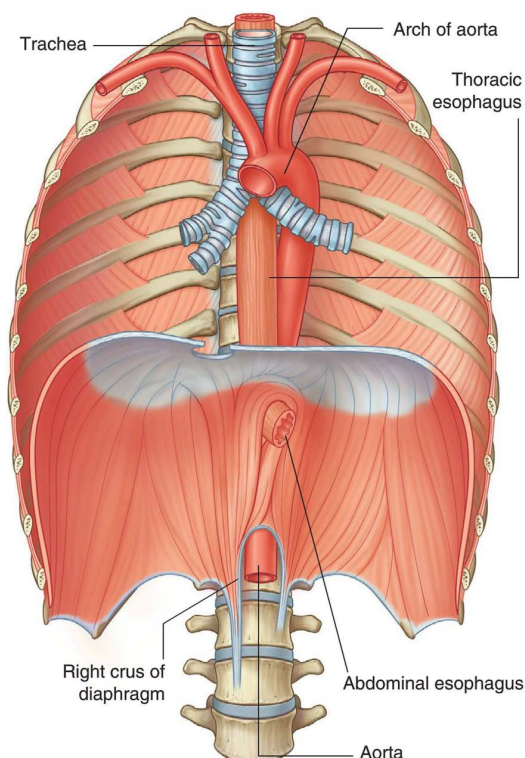


Fig. 4.59 Abdominal esophagus.

The arterial supply to the abdominal esophagus (Fig. 4.60) includes:

- esophageal branches from the left gastric artery (from the celiac trunk), and
- esophageal branches from the left inferior phrenic artery (from the abdominal aorta).

Stomach

The stomach is the most dilated part of the gastrointestinal tract and has a J-like shape (Figs. 4.61 and 4.62). Positioned between the abdominal esophagus and the small intestine, the stomach is in the epigastric, umbilical, and left hypochondrium regions of the abdomen.

The stomach is divided into four regions:

- the cardia, which surrounds the opening of the esophagus into the stomach;
- the fundus of the stomach, which is the area above the level of the cardiac orifice;
- the body of the stomach, which is the largest region of the stomach; and
- the pyloric part, which is divided into the pyloric antrum and pyloric canal and is the distal end of the stomach.

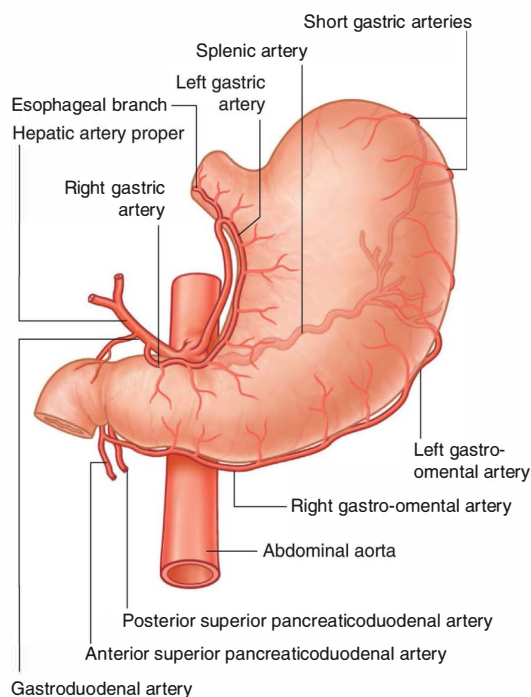


Fig. 4.60 Arterial supply to the abdominal esophagus and stomach.

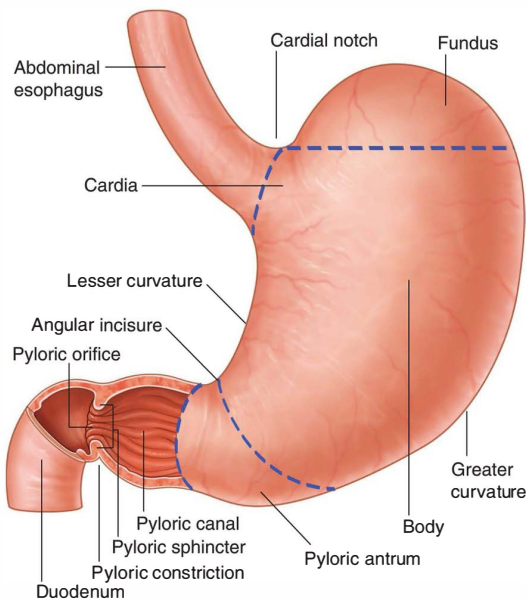


Fig. 4.61 Stomach.

The most distal portion of the pyloric part of the stomach is the **pylorus** (Fig. 4.61). It is marked on the surface of the organ by the **pyloric constriction** and contains a thickened ring of gastric circular muscle, the **pyloric sphincter**, that surrounds the distal opening of the stomach, the **pyloric orifice** (Figs. 4.61 and 4.62B). The pyloric orifice is just to the right of midline in a plane that passes through the lower border of vertebra L1 (the **transpyloric plane**).

Other features of the stomach include:

- the **greater curvature**, which is a point of attachment for the gastrosplenic ligament and the greater omentum;
- the **lesser curvature**, which is a point of attachment for the lesser omentum;
- the **cardial notch**, which is the superior angle created when the esophagus enters the stomach; and
- the **angular incisure**, which is a bend on the lesser curvature.

The arterial supply to the stomach (Fig. 4.60) includes:

- the left gastric artery from the celiac trunk,
- the right gastric artery from the hepatic artery proper,

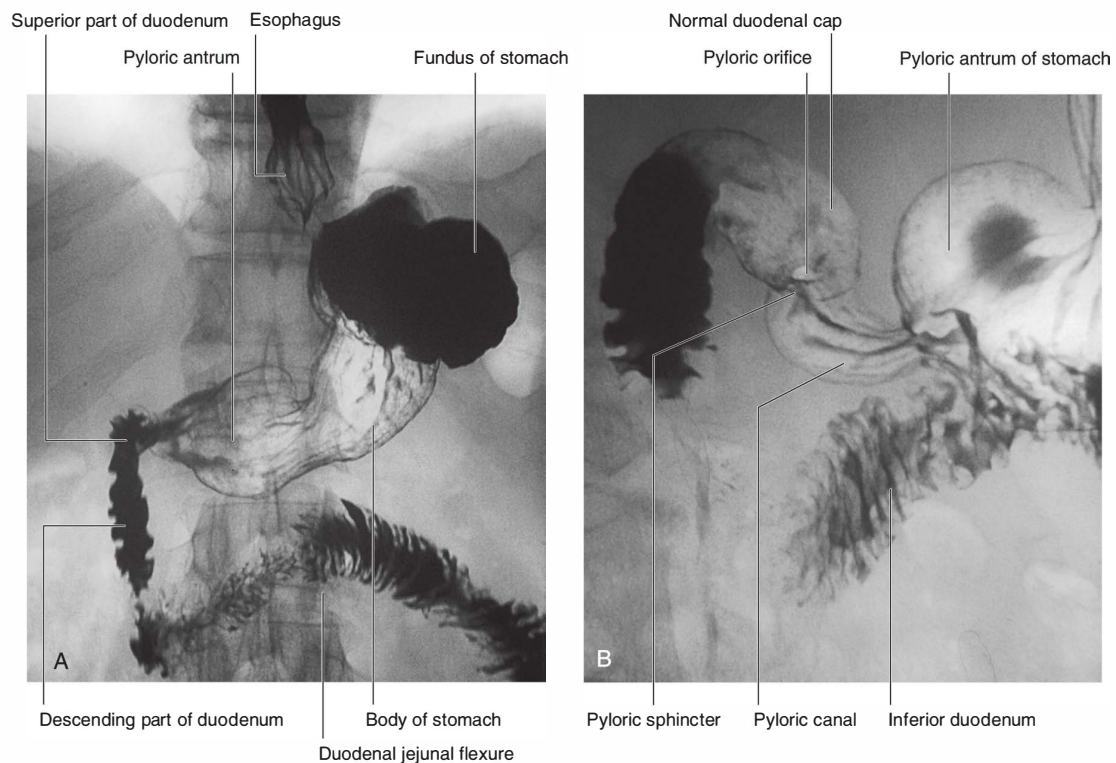


Fig. 4.62 Radiograph, using barium, showing the stomach and duodenum. A. Double-contrast radiograph of the stomach. B. Double-contrast radiograph showing the duodenal cap.



- The duodenum is divided into four parts (**Fig. 4.63**).

- The **descending part** (second part) of the duodenum is just to the right of midline and extends from the neck of the gallbladder to the lower border of vertebra LIII. Its anterior surface is crossed by the transverse colon, posterior to it is the right kidney, and medial to it is the head of the pancreas. This part of the duodenum contains the **major duodenal papilla**, which is the

The first part of the small intestine is the duodenum. This C-shaped structure, adjacent to the head of the pancreas, is 20 to 25 cm long and is above the level of the umbilicus; its lumen is the widest of the small intestine (Fig. 4.63). It

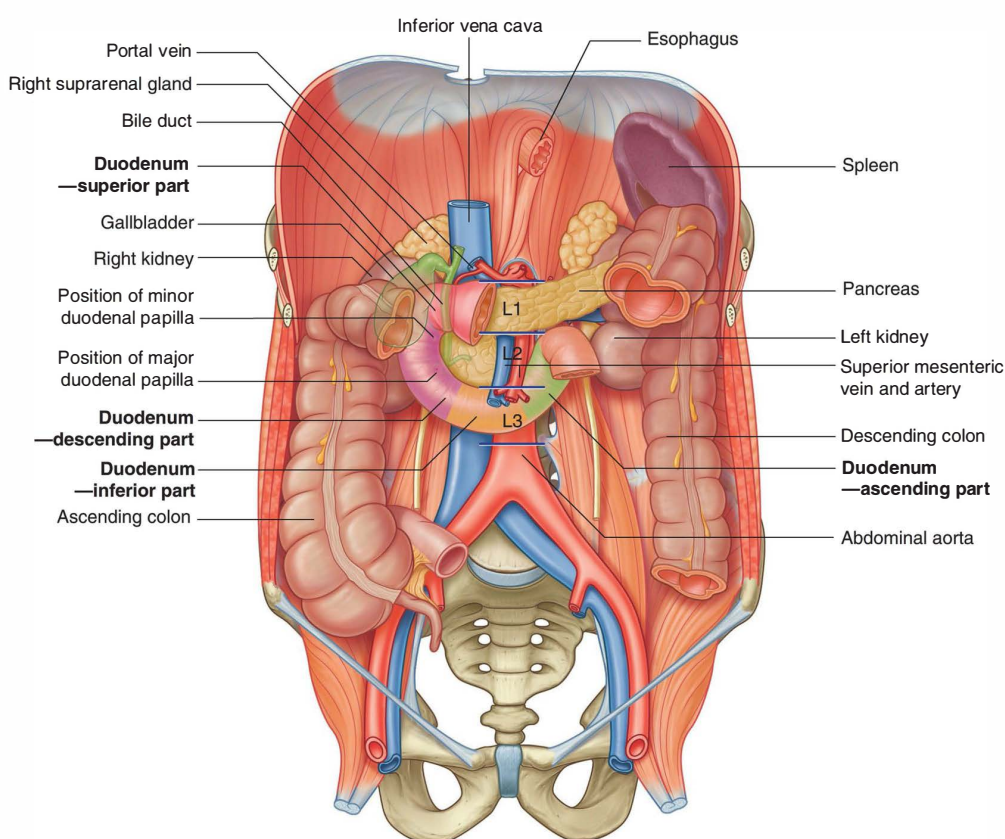


Fig. 4.63 Duodenum.

common entrance for the bile and pancreatic ducts, and the **minor duodenal papilla**, which is the entrance for the accessory pancreatic duct, and the junction of the foregut and the midgut just below the major duodenal papilla.

- The **inferior part** (third part) of the duodenum is the longest section, crossing the inferior vena cava, the aorta, and the vertebral column (Figs. 4.62B and 4.63). It is crossed anteriorly by the superior mesenteric artery and vein.
- The **ascending part** (fourth part) of the duodenum passes upward on, or to the left of, the aorta to approximately the upper border of vertebra LII and terminates at the **duodenojejunal flexure**.

This duodenojejunal flexure is surrounded by a fold of peritoneum containing muscle fibers called the **suspensory muscle (ligament) of duodenum (ligament of Treitz)**.

The arterial supply to the duodenum (Fig. 4.64) includes:

- branches from the gastroduodenal artery,
- the supraduodenal artery from the gastroduodenal artery,
- duodenal branches from the anterior superior pancreaticoduodenal artery (from the gastroduodenal artery),
- duodenal branches from the posterior superior pancreaticoduodenal artery (from the gastroduodenal artery),
- duodenal branches from the anterior inferior pancreaticoduodenal artery (from the inferior pancreaticoduodenal artery—a branch of the superior mesenteric artery),
- duodenal branches from the posterior inferior pancreaticoduodenal artery (from the inferior pancreaticoduodenal artery—a branch of the superior mesenteric artery), and
- the first jejunal branch from the superior mesenteric artery.

Jejunum

The jejunum and ileum make up the last two sections of the small intestine (Fig. 4.65). The jejunum represents the proximal two-fifths. It is mostly in the left upper quadrant

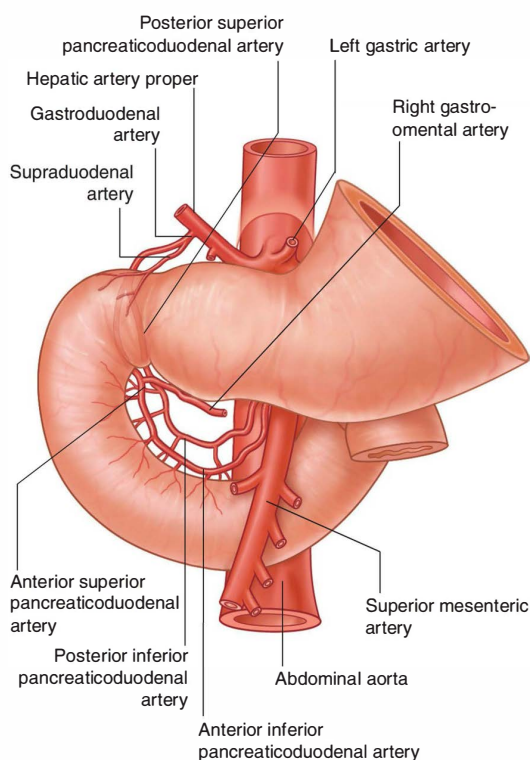


Fig. 4.64 Arterial supply to the duodenum.

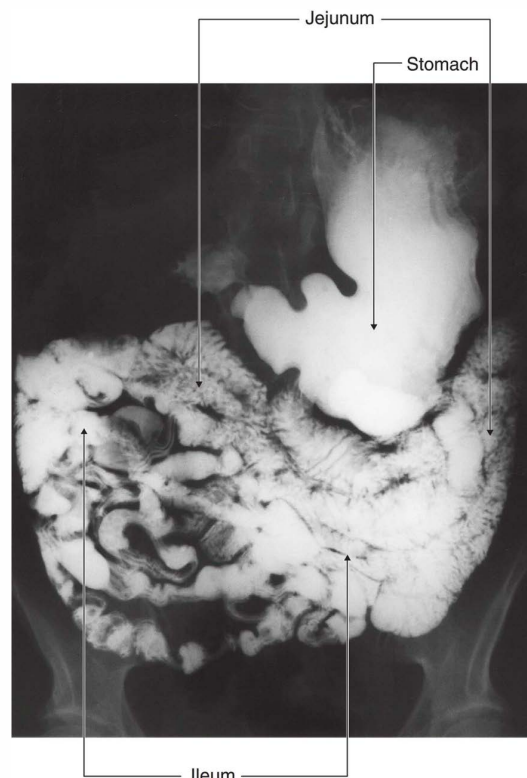


Fig. 4.65 Radiograph, using barium, showing the jejunum and ileum.



Abdomen

of the abdomen and is larger in diameter and has a thicker wall than the ileum. Additionally, the inner mucosal lining of the jejunum is characterized by numerous prominent folds that circle the lumen (plicae circulares). The less prominent arterial arcades and longer vasa recta (straight arteries) compared to those of the ileum are a unique characteristic of the jejunum (Fig. 4.66).

The arterial supply to the jejunum includes jejunal arteries from the superior mesenteric artery.

Ileum

The ileum makes up the distal three-fifths of the small intestine and is mostly in the right lower quadrant. Compared to the jejunum, the ileum has thinner walls, fewer and less prominent mucosal folds (plicae circulares), shorter vasa recta, more mesenteric fat, and more arterial arcades (Fig. 4.66).

The ileum opens into the large intestine, where the cecum and ascending colon join together. Two flaps projecting into the lumen of the large intestine (the **ileocecal fold**) surround the opening (Fig. 4.67). The flaps of the

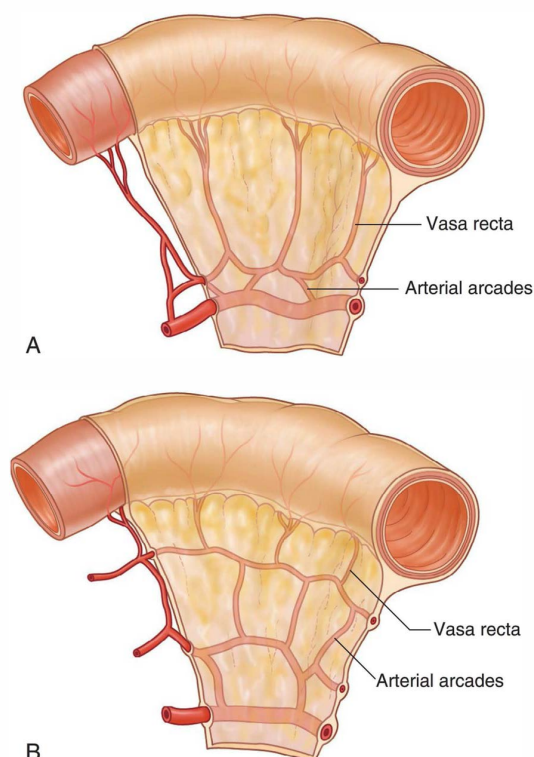
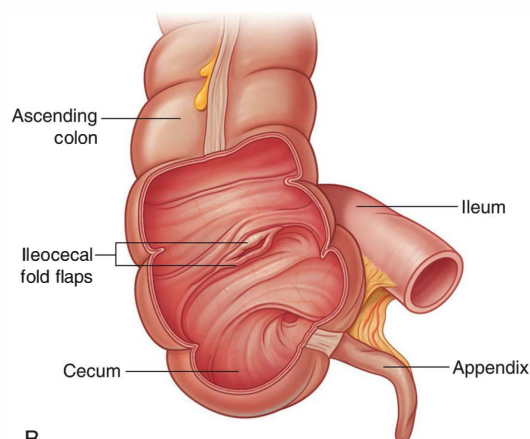
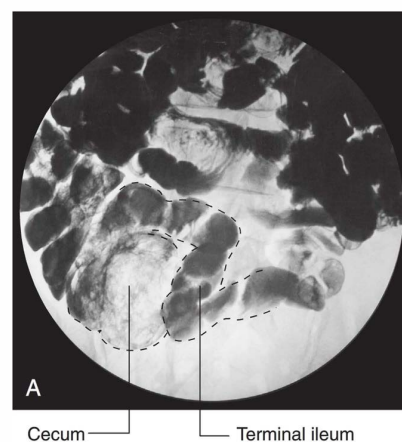
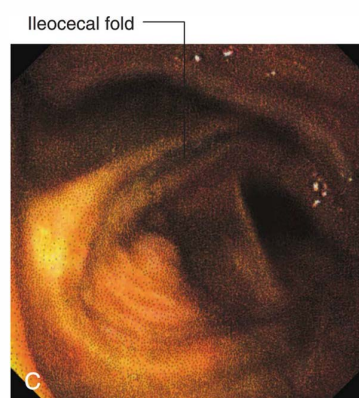


Fig. 4.66 Differences in the arterial supply to the small intestine. **A.** Jejunum. **B.** Ileum.



B



C

Fig. 4.67 Ileocecal junction. **A.** Radiograph showing ileocecal junction. **B.** Illustration showing ileocecal junction and the ileocecal fold. **C.** Endoscopic image of the ileocecal fold.

ileocecocolic fold come together at their end, forming ridges. Musculature from the ileum continues into each flap, forming a sphincter. Possible functions of the ileocecal fold include preventing reflux from the cecum to the ileum, and regulating the passage of contents from the ileum to the cecum.

The arterial supply to the ileum (Fig. 4.68) includes:

- ileal arteries from the superior mesenteric artery, and
- an ileal branch from the ileocolic artery (from the superior mesenteric artery).

In the clinic

Epithelial transition between the abdominal esophagus and stomach

The gastroesophageal junction is demarcated by a transition from one epithelial type to another epithelial type. In some people, the histological junction does not lie at the physiological gastroesophageal junction but is in the lower one-third of the esophagus. This may predispose these people to esophageal ulceration and is also associated with an increased risk of adenocarcinoma.

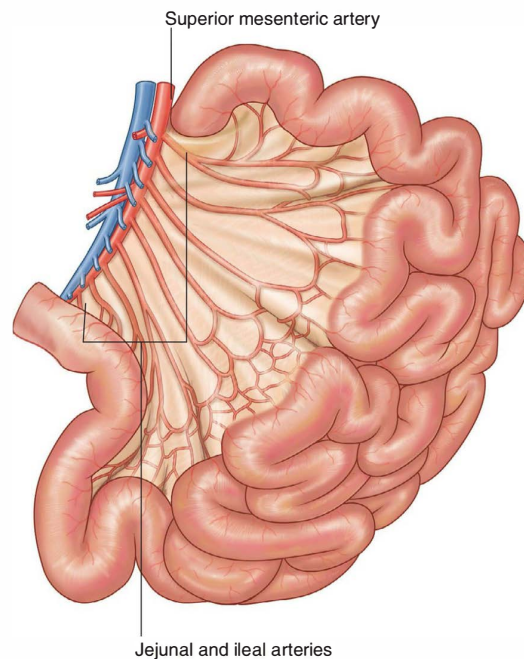


Fig. 4.68 Arterial supply to the ileum.

In the clinic

Duodenal ulceration

Duodenal ulcers usually occur in the superior part of the duodenum and are much less common than they were 50 years ago. At first, there was no treatment and patients died from hemorrhage or peritonitis. As surgical techniques developed, patients with duodenal ulcers were subjected to extensive upper gastrointestinal surgery to prevent ulcer recurrence and for some patients the treatment was dangerous. As knowledge and understanding of the mechanisms for acid secretion in the stomach increased, drugs were developed to block acid stimulation and secretion indirectly (histamine H_2 -receptor antagonists) and these have significantly reduced the morbidity and mortality rates of this disease. Pharmacological therapy can now directly inhibit the cells of the stomach that produce acid with, for example, proton pump inhibitors. Patients are also screened for the bacteria *Helicobacter pylori*, which when eradicated (by antibiotic treatment) significantly reduces duodenal ulcer formation.

Anatomically, duodenal ulcers tend to occur either anteriorly or posteriorly.

Posterior duodenal ulcers erode either directly onto the gastroduodenal artery or, more commonly, onto the posterior superior pancreaticoduodenal artery, which can produce torrential hemorrhage, which may be fatal in some patients. Treatment may involve extensive upper abdominal surgery with ligation of the vessels or by endovascular means whereby the radiologist may place a very fine catheter retrogradely from the femoral artery into the celiac artery. The common hepatic artery and the gastroduodenal artery are cannulated and the bleeding area may be blocked using small coils, which stem the flow of blood.

Anterior duodenal ulcers erode into the peritoneal cavity, causing peritonitis. This intense inflammatory reaction and the local ileus promote adhesion of the greater omentum, which attempts to seal off the perforation. The stomach and duodenum usually contain considerable amounts of gas, which enters the peritoneal cavity and can be observed on a chest radiograph of an erect patient as subdiaphragmatic gas. In most instances, treatment for the ulcer is surgical.



Abdomen

In the clinic

Examination of the upper gastrointestinal tract

It is often necessary to examine the esophagus, stomach, duodenum, and proximal jejunum for disease. After taking an appropriate history and examining the patient, most physicians arrange a series of simple blood tests to look for bleeding, inflammation, and tumors. The next steps in the investigation assess the three components of any loop of bowel, namely, the lumen, the wall, and masses extrinsic to the bowel, which may compress or erode into it.

Examination of the bowel lumen

Barium sulfate solutions may be swallowed by the patient and can be visualized using an X-ray fluoroscopy unit. The lumen can be examined for masses (e.g., polyps and tumors) and peristaltic waves can be assessed. Patients may also be given carbon dioxide-releasing granules to fill the stomach so that the barium thinly coats the mucosa, resulting in images displaying fine mucosal detail. These tests are relatively simple and can be used to image the esophagus, stomach, duodenum, and small bowel.

Examination of the bowel wall and extrinsic masses

Endoscopy is a minimally invasive diagnostic medical procedure that can be used to assess the interior surfaces of an organ by inserting a tube into the body. The instrument is typically made of a flexible plastic material through which a light source and eyepiece are attached at one end. Some systems allow passage of small instruments through the main bore of the endoscope to obtain biopsies and to also undertake small procedures (e.g., the removal of polyps).

In gastrointestinal and abdominal medicine an endoscope is used to assess the esophagus, stomach, duodenum, and proximal small bowel (Figs. 4.69 to 4.72). The tube is swallowed by the patient under light sedation and is extremely well tolerated.

Assessment of the colon is performed by passage of the tube through the anus and into the rectum. The whole of the colon can be readily assessed; biopsies and the placement of stents can also be performed using this device.



Fig. 4.69 The endoscope is a flexible plastic tube that can be controlled from the proximal end. Through a side portal various devices can be inserted, which run through the endoscope and can be used to obtain biopsies and to perform minor endoluminal surgical procedures (e.g., excision of polyps).

In the clinic—cont'd

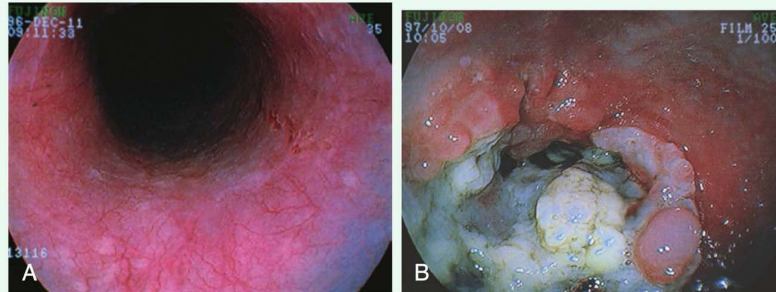


Fig. 4.70 Endoscopic images of the gastroesophageal junction. **A.** Normal. **B.** Esophageal cancer at esophageal junction.



Fig. 4.71 Endoscopic image of the pyloric antrum of the stomach looking toward the pylorus.



Fig. 4.72 Endoscopic image showing normal appearance of the second part of the duodenum.



Abdomen

In the clinic

Meckel's diverticulum

A Meckel's diverticulum (Fig. 4.73) is the remnant of the proximal part of the yolk stalk (vitelline duct) that extends into the umbilical cord in the embryo and lies on the antimesenteric border of the ileum. It appears as a blind-ended tubular outgrowth of bowel. Although it is an

uncommon finding (occurring in approximately 2% of the population), it is always important to consider the diagnosis of Meckel's diverticulum because it does produce symptoms in a small number of patients. Typical findings include hemorrhage, intussusception, diverticulitis, ulceration, and obstruction.

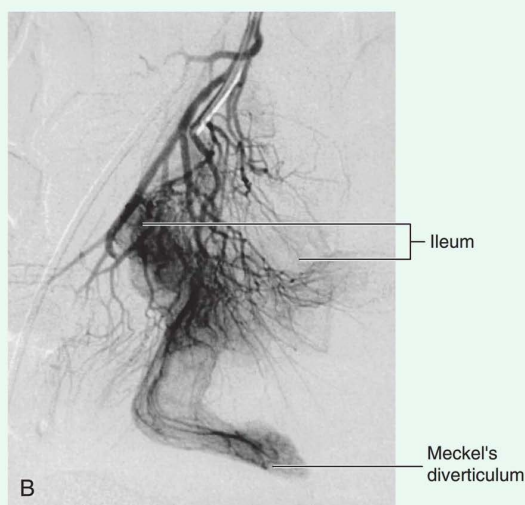


Fig. 4.73 Vasculature associated with a Meckel's diverticulum. **A.** Surgical image of Meckel's diverticulum. **B.** Digital subtraction angiography.

In the clinic

Computed tomography (CT) scanning and magnetic resonance imaging (MRI)

These imaging techniques can provide important information about the wall of the bowel that may not be obtained from barium or endoscopic studies. Thickening of the wall may indicate inflammatory change or tumor and is always regarded with suspicion. If a tumor is demonstrated, the locoregional spread can be assessed, along with lymphadenopathy and metastatic spread.

Advanced imaging methods

A small ultrasound device placed on the end of the endoscope can produce extremely high-powered views of the mucosa and submucosa of the upper gastrointestinal tract. These views can show whether a tumor is resectable and guide the clinician in taking a biopsy.

In the clinic

Carcinoma of the stomach

Carcinoma of the stomach is a common gastrointestinal malignancy. Chronic gastric inflammation (gastritis), pernicious anemia, and polyps predispose to the development of this aggressive cancer, which is usually not diagnosed until late in the course of the disease. Symptoms include vague epigastric pain, early fullness with eating, bleeding leading to chronic anemia, and obstruction.

The diagnosis may be made using barium and conventional radiology or endoscopy, which allows a biopsy to be obtained at the same time. Ultrasound scanning is used to check the liver for metastatic spread, and, if negative, computed tomography is carried out to assess for surgical resectability. If carcinoma of the stomach is diagnosed early, a curative surgical resection is possible. However, because most patients do not seek treatment until late in the disease, the overall 5-year survival rate is between 5% and 20%, with a mean survival time of between 5 and 8 months.

Large intestine

The large intestine extends from the distal end of the ileum to the anus, a distance of approximately 1.5 m in adults. It absorbs fluids and salts from the gut contents, thus forming feces, and consists of the cecum, appendix, colon, rectum, and anal canal (Figs. 4.74 and 4.75).

Beginning in the right groin as the cecum, with its associated appendix, the large intestine continues upward as

the **ascending colon** through the right flank and into the right hypochondrium (Fig. 4.76). Just below the liver, it bends to the left, forming the **right colic flexure (hepatic flexure)**, and crosses the abdomen as the **transverse colon** to the left hypochondrium. At this position, just below the spleen, the large intestine bends downward, forming the **left colic flexure (splenic flexure)**, and continues as the **descending colon** through the left flank and into the left groin.

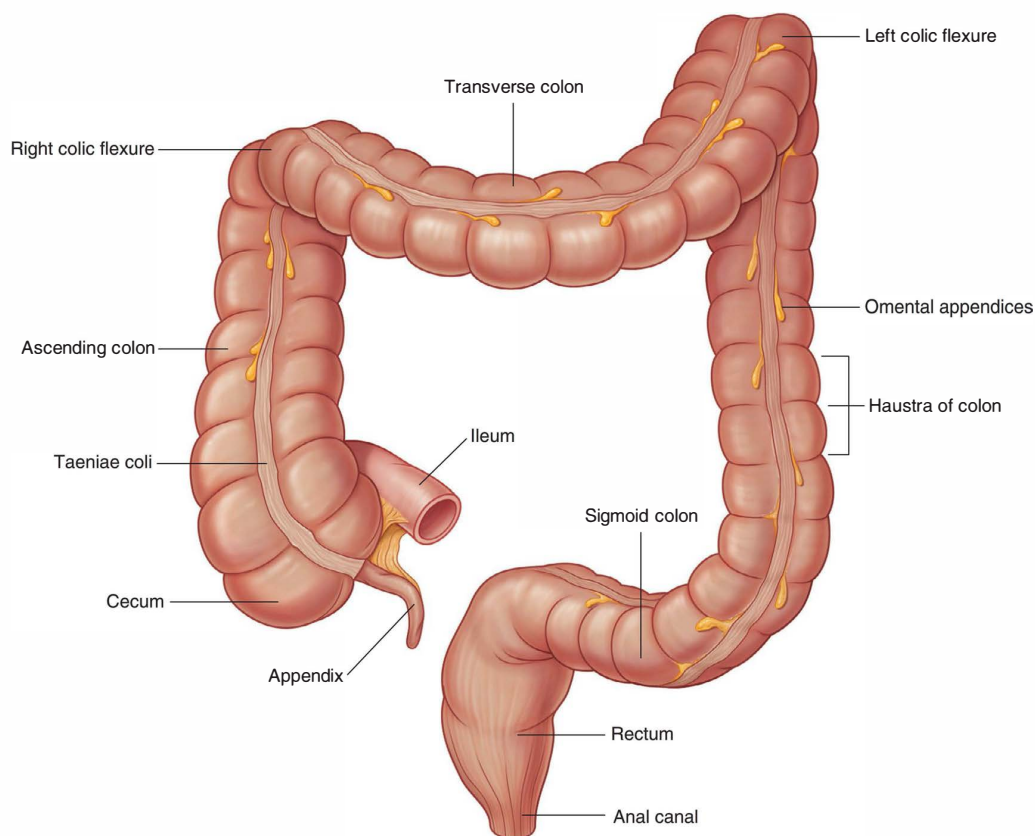


Fig. 4.74 Large intestine.



Abdomen



Fig. 4.75 Radiograph, using barium, showing the large intestine.

It enters the upper part of the pelvic cavity as the sigmoid colon, continues on the posterior wall of the pelvic cavity as the rectum, and terminates as the anal canal.

The general characteristics of most of the large intestine (Fig. 4.74) are:

- its large internal diameter compared to that of the small intestine;
- peritoneal-covered accumulations of fat (the **omental appendices**) are associated with the colon;
- the segregation of longitudinal muscle in its walls into three narrow bands (the **taeniae coli**), which are primarily observed in the cecum and colon and less visible in the rectum; and
- the sacculations of the colon (the **haustra of the colon**).

Cecum and appendix

The **cecum** is the first part of the large intestine (Fig. 4.77). It is inferior to the ileocecal opening and in the right iliac fossa. It is an intraperitoneal structure because of its mobility, not because of its suspension by a mesentery.

The cecum is continuous with the ascending colon at the entrance of the ileum and is usually in contact with

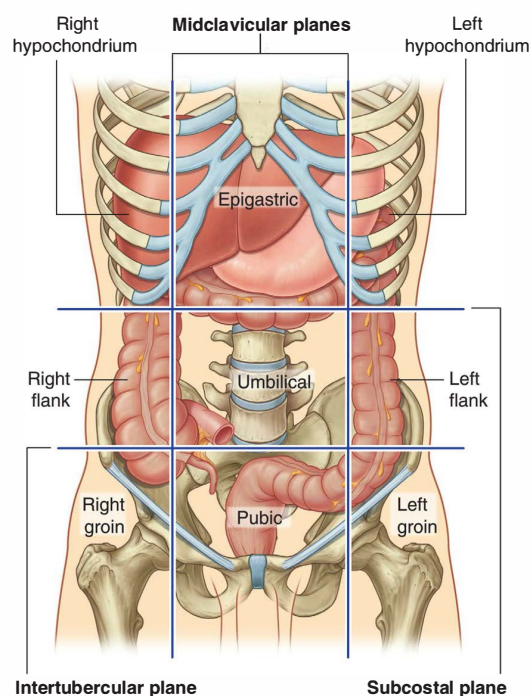


Fig. 4.76 Position of the large intestine in the nine-region organizational pattern.

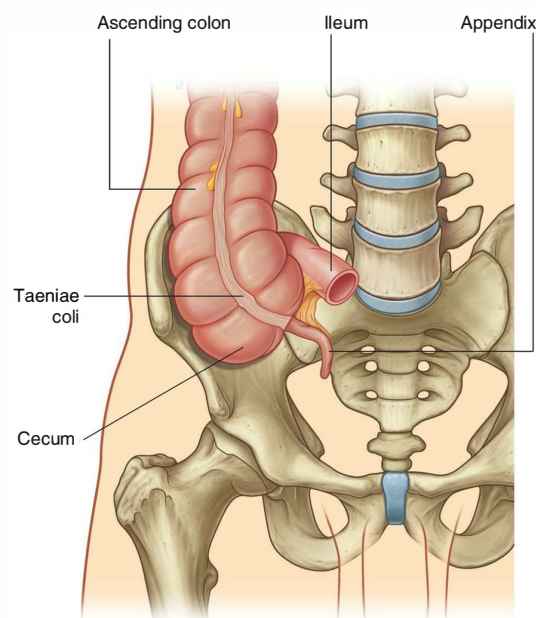


Fig. 4.77 Cecum and appendix.

the anterior abdominal wall. It may cross the pelvic brim to lie in the true pelvis. The appendix is attached to the posteromedial wall of the cecum, just inferior to the end of the ileum (Fig. 4.77).

The **appendix** is a narrow, hollow, blind-ended tube connected to the cecum. It has large aggregations of lymphoid tissue in its walls and is suspended from the terminal ileum by the **mesoappendix** (Fig. 4.78), which contains the **appendicular vessels**. Its point of attachment to the cecum is consistent with the highly visible free taeniae leading directly to the base of the appendix, but the location of the rest of the appendix varies considerably (Fig. 4.79). It may be:

- posterior to the cecum or the lower ascending colon, or both, in a retrocecal or retrocolic position;
- suspended over the pelvic brim in a pelvic or descending position;
- below the cecum in a subcecal location; or
- anterior to the terminal ileum, possibly contacting the body wall, in a pre-ileal position or posterior to the terminal ileum in a postileal position.

The surface projection of the base of the appendix is at the junction of the lateral and middle one-third of a line from the anterior superior iliac spine to the umbilicus (McBurney's point). People with appendicular problems may describe pain near this location.

The arterial supply to the cecum and appendix (Fig. 4.80) includes:

- the anterior cecal artery from the ileocolic artery (from the superior mesenteric artery),
- the posterior cecal artery from the ileocolic artery (from the superior mesenteric artery), and
- the appendicular artery from the ileocolic artery (from the superior mesenteric artery).

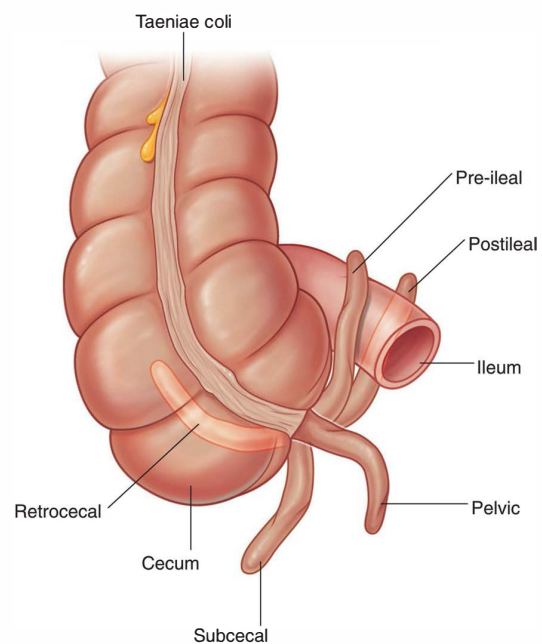


Fig. 4.79 Positions of the appendix.

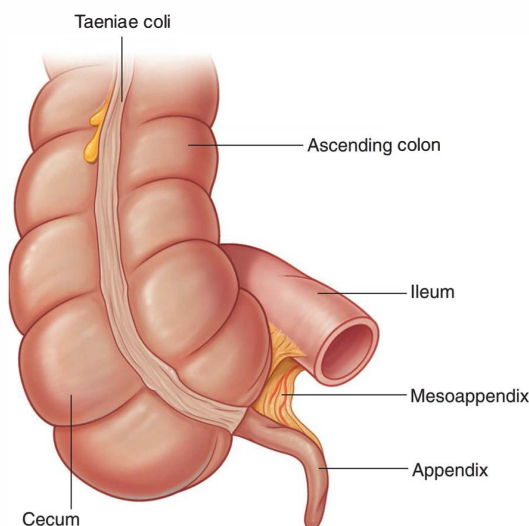


Fig. 4.78 Mesoappendix and appendicular vessels.

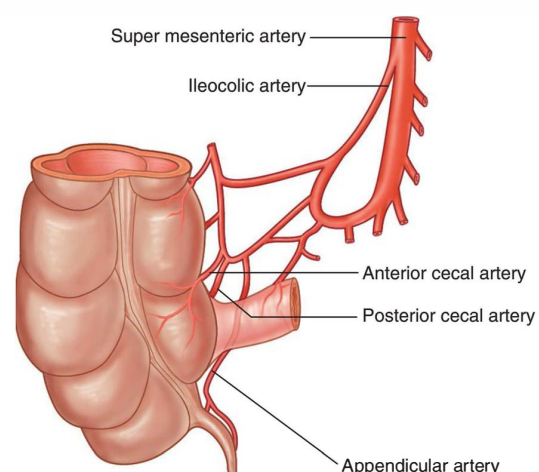


Fig. 4.80 Arterial supply to the cecum and appendix.



Abdomen

In the clinic

Appendicitis

Acute appendicitis is an abdominal emergency. It usually occurs when the appendix is obstructed by either a fecalith or enlargement of the lymphoid nodules. Within the obstructed appendix, bacteria proliferate and invade the appendix wall, which becomes damaged by pressure necrosis. In some instances, this may resolve spontaneously; in other cases, inflammatory change (Fig. 4.81) continues and perforation ensues, which may lead to localized or generalized peritonitis.

Most patients with acute appendicitis have localized tenderness in the right groin. Initially, the pain begins as a central, periumbilical, colicky type of pain, which tends to come and go. After 6 to 10 hours, the pain tends to localize in the right iliac fossa and becomes constant. Patients may develop a fever, nausea, and vomiting. The etiology of the pain for appendicitis is described in Case 1 of Chapter 1 on p. 50.

The treatment for appendicitis is appendectomy.



Fig. 4.81 Inflamed appendix. Ultrasound scan.

Colon

The colon extends superiorly from the cecum and consists of the ascending, transverse, descending, and sigmoid colon (Fig. 4.82). Its ascending and descending segments are (secondarily) retroperitoneal and its transverse and sigmoid segments are intraperitoneal.

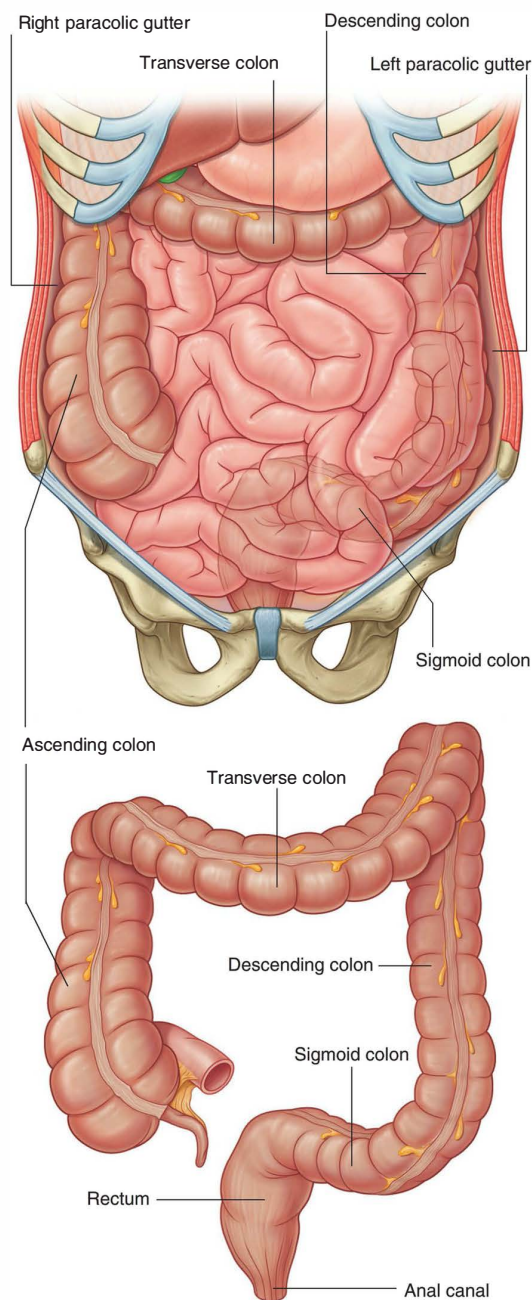


Fig. 4.82 Colon.

At the junction of the ascending and transverse colon is the right colic flexure, which is just inferior to the right lobe of the liver (Fig. 4.83). A similar, but more acute bend (the left colic flexure) occurs at the junction of the transverse and descending colon. This bend is just inferior to the

spleen, is higher and more posterior than the right colic flexure, and is attached to the diaphragm by the phrenicocolic ligament.

Immediately lateral to the ascending and descending colon are the **right and left paracolic gutters** (Fig. 4.82). These depressions are formed between the lateral margins of the ascending and descending colon and the posterolateral abdominal wall and are gutters through which material can pass from one region of the peritoneal cavity to another. Because major vessels and lymphatics are on the medial or posteromedial sides of the ascending and descending colon, a relatively blood-free mobilization of the ascending and descending colon is possible by cutting the peritoneum along these lateral paracolic gutters.

The final segment of the colon (the sigmoid colon) begins above the pelvic inlet and extends to the level of vertebra SIII, where it is continuous with the rectum (Fig. 4.82). This S-shaped structure is quite mobile except at its beginning, where it continues from the descending colon, and at its end, where it continues as the rectum. Between these points, it is suspended by the sigmoid mesocolon.

The arterial supply to the ascending colon (Fig. 4.84) includes:

- the colic branch from the ileocolic artery (from the superior mesenteric artery),
- the anterior cecal artery from the ileocolic artery (from the superior mesenteric artery),

- the posterior cecal artery from the ileocolic artery (from the superior mesenteric artery), and
- the right colic artery from the superior mesenteric artery.

The arterial supply to the transverse colon (Fig. 4.84) includes:

- the right colic artery from the superior mesenteric artery,
- the middle colic artery from the superior mesenteric artery, and
- the left colic artery from the inferior mesenteric artery.

The arterial supply to the descending colon (Fig. 4.84) includes the left colic artery from the inferior mesenteric artery.

The arterial supply to the sigmoid colon (Fig. 4.84) includes sigmoidal arteries from the inferior mesenteric artery.

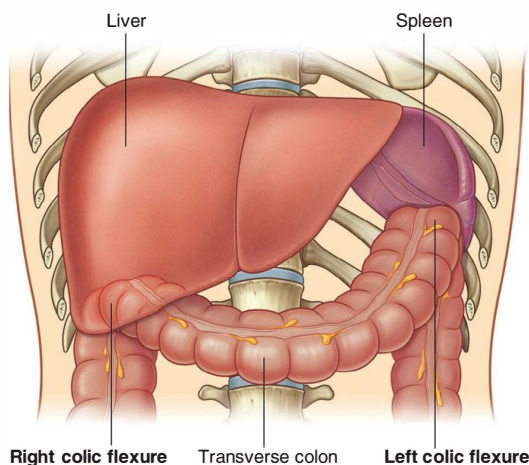


Fig. 4.83 Right and left colic flexures.

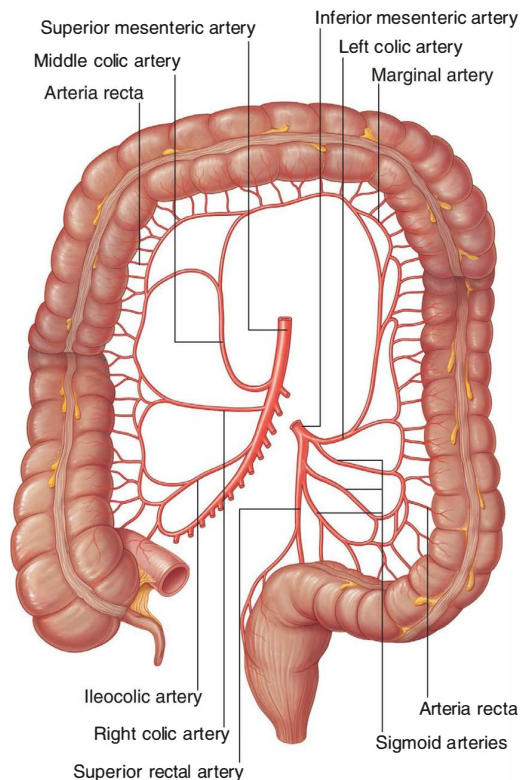


Fig. 4.84 Arterial supply to the colon.



Abdomen

Rectum and anal canal

Extending from the sigmoid colon is the rectum (Fig. 4.85). The rectosigmoid junction is usually described as being at the level of vertebra SIII or at the end of the sigmoid mesocolon because the rectum is a retroperitoneal structure.

The anal canal is the continuation of the large intestine inferior to the rectum.

The arterial supply to the rectum and anal canal (Fig. 4.86) includes:

- the superior rectal artery from the inferior mesenteric artery,
- the middle rectal artery from the internal iliac artery, and
- the inferior rectal artery from the internal pudendal artery (from the internal iliac artery).

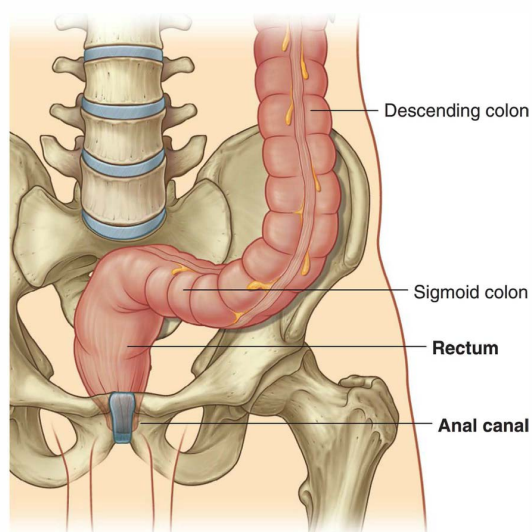


Fig. 4.85 Rectum and anal canal.

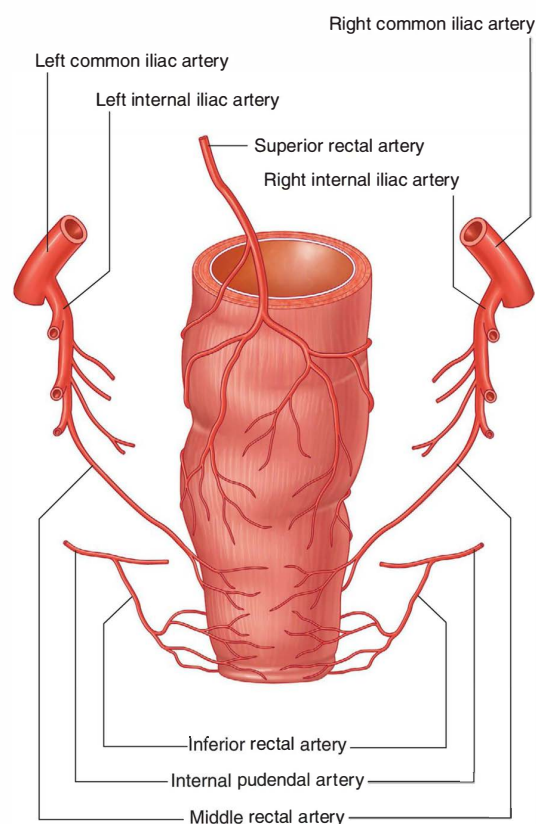


Fig. 4.86 Arterial supply to the rectum and anal canal. Posterior view.

In the clinic**Congenital disorders of the gastrointestinal tract**

The normal positions of the abdominal viscera result from a complex series of rotations that the gut tube undergoes and from the growth of the abdominal cavity to accommodate changes in the size of the developing organs (see pp. 265–268). A number of developmental anomalies can occur during gut development, many of which appear in the neonate or infant, and some of which are surgical emergencies. Occasionally, such disorders are diagnosed only in adults.

Malrotation and midgut volvulus

Malrotation is incomplete rotation and fixation of the midgut after it has passed from the umbilical sac and returned to the abdominal coelom (Figs. 4.87 and 4.88).

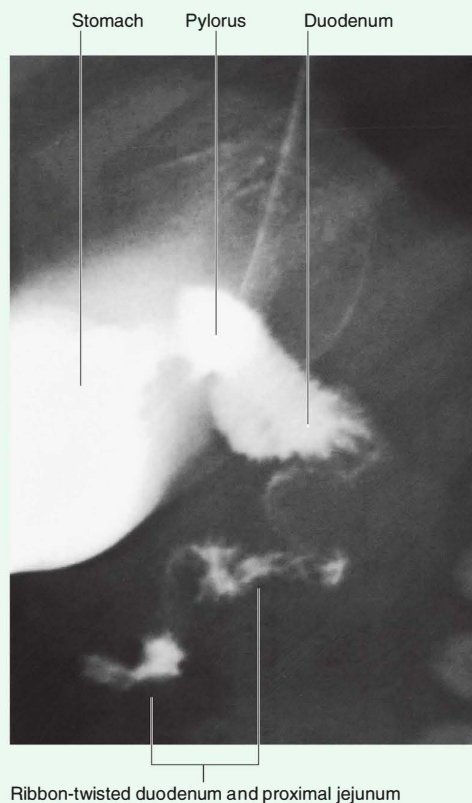


Fig. 4.87 Small bowel malrotation and volvulus. Radiograph of stomach, duodenum, and upper jejunum using barium.

The proximal attachment of the small bowel mesentery begins at the **suspensory muscle of duodenum (ligament of Treitz)**, which determines the position of the duodenojejunal junction. The mesentery of the small bowel ends at the level of the ileocecal junction in the right lower quadrant. This long line of fixation of the mesentery prevents accidental twists of the gut.

If the duodenojejunal flexure or the cecum does not end up in its usual site, the origin of the small bowel mesentery shortens, which permits twisting of the small bowel around the axis of the superior mesenteric artery. Twisting of the bowel, in general, is termed **volvulus**. Volvulus of the small bowel may lead to a reduction of blood flow and infarction.

In some patients, the cecum ends up in the midabdomen. From the cecum and the right side of the colon a series of peritoneal folds (**Ladd's bands**) develop that extend to the right undersurface of the liver and compress the duodenum. A small bowel volvulus may then occur as well as duodenal obstruction. Emergency surgery may be necessary to divide the bands.

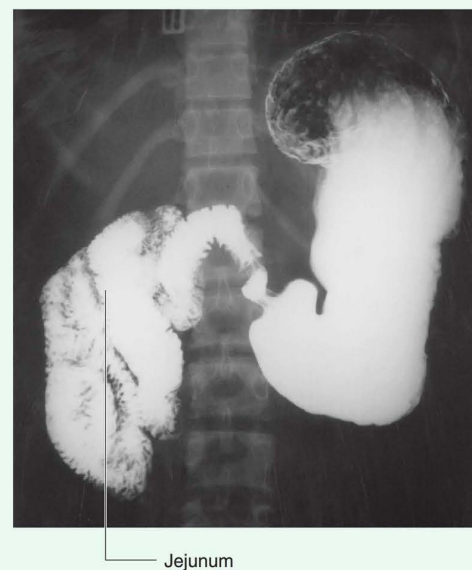


Fig. 4.88 Small bowel malrotation. Radiograph of stomach, duodenum, and jejunum using barium.



Abdomen

In the clinic

Bowel obstruction

A bowel obstruction can be either functional or due to a true obstruction. Mechanical obstruction is caused by an intraluminal, mural, or extrinsic mass which can be secondary to a foreign body, obstructing tumor in the wall, or extrinsic compression from an adhesion, or embryological band (Fig. 4.89).

A functional obstruction is usually due to an inability of the bowel to peristaltise, which again has a number of causes, and most frequently is a postsurgical state due to excessive intraoperative bowel handling. Other causes may well include abnormality of electrolytes (e.g., sodium and potassium) rendering the bowel paralyzed until correction has occurred.

The signs and symptoms of obstruction depend on the level at which the obstruction has occurred. The primary symptom is central abdominal, intermittent, colicky pain as the peristaltic waves try to overcome the obstruction. Abdominal distention will occur if it is a low obstruction (distal), allowing more proximal loops of bowel to fill with

fluid. A high obstruction (in the proximal small bowel) may not produce abdominal distention.

Vomiting and absolute constipation, including the inability to pass flatus, will ensue.

Early diagnosis is important because considerable fluid and electrolytes enter the bowel lumen and fail to be reabsorbed, which produces dehydration and electrolyte abnormalities. Furthermore, the bowel continues to distend, compromising the blood supply within the bowel wall, which may lead to ischemia and perforation. The symptoms and signs are variable and depend on the level of obstruction.

Small bowel obstruction is typically caused by adhesions following previous surgery, and history should always be sought for any operations or abdominal interventions (e.g., previous appendectomy). Other causes include bowel passing into hernias (e.g., inguinal) and bowel twisting on its own mesentery (volvulus). Examination of hernial orifices is mandatory in patients with bowel obstruction.

Large bowel obstruction is commonly caused by a tumor. Other potential causes include hernias and inflammatory diverticular disease of the sigmoid colon.

The treatment is intravenous replacement of fluid and electrolytes, analgesia, and relief of obstruction. The passage of a nasogastric tube allows aspiration of fluid from the stomach. In many instances, small bowel obstruction, typically secondary to adhesions, will settle with nonoperative management. Large bowel obstruction may require an urgent operation to remove the obstructing lesion, or a temporary bypass procedure (e.g., defunctioning colostomy) (Fig. 4.90).



Fig. 4.89 This radiograph of the abdomen, anteroposterior view, demonstrates a number of dilated loops of small bowel. Small bowel can be identified by the plicae circulares that pass from wall to wall as indicated. The large bowel is not dilated. The cause of the small bowel dilatation is an adhesion after pelvic surgery.

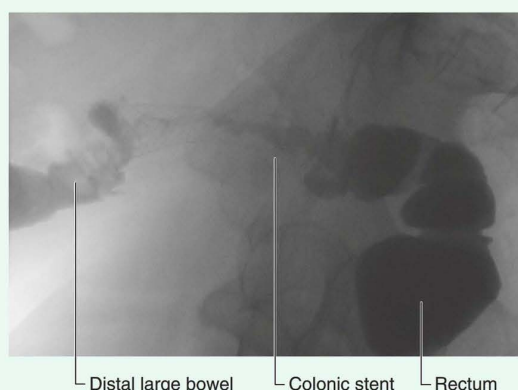


Fig. 4.90 This oblique radiograph demonstrates contrast passing through a colonic stent that has been placed to relieve bowel obstruction prior to surgery.

In the clinic**Diverticular disease**

Diverticular disease is the development of multiple colonic diverticula, predominantly throughout the sigmoid colon, though the whole colon may be affected (Fig. 4.91). The sigmoid colon has the smallest diameter of any portion of the colon and is therefore the site where intraluminal pressure is potentially the highest. Poor dietary fiber intake and obesity are also linked to diverticular disease.

The presence of multiple diverticula does not necessarily mean the patient requires any treatment. Moreover, many patients have no other symptoms or signs.

Patients tend to develop symptoms and signs when the neck of the diverticulum becomes obstructed by feces and becomes infected. Inflammation may spread along the wall, causing abdominal pain. When the sigmoid colon becomes inflamed (diverticulitis), abdominal pain and fever ensue.

Because of the anatomical position of the sigmoid colon there are a number of complications that may occur. The diverticula can perforate to form an abscess in the pelvis. The inflammation may produce an inflammatory mass, obstructing the left ureter. Inflammation may also spread to the bladder, producing a fistula between the sigmoid colon and the bladder. In these circumstances patients may develop a urinary tract infection and rarely have fecal material and gas passing per urethra.

The diagnosis is based upon clinical examination and often CT scanning. In the first instance, patients will be treated with antibiotic therapy; however, a surgical resection may be necessary if symptoms persist.

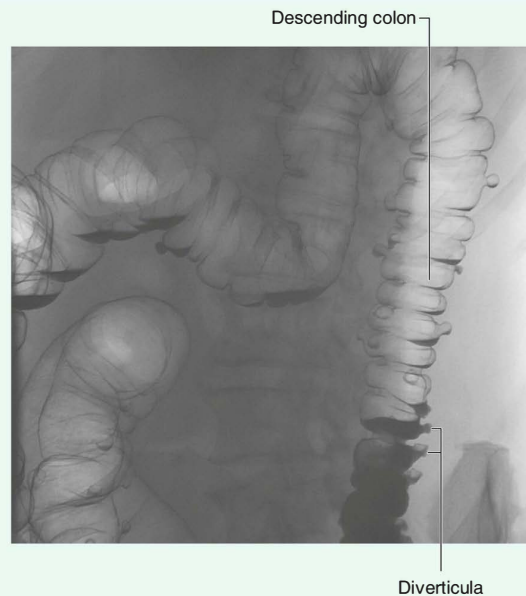


Fig. 4.91 This double-contrast barium enema demonstrates numerous small outpouchings throughout the distal large bowel predominantly within the descending colon and the sigmoid colon. These small outpouchings are diverticula and in most instances remain quiescent.

In the clinic**Ostomies**

It is occasionally necessary to surgically externalize bowel to the anterior abdominal wall. Externalization of bowel plays an important role in patient management. These extraanatomical bypass procedures use our anatomical knowledge and in many instances are life saving.

Gastrostomy

Gastrostomy is performed when the stomach is attached to the anterior abdominal wall and a tube is placed through the skin into the stomach. Typically this is performed to feed the patient when it is impossible to take food and fluid orally (e.g., complex head and neck cancer). The procedure can be performed either surgically or through a direct needlestick puncture under sedation in the anterior abdominal wall.

Jejunostomy

Similarly the jejunum is brought to the anterior abdominal wall and fixed. The jejunostomy is used as a site where a feeding tube is placed through the anterior abdominal wall into the proximal efferent small bowel.

Ileostomy

An ileostomy is performed when small bowel contents need to be diverted from the distal bowel. An ileostomy is often performed to protect a distal surgical anastomosis, such as in the colon to allow healing after surgery.

Colostomy

There are a number of instances when a colostomy may be necessary. In many circumstances it is performed to protect the distal large bowel after surgery. A further

(continues)



Abdomen

In the clinic—cont'd

indication would include large bowel obstruction with imminent perforation wherein a colostomy allows decompression of the bowel and its contents. This is a safe and temporizing procedure performed when the patient is too unwell for extensive bowel surgery. It is relatively straightforward and carries reduced risk, preventing significant morbidity and mortality.

An end colostomy is necessary when the patient has undergone a surgical resection of the rectum and anus (typically for cancer).

Ileal conduit

An ileal conduit is an extraanatomical procedure and is performed after resection of the bladder for tumor. In this situation a short segment of small bowel is identified. The

bowel is divided twice to produce a 20-cm segment of small bowel on its own mesentery. This isolated segment of bowel is used as a conduit. The remaining bowel is joined together. The proximal end is anastomosed to the ureters, and the distal end is anastomosed to the anterior abdominal wall. Hence, urine passes from the kidneys into the ureters and through the short segment of small bowel to the anterior abdominal wall.

When patients have either an ileostomy, colostomy, or ileal conduit it is necessary for them to fix a collecting bag onto the anterior abdominal wall. Contrary to one's initial thoughts these bags are tolerated extremely well by most patients and allow patients to live a nearly normal and healthy life.

Liver

The liver is the largest visceral organ in the body and is primarily in the right hypochondrium and epigastric region, extending into the left hypochondrium (or in the right upper quadrant, extending into the left upper quadrant) (Fig. 4.92).

Surfaces of the liver include:

- a **diaphragmatic surface** in the anterior, superior, and posterior directions; and
- a **visceral surface** in the inferior direction (Fig. 4.93).

Diaphragmatic surface

The diaphragmatic surface of the liver, which is smooth and domed, lies against the inferior surface of the diaphragm (Fig. 4.94). Associated with it are the subphrenic and hepatorenal recesses (Fig. 4.93):

- The **subphrenic recess** separates the diaphragmatic surface of the liver from the diaphragm and is divided into right and left areas by the **falciform ligament**, a structure derived from the ventral mesentery in the embryo.
- The hepatorenal recess is a part of the peritoneal cavity on the right side between the liver and the right kidney and right suprarenal gland.

The subphrenic and hepatorenal recesses are continuous anteriorly.

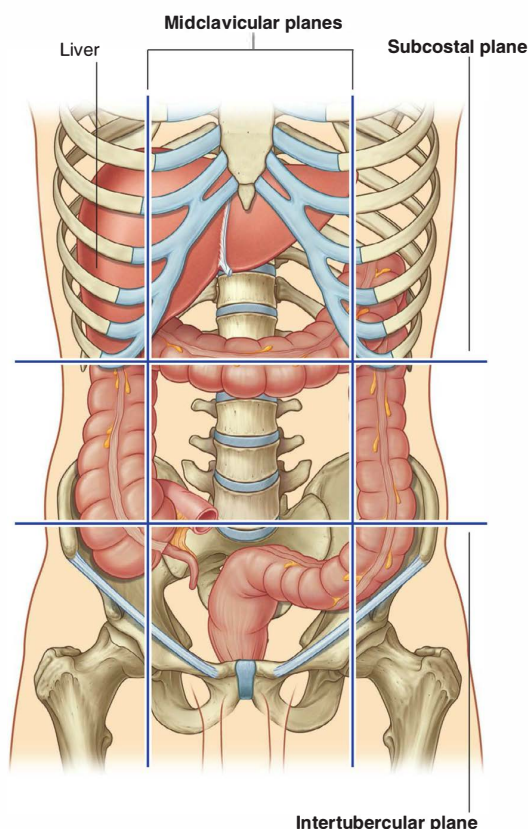


Fig. 4.92 Position of the liver in the abdomen.

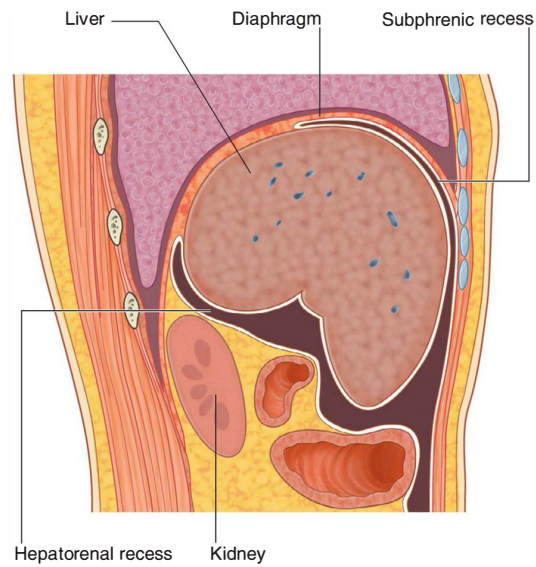


Fig. 4.93 Surfaces of the liver and recesses associated with the liver.

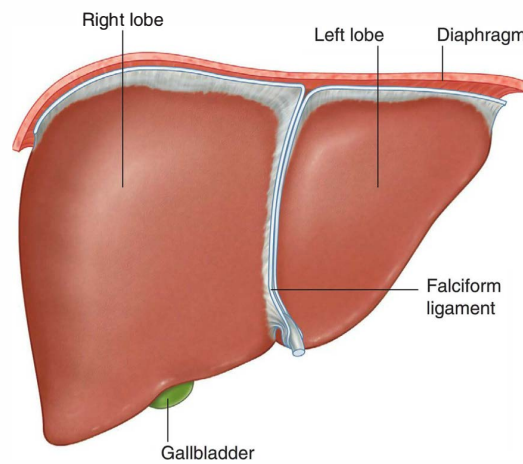


Fig. 4.94 Diaphragmatic surface of the liver.



Abdomen

Visceral surface

The visceral surface of the liver is covered with visceral peritoneum except in the **fossa for the gallbladder** and at the **porta hepatis** (gateway to the liver; Fig. 4.95), and structures related to it include the following (Fig. 4.96):

- esophagus,
- right anterior part of the stomach,
- superior part of the duodenum,
- lesser omentum,
- gallbladder,

- right colic flexure,
- right transverse colon,
- right kidney, and
- right suprarenal gland.

The **porta hepatis** serves as the point of entry into the liver for the hepatic arteries and the portal vein, and the exit point for the hepatic ducts (Fig. 4.95).

Associated ligaments

The liver is attached to the anterior abdominal wall by the **falciform ligament** and, except for a small area of the

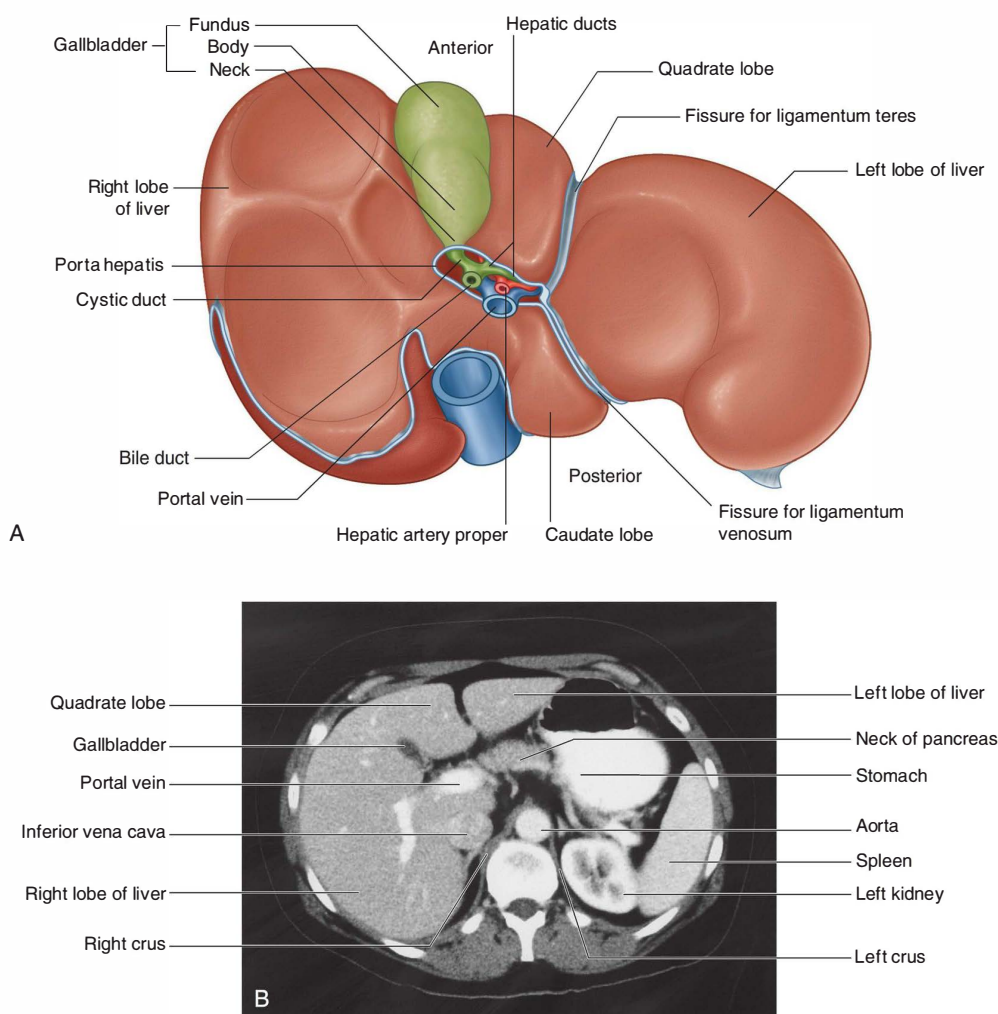


Fig. 4.95 Visceral surface of the liver. **A.** Illustration. **B.** Abdominal computed tomogram, with contrast, in the axial plane.

liver against the diaphragm (the **bare area**), the liver is almost completely surrounded by visceral peritoneum (Fig. 4.96). Additional folds of peritoneum connect the liver to the stomach (**hepatogastric ligament**), the duodenum (**hepatoduodenal ligament**), and the diaphragm (**right and left triangular ligaments** and **anterior and posterior coronary ligaments**).

The bare area of the liver is a part of the liver on the diaphragmatic surface where there is no intervening peritoneum between the liver and the diaphragm (Fig. 4.96):

- The anterior boundary of the bare area is indicated by a reflection of peritoneum—the anterior coronary ligament.
- The posterior boundary of the bare area is indicated by a reflection of peritoneum—the posterior coronary ligament.
- Where the coronary ligaments come together laterally, they form the right and left triangular ligaments.

Lobes

The liver is divided into right and left lobes by fossae for the gallbladder and the inferior vena cava (Fig. 4.95). The **right lobe of the liver** is the largest lobe, whereas the **left lobe of the liver** is smaller. The quadrate and caudate lobes are described as arising from the right lobe of the liver but functionally are distinct.

- The **quadrate lobe** is visible on the anterior part of the visceral surface of the liver and is bounded on the left by the fissure for the ligamentum teres and on the right by the fossa for the gallbladder. Functionally, it is related to the left lobe of the liver.
- The **caudate lobe** is visible on the posterior part of the visceral surface of the liver. It is bounded on the left by the fissure for the ligamentum venosum and on the right by the groove for the inferior vena cava. Functionally, it is separate from the right and the left lobes of the liver.

The arterial supply to the liver includes:

- the right hepatic artery from the hepatic artery proper (a branch of the common hepatic artery from the celiac trunk), and
- the left hepatic artery from the hepatic artery proper (a branch of the common hepatic artery from the celiac trunk).

Gallbladder

The **gallbladder** is a pear-shaped sac lying on the visceral surface of the right lobe of the liver in a fossa between the right and quadrate lobes (Fig. 4.95). It has:

- a rounded end (**fundus of the gallbladder**), which may project from the inferior border of the liver;

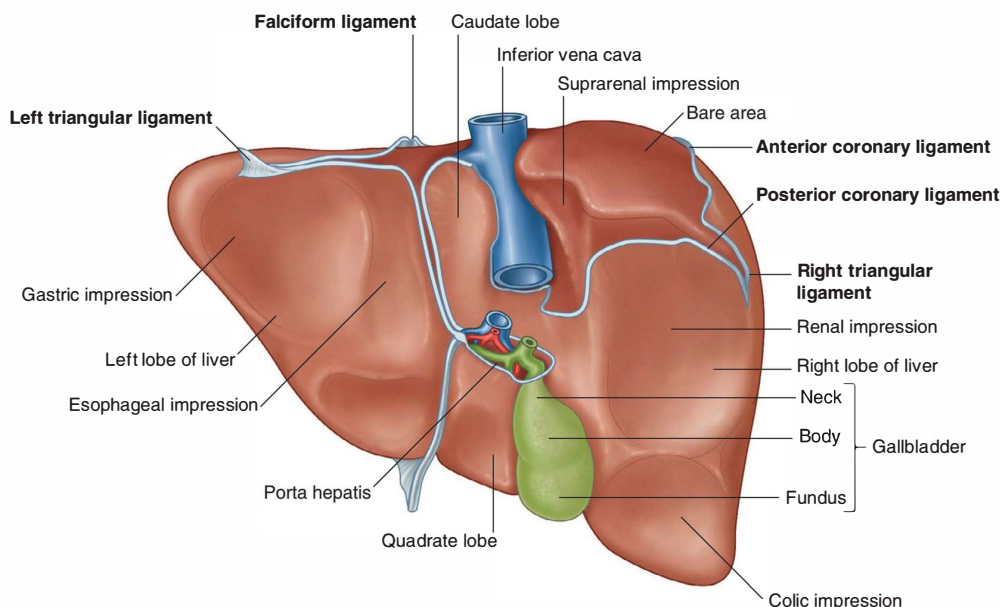


Fig. 4.96 Posterior view of the bare area of the liver and associated ligaments.



Abdomen

- a major part in the fossa (**body of the gallbladder**), which may be against the transverse colon and the superior part of the duodenum; and
- a narrow part (**neck of the gallbladder**) with mucosal folds forming the spiral fold.

The arterial supply to the gallbladder (Fig. 4.97) is the cystic artery from the right hepatic artery (a branch of the hepatic artery proper).

The gallbladder receives, concentrates, and stores bile from the liver.

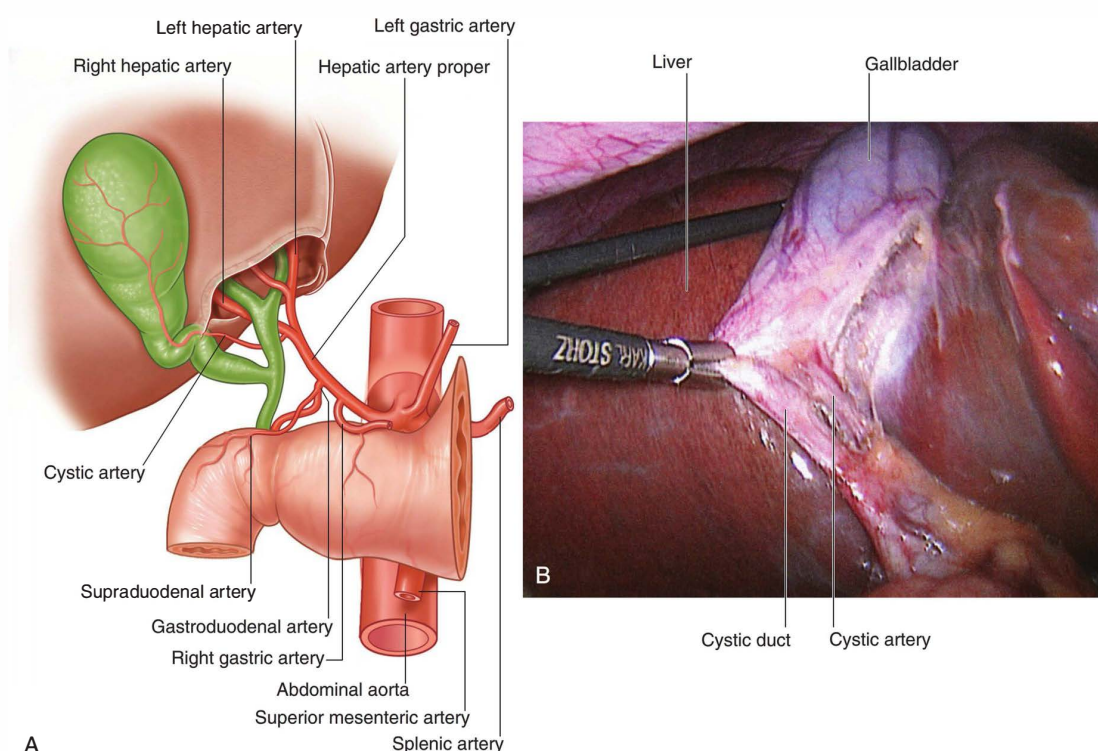


Fig. 4.97 Arterial supply to the liver and gallbladder. **A.** Schematic. **B.** Laparoscopic surgical view of cystic duct and cystic artery.

Pancreas

The pancreas lies mostly posterior to the stomach (Figs. 4.98 and 4.99). It extends across the posterior abdominal wall from the duodenum, on the right, to the spleen, on the left.

The pancreas is (secondarily) retroperitoneal except for a small part of its tail and consists of a head, uncinate process, neck, body, and tail.

- The **head of the pancreas** lies within the C-shaped concavity of the duodenum.

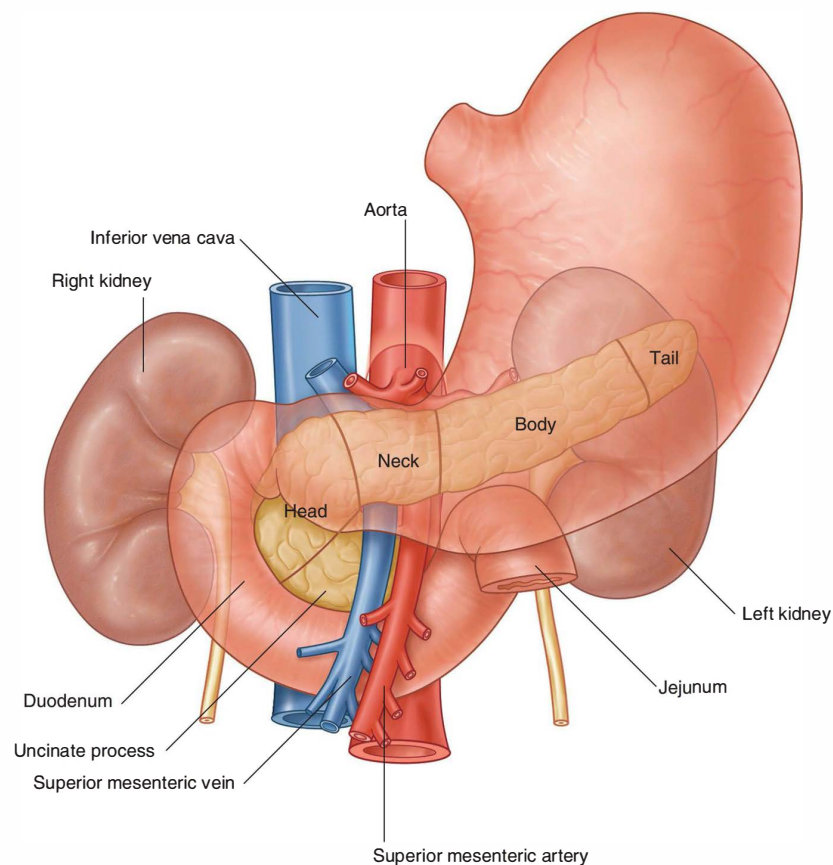


Fig. 4.98 Pancreas.



Abdomen

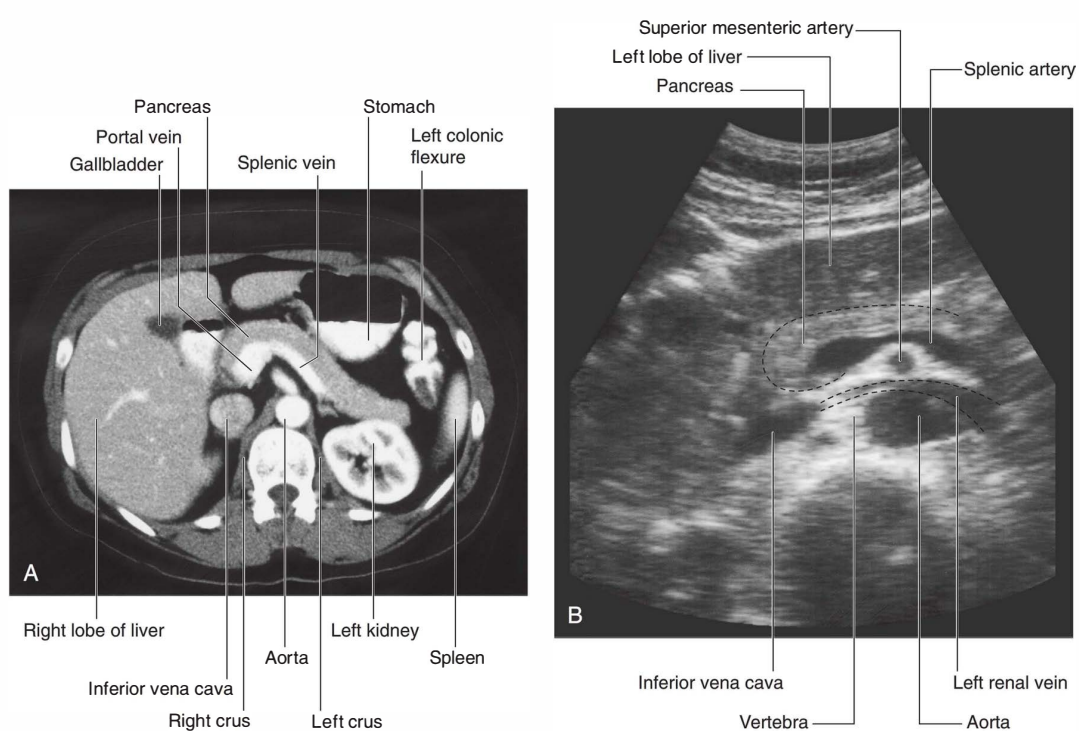


Fig. 4.99 Abdominal images. **A.** Abdominal computed tomogram, with contrast, in the axial plane. **B.** Abdominal ultrasound scan.

- Projecting from the lower part of the head is the **uncinate process**, which passes posterior to the superior mesenteric vessels.
- The **neck of the pancreas** is anterior to the superior mesenteric vessels. Posterior to the neck of the pancreas, the superior mesenteric and splenic veins join to form the portal vein.
- The **body of the pancreas** is elongate and extends from the neck to the tail of the pancreas.
- The **tail of the pancreas** passes between layers of the splenorenal ligament.

The **pancreatic duct** begins in the tail of the pancreas (Fig. 4.100). It passes to the right through the body of the pancreas and, after entering the head of the pancreas, turns inferiorly. In the lower part of the head of the pancreas, the pancreatic duct joins the bile duct. The joining of these two structures forms the **hepatopancreatic ampulla** (ampulla of Vater), which enters the descending (second) part of the duodenum at the **major duodenal**

papilla. Surrounding the ampulla is the **sphincter of ampulla** (sphincter of Oddi), which is a collection of smooth muscles.

The **accessory pancreatic duct** empties into the duodenum just above the major duodenal papilla at the **minor duodenal papilla** (Fig. 4.100). If the accessory duct is followed from the minor papilla into the head of the pancreas, a branch point is discovered:

- One branch continues to the left, through the head of the pancreas, and may connect with the pancreatic duct at the point where it turns inferiorly.
- A second branch descends into the lower part of the head of the pancreas, anterior to the pancreatic duct, and ends in the uncinate process.

The main and accessory pancreatic ducts usually communicate with each other. The presence of these two ducts reflects the embryological origin of the pancreas from dorsal and ventral buds from the foregut.

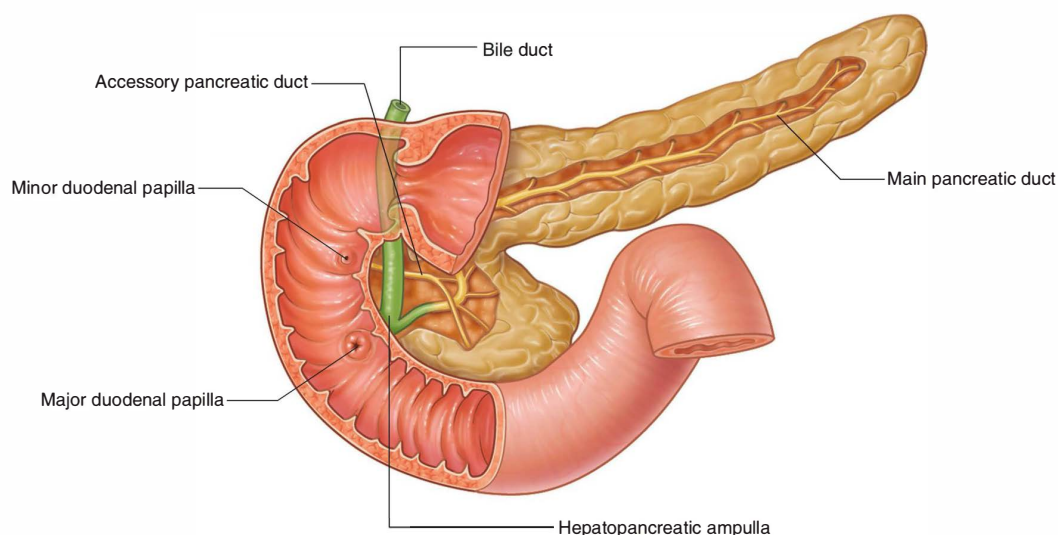


Fig. 4.100 Pancreatic duct system.



Abdomen

The arterial supply to the pancreas (Fig. 4.101) includes the:

- gastroduodenal artery from the common hepatic artery (a branch of the celiac trunk),
- anterior superior pancreaticoduodenal artery from the gastroduodenal artery,
- posterior superior pancreaticoduodenal artery from the gastroduodenal artery,
- dorsal pancreatic artery from the inferior pancreatic artery (a branch of the splenic artery),
- great pancreatic artery from the inferior pancreatic artery (a branch of the splenic artery),
- anterior inferior pancreaticoduodenal artery from the inferior pancreaticoduodenal artery (a branch of the superior mesenteric artery), and
- posterior inferior pancreaticoduodenal artery from the inferior pancreaticoduodenal artery (a branch of the superior mesenteric artery).

In the clinic

Annular pancreas

The pancreas develops from ventral and dorsal buds from the foregut. The dorsal bud forms most of the head, neck, and body of the pancreas. The ventral bud rotates around the bile duct to form part of the head and the uncinus process. If the ventral bud splits (becomes bifid), the two segments may encircle the duodenum. The duodenum is therefore constricted and may even undergo atresia, and be absent at birth because of developmental problems. After birth, the child may fail to thrive and may vomit due to poor gastric emptying.

Sometimes an annular pancreas is diagnosed in utero by ultrasound scanning. The obstruction of the duodenum may prevent the fetus from swallowing enough amniotic fluid, which may increase the overall volume of amniotic fluid in the amniotic sac surrounding the fetus (**polyhydramnios**).

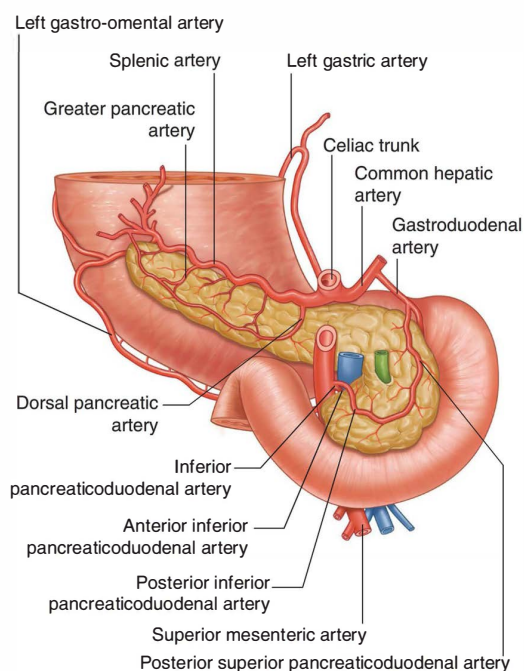


Fig. 4.101 Arterial supply to the pancreas. Posterior view.

In the clinic

Pancreatic cancer

Pancreatic cancer accounts for a significant number of deaths and is often referred to as the "silent killer." Malignant tumors of the pancreas may occur anywhere within the pancreas but are most frequent within the head and the neck. There are a number of nonspecific findings in patients with pancreatic cancer, including upper abdominal pain, loss of appetite, and weight loss. Depending on the exact site of the cancer, obstruction of the bile duct may occur, which can produce obstructive jaundice. Although surgery is indicated in patients where there is a possibility of cure, most detected cancers have typically spread locally, invading the portal vein and superior mesenteric vessels, and may extend into the porta hepatis. Lymph node spread also is common and these factors would preclude curative surgery.

Given the position of the pancreas, a surgical resection is a complex procedure involving resection of the region of pancreatic tumor usually with part of the duodenum, necessitating a complex bypass procedure.

Duct system for bile

The duct system for the passage of bile extends from the liver, connects with the gallbladder, and empties into the descending part of the duodenum (Fig. 4.102). The coalescence of ducts begins in the liver parenchyma and continues until the **right** and **left hepatic ducts** are formed. These drain the respective lobes of the liver.

The two hepatic ducts combine to form the **common hepatic duct**, which runs near the liver, with the hepatic artery proper and portal vein in the free margin of the lesser omentum.

As the common hepatic duct continues to descend, it is joined by the **cystic duct** from the gallbladder. This completes the formation of the **bile duct**. At this point, the bile duct lies to the right of the hepatic artery proper and usually to the right of, and anterior to, the portal vein in the free margin of the lesser omentum. The **omental foramen** is posterior to these structures at this point.

The bile duct continues to descend, passing posteriorly to the superior part of the duodenum before joining with the pancreatic duct to enter the descending part of the duodenum at the major duodenal papilla (Fig. 4.102).

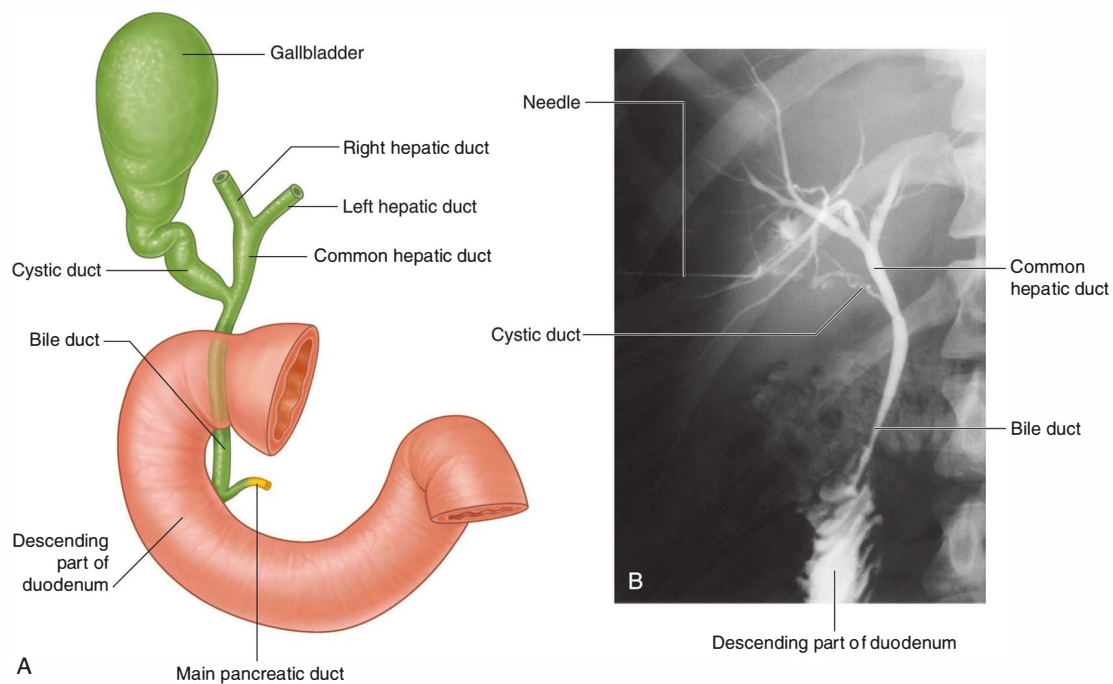


Fig. 4.102 Bile drainage. **A.** Duct system for passage of bile. **B.** Percutaneous transhepatic cholangiogram demonstrating the bile duct system.



Abdomen

Spleen

The spleen develops as part of the vascular system in the part of the dorsal mesentery that suspends the developing stomach from the body wall. In the adult, the spleen lies against the diaphragm, in the area of rib IX to rib X (Fig. 4.103). It is therefore in the left upper quadrant, or left hypochondrium, of the abdomen.

The spleen is connected to the:

- greater curvature of the stomach by the gastrosplenic ligament, which contains the short gastric and gastro-omental vessels; and

- left kidney by the splenorenal ligament (Fig. 4.104), which contains the splenic vessels.

Both these ligaments are parts of the greater omentum.

The spleen is surrounded by visceral peritoneum except in the area of the hilum on the medial surface of the spleen (Fig. 4.105). The **splenic hilum** is the entry point for the splenic vessels, and occasionally the tail of the pancreas reaches this area.

The arterial supply to the spleen (Fig. 4.106) is the splenic artery from the celiac trunk.

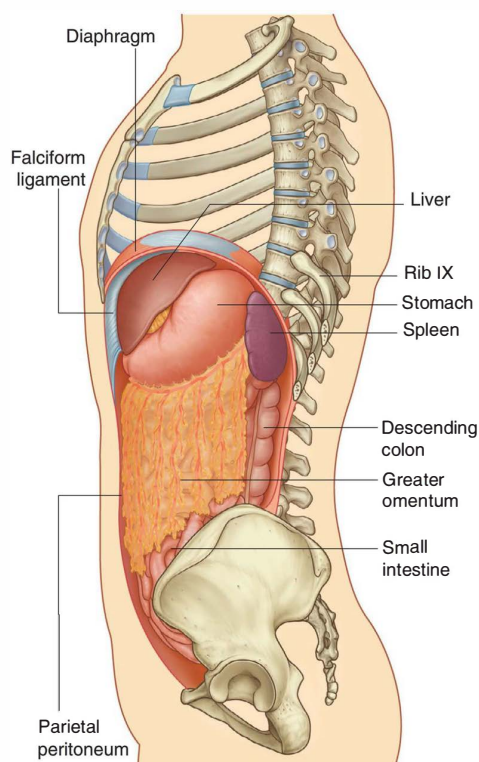


Fig. 4.103 Spleen.

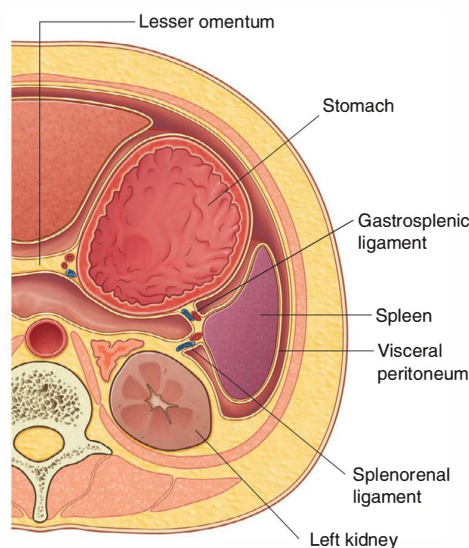


Fig. 4.104 Splenic ligaments and related vasculature.

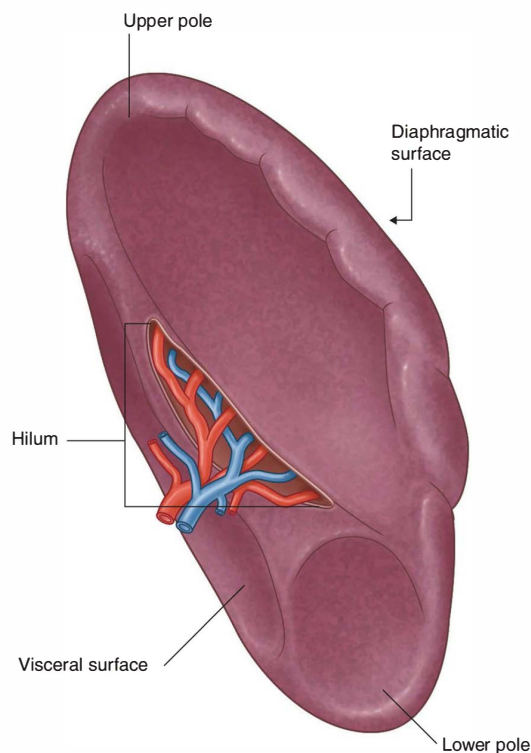


Fig. 4.105 Surfaces and hilum of the spleen.

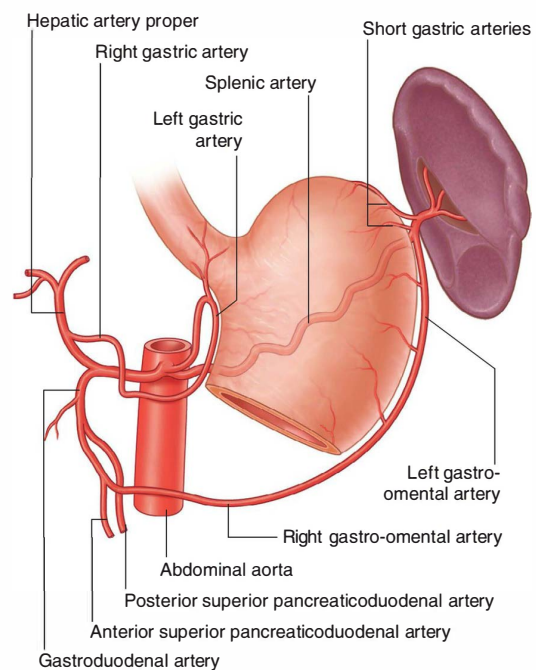


Fig. 4.106 Arterial supply to the spleen.

In the clinic

Segmental anatomy of the liver

For many years the segmental anatomy of the liver was of little importance. However, since the development of liver resection surgery, the size, shape, and segmental anatomy of the liver have become clinically important, especially with regard to liver resection for metastatic disease. Indeed, with detailed knowledge of the segments, curative surgery can be performed in patients with tumor metastases.

The liver is divided by the **principal plane**, which divides the organ into halves of approximately equal size. This imaginary line is defined by a parasagittal line that passes through the gallbladder fossa to the inferior vena cava. It is in this plane that the middle hepatic vein is found. Importantly, the principal plane divides the left half of the liver from the right half. The lobes of the liver are unequal in size and bear only little relevance to operative anatomy.

(continues)



Abdomen

In the clinic—cont'd

The traditional eight-segment anatomy of the liver relates to the hepatic arterial, portal, and biliary drainage of these segments (Fig. 4.107).

The caudate lobe is defined as segment I, and the remaining segments are numbered in a clockwise fashion up to segment VIII. The features are extremely consistent between individuals.

From a surgical perspective, a right hepatectomy would involve division of the liver in the principal plane in which segments V, VI, VII, and VIII would be removed, leaving segments I, II, III, and IV.

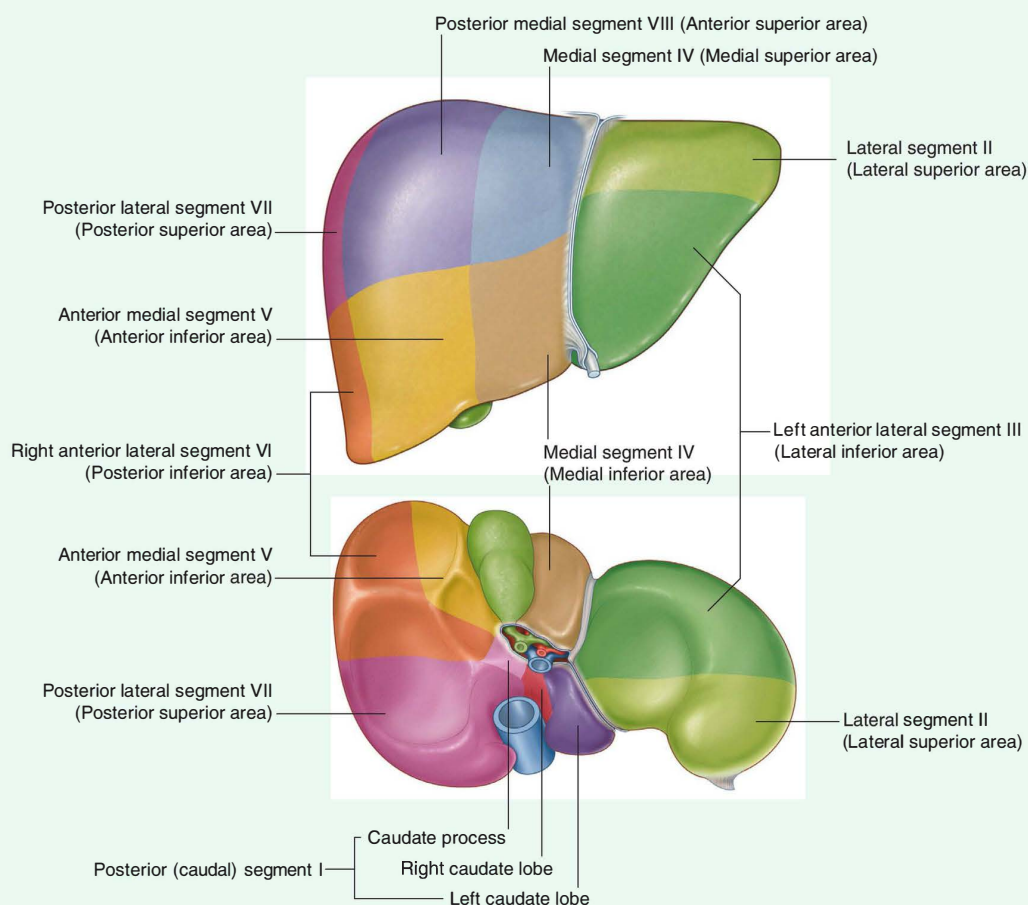


Fig. 4.107 Division of the liver into segments based upon the distributions of the bile ducts and hepatic vessels (Couinaud's segments).

In the clinic**Gallstones**

Gallstones are present in approximately 10% of people over the age of 40 and are more common in women. They consist of a variety of components but are predominantly a mixture of cholesterol and bile pigment. They may undergo calcification, which can be demonstrated on plain radiographs. Gallstones may be visualized incidentally as part of a routine abdominal ultrasound scan (Fig. 4.108) or on a plain radiograph.

From time to time, gallstones impact in the region of **Hartmann's pouch**, which is a bulbous region of the neck of the gallbladder. When the gallstone lodges in this area, the gallbladder cannot empty normally and contractions of the gallbladder wall produce severe pain. If this persists, a **cholecystectomy** (removal of the gallbladder) may be necessary.

Sometimes the gallbladder may become inflamed (**cholecystitis**). If the inflammation involves the related parietal peritoneum of the diaphragm, pain may not only occur in the right upper quadrant of the abdomen but may also be referred to the shoulder on the right side. This referred pain is due to the innervation of the visceral peritoneum of the diaphragm by spinal cord levels (C3 to C5) that also innervate skin over the shoulder. In this case, one somatic sensory region of low sensory output (diaphragm) is referred to another somatic sensory region of high sensory output (dermatomes).

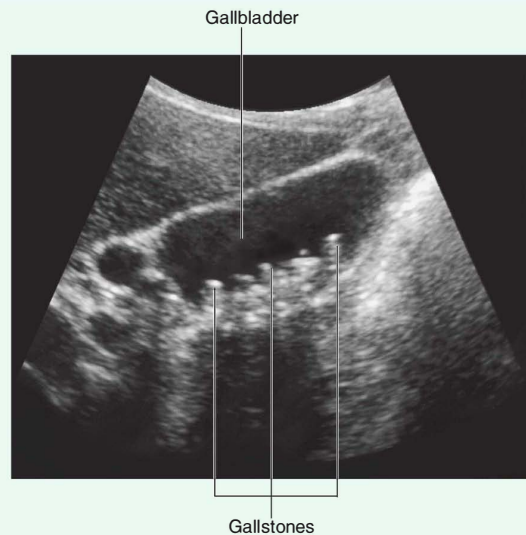


Fig. 4.108 Gallbladder containing multiple stones. Ultrasound scan.

From time to time, small gallstones pass into the bile duct and are trapped in the region of the sphincter of the ampulla, which obstructs the flow of bile into the duodenum. This, in turn, produces jaundice.

In the clinic**Jaundice**

Jaundice is a yellow discoloration of the skin caused by excess bile pigment (bilirubin) within the plasma. The yellow color is best appreciated by looking at the normally white sclerae of the eyes, which turn yellow.

The extent of the elevation of the bile pigments and the duration for which they have been elevated account for the severity of jaundice.

Simplified explanation to understanding the types of jaundice and their anatomical causes

When red blood cells are destroyed by the reticuloendothelial system, the iron from the hemoglobin molecule is recycled, whereas the porphyrin ring (globin) compounds are broken down to form fat-soluble bilirubin. On reaching the liver via the bloodstream, the fat-soluble bilirubin is converted to a water-soluble form of bilirubin. This water-soluble bilirubin is secreted into the biliary tree and then in turn into the bowel, where it forms the dark color of the stool.

Prehepatic jaundice

This type of jaundice is usually produced by conditions where there is an excessive breakdown of red blood cells (e.g., in incompatible blood transfusion and hemolytic anemia).

Hepatic jaundice

The complex biochemical reactions for converting fat-soluble into water-soluble bilirubin may be affected by inflammatory change within the liver (e.g., from hepatitis or chronic liver disease, such as liver cirrhosis) and poisons (e.g., paracetamol overdose).

Posthepatic jaundice

Any obstruction of the biliary tree can produce jaundice, but the two most common causes are gallstones within the bile duct and an obstructing tumor at the head of the pancreas.



Abdomen

In the clinic

Spleen disorders

From a clinical point of view, there are two main categories of spleen disorders: rupture and enlargement.

Splenic rupture

This tends to occur when there is localized trauma to the left upper quadrant. It may be associated with left lower rib fractures. Because the spleen has such an extremely thin capsule, it is susceptible to injury even when there is no damage to surrounding structures, and because the spleen is highly vascular, when ruptured, it bleeds profusely into the peritoneal cavity. Splenic rupture should always be suspected with blunt abdominal injury. Current treatments preserve as much of the spleen as possible, but some patients require splenectomy.

Splenic enlargement

The spleen is an organ of the reticuloendothelial system. Diseases that affect the reticuloendothelial system (e.g., leukemia, lymphoma, and certain infections) may produce generalized lymphadenopathy and enlargement of the spleen (**splenomegaly**) (Fig. 4.109).



Fig. 4.109 Coronal CT of the abdomen containing a massively enlarged spleen (splenomegaly).

Arterial supply

The **abdominal aorta** begins at the aortic hiatus of the diaphragm, anterior to the lower border of vertebra TXII (Fig. 4.110). It descends through the abdomen, anterior to the vertebral bodies, and by the time it ends at the level of vertebra LIV it is slightly to the left of midline. The terminal branches of the abdominal aorta are the two **common iliac arteries**.

Anterior branches of the abdominal aorta

The abdominal aorta has anterior, lateral, and posterior branches as it passes through the abdominal cavity. The three anterior branches supply the gastrointestinal viscera: the **celiac trunk** and the **superior mesenteric** and **inferior mesenteric arteries** (Fig. 4.110).

The primitive gut tube can be divided into foregut, midgut, and hindgut regions. The boundaries of these

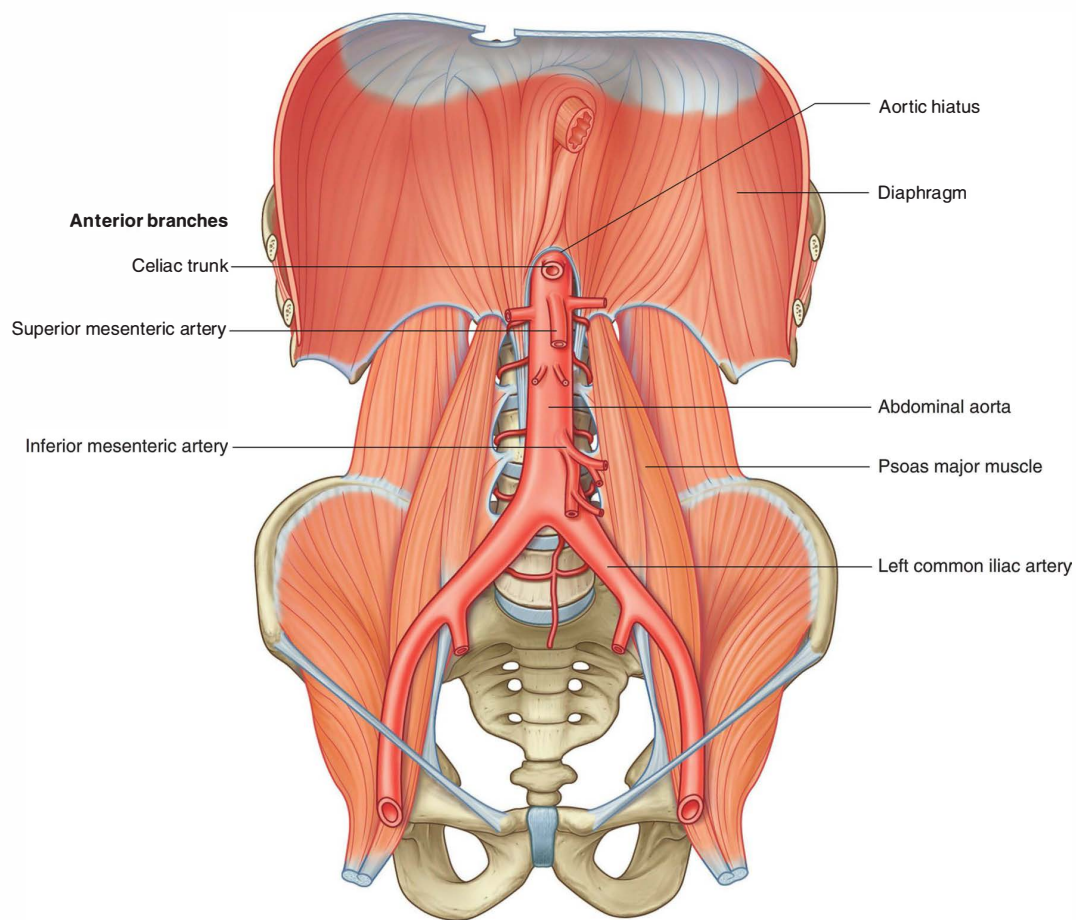


Fig. 4.110 Anterior branches of the abdominal aorta.



Abdomen

regions are directly related to the areas of distribution of the three anterior branches of the abdominal aorta (Fig. 4.111).

- The **foregut** begins with the abdominal esophagus and ends just inferior to the major duodenal papilla, midway along the descending part of the duodenum. It includes the abdominal esophagus, stomach,

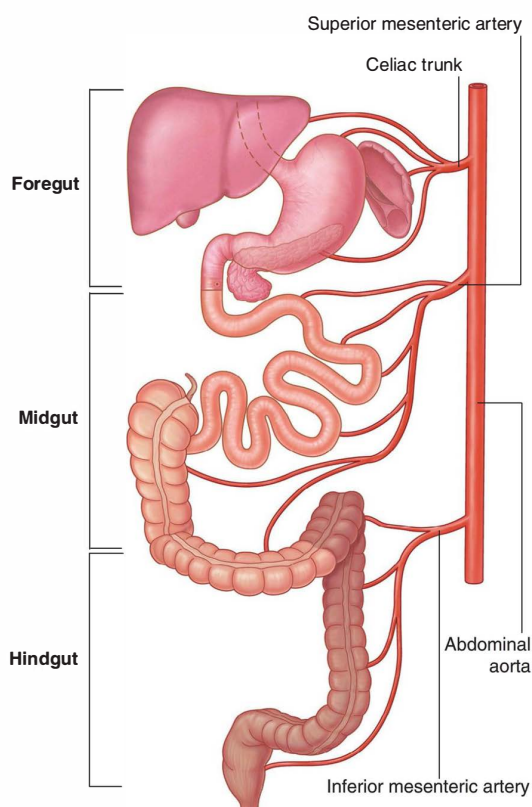


Fig. 4.111 Divisions of the gastrointestinal tract into foregut, midgut, and hindgut, summarizing the primary arterial supply to each segment.

duodenum (superior to the major papilla), liver, pancreas, and gallbladder. The spleen also develops in relation to the foregut region. The foregut is supplied by the celiac trunk.

- The **midgut** begins just inferior to the major duodenal papilla, in the descending part of the duodenum, and ends at the junction between the proximal two-thirds and distal one-third of the transverse colon. It includes the duodenum (inferior to the major duodenal papilla), jejunum, ileum, cecum, appendix, ascending colon, and right two-thirds of the transverse colon. The midgut is supplied by the superior mesenteric artery (Fig. 4.111).
- The **hindgut** begins just before the left colic flexure (the junction between the proximal two-thirds and distal one-third of the transverse colon) and ends midway through the anal canal. It includes the left one-third of the transverse colon, descending colon, sigmoid colon, rectum, and upper part of the anal canal. The hindgut is supplied by the inferior mesenteric artery (Fig. 4.111).

Celiac trunk

The celiac trunk is the anterior branch of the abdominal aorta supplying the foregut. It arises from the abdominal aorta immediately below the aortic hiatus of the diaphragm (Fig. 4.112), anterior to the upper part of vertebra L1. It immediately divides into the left gastric, splenic, and common hepatic arteries.

Left gastric artery

The **left gastric artery** is the smallest branch of the celiac trunk. It ascends to the cardioesophageal junction and sends **esophageal branches** upward to the abdominal part of the esophagus (Fig. 4.112). Some of these branches continue through the esophageal hiatus of the diaphragm and anastomose with esophageal branches from the thoracic aorta. The left gastric artery itself turns to the right and descends along the lesser curvature of the stomach in the lesser omentum. It supplies both surfaces of the stomach in this area and anastomoses with the right gastric artery.

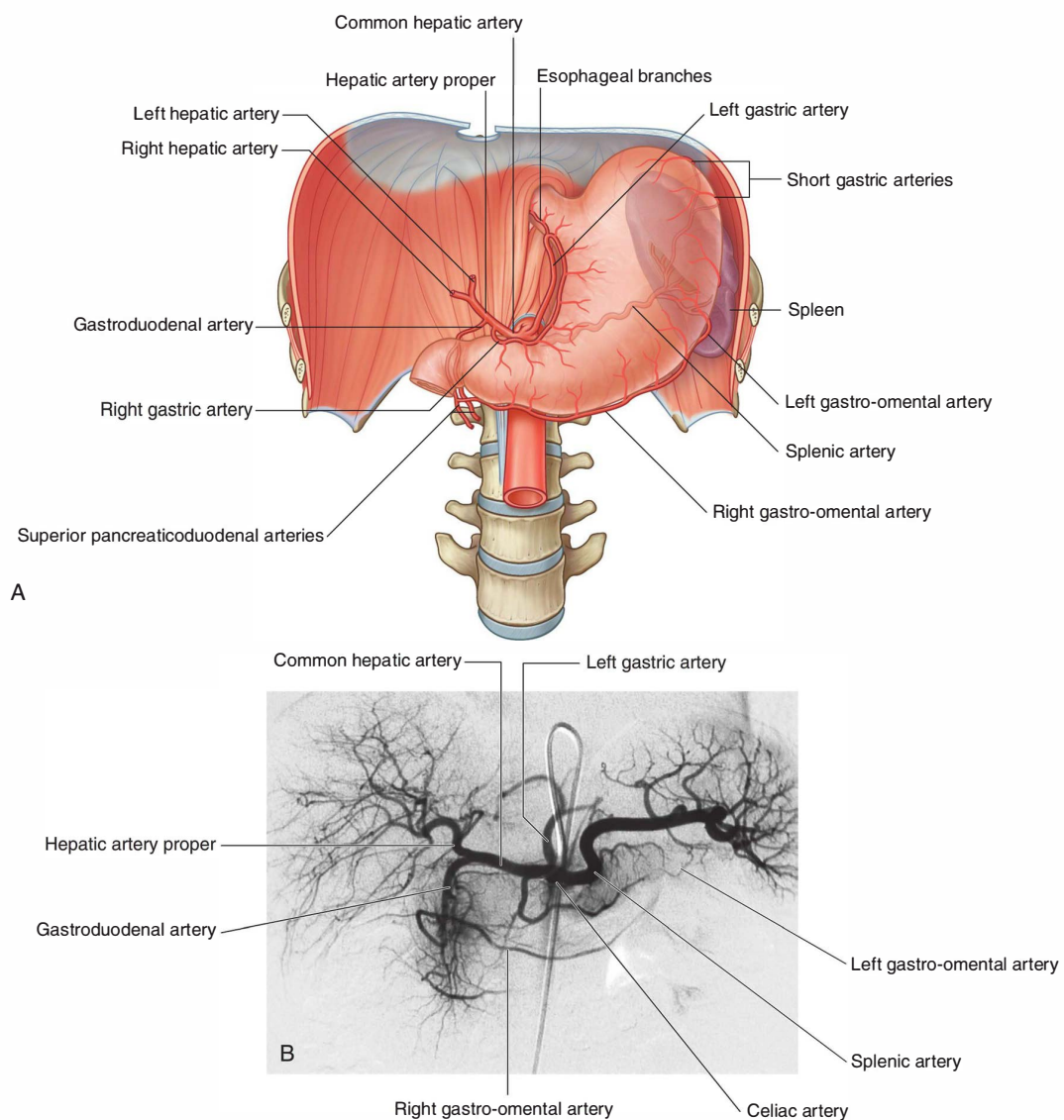


Fig. 4.112 Celiac trunk. **A.** Distribution of the celiac trunk. **B.** Digital subtraction angiography of the celiac trunk and its branches.



Abdomen

Splenic artery

The **splenic artery**, the largest branch of the celiac trunk, takes a tortuous course to the left along the superior border of the pancreas (Fig. 4.112). It travels in the splenorenal ligament and divides into numerous branches, which enter the hilum of the spleen. As the splenic artery passes along the superior border of the pancreas, it gives off numerous small branches to supply the neck, body, and tail of the pancreas (Fig. 4.113).

Approaching the spleen, the splenic artery gives off **short gastric arteries**, which pass through the gastro-splenic ligament to supply the fundus of the stomach. It also gives off the **left gastro-omental artery**, which runs to the right along the greater curvature of the stomach, and anastomoses with the right gastro-omental artery.

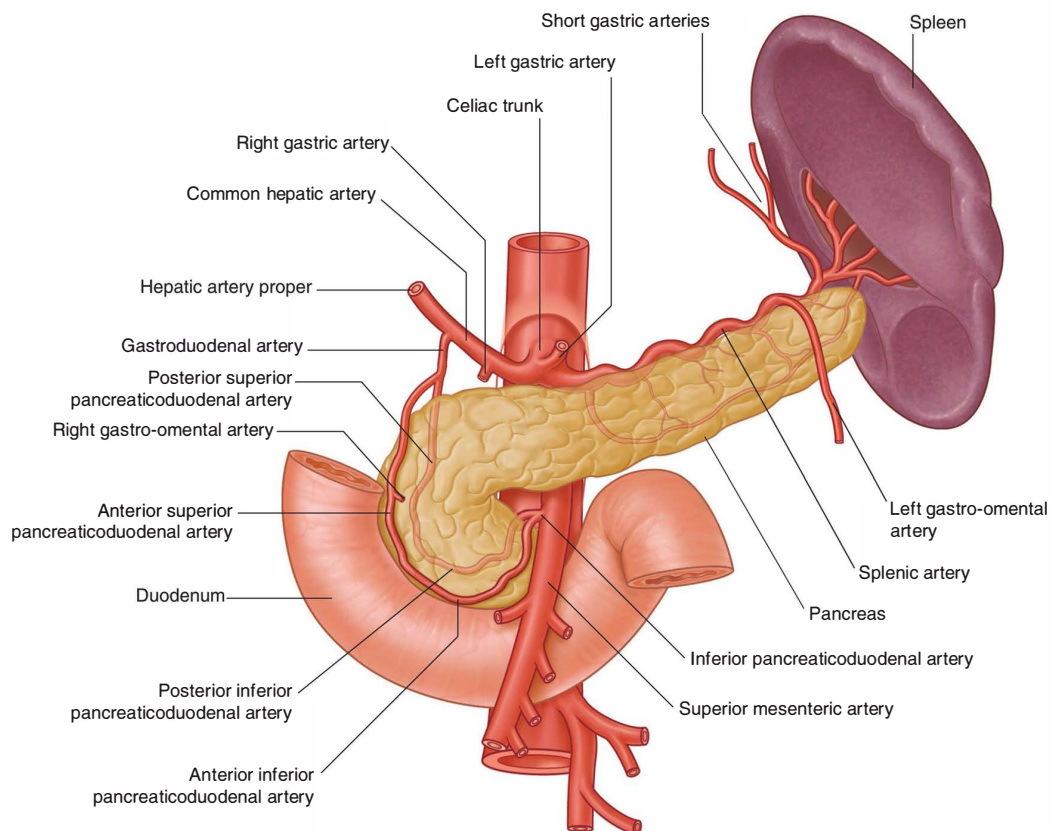


Fig. 4.113 Arterial supply to the pancreas.

Common hepatic artery

The **common hepatic artery** is a medium-sized branch of the celiac trunk that runs to the right and divides into its two terminal branches, the **hepatic artery proper** and the **gastroduodenal artery** (Figs. 4.112 and 4.113).

The hepatic artery proper ascends toward the liver in the free edge of the lesser omentum. It runs to the left of the bile duct and anterior to the portal vein, and divides into the **right** and **left hepatic arteries** near the porta hepatis (Fig. 4.114).

As the right hepatic artery nears the liver, it gives off the cystic artery to the gallbladder.

The gastroduodenal artery may give off the **supraduodenal artery** and does give off the posterior superior pancreaticoduodenal artery near the upper border of the superior part of the duodenum. After these branches the gastroduodenal artery continues descending posterior

to the superior part of the duodenum. Reaching the lower border of the superior part of the duodenum, the gastroduodenal artery divides into its terminal branches, the **right gastro-omental artery** and the **anterior superior pancreaticoduodenal artery** (Fig. 4.113).

The right gastro-omental artery passes to the left, along the greater curvature of the stomach, eventually anastomosing with the left gastro-omental artery from the splenic artery. The right gastro-omental artery sends branches to both surfaces of the stomach and additional branches descend into the greater omentum.

The anterior superior pancreaticoduodenal artery descends and, along with the posterior superior pancreaticoduodenal artery, supplies the head of the pancreas and the duodenum (Fig. 4.113). These vessels eventually anastomose with the anterior and posterior branches of the inferior pancreaticoduodenal artery.

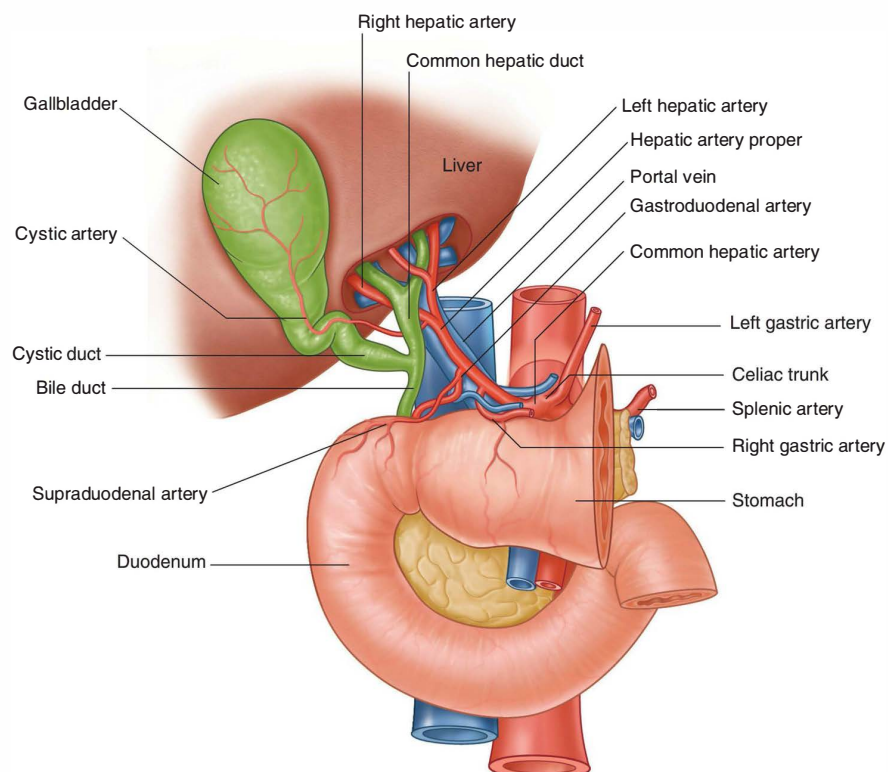


Fig. 4.114 Distribution of the common hepatic artery.



Abdomen

Superior mesenteric artery

The superior mesenteric artery is the anterior branch of the abdominal aorta supplying the midgut. It arises from the abdominal aorta immediately below the celiac artery (Fig. 4.115), anterior to the lower part of vertebra L1.

The superior mesenteric artery is crossed anteriorly by the splenic vein and the neck of the pancreas. Posterior to the artery are the left renal vein, the uncinate process of the pancreas, and the inferior part of the duodenum. After giving off its first branch (the **inferior pancreaticoduodenal artery**), the superior mesenteric artery gives off **jejunal** and **ileal arteries** on its left (Fig. 4.115). Branching from the right side of the main trunk of the superior

mesenteric artery are three vessels—the **middle colic**, **right colic**, and **ileocolic arteries**—which supply the terminal ileum, cecum, ascending colon, and two-thirds of the transverse colon.

Inferior pancreaticoduodenal artery

The inferior pancreaticoduodenal artery is the first branch of the superior mesenteric artery. It divides immediately into anterior and posterior branches, which ascend on the corresponding sides of the head of the pancreas. Superiorly, these arteries anastomose with anterior and posterior superior pancreaticoduodenal arteries (see Figs. 4.114 and 4.115). This arterial network supplies the head and uncinate process of the pancreas and the duodenum.

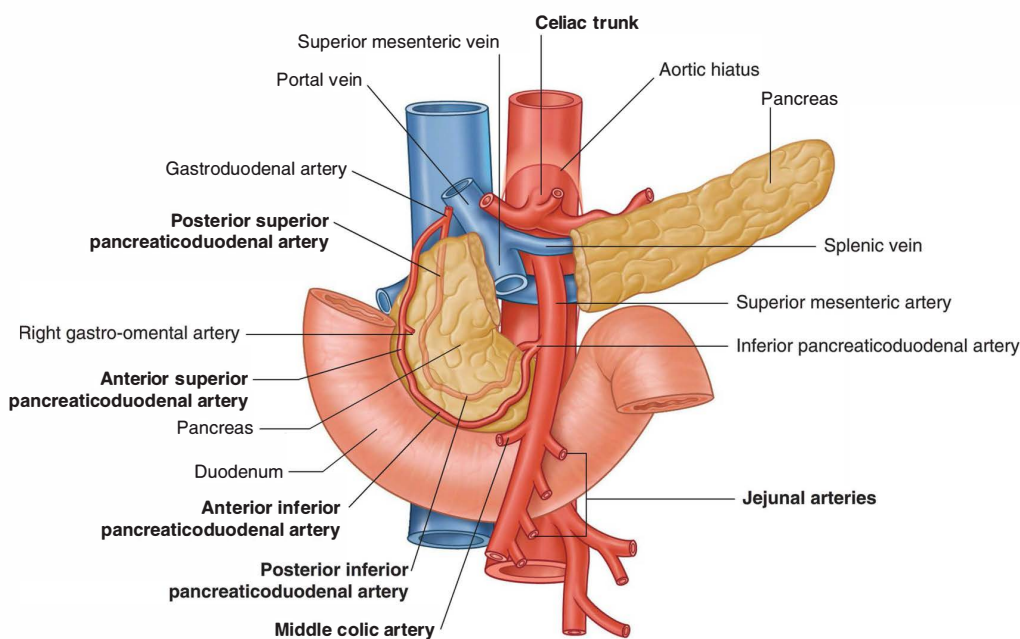


Fig. 4.115 Initial branching and relationships of the superior mesenteric artery.

Jejunal and ileal arteries

Distal to the inferior pancreaticoduodenal artery, the superior mesenteric artery gives off numerous branches. Arising on the left is a large number of jejunal and ileal arteries supplying the jejunum and most of the ileum (Fig. 4.116). These branches leave the main trunk of the

artery, pass between two layers of the mesentery, and form anastomosing arches or arcades as they pass outward to supply the small intestine. The number of arterial arcades increases distally along the gut.

There may be single and then double arcades in the area of the jejunum, with a continued increase in the number

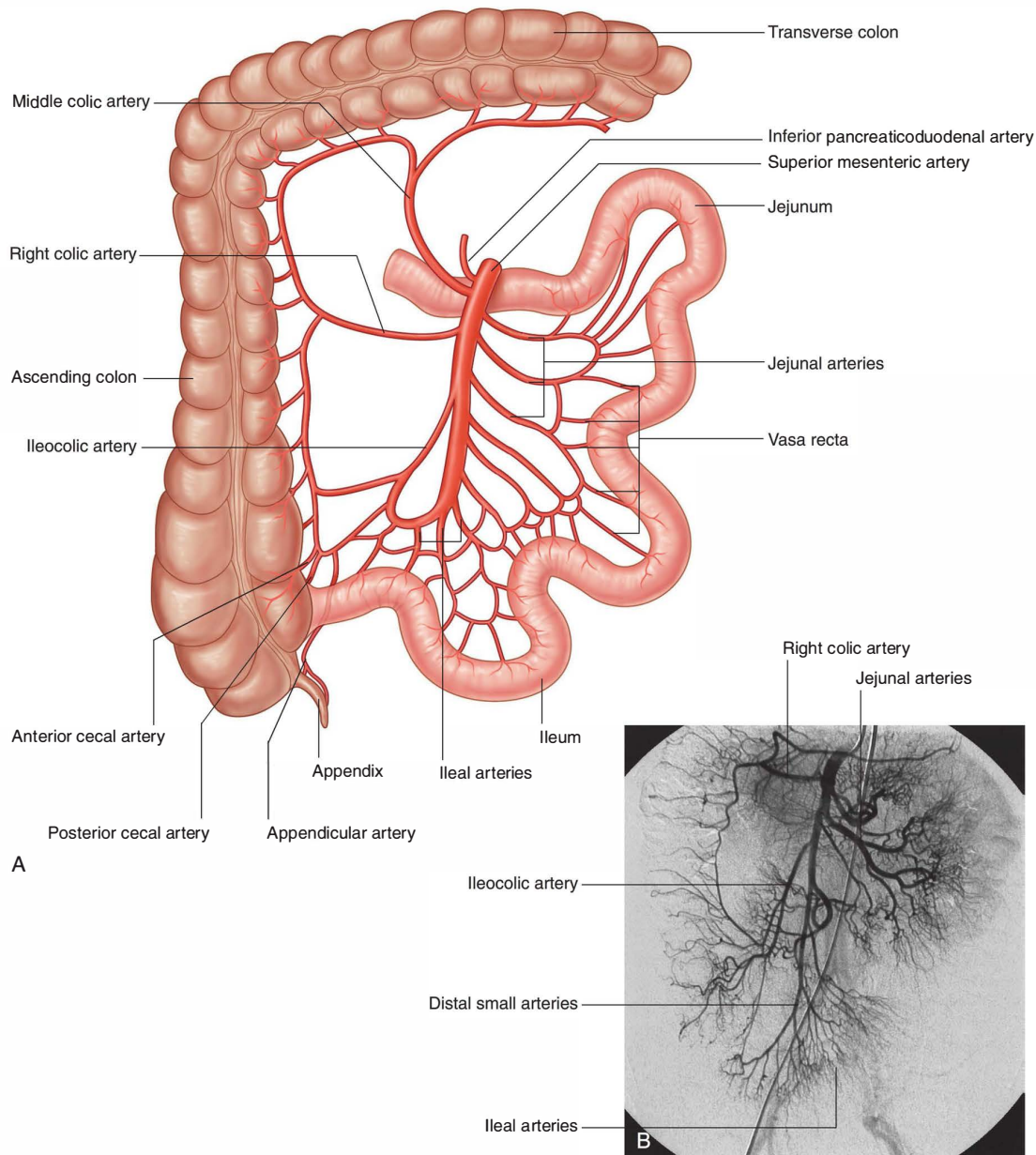


Fig. 4.116 Superior mesenteric artery. **A.** Distribution of the superior mesenteric artery. **B.** Digital subtraction angiography of the superior mesenteric artery and its branches.



Abdomen

of arcades moving into and through the area of the ileum. Extending from the terminal arcade are vasa recta (straight arteries), which provide the final direct vascular supply to the walls of the small intestine. The **vasa recta** supplying the jejunum are usually long and close together, forming narrow windows visible in the mesentery. The vasa recta supplying the ileum are generally short and far apart, forming low broad windows.

Middle colic artery

The middle colic artery is the first of the three branches from the right side of the main trunk of the superior mesenteric artery (Fig. 4.116). Arising as the superior mesenteric artery emerges from beneath the pancreas, the middle colic artery enters the transverse mesocolon and divides into right and left branches. The right branch anastomoses with the right colic artery while the left branch anastomoses with the left colic artery, which is a branch of the inferior mesenteric artery.

Right colic artery

Continuing distally along the main trunk of the superior mesenteric artery, the right colic artery is the second of the three branches from the right side of the main trunk of the superior mesenteric artery (Fig. 4.115). It is an inconsistent branch, and passes to the right in a retroperitoneal position to supply the ascending colon. Nearing the colon, it divides into a descending branch, which anastomoses with the ileocolic artery, and an ascending branch, which anastomoses with the middle colic artery.

Ileocolic artery

The final branch arising from the right side of the superior mesenteric artery is the ileocolic artery (Fig. 4.116). This passes downward and to the right toward the right iliac fossa where it divides into superior and inferior branches:

- The superior branch passes upward along the ascending colon to anastomose with the right colic artery.
- The inferior branch continues toward the ileocolic junction, dividing into **colic**, **cecal**, **appendicular**, and **ileal branches** (Fig. 4.116).

The specific pattern of distribution and origin of these branches is variable:

- The colic branch crosses to the ascending colon and passes upward to supply the first part of the ascending colon.
- Anterior and posterior cecal branches, arising either as a common trunk or as separate branches, supply corresponding sides of the cecum.

- The appendicular branch enters the free margin of and supplies the mesoappendix and the appendix.
- The ileal branch passes to the left and ascends to supply the final part of the ileum before anastomosing with the superior mesenteric artery.

Inferior mesenteric artery

The inferior mesenteric artery is the anterior branch of the abdominal aorta that supplies the hindgut. It is the smallest of the three anterior branches of the abdominal aorta and arises anterior to the body of vertebra LIII. Initially, the inferior mesenteric artery descends anteriorly to the aorta and then passes to the left as it continues inferiorly (Fig. 4.117). Its branches include the **left colic artery**, **several sigmoid arteries**, and the **superior rectal artery**.

Left colic artery

The left colic artery is the first branch of the inferior mesenteric artery (Fig. 4.117). It ascends retroperitoneally, dividing into ascending and descending branches:

- The ascending branch passes anteriorly to the left kidney, then enters the transverse mesocolon, and passes superiorly to supply the upper part of the descending colon and the distal part of the transverse colon; it anastomoses with branches of the middle colic artery.
- The descending branch passes inferiorly, supplying the lower part of the descending colon, and anastomoses with the first sigmoid artery.

Sigmoid arteries

The sigmoid arteries consist of two to four branches, which descend to the left, in the sigmoid mesocolon, to supply the lowest part of the descending colon and the sigmoid colon (Fig. 4.117). These branches anastomose superiorly with branches from the left colic artery and inferiorly with branches from the superior rectal artery.

Superior rectal artery

The terminal branch of the inferior mesenteric artery is the superior rectal artery (Fig. 4.117). This vessel descends into the pelvic cavity in the sigmoid mesocolon, crossing the left common iliac vessels. Opposite vertebra SIII, the superior rectal artery divides. The two terminal branches descend on each side of the rectum, dividing into smaller branches in the wall of the rectum. These smaller branches continue inferiorly to the level of the internal anal sphincter, anastomosing along the way with branches from the middle rectal arteries (from the internal iliac artery) and the inferior rectal arteries (from the internal pudendal artery).

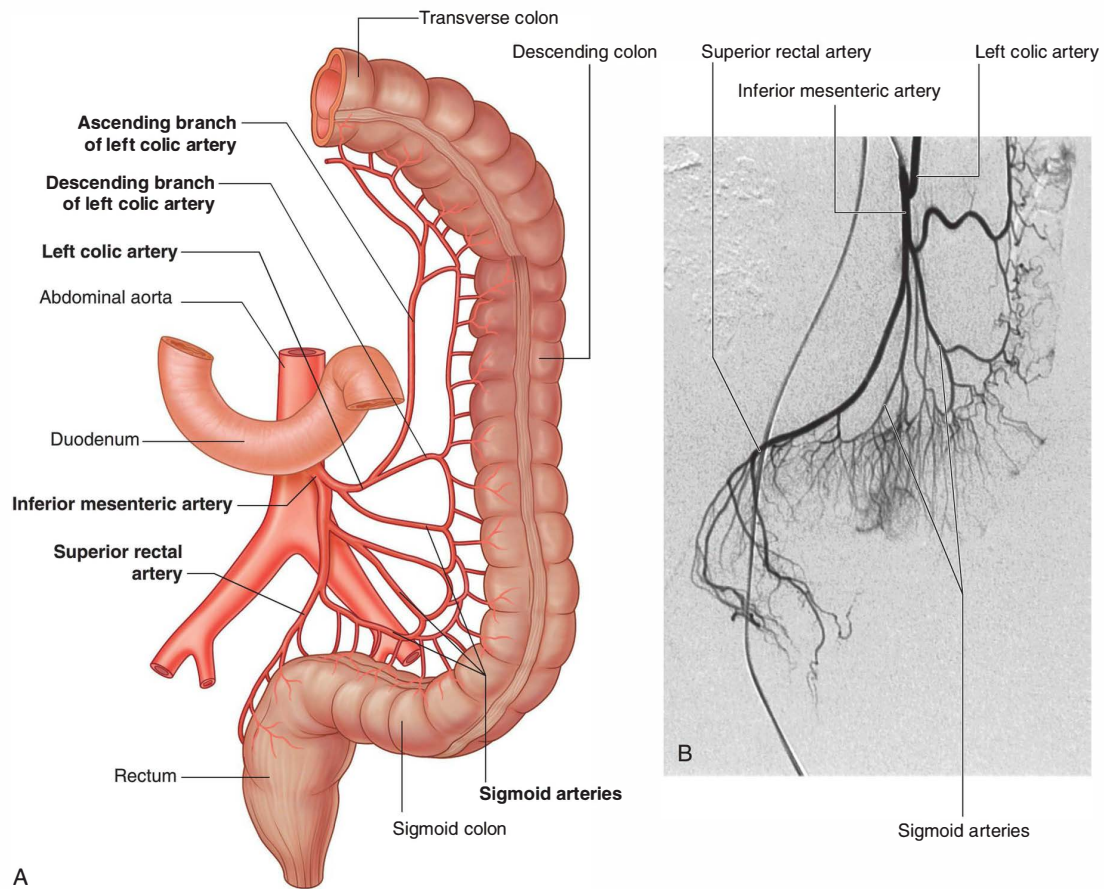


Fig. 4.117 Inferior mesenteric artery. **A.** Distribution of the inferior mesenteric artery. **B.** Digital subtraction angiography of the inferior mesenteric artery and its branches.

In the clinic

Vascular supply to the gastrointestinal system

The abdominal parts of the gastrointestinal system are supplied mainly by the celiac trunk and the superior mesenteric and inferior mesenteric arteries (Fig. 4.118):

- The celiac trunk supplies the lower esophagus, stomach, superior part of the duodenum, and proximal half of the descending part of the duodenum.
- The superior mesenteric artery supplies the rest of the duodenum, the jejunum, the ileum, the ascending colon, and the proximal two-thirds of the transverse colon.
- The inferior mesenteric artery supplies the rest of the transverse colon, the descending colon, the sigmoid colon, and most of the rectum.

Along the descending part of the duodenum there is a potential watershed area between the celiac trunk blood supply and the superior mesenteric arterial blood supply. It is unusual for this area to become ischemic, whereas the watershed area between the superior mesenteric artery and the inferior mesenteric artery, at the splenic flexure, is extremely vulnerable to ischemia.

In certain disease states, the region of the splenic flexure of the colon can become ischemic. When this occurs, the mucosa sloughs off, rendering the patient susceptible to infection and perforation of the large bowel, which then requires urgent surgical attention.

Arteriosclerosis may occur throughout the abdominal aorta and at the openings of the celiac trunk and the superior mesenteric and inferior mesenteric arteries. Not
(continues)



Abdomen

In the clinic—cont'd

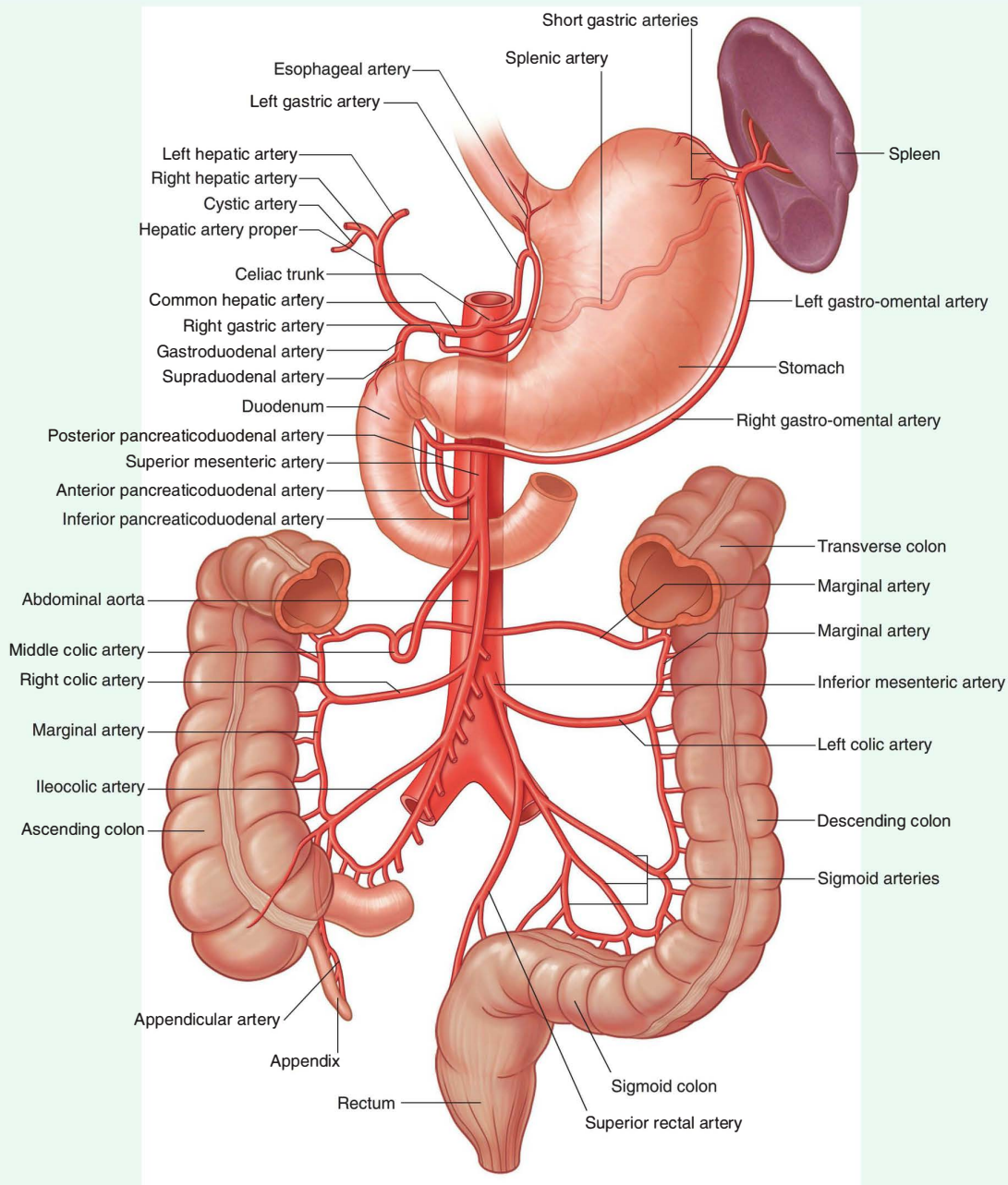


Fig. 4.118 Arterial supply to the abdominal parts of the gastrointestinal system and to the spleen.

In the clinic—cont'd

infrequently, the inferior mesenteric artery becomes occluded. Interestingly, many of these patients do not suffer any complications, because anastomoses between the right, middle, and left colic arteries gradually enlarge, forming a continuous **marginal artery**. The distal large bowel therefore becomes supplied by this enlarged marginal artery (marginal artery of Drummond), which replaces the blood supply of the inferior mesenteric artery (Fig. 4.119).

If the openings of the celiac trunk and superior mesenteric artery become narrowed, the blood supply to the gut is diminished. After a heavy meal, the oxygen demand of the bowel therefore outstrips the limited supply of blood through the stenosed vessels, resulting in severe pain and discomfort (**mesenteric angina**). Patients with this condition tend not to eat because of the pain and rapidly lose weight. The diagnosis is determined by aortic angiography, and the stenoses of the celiac trunk and superior mesenteric artery are best appreciated in the lateral view.



Fig. 4.119 Enlarged marginal artery connecting the superior and inferior mesenteric arteries. Digital subtraction angiogram.



Abdomen

Venous drainage

Venous drainage of the spleen, pancreas, gallbladder, and abdominal part of the gastrointestinal tract, except for the inferior part of the rectum, is through the portal system of veins, which deliver blood from these structures to the liver. Once blood passes through the hepatic sinusoids, it passes through progressively larger veins until it enters the hepatic veins, which return the venous blood to the inferior vena cava just inferior to the diaphragm.

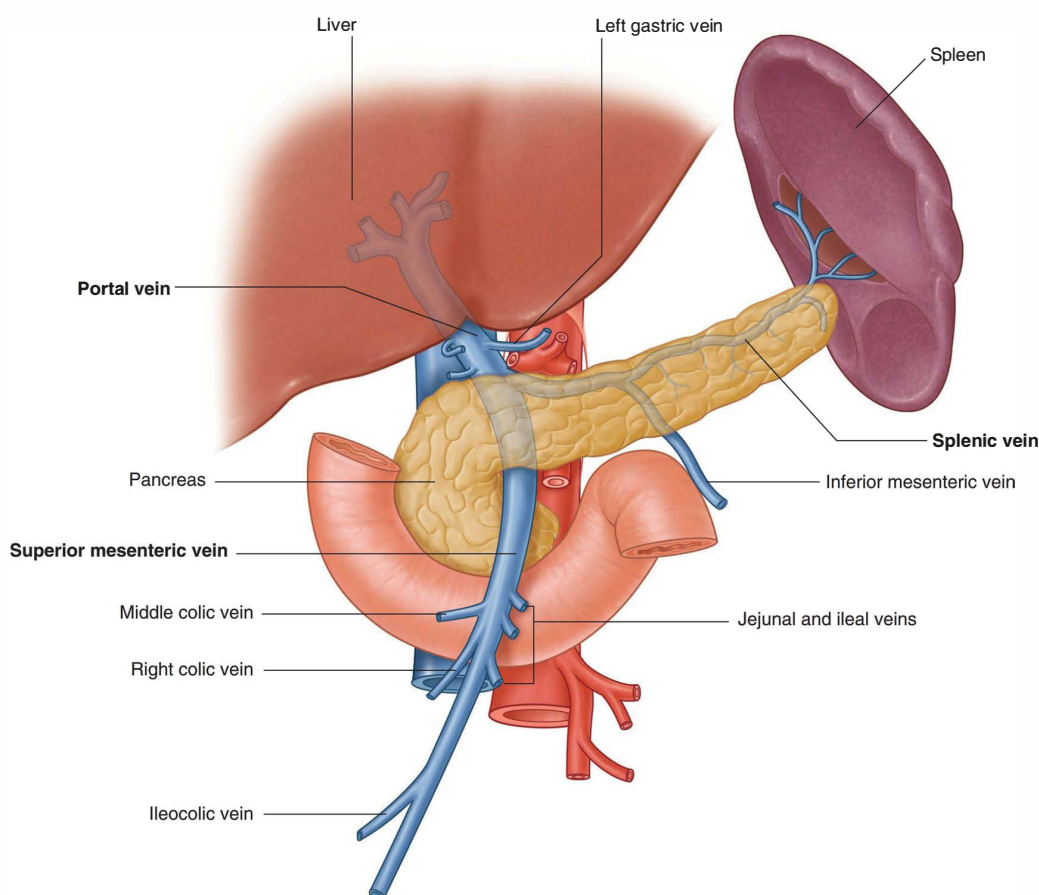
Portal vein

The **portal vein** is the final common pathway for the transport of venous blood from the spleen, pancreas, gallbladder, and abdominal part of the gastrointestinal tract. It is formed by the union of the **splenic vein** and the **superior mesenteric vein** posterior to the neck of the pancreas at the level of vertebra LII (Fig. 4.120).

Ascending toward the liver, the portal vein passes posterior to the superior part of the duodenum and enters the right margin of the lesser omentum. As it passes through this part of the lesser omentum, it is anterior to the omental foramen and posterior to both the bile duct, which is slightly to its right, and the hepatic artery proper, which is slightly to its left (see Fig. 4.114, p. 347).

On approaching the liver, the portal vein divides into **right** and **left branches**, which enter the liver parenchyma. Tributaries to the portal vein include:

- **right** and **left gastric veins** draining the lesser curvature of the stomach and abdominal esophagus,
- **cystic veins** from the gallbladder, and
- the **para-umbilical veins**, which are associated with the obliterated umbilical vein and connect to veins on the anterior abdominal wall (Fig. 4.122 on p. 357).



Splenic vein

The splenic vein forms from numerous smaller vessels leaving the hilum of the spleen (Fig. 4.121). It passes to the right, passing through the splenorenal ligament with the splenic artery and the tail of the pancreas. Continuing to the right, the large, straight splenic vein is in contact with the body of the pancreas as it crosses the posterior abdominal wall. Posterior to the neck of the pancreas, the splenic vein joins the superior mesenteric vein to form the portal vein.

Tributaries to the splenic vein include:

- **short gastric veins** from the fundus and left part of the greater curvature of the stomach,

- the **left gastro-omental vein** from the greater curvature of the stomach,
- **pancreatic veins** draining the body and tail of the pancreas, and
- usually the **inferior mesenteric vein**.

Superior mesenteric vein

The superior mesenteric vein drains blood from the small intestine, cecum, ascending colon, and transverse colon (Fig. 4.121). It begins in the right iliac fossa as veins draining the terminal ileum, cecum, and appendix join, and ascends in the mesentery to the right of the superior mesenteric artery.

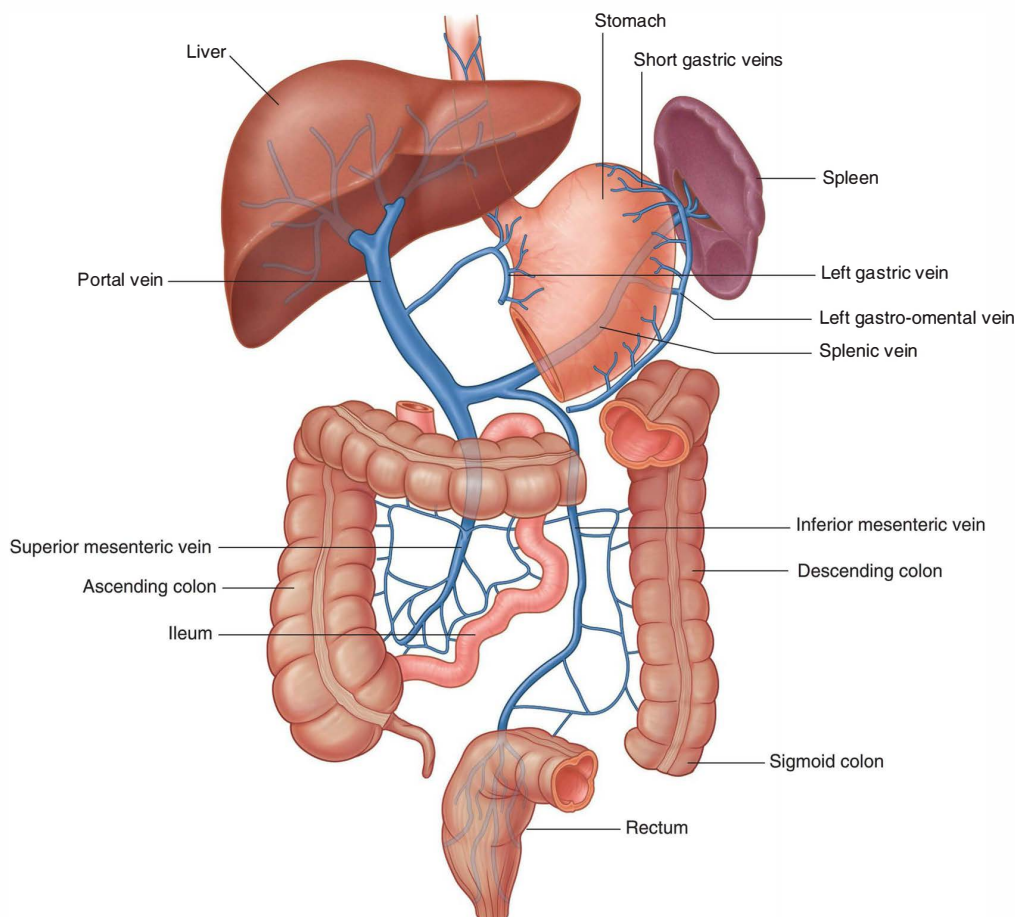


Fig. 4.121 Venous drainage of the abdominal portion of the gastrointestinal tract.



Abdomen

Posterior to the neck of the pancreas, the superior mesenteric vein joins the splenic vein to form the portal vein.

As a corresponding vein accompanies each branch of the superior mesenteric artery, tributaries to the superior mesenteric vein include jejunal, ileal, ileocolic, right colic, and middle colic veins. Additional tributaries include:

- the **right gastro-omental vein**, draining the right part of the greater curvature of the stomach, and
- the **anterior and posterior inferior pancreaticoduodenal veins**, which pass alongside the arteries of the same name; the anterior superior pancreaticoduodenal vein usually empties into the right gastro-omental vein, and the posterior superior pancreaticoduodenal vein usually empties directly into the portal vein.

Inferior mesenteric vein

The **inferior mesenteric vein** drains blood from the rectum, sigmoid colon, descending colon, and **splenic flexure** (Fig. 4.121). It begins as the **superior rectal vein** and ascends, receiving tributaries from the sigmoid veins and the **left colic vein**. All these veins accompany arteries of the same name. Continuing to ascend, the inferior mesenteric vein passes posterior to the body of the pancreas and usually joins the splenic vein. Occasionally, it ends at the junction of the splenic and superior mesenteric veins or joins the superior mesenteric vein.

In the clinic

Hepatic cirrhosis

Cirrhosis is a complex disorder of the liver, the diagnosis of which is confirmed histologically. When a diagnosis is suspected, a liver biopsy is necessary.

Cirrhosis is characterized by widespread hepatic fibrosis interspersed with areas of nodular regeneration and abnormal reconstruction of preexisting lobular architecture. The presence of cirrhosis implies previous or continuing liver cell damage.

The etiology of cirrhosis is complex and includes toxins (alcohol), viral inflammation, biliary obstruction, vascular outlet obstruction, nutritional (malnutrition) causes, and inherited anatomical and metabolic disorders.

As the cirrhosis progresses, the intrahepatic vasculature is distorted, which in turn leads to increased pressure in the portal vein and its draining tributaries (portal hypertension). Portal hypertension produces increased pressure in the splenic venules, leading to splenic enlargement. At the sites of portosystemic anastomosis (see below), large dilated veins (varices) develop. These veins are susceptible to bleeding and may produce marked blood loss, which in some instances can be fatal.

The liver is responsible for the production of numerous proteins, including those of the clotting cascade. Any disorder of the liver (including infection and cirrhosis) may decrease the production of these proteins and so prevent adequate blood clotting. Patients with severe cirrhosis of

the liver have a significant risk of serious bleeding, even from small cuts; in addition, when varices rupture, there is a danger of rapid exsanguination.

As the liver progressively fails, the patient develops salt and water retention, which produces skin and subcutaneous edema. Fluid (ascites) is also retained in the peritoneal cavity, which can hold many liters.

The poorly functioning liver cells (hepatocytes) are unable to break down blood and blood products, leading to an increase in the serum bilirubin level, which manifests as jaundice.

With the failure of normal liver metabolism, toxic metabolic by-products do not convert to nontoxic metabolites. This buildup of noxious compounds is made worse by the numerous portosystemic shunts, which allow the toxic metabolites to bypass the liver. Patients may develop severe neurological features, which may lead to epileptic fits, dementia, and irreversible neurological damage.

Portosystemic anastomosis

The hepatic portal system drains blood from the visceral organs of the abdomen to the liver. In normal individuals, 100% of the portal venous blood flow can be recovered from the hepatic veins, whereas in patients with elevated portal vein pressure (e.g., from cirrhosis), there is significantly less blood flow to the liver. The rest of the blood enters collateral channels, which drain into the

In the clinic—cont'd

systemic circulation at specific points (Fig. 4.122). The largest of these collaterals occur at:

- the gastroesophageal junction around the cardia of the stomach—where the left gastric vein and its tributaries form a portosystemic anastomosis with tributaries to the azygos system of veins of the caval system;
- the anus—the superior rectal vein of the portal system anastomoses with the middle and inferior rectal veins of the systemic venous system; and
- the anterior abdominal wall around the umbilicus—the para-umbilical veins anastomose with veins on the anterior abdominal wall.

When the pressure in the portal vein is elevated, venous enlargement (varices) tend to occur at and around the sites of portosystemic anastomoses and these enlarged veins are called:

- varices at the anorectal junction,
- esophageal varices at the gastroesophageal junction, and
- caput medusae at the umbilicus.

Esophageal varices are susceptible to trauma and, once damaged, may bleed profusely, requiring urgent surgical intervention.

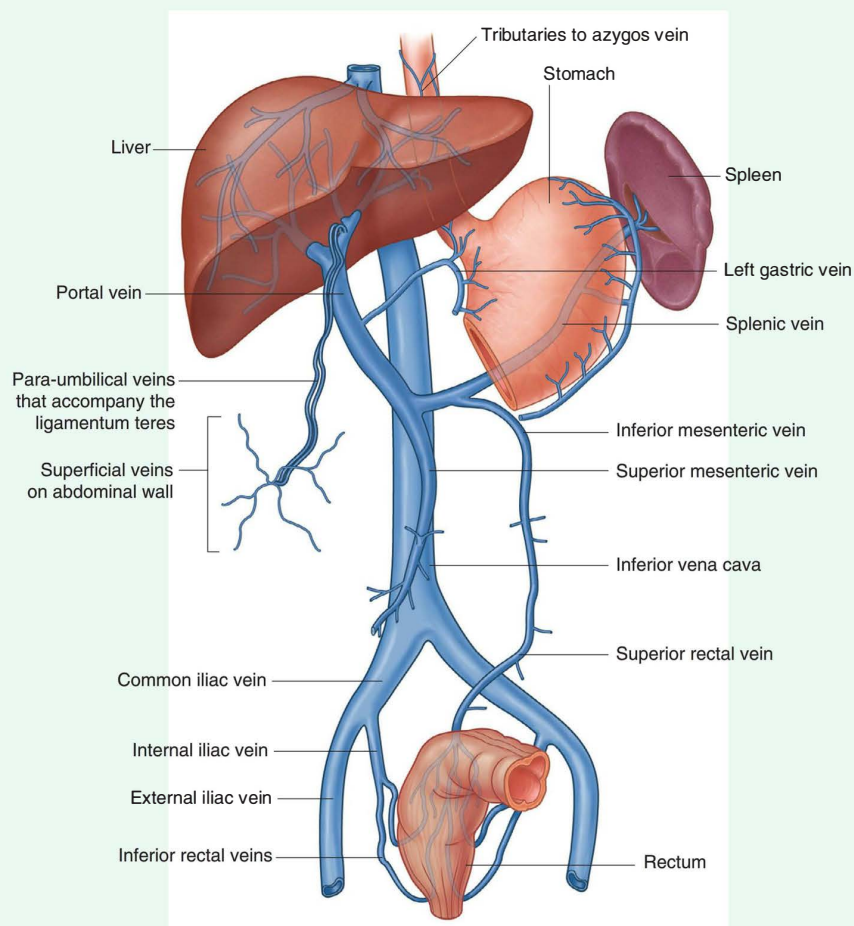


Fig. 4.122 Portosystemic anastomoses.



Abdomen

Lymphatics

Lymphatic drainage of the abdominal part of the gastrointestinal tract, as low as the inferior part of the rectum, is through vessels and nodes that eventually end in large collections of **pre-aortic lymph nodes** at the origins of the three anterior branches of the abdominal aorta, which supply these structures. These collections are therefore referred to as the **celiac**, **superior mesenteric**, and **inferior mesenteric** groups of pre-aortic lymph nodes. Lymph from viscera is supplied by three routes:

- The celiac trunk (i.e., structures that are part of the abdominal foregut) drains to pre-aortic nodes near the origin of the celiac trunk (Fig. 4.123)—these celiac nodes also receive lymph from the superior mesenteric and inferior mesenteric groups of pre-aortic nodes, and lymph from the celiac nodes enters the **cisterna chyli**.
- The superior mesenteric artery (i.e., structures that are part of the abdominal midgut) drains to pre-aortic nodes near the origin of the superior mesenteric artery (Fig. 4.123)—these superior mesenteric nodes also receive lymph from the inferior mesenteric groups of pre-aortic nodes, and lymph from the superior mesenteric nodes drains to the celiac nodes.
- The inferior mesenteric artery (i.e., structures that are part of the abdominal hindgut) drains to pre-aortic nodes near the origin of the inferior mesenteric artery (Fig. 4.123), and lymph from the inferior mesenteric nodes drains to the superior mesenteric nodes.

Innervation

Abdominal viscera are innervated by both extrinsic and intrinsic components of the nervous system:

- Extrinsic innervation involves receiving motor impulses from, and sending sensory information to, the central nervous system.
- Intrinsic innervation involves the regulation of digestive tract activities by a generally self-sufficient network of sensory and motor neurons (the enteric nervous system).

Abdominal viscera receiving extrinsic innervation include the abdominal part of the gastrointestinal tract, the spleen, the pancreas, the gallbladder, and the liver. These viscera send sensory information back to the central nervous system through visceral afferent fibers and receive motor impulses from the central nervous system through visceral efferent fibers.

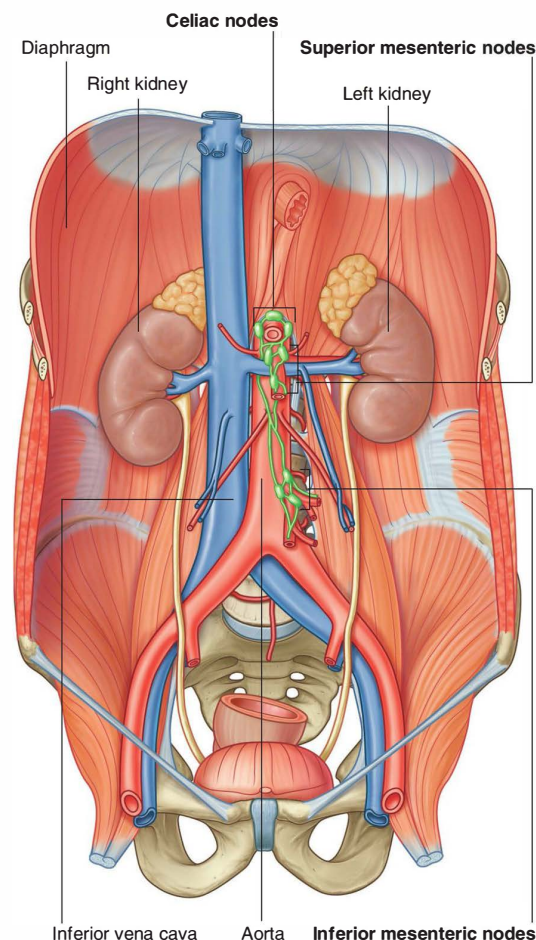


Fig. 4.123 Lymphatic drainage of the abdominal portion of the gastrointestinal tract.

The visceral efferent fibers are part of the sympathetic and parasympathetic parts of the autonomic division of the peripheral nervous system.

Structural components serving as conduits for these afferent and efferent fibers include posterior and anterior roots of the spinal cord, respectively, spinal nerves, anterior rami, white and gray rami communicantes, the sympathetic trunks, splanchnic nerves carrying sympathetic fibers (thoracic, lumbar, and sacral), parasympathetic fibers (pelvic), the prevertebral plexus and related ganglia, and the vagus nerves [X].

The enteric nervous system consists of motor and sensory neurons in two interconnected plexuses in the walls of the gastrointestinal tract. These neurons control the coordinated contraction and relaxation of intestinal smooth muscle and regulate gastric secretion and blood flow.

Sympathetic trunks

The sympathetic trunks are two parallel nerve cords extending on either side of the vertebral column from the base of the skull to the coccyx (Fig. 4.124). As they pass through the neck, they lie posterior to the carotid sheath. In the upper thorax, they are anterior to the necks of the ribs, while in the lower thorax they are on the lateral

aspect of the vertebral bodies. In the abdomen, they are anterolateral to the lumbar vertebral bodies and, continuing into the pelvis, they are anterior to the sacrum. The two sympathetic trunks come together anterior to the coccyx to form the **ganglion impar**.

Throughout the extent of the sympathetic trunks, small raised areas are visible. These collections of neuronal cell bodies outside the CNS are the paravertebral sympathetic ganglia. There are usually:

- three ganglia in the cervical region,
- eleven or twelve ganglia in the thoracic region,
- four ganglia in the lumbar region,
- four or five ganglia in the sacral region, and
- the ganglion impar anterior to the coccyx (Fig. 4.124).

The ganglia and trunks are connected to adjacent spinal nerves by gray rami communicantes throughout the length of the sympathetic trunk and by white rami communicantes in the thoracic and upper lumbar parts of the trunk (T1 to L2). Neuronal fibers found in the sympathetic trunks include **preganglionic** and **postganglionic sympathetic fibers** and **visceral afferent fibers**.

Splanchnic nerves

The splanchnic nerves are important components in the innervation of the abdominal viscera. They pass from the sympathetic trunk or sympathetic ganglia associated with the trunk, to the prevertebral plexus and ganglia anterior to the abdominal aorta.

There are two different types of splanchnic nerves, depending on the type of visceral efferent fiber they are carrying:

- The thoracic, lumbar, and sacral splanchnic nerves carry preganglionic sympathetic fibers from the sympathetic trunk to ganglia in the prevertebral plexus, and also visceral afferent fibers.
- The pelvic splanchnic nerves (parasympathetic root) carry preganglionic parasympathetic fibers from anterior rami of S2, S3, and S4 spinal nerves to an extension of the prevertebral plexus in the pelvis (the **inferior hypogastric plexus** or **pelvic plexus**).

Thoracic splanchnic nerves

Three **thoracic splanchnic nerves** pass from sympathetic ganglia along the sympathetic trunk in the thorax to the prevertebral plexus and ganglia associated with the abdominal aorta in the abdomen (Fig. 4.125):

- The greater splanchnic nerve arises from the fifth to the ninth (or tenth) thoracic ganglia and travels to the

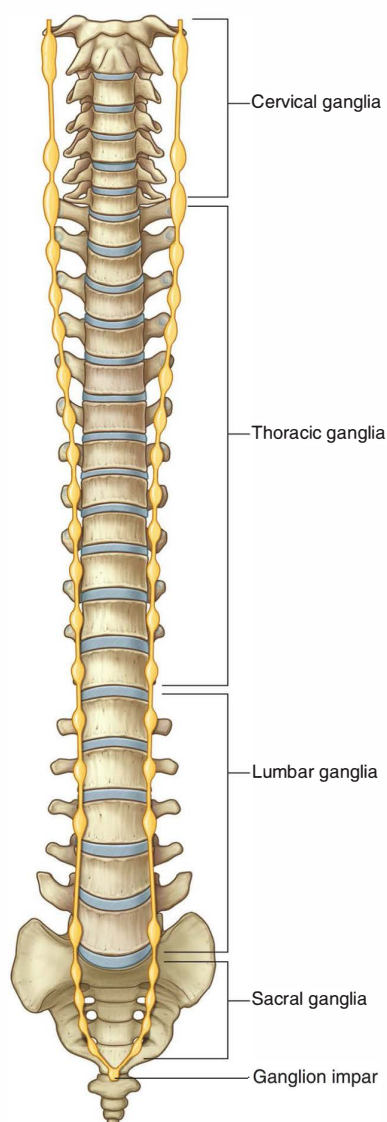


Fig. 4.124 Sympathetic trunks.



Abdomen

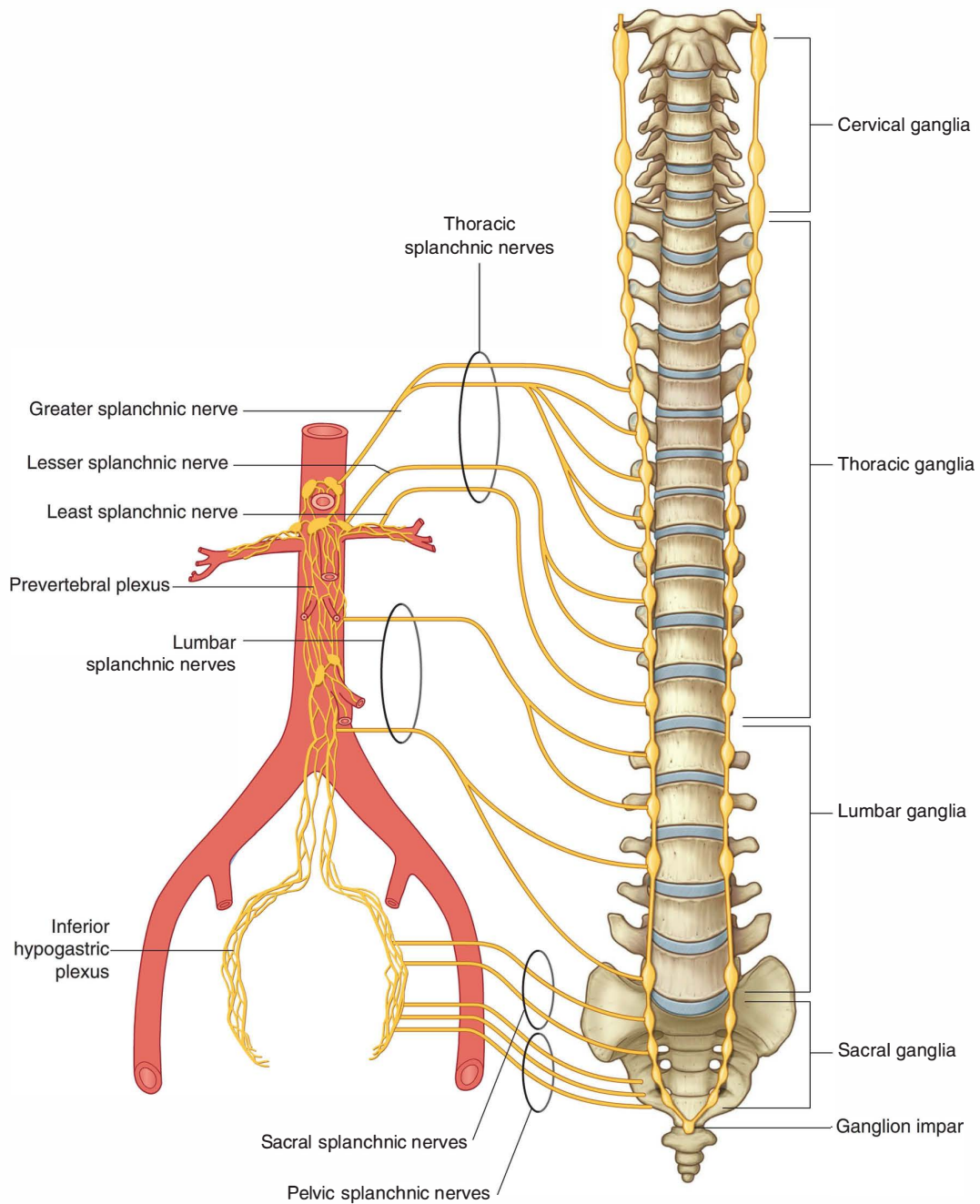


Fig. 4.125 Splanchnic nerves.

celiac ganglion in the abdomen (a prevertebral ganglion associated with the celiac trunk).

- The lesser splanchnic nerve arises from the ninth and tenth (or tenth and eleventh) thoracic ganglia and travels to the aorticorenal ganglion.
- The least splanchnic nerve, when present, arises from the twelfth thoracic ganglion and travels to the renal plexus.

Lumbar and sacral splanchnic nerves

There are usually two to four **lumbar splanchnic nerves**, which pass from the lumbar part of the sympathetic trunk or associated ganglia and enter the prevertebral plexus (Fig. 4.125).

Similarly, the **sacral splanchnic nerves** pass from the sacral part of the sympathetic trunk or associated ganglia and enter the inferior hypogastric plexus, which is an extension of the prevertebral plexus into the pelvis.

Pelvic splanchnic nerves

The **pelvic splanchnic nerves (parasympathetic root)** are unique. They are the only splanchnic nerves that carry parasympathetic fibers. In other words, they do not originate from the sympathetic trunks. Rather, they originate directly from the anterior rami of S2 to S4. Preganglionic parasympathetic fibers originating in the sacral spinal cord pass from the S2 to S4 spinal nerves to the inferior hypogastric plexus (Fig. 4.125). Once in this plexus, some of these fibers pass upward, enter the abdominal prevertebral plexus, and distribute with the arteries supplying the hindgut. This provides the pathway for innervation of the distal one-third of the transverse colon, the descending colon, and the sigmoid colon by preganglionic parasympathetic fibers.

Abdominal prevertebral plexus and ganglia

The abdominal prevertebral plexus is a collection of nerve fibers that surrounds the abdominal aorta and is continuous onto its major branches. Scattered throughout the length of the abdominal prevertebral plexus are cell bodies of postganglionic sympathetic fibers. Some of these cell bodies are organized into distinct ganglia, while others are more random in their distribution. The ganglia are usually associated with specific branches of the abdominal aorta and named after these branches.

The three major divisions of the abdominal prevertebral plexus and associated ganglia are the celiac, aortic, and superior hypogastric plexuses (Fig. 4.126).

- The celiac plexus is the large accumulation of nerve fibers and ganglia associated with the roots of the celiac trunk and superior mesenteric artery immediately below the aortic hiatus of the diaphragm. Ganglia associated with the celiac plexus include two celiac ganglia, a single superior mesenteric ganglion, and two aorticorenal ganglia.
- The aortic plexus consists of nerve fibers and associated ganglia on the anterior and lateral surfaces of the abdominal aorta extending from just below the origin of the superior mesenteric artery to the bifurcation of the aorta into the two common iliac arteries. The major ganglion in this plexus is the inferior mesenteric ganglion at the root of the inferior mesenteric artery.
- The superior hypogastric plexus contains numerous small ganglia and is the final part of the abdominal prevertebral plexus before the prevertebral plexus continues into the pelvic cavity.

Each of these major plexuses gives origin to a number of secondary plexuses, which may also contain small ganglia. These plexuses are usually named after the vessels with which they are associated. For example, the celiac plexus is usually described as giving origin to the superior mesenteric plexus and the renal plexus, as well as other plexuses that extend out along the various branches of the celiac trunk. Similarly, the aortic plexus has secondary plexuses consisting of the inferior mesenteric plexus, the spermatic plexus, and the external iliac plexus.

Inferiorly, the superior hypogastric plexus divides into the **hypogastric nerves**, which descend into the pelvis and contribute to the formation of the inferior hypogastric or pelvic plexus (Fig. 4.126).

The abdominal prevertebral plexus receives:

- preganglionic parasympathetic and visceral afferent fibers from the vagus nerves [X],
- preganglionic sympathetic and visceral afferent fibers from the thoracic and lumbar splanchnic nerves, and
- preganglionic parasympathetic fibers from the pelvic splanchnic nerves.

Parasympathetic innervation

Parasympathetic innervation of the abdominal part of the gastrointestinal tract and of the spleen, pancreas, gallbladder, and liver is from two sources—the vagus nerves [X] and the pelvic splanchnic nerves.



Abdomen

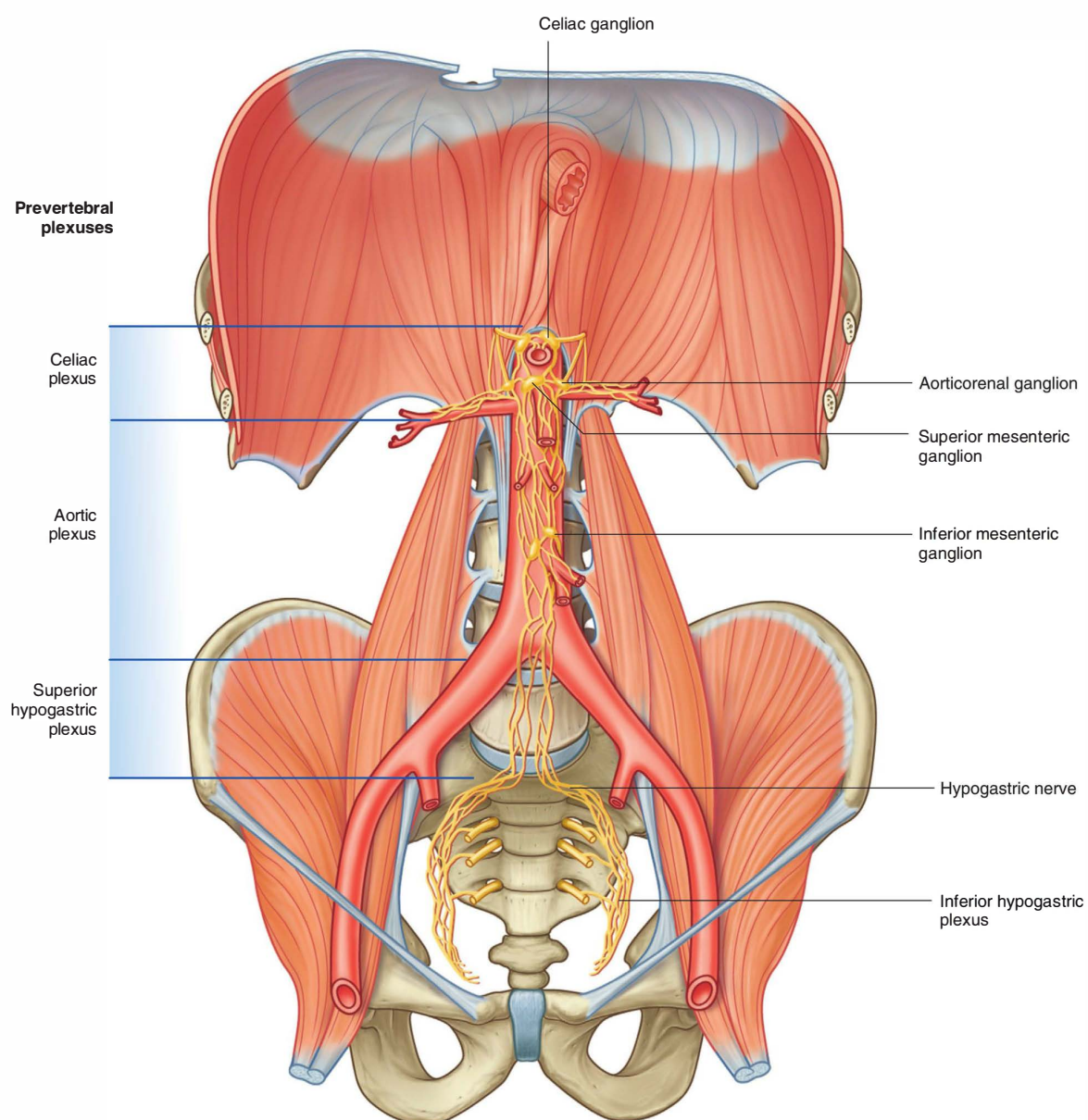


Fig. 4.126 Abdominal prevertebral plexus and ganglia.

Vagus nerves

The **vagus nerves** [X] enter the abdomen associated with the esophagus as the esophagus passes through the diaphragm (Fig. 4.127) and provide parasympathetic innervation to the foregut and midgut.

After entering the abdomen as the **anterior and posterior vagal trunks**, they send branches to the abdominal prevertebral plexus. These branches contain preganglionic parasympathetic fibers and visceral afferent fibers, which

are distributed with the other components of the prevertebral plexus along the branches of the abdominal aorta.

Pelvic splanchnic nerves

The **pelvic splanchnic nerves**, carrying preganglionic parasympathetic fibers from S2 to S4 spinal cord levels, enter the inferior hypogastric plexus in the pelvis. Some of these fibers move upward into the inferior mesenteric part of the prevertebral plexus in the abdomen (Fig. 4.127). Once there, these fibers are distributed with branches of

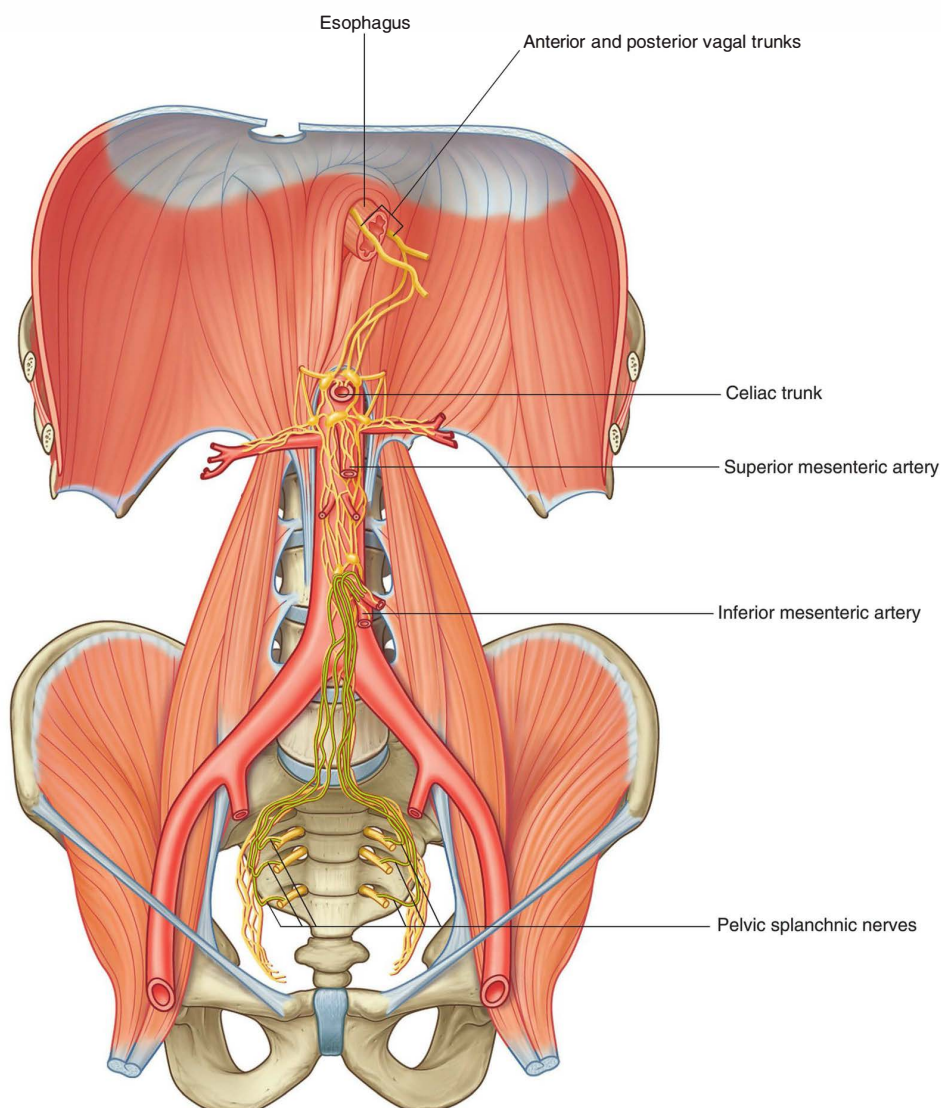


Fig. 4.127 Parasympathetic innervation of the abdominal portion of the gastrointestinal tract.



Abdomen

the inferior mesenteric artery and provide parasympathetic innervation to the hindgut.

Enteric system

The enteric system is a division of the visceral part of the nervous system and is a local neuronal circuit in the wall of the gastrointestinal tract. It consists of motor and sensory neurons organized into two interconnected plexuses (the **myenteric** and **submucosal plexuses**) between the layers of the gastrointestinal wall, and the associated nerve fibers that pass between the plexuses and from the plexuses to the adjacent tissue (Fig. 4.128).

The enteric system regulates and coordinates numerous gastrointestinal tract activities, including gastric secretory activity, gastrointestinal blood flow, and the contraction and relaxation cycles of smooth muscle (**peristalsis**).

Although the enteric system is generally independent of the central nervous system, it does receive input from postganglionic sympathetic and preganglionic parasympathetic neurons that modifies its activities.

Sympathetic innervation of the stomach

The pathway of sympathetic innervation of the stomach is as follows:

- A preganglionic sympathetic fiber originating at the T6 level of the spinal cord enters an anterior root to leave the spinal cord.

- At the level of the intervertebral foramen, the anterior root (which contains the preganglionic fiber) and a posterior root join to form a spinal nerve.
- Outside the vertebral column, the preganglionic fiber leaves the anterior ramus of the spinal nerve through the white ramus communicans.
- The white ramus communicans, containing the preganglionic fiber, connects to the sympathetic trunk.
- Entering the sympathetic trunk, the preganglionic fiber does not synapse but passes through the trunk and enters the greater splanchnic nerve.
- The greater splanchnic nerve passes through the crura of the diaphragm and enters the celiac ganglion.
- In the celiac ganglion, the preganglionic fiber synapses with a postganglionic neuron.
- The postganglionic fiber joins the plexus of nerve fibers surrounding the celiac trunk and continues along its branches.
- The postganglionic fiber travels through the plexus of nerves accompanying the branches of the celiac trunk supplying the stomach and eventually reaches its point of distribution.
- This input from the sympathetic system may modify the activities of the gastrointestinal tract controlled by the enteric nervous system.

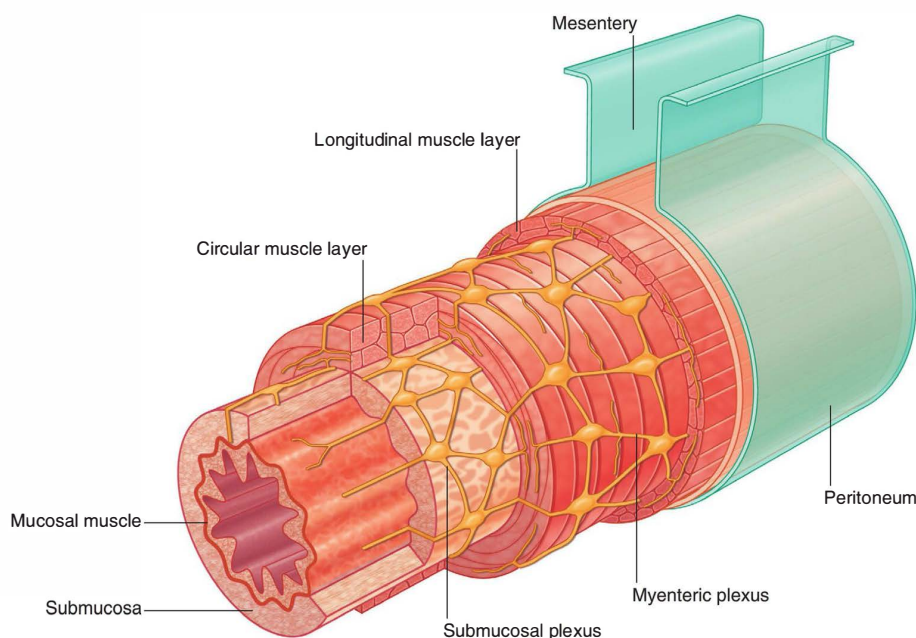


Fig. 4.128 The enteric system.

In the clinic**Surgery for obesity**

Surgery for obesity is also known as weight loss surgery and bariatric surgery. This type of surgery has become increasingly popular over the last few years for patients who are unable to achieve significant weight loss through appropriate diet modification and exercise programs. It is often regarded as a last resort. Importantly, we have to recognize the increasing medical impact that overweight patients pose. With obesity the patient is more likely to develop diabetes and cardiovascular problems and may suffer from increased general health disorders. All of these have a significant impact on health care budgeting and are regarded as serious conditions for the “health of a nation.”

There are a number of surgical options to treat obesity. Surgery for patients who are morbidly obese can be categorized into two main groups: malabsorptive procedures and restrictive procedures.

Malabsorptive procedures

There are a variety of bypass procedures that produce a malabsorption state, preventing further weight gain and

also producing weight loss. There are complications, which may include anemia, osteoporosis, and diarrhea (e.g., jejunioileal bypass).

Predominantly restrictive procedures

Restrictive procedures involve placing a band or stapling in or around the stomach to decrease the size of the organ. This reduction produces an earlier feeling of satiety and prevents the patient from overeating.

Combination procedure

Probably the most popular procedure currently in the United States, this procedure involves stapling the proximal stomach and joining a loop of small bowel to the small gastric remnant.

Any overweight patient undergoing surgery faces significant risk and increased morbidity, with mortality rates from 1% to 5%.



Abdomen

POSTERIOR ABDOMINAL REGION

The posterior abdominal region is posterior to the abdominal part of the gastrointestinal tract, the spleen, and the pancreas (Fig. 4.129). This area, bounded by bones and muscles making up the posterior abdominal wall, contains numerous structures that not only are directly involved in the activities of the abdominal contents but also use this area as a conduit between body regions. Examples include

the abdominal aorta and its associated nerve plexuses, the inferior vena cava, the sympathetic trunks, and lymphatics. There are also structures originating in this area that are critical to the normal function of other regions of the body (i.e., the lumbar plexus of nerves), and there are organs that associate with this area during development and remain in it in the adult (i.e., the kidneys and suprarenal glands).

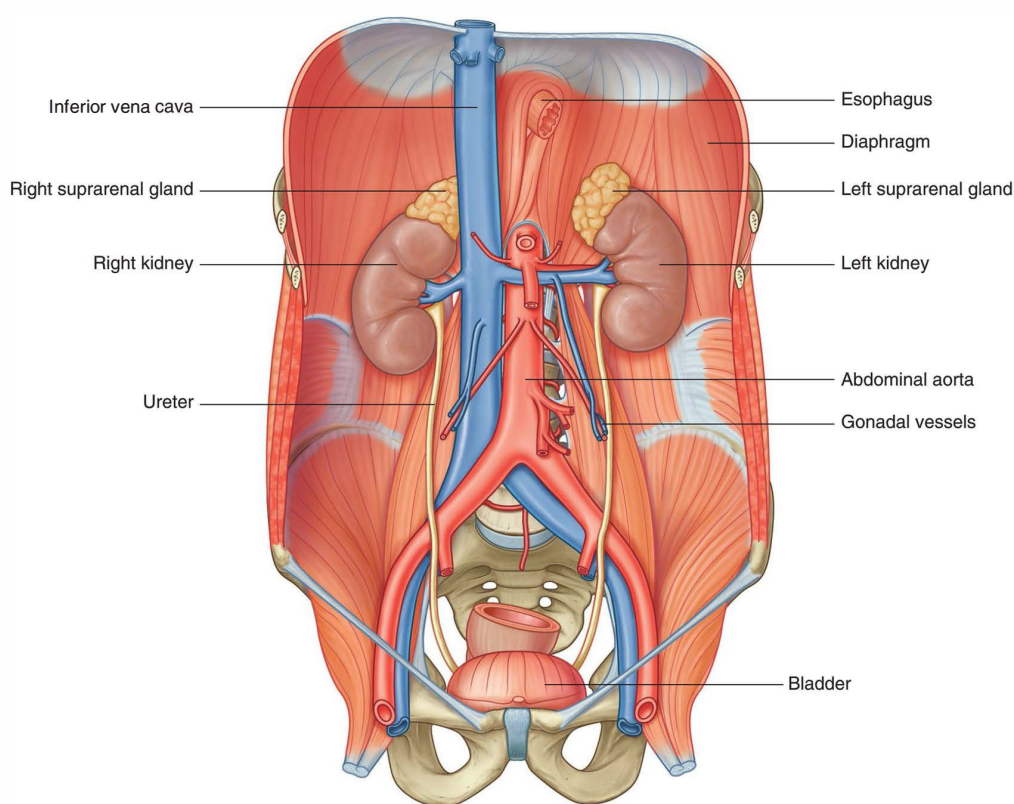


Fig. 4.129 Posterior abdominal region.

Posterior abdominal wall

Bones

Lumbar vertebrae and the sacrum

Projecting into the midline of the posterior abdominal area are the bodies of the five lumbar vertebrae (Fig. 4.130). The prominence of these structures in this region is due to the secondary curvature (a forward convexity) of the lumbar part of the vertebral column.

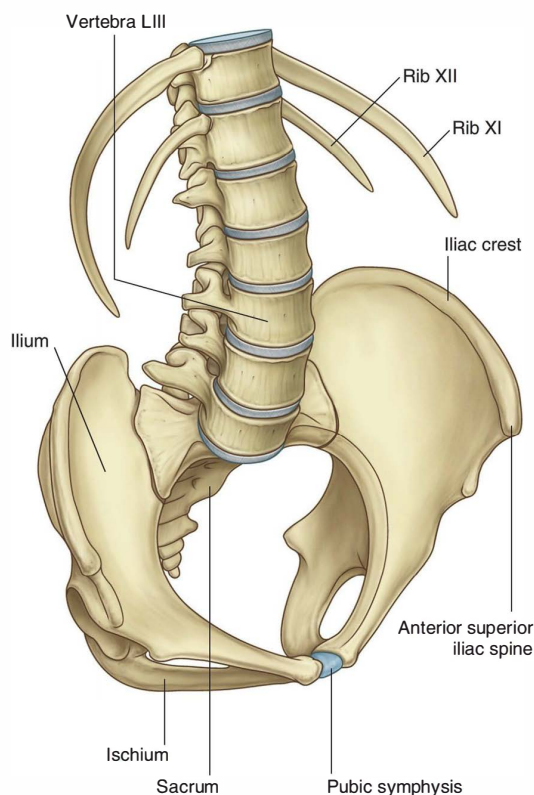


Fig. 4.130 Osteology of the posterior abdominal wall.

The lumbar vertebrae can be distinguished from cervical and thoracic vertebrae because of their size. They are much larger than any other vertebrae in any other region. The vertebral bodies are massive and progressively increase in size from vertebra L1 to L5. The pedicles are short and stocky, the transverse processes are long and slender, and the spinous processes are large and stubby. The articular processes are large and oriented medially and laterally, which promotes flexion and extension in this part of the vertebral column.

Between each lumbar vertebra is an intervertebral disc, which completes this part of the midline boundary of the posterior abdominal wall.

The midline boundary of the posterior abdominal wall, inferior to the lumbar vertebrae, consists of the upper margin of the sacrum (Fig. 4.130). The sacrum is formed by the fusion of the five sacral vertebrae into a single, wedge-shaped bony structure that is broad superiorly and narrows inferiorly. Its concave anterior surface and its convex posterior surface contain anterior and posterior sacral foramina for the anterior and posterior rami of spinal nerves to pass through.

Pelvic bones

The **ilia**, which are components of each pelvic bone, attach laterally to the sacrum at the sacro-iliac joints (Fig. 4.130). The upper part of each ilium expands outward into a thin wing-like area (the **iliac fossa**). The medial side of this region of each iliac bone, and the related muscles, are components of the posterior abdominal wall.

Ribs

Superiorly, ribs XI and XII complete the bony framework of the posterior abdominal wall (Fig. 4.130). These ribs are unique in that they do not articulate with the sternum or other ribs, they have a single articular facet on their heads, and they do not have necks or tubercles.

Rib XI is posterior to the superior part of the left kidney, and rib XII is posterior to the superior part of both kidneys. Also, rib XII serves as a point of attachment for numerous muscles and ligaments.



Abdomen

Muscles

Muscles forming the medial, lateral, inferior, and superior boundaries of the posterior abdominal region fill in the bony framework of the posterior abdominal wall (Table 4.2). Medially are the psoas major and minor muscles, laterally is the quadratus lumborum muscle, inferiorly is the iliacus muscle, and superiorly is the diaphragm (Figs. 4.131 and 4.132).

Psoas major and minor

Medially, the **psoas major** muscles cover the anterolateral surface of the bodies of the lumbar vertebrae, filling in the space between the vertebral bodies and the transverse processes (Fig. 4.131). Each of these muscles arises from the bodies of vertebra TXII and all five lumbar vertebrae, from the intervertebral discs between each vertebra, and from the transverse processes of the lumbar vertebrae. Passing inferiorly along the pelvic brim, each muscle continues into the anterior thigh, under the inguinal ligament, to attach to the lesser trochanter of the femur.

The psoas major muscle flexes the thigh at the hip joint when the trunk is stabilized and flexes the trunk against gravity when the body is supine. It is innervated by anterior rami of nerves L1 to L3.

Associated with the psoas major muscle is the **psoas minor** muscle, which is sometimes absent. Lying on the surface of the psoas major when present, this slender muscle arises from vertebrae TXII and LI and the intervening intervertebral disc; its long tendon inserts into the pectineal line of the pelvic brim and the iliopubic eminence.

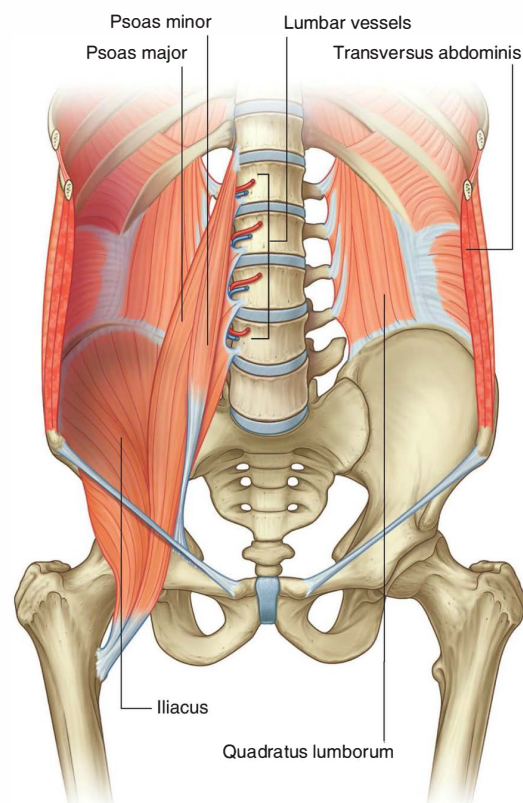


Fig. 4.131 Muscles of the posterior abdominal wall.

Table 4.2 Posterior abdominal wall muscles

Muscle	Origin	Insertion	Innervation	Function
Psoas major	Lateral surface of bodies of TXII and LI to LV vertebrae, transverse processes of the lumbar vertebrae, and the intervertebral discs between TXII and LI to LV vertebrae	Lesser trochanter of the femur	Anterior rami of L1 to L3	Flexion of thigh at hip joint
Psoas minor	Lateral surface of bodies of TXII and LI vertebrae and intervening intervertebral disc	Pectineal line of the pelvic brim and iliopubic eminence	Anterior rami of L1	Weak flexion of lumbar vertebral column
Quadratus lumborum	Transverse process of LV vertebra, iliolumbar ligament, and iliac crest	Transverse processes of LI to LIV vertebrae and inferior border of rib XII	Anterior rami of T12 and L1 to L4	Depress and stabilize rib XII and some lateral bending of trunk
Iliacus	Upper two-thirds of iliac fossa, anterior sacro-iliac and iliolumbar ligaments, and upper lateral surface of sacrum	Lesser trochanter of femur	Femoral nerve (L2 to L4)	Flexion of thigh at hip joint

The psoas minor is a weak flexor of the lumbar vertebral column and is innervated by the anterior ramus of nerve L1.

Quadratus lumborum

Laterally, the quadratus lumborum muscles fill the space between rib XII and the iliac crest on both sides of the vertebral column (Fig. 4.131). They are overlapped medially by the psoas major muscles; along their lateral borders are the transversus abdominis muscles.

Each quadratus lumborum muscle arises from the transverse process of vertebra LV, the iliolumbar ligament, and the adjoining part of the iliac crest. The muscle attaches superiorly to the transverse process of the first four lumbar vertebrae and the inferior border of rib XII.

The quadratus lumborum muscles depress and stabilize the twelfth ribs and contribute to lateral bending of the trunk. Acting together, the muscles may extend the lumbar part of the vertebral column. They are innervated by anterior rami of T12 and L1 to L4 spinal nerves.

Iliacus

Inferiorly, an **iliacus** muscle fills the iliac fossa on each side (Fig. 4.131). From this expansive origin covering the iliac fossa, the muscle passes inferiorly, joins with the psoas major muscle, and attaches to the lesser trochanter of the femur. As they pass into the thigh, these combined muscles are referred to as the **iliopsoas** muscle.

Like the psoas major muscle, the iliacus flexes the thigh at the hip joint when the trunk is stabilized and flexes the trunk against gravity when the body is supine. It is innervated by branches of the femoral nerve.

Diaphragm

Superiorly, the diaphragm forms the boundary of the posterior abdominal region. This musculotendinous sheet also separates the abdominal cavity from the thoracic cavity.

Structurally, the diaphragm consists of a central tendinous part into which the circumferentially arranged muscle fibers attach (Fig. 4.132). The diaphragm is

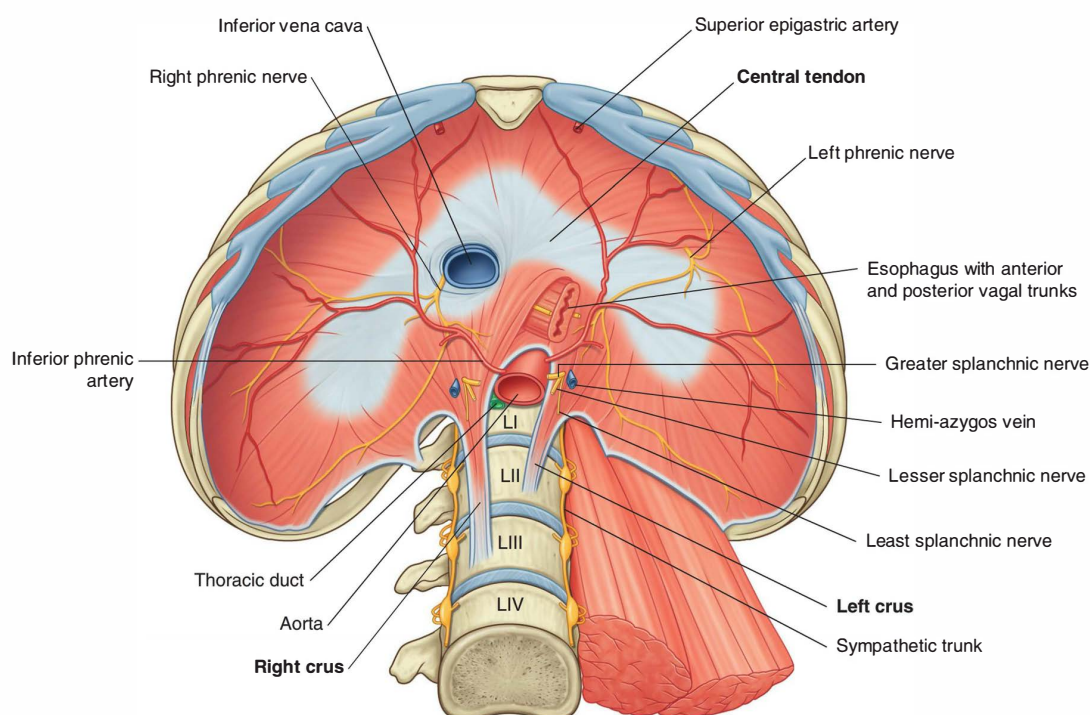


Fig. 4.132 Diaphragm.



Abdomen

anchored to the lumbar vertebrae by musculotendinous crura, which blend with the anterior longitudinal ligament of the vertebral column:

- The right crus is the longest and broadest of the crura and is attached to the bodies of vertebrae LI to LIII and the intervening intervertebral discs (Fig. 4.133).
- Similarly, the left crus is attached to vertebrae LI and LII and the associated intervertebral disc.

The crura are connected across the midline by a tendinous arch (the **median arcuate ligament**), which passes anterior to the aorta (Fig. 4.133).

Lateral to the crura, a second tendinous arch is formed by the fascia covering the upper part of the psoas major muscle. This is the **medial arcuate ligament**, which is attached medially to the sides of vertebrae LI and LII and laterally to the transverse process of vertebra LI (Fig. 4.133).

A third tendinous arch, the **lateral arcuate ligament**, is formed by a thickening in the fascia that covers the quadratus lumborum. It is attached medially to the

transverse process of vertebra LI and laterally to rib XII (Fig. 4.133).

The medial and lateral arcuate ligaments serve as points of origin for some of the muscular components of the diaphragm.

Structures passing through or around the diaphragm

Numerous structures pass through or around the diaphragm (Fig. 4.132):

- The aorta passes posterior to the diaphragm and anterior to the vertebral bodies at the lower level of vertebra TXII; it is between the two crura of the diaphragm and posterior to the median arcuate ligament, just to the left of midline.
- Accompanying the aorta through the aortic hiatus is the thoracic duct and, sometimes, the azygos vein.
- The esophagus passes through the musculature of the right crus of the diaphragm at the level of vertebra TX, just to the left of the aortic hiatus.
- Passing through the esophageal hiatus with the esophagus are the anterior and posterior vagal trunks, the esophageal branches of the left gastric artery and vein, and a few lymphatic vessels.
- The third large opening in the diaphragm is the caval opening, through which the inferior vena cava passes from the abdominal cavity to the thoracic cavity (Fig. 4.132) at approximately vertebra TVIII in the central tendinous part of the diaphragm.
- Accompanying the inferior vena cava through the caval opening is the right phrenic nerve.
- The left phrenic nerve passes through the muscular part of the diaphragm just anterior to the central tendon on the left side.

Additional structures pass through small openings either in or just outside the diaphragm as they pass from the thoracic cavity to the abdominal cavity (Fig. 4.132):

- The greater, lesser, and least (when present) splanchnic nerves pass through the crura, on either side.
- The hemi-azygos vein passes through the left crus.
- Passing posterior to the median arcuate ligament, on either side, are the sympathetic trunks.
- Passing anterior to the diaphragm, just deep to the ribs, are the superior epigastric vessels.
- Other vessels and nerves (i.e., the musculophrenic vessels and intercostal nerves) also pass through the diaphragm at various points.

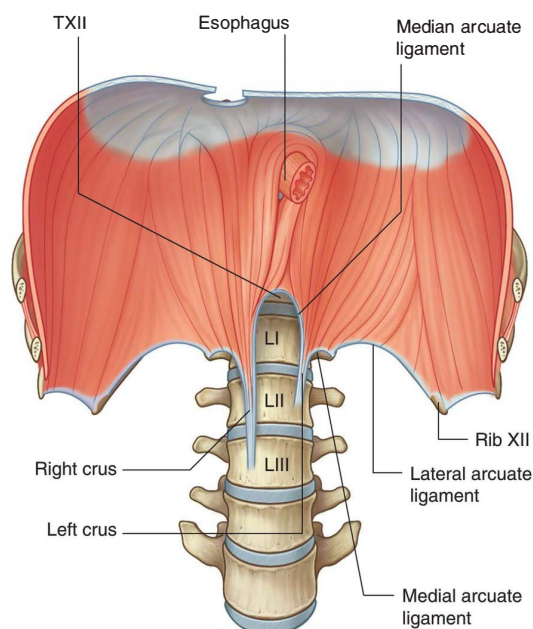


Fig. 4.133 Crura of the diaphragm.

Domes

The classic appearance of the right and left domes of the diaphragm is caused by the underlying abdominal contents pushing these lateral areas upward, and by the fibrous pericardium, which is attached centrally, causing a flattening of the diaphragm in this area (Fig. 4.134).

The domes are produced by:

- the liver on the right, with some contribution from the right kidney and the right suprarenal gland, and
- the fundus of the stomach and spleen on the left, with contributions from the left kidney and the left suprarenal gland.

Although the height of these domes varies during breathing, a reasonable estimate in normal expiration places the left dome at the fifth intercostal space and the right dome at rib V. This is important to remember when percussing the thorax.

During inspiration, the muscular part of the diaphragm contracts, causing the central tendon of the diaphragm to be drawn inferiorly. This results in some flattening of the

domes, enlargement of the thoracic cavity, and a reduction in intrathoracic pressure. The physiological effect of these changes is that air enters the lungs and venous return to the heart is enhanced.

Blood supply

There is blood supply to the diaphragm on its superior and inferior surfaces:

- Superiorly, the musculophrenic and pericardiophrenic arteries, both branches of the internal thoracic artery, and the superior phrenic artery, a branch of the thoracic aorta, supply the diaphragm.
- Inferiorly, the inferior phrenic arteries, branches of the abdominal aorta, supply the diaphragm (see Fig. 4.132).

Venous drainage is through companion veins to these arteries.

Innervation

Innervation of the diaphragm is primarily by the **phrenic nerves**. These nerves, from the C3 to C5 spinal cord levels, provide all motor innervation to the diaphragm and sensory fibers to the central part. They pass through the thoracic cavity, between the mediastinal pleura and the pericardium, to the superior surface of the diaphragm. At this point, the right phrenic nerve accompanies the inferior vena cava through the diaphragm and the left phrenic nerve passes through the diaphragm by itself (see Fig. 4.132). Additional sensory fibers are supplied to the peripheral areas of the diaphragm by intercostal nerves.



Fig. 4.134 Right and left domes of the diaphragm. Chest radiograph.

In the clinic

Psoas muscle abscess

At first glance, it is difficult to appreciate why the psoas muscle sheath is of greater importance than any other muscle sheath. The psoas muscle and its sheath arise not only from the lumbar vertebrae but also from the intervertebral discs between each vertebra. This disc origin is of critical importance. In certain types of infection, the intervertebral disc is preferentially affected (e.g., tuberculosis and salmonella discitis). As the infection of the disc develops, the infection spreads anteriorly and anterolaterally. In the anterolateral position, the infection passes into the psoas muscle sheath, and spreads within the muscle and sheath, and may appear below the inguinal ligament as a mass.



Abdomen

In the clinic

Diaphragmatic hernias

To understand why a hernia occurs through the diaphragm, it is necessary to consider the embryology of the diaphragm.

The diaphragm is formed from four structures—the septum transversum, the posterior esophageal mesentery, the pleuroperitoneal membrane, and the peripheral rim—which eventually fuse together, so separating the abdominal cavity from the thoracic cavity. The septum transversum forms the central tendon, which develops from a mesodermal origin in front of the embryo's head and then moves to its more adult position during formation of the head fold.

Fusion of the various components of the diaphragm may fail, and hernias may occur through the failed points of fusion (Fig. 4.135). The commonest sites are:

- between the xiphoid process and the costal margins on the right (Morgagni's hernia), and
 - through an opening on the left when the pleuroperitoneal membrane fails to close the pericardioperitoneal canal (Bochdalek's hernia).
- Hernias may also occur through the central tendon and through a congenitally large esophageal hiatus.
- Morgagni's and Bochdalek's hernias tend to appear at or around the time of birth or in early infancy. They allow abdominal bowel to enter the thoracic cavity, which may compress the lungs and reduce respiratory function. Most of these hernias require surgical closure of the diaphragmatic defect.
- Occasionally, small defects within the diaphragm fail to permit bowel through, but do allow free movement of fluid. Patients with ascites may develop pleural effusions, while patients with pleural effusions may develop ascites when these defects are present.

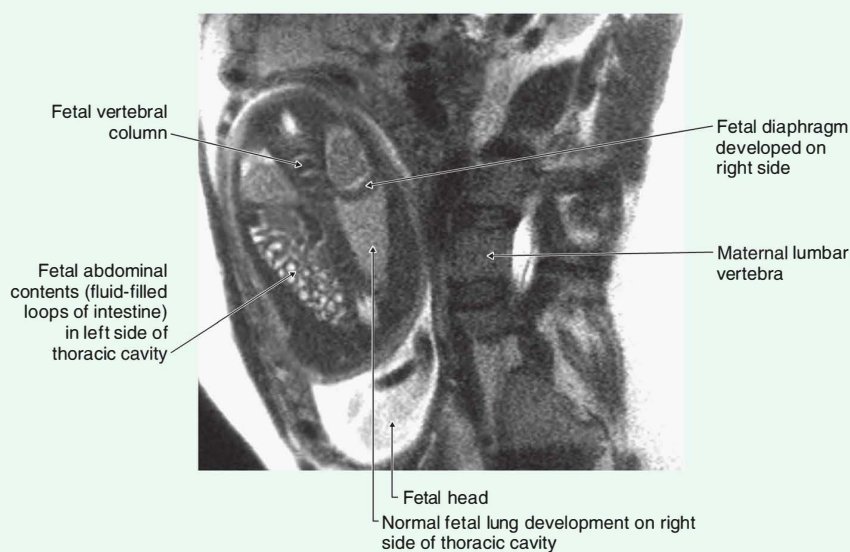


Fig. 4.135 Fetal diaphragmatic hernia in utero. T2-weighted MR image. Fetus in coronal plane, mother in sagittal plane.

In the clinic**Hiatus hernia**

At the level of the esophageal hiatus, the diaphragm may be lax, allowing the fundus of the stomach to herniate into the posterior mediastinum (Fig. 4.136). This typically causes symptoms of acid reflux. Ulceration may occur and may produce bleeding and anemia. The diagnosis is usually made by barium studies or endoscopy. Treatment in the first instance is by medical management, although surgery may be necessary.

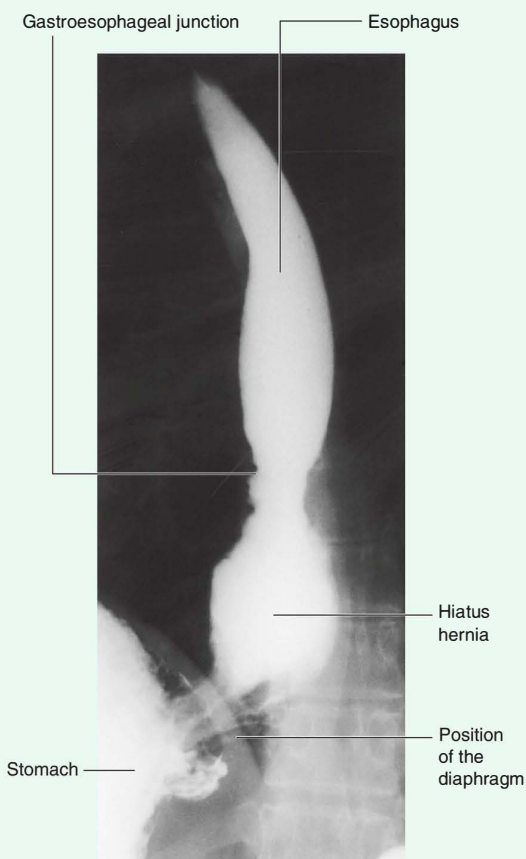


Fig. 4.136 Lower esophagus and upper stomach showing a hiatus hernia. Radiograph using barium.

Viscera**Kidneys**

The bean-shaped kidneys are retroperitoneal in the posterior abdominal region (Fig. 4.137). They lie in the extra-peritoneal connective tissue immediately lateral to the vertebral column. In the supine position, the kidneys extend from approximately vertebra TXII superiorly to vertebra LIII inferiorly, with the right kidney somewhat lower than the left because of its relationship with the liver. Although they are similar in size and shape, the left kidney is a longer and more slender organ than the right kidney, and nearer to the midline.

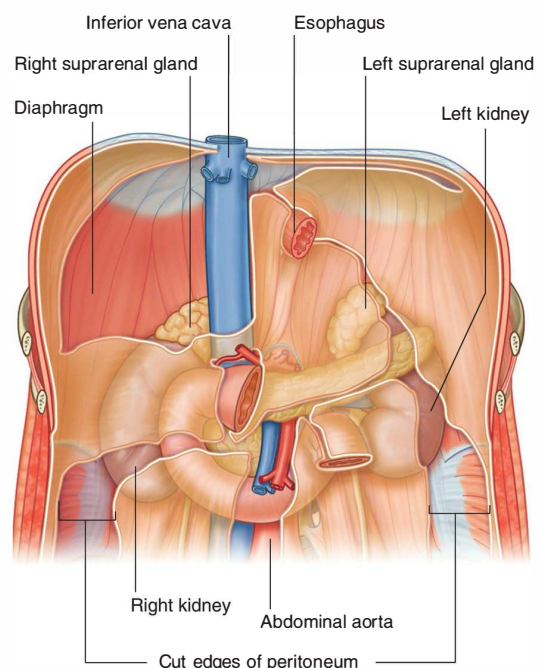


Fig. 4.137 Retroperitoneal position of the kidneys in the posterior abdominal region.



Abdomen

Relationships to other structures

The anterior surface of the right kidney is related to numerous structures, some of which are separated from the kidney by a layer of peritoneum and some of which are directly against the kidney (Fig. 4.138):

- A small part of the superior pole is covered by the right suprarenal gland.
- Moving inferiorly, a large part of the rest of the upper part of the anterior surface is against the liver and is separated from it by a layer of peritoneum.
- Medially, the descending part of the duodenum is retroperitoneal and contacts the kidney.
- The inferior pole of the kidney, on its lateral side, is directly associated with the right colic flexure and, on

its medial side, is covered by a segment of the intraperitoneal small intestine.

The anterior surface of the left kidney is also related to numerous structures, some with an intervening layer of peritoneum and some directly against the kidney (Fig. 4.138):

- A small part of the superior pole, on its medial side, is covered by the left suprarenal gland.
- The rest of the superior pole is covered by the intraperitoneal stomach and spleen.
- Moving inferiorly, the retroperitoneal pancreas covers the middle part of the kidney.
- On its lateral side, the lower half of the kidney is covered by the left colic flexure and the beginning of the

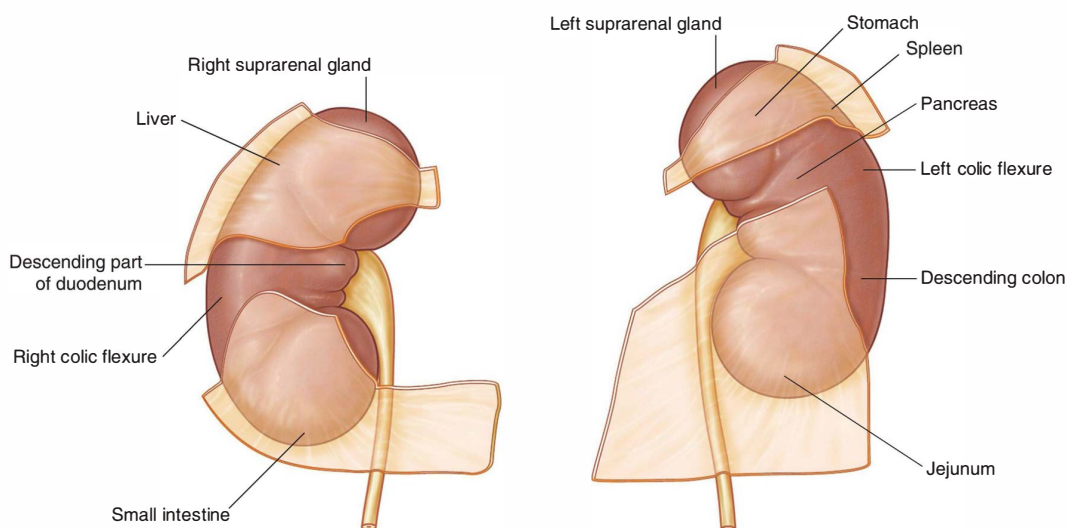


Fig. 4.138 Structures related to the anterior surface of each kidney.

descending colon, and, on its medial side, by the parts of the intraperitoneal jejunum.

Posteriorly, the right and left kidneys are related to similar structures (Fig. 4.139). Superiorly is the diaphragm and inferior to this, moving in a medial to lateral direction, are the psoas major, quadratus lumborum, and transversus abdominis muscles.

The superior pole of the right kidney is anterior to rib XII, while the same region of the left kidney is anterior to ribs XI and XII. The pleural sacs and specifically, the costo-diaphragmatic recesses therefore extend posterior to the kidneys.

Also passing posterior to the kidneys are the subcostal vessels and nerves and the iliohypogastric and ilio-inguinal nerves.

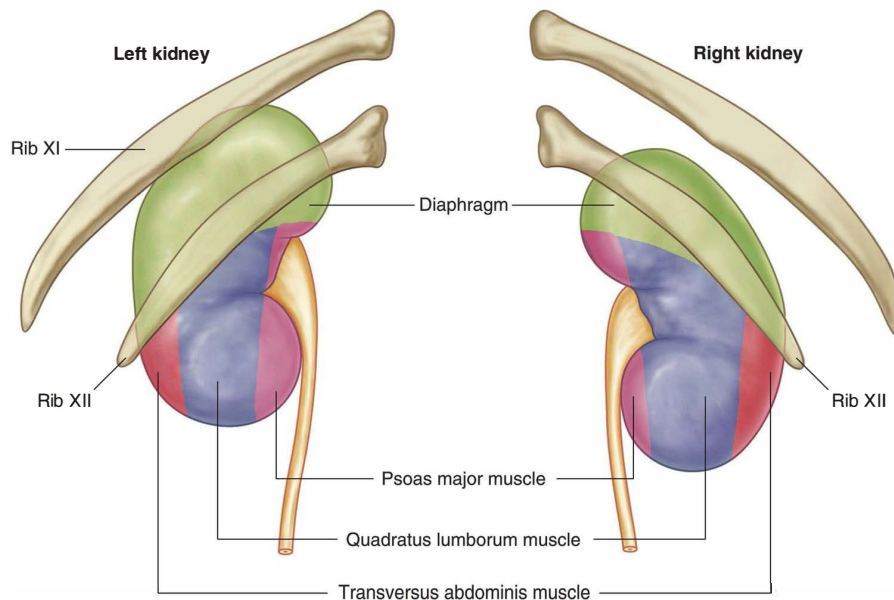


Fig. 4.139 Structures related to the posterior surface of each kidney.



Abdomen

Renal fat and fascia

The kidneys are enclosed in and associated with a unique arrangement of fascia and fat. Immediately outside the renal capsule, there is an accumulation of extraperitoneal fat—the **perinephric fat (perirenal fat)**, which completely surrounds the kidney (Fig. 4.140). Enclosing the perinephric fat is a membranous condensation of the extraperitoneal fascia (the **renal fascia**). The suprarenal glands are also enclosed in this fascial compartment, usually separated from the kidneys by a thin septum. The renal fascia must be incised in any surgical approach to this organ.

At the lateral margins of each kidney, the anterior and posterior layers of the renal fascia fuse (Fig. 4.140). This fused layer may connect with the transversalis fascia on the lateral abdominal wall.

Above each suprarenal gland, the anterior and posterior layers of the renal fascia fuse and blend with the fascia that covers the diaphragm.

Medially, the anterior layer of the renal fascia continues over the vessels in the hilum and fuses with the connective tissue associated with the abdominal aorta and the inferior vena cava (Fig. 4.140). In some cases, the anterior layer may cross the midline to the opposite side and blend with its companion layer.

The posterior layer of the renal fascia passes medially between the kidney and the fascia covering the quadratus lumborum muscle to fuse with the fascia covering the psoas major muscle.

Inferiorly, the anterior and posterior layers of the renal fascia enclose the ureters.

In addition to perinephric fat and the renal fascia, a final layer of **paranephric fat (pararenal fat)** completes the fat and fascias associated with the kidney (Fig. 4.140). This fat accumulates posterior and posterolateral to each kidney.

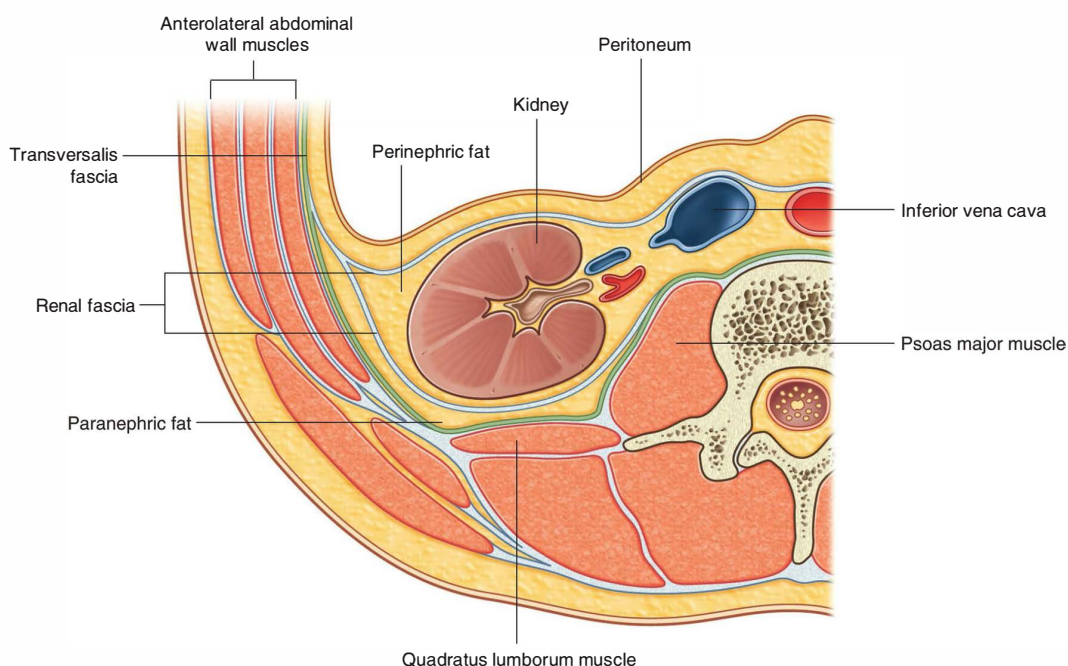


Fig. 4.140 Organization of fat and fascia surrounding the kidney.

Kidney structure

Each kidney has a smooth anterior and posterior surface covered by a fibrous capsule, which is easily removable except during disease.

On the medial margin of each kidney is the **hilum of the kidney**, which is a deep vertical slit through which renal vessels, lymphatics, and nerves enter and leave the substance of the kidney (Fig. 4.141). Internally, the hilum is continuous with the renal sinus. Perinephric fat continues into the hilum and sinus and surrounds all structures.

Each kidney consists of an outer **renal cortex** and an inner renal medulla. The renal cortex is a continuous band of pale tissue that completely surrounds the renal medulla.

Extensions of the renal cortex (the **renal columns**) project into the inner aspect of the kidney, dividing the renal medulla into discontinuous aggregations of triangular-shaped tissue (the **renal pyramids**).

The bases of the renal pyramids are directed outward, toward the renal cortex, while the apex of each renal pyramid projects inward, toward the **renal sinus**. The apical projection (**renal papilla**) is surrounded by a **minor calyx**.

The minor calices receive urine and represent the proximal parts of the tube that will eventually form the ureter (Fig. 4.141). In the renal sinus, several minor calices unite to form a **major calyx**, and two or three major calices unite to form the **renal pelvis**, which is the funnel-shaped superior end of the ureters.

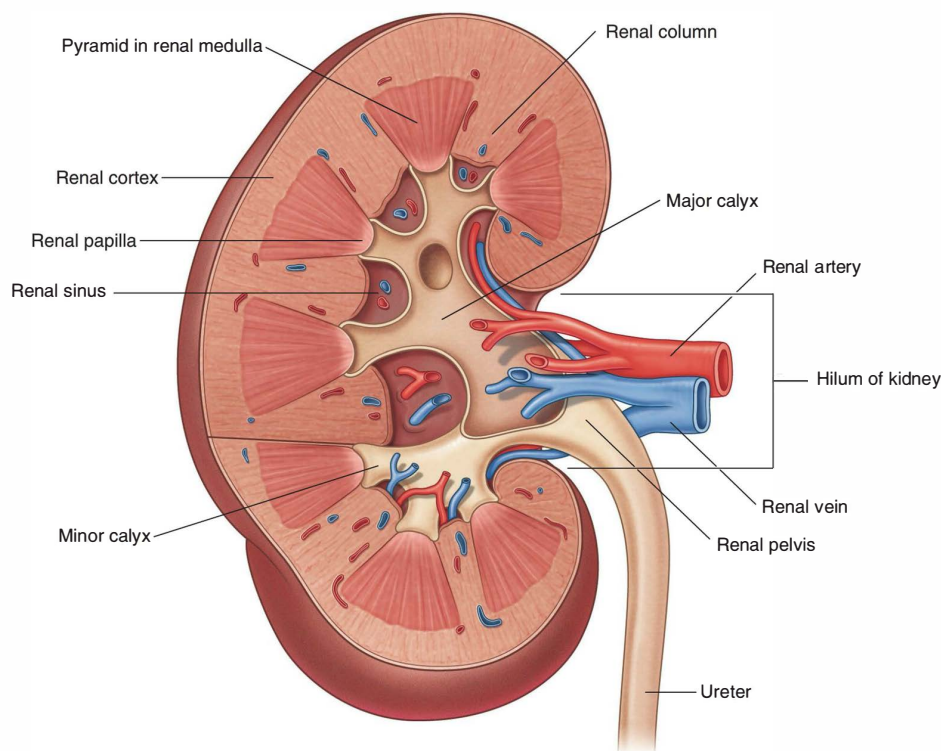


Fig. 4.141 Internal structure of the kidney.



Abdomen

Renal vasculature and lymphatics

A single large **renal artery**, a lateral branch of the abdominal aorta, supplies each kidney. These vessels usually arise just inferior to the origin of the superior mesenteric artery between vertebrae LI and LII (Fig. 4.142). The **left renal artery** usually arises a little higher than the right, and the **right renal artery** is longer and passes posterior to the inferior vena cava.

As each renal artery approaches the renal hilum, it divides into anterior and posterior branches, which supply the renal parenchyma. Accessory renal arteries are common. They originate from the lateral aspect of the abdominal aorta, either above or below the primary renal

arteries, enter the hilum with the primary arteries or pass directly into the kidney at some other level, and are commonly called **extrahilar arteries**.

Multiple renal veins contribute to the formation of the **left** and **right renal veins**, both of which are anterior to the renal arteries (Fig. 4.142). Importantly, the longer left renal vein crosses the midline anterior to the abdominal aorta and posterior to the superior mesenteric artery and can be compressed by an aneurysm in either of these two vessels.

The lymphatic drainage of each kidney is to the **lateral aortic (lumbar) nodes** around the origin of the renal artery.

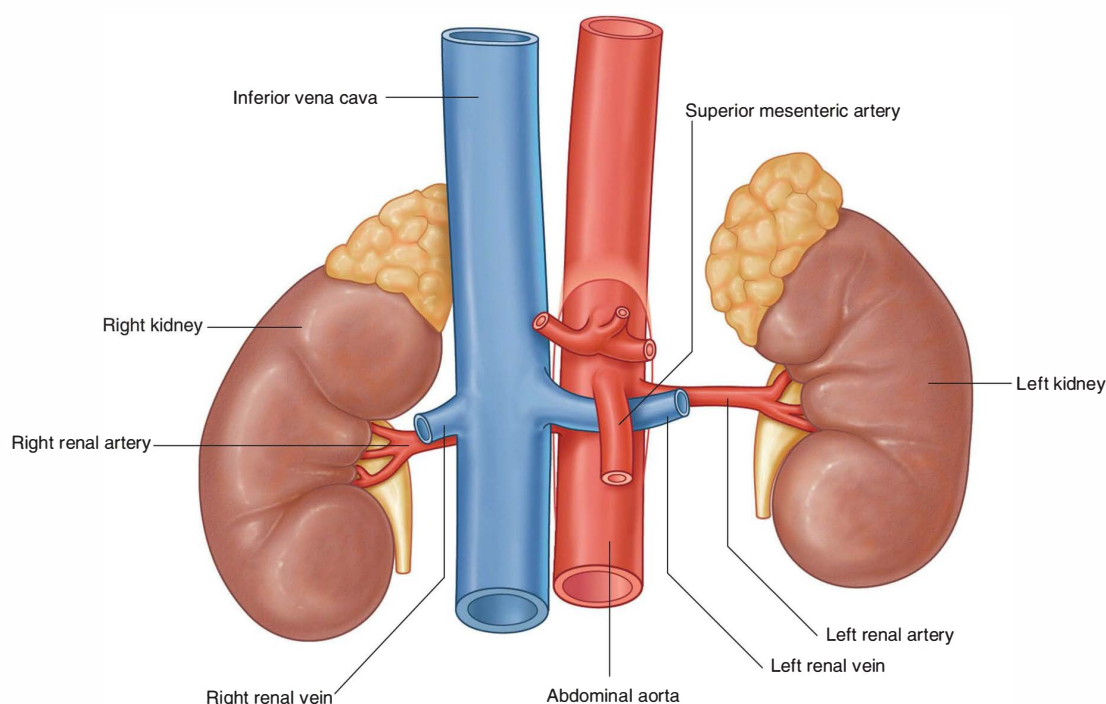


Fig. 4.142 Renal vasculature.

Ureters

The ureters are muscular tubes that transport urine from the kidneys to the bladder. They are continuous superiorly with the renal pelvis, which is a funnel-shaped structure in the renal sinus. The renal pelvis is formed from a condensation of two or three major calices, which in turn are formed by the condensation of several minor calices (see Fig. 4.141). The minor calices surround a renal papilla.

The renal pelvis narrows as it passes inferiorly through the hilum of the kidney and becomes continuous with the ureter at the **ureteropelvic junction** (Fig. 4.143). Inferior to this junction, the ureters descend retroperitoneally on the medial aspect of the psoas major muscle. At the pelvic brim, the ureters cross either the end of the common iliac artery or the beginning of the external iliac artery, enter the pelvic cavity, and continue their journey to the bladder.

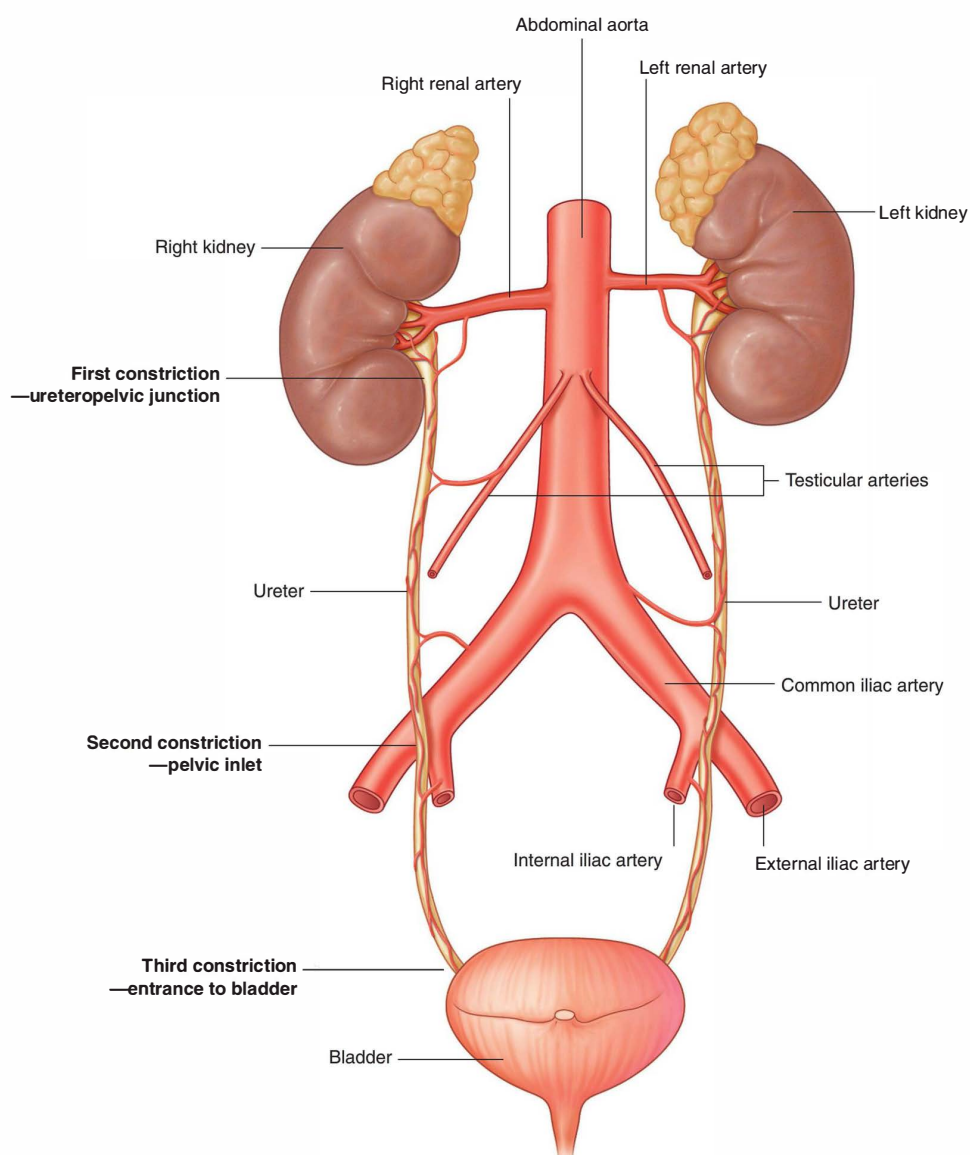


Fig. 4.143 Ureters.



Abdomen

At three points along their course the ureters are constricted (Fig. 4.143):

- The first point is at the ureteropelvic junction.
- The second point is where the ureters cross the common iliac vessels at the pelvic brim.
- The third point is where the ureters enter the wall of the bladder.

Kidney stones can become lodged at these constrictions.

Ureteric vasculature and lymphatics

The ureters receive arterial branches from adjacent vessels as they pass toward the bladder (Fig. 4.143):

- The renal arteries supply the upper end.
- The middle part may receive branches from the abdominal aorta, the testicular or ovarian arteries, and the common iliac arteries.
- In the pelvic cavity, the ureters are supplied by one or more arteries from branches of the internal iliac arteries.

In all cases, arteries reaching the ureters divide into ascending and descending branches, which form longitudinal anastomoses.

Lymphatic drainage of the ureters follows a pattern similar to that of the arterial supply. Lymph from:

- the upper part of each ureter drains to the lateral aortic (lumbar) nodes,
- the middle part of each ureter drains to lymph nodes associated with the common iliac vessels, and
- the inferior part of each ureter drains to lymph nodes associated with the external and internal iliac vessels.

Ureteric innervation

Ureteric innervation is from the renal, aortic, superior hypogastric, and inferior hypogastric plexuses through nerves that follow the blood vessels.

Visceral efferent fibers come from both sympathetic and parasympathetic sources, whereas visceral afferent fibers return to T11 to L2 spinal cord levels. Ureteric pain, which is usually related to distention of the ureter, is therefore referred to cutaneous areas supplied by T11 to L2 spinal cord levels. These areas would most likely include the posterior and lateral abdominal wall below the ribs and above the iliac crest, the pubic region, the scrotum in males, the labia majora in females, and the proximal anterior aspect of the thigh.

In the clinic

Urinary tract stones

Urinary tract stones (calculi) occur more frequently in men than in women, are most common in people aged between 20 and 60 years, and are usually associated with sedentary lifestyles. The stones are polycrystalline aggregates of calcium, phosphate, oxalate, urate, and other soluble salts within an organic matrix. The urine becomes saturated with these salts, and small variations in the pH cause the salts to precipitate.

Typically the patient has pain that radiates from the infrascapular region (loin) into the groin, and even into the scrotum or labia majora. Blood in the urine (**hematuria**) may also be noticed.

Infection must be excluded because certain species of bacteria are commonly associated with urinary tract stones.

The complications of urinary tract stones include infection, urinary obstruction, and renal failure. Stones may also develop within the bladder and produce marked irritation, causing pain and discomfort.

The diagnosis of urinary tract stones is based upon history and examination. Stones are often visible on abdominal radiographs. Special investigations include:

- ultrasound scanning, which may demonstrate the dilated renal pelvis and calices when the urinary system is obstructed; and
- an intravenous urogram, which will demonstrate the obstruction, pinpoint the exact level, and enable the surgeon to plan a procedure to remove the stone if necessary.

In the clinic**Urinary tract cancer**

Most tumors that arise in the kidney are renal cell carcinomas. These tumors develop from the proximal tubular epithelium. Approximately 5% of tumors within the kidney are transitional cell tumors, which arise from the urothelium of the renal pelvis. Most patients typically have blood in the urine (hematuria), pain in the infrascapular region (loin), and a mass.

Renal cell tumors (Figs. 4.144 and 4.145) are unusual because not only do they grow outward from the kidney, invading the fat and fascia, but they also spread into the

renal vein. This venous extension is rare for any other type of tumor, so, when seen, renal cell carcinoma should be suspected. In addition, the tumor may spread along the renal vein and into the inferior vena cava, and in rare cases can grow into the right atrium across the tricuspid valve and into the pulmonary artery.

Treatment for most renal cancers is surgical removal, even when metastatic spread is present, because some patients show regression of metastases.

Transitional cell carcinoma arises from the urothelium. The urothelium is present from the calices to the urethra

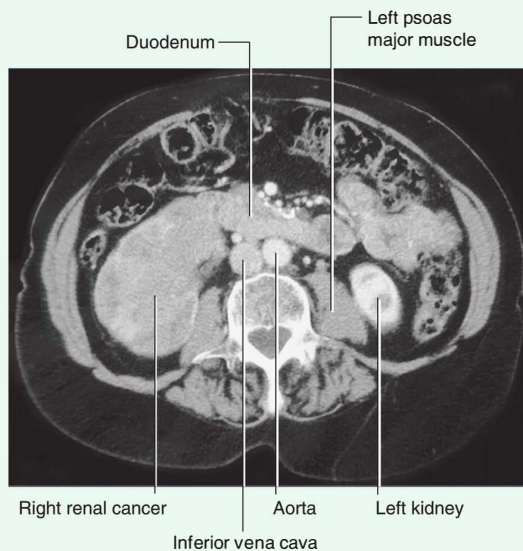


Fig. 4.144 Tumor in the right kidney growing toward, and possibly invading, the duodenum. Computed tomogram in the axial plane.

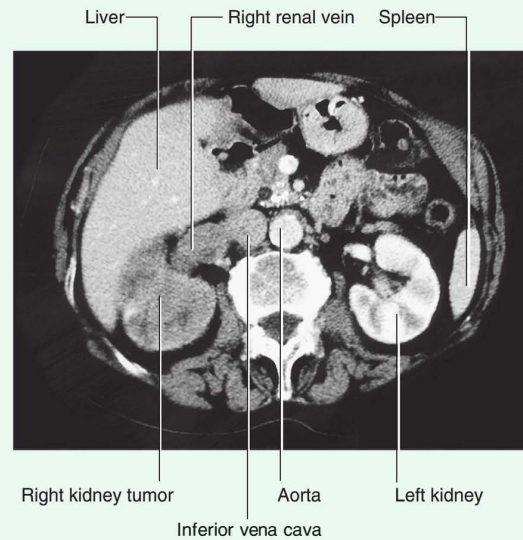


Fig. 4.145 Tumor in the right kidney spreading into the right renal vein. Computed tomogram in the axial plane.

(continues)



Abdomen

In the clinic—cont'd

and behaves as a “single unit.” Therefore, when patients develop transitional carcinomas within the bladder, similar tumors may also be present within upper parts of the urinary tract. In patients with bladder cancer, the whole of the urinary tract must always be investigated to exclude the possibility of other tumors (Fig. 4.146).

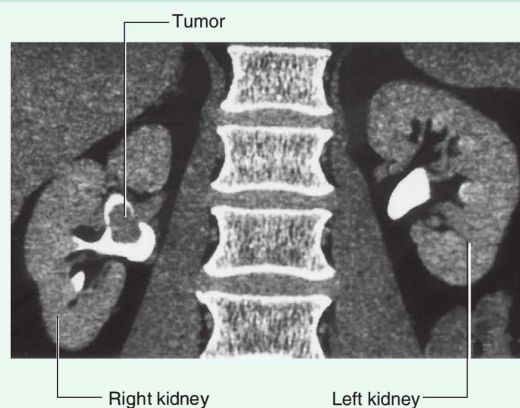


Fig. 4.146 Transitional cell carcinoma in the pelvis of the right kidney. Coronal computed tomogram reconstruction.

In the clinic

Nephrostomy

A nephrostomy is a procedure where a tube is placed through the lateral or posterior abdominal wall into the renal cortex to lie within the renal pelvis. The function of this tube is to allow drainage of urine from the renal pelvis through the tube externally (Fig. 4.147).

The kidneys are situated on the posterior abdominal wall, and in thin healthy subjects may be only up to 2 to 3 cm from the skin. Access to the kidney is relatively straightforward, because the kidney can be easily visualized under ultrasound guidance. Using local anesthetic, a needle can be placed, under ultrasound

direction, through the skin into the renal cortex and into the renal pelvis. A series of wires and tubes can be passed through the needle to position the drainage catheter.

The indications for such a procedure are many. In patients with distal ureteric obstruction the back pressure of urine within the ureters and the kidney significantly impairs the function of the kidney. This will produce renal failure and ultimately death. Furthermore, a dilated obstructed system is also susceptible to infection. In many cases, there is not only obstruction producing renal failure but also infected urine within the system.

In the clinic—cont'd

Fig. 4.147 This radiograph demonstrates a double-J stent (anteroposterior view). The superior aspect of the double-J stent is situated within the renal pelvis. The stent passes through the ureter, describing the path of the ureter, and the tip of the double-J stent is projected over the bladder, which appears as a slightly dense area on the radiograph.

In the clinic**Kidney transplant**

Kidney transplantation began in the United States in the 1950s. Since the first transplant, the major problem for kidney transplantation has been tissue rejection. A number of years have passed since this initial procedure and there have been significant breakthroughs in transplant rejection medicine. Renal transplantation is now a common procedure undertaken in patients with end-stage renal failure.

Transplant kidneys are obtained from either living or deceased donors. The living donors are carefully assessed, because harvesting a kidney from a normal healthy individual, even with modern-day medicine, carries a small risk.

Deceased kidney donors are brain dead or have suffered cardiac death. The donor kidney is harvested with a small cuff of aortic and venous tissue. The ureter is also harvested. *(continues)*



Abdomen

In the clinic—cont'd

An ideal place to situate the transplant kidney is in the left or the right iliac fossa (Fig. 4.148). A curvilinear incision is made paralleling the iliac crest and pubic symphysis. The external oblique muscle, internal oblique muscle, transversus abdominis muscle, and transversalis fascia are divided. The surgeon identifies the parietal peritoneum but does not enter the peritoneal cavity. The parietal peritoneum is medially retracted to reveal the external iliac artery, external iliac vein, and bladder. In some instances the internal iliac artery of the recipient is mobilized and anastomosed directly as an end-to-end procedure onto the renal artery of the donor kidney. Similarly the internal iliac vein is anastomosed to the donor vein. In the presence of a small aortic cuff of tissue

the donor artery is anastomosed to the recipient external iliac artery and similarly for the venous anastomosis. The ureter is easily tunneled obliquely through the bladder wall with a straightforward anastomosis.

The left and right iliac fossae are ideal locations for the transplant kidney because a new space can be created without compromise to other structures. The great advantage of this procedure is the proximity to the anterior abdominal wall, which permits easy ultrasound visualization of the kidney and Doppler vascular assessment. Furthermore, in this position biopsies are easily obtained. The extraperitoneal approach enables patients to make a swift recovery.

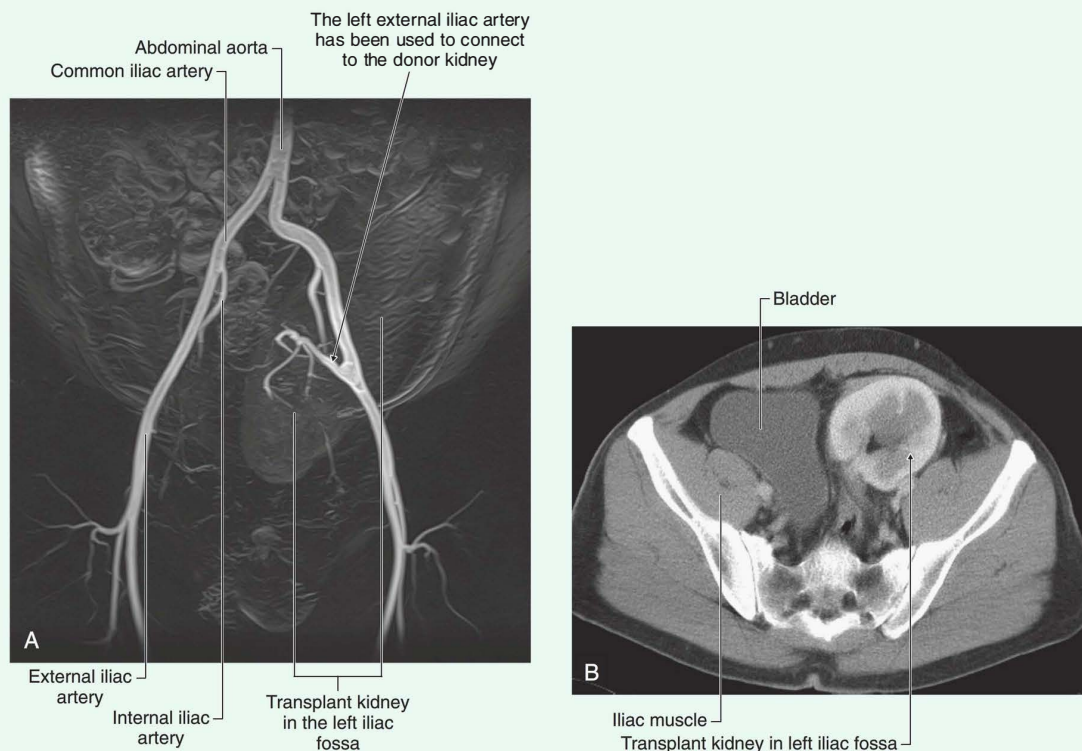


Fig. 4.148 Kidney transplant. **A.** This image demonstrates an MR angiogram of the bifurcation of the aorta. Attaching to the left external iliac artery is the donor artery for a kidney that has been transplanted into the left iliac fossa. **B.** Abdominal computed tomogram, in the axial plane, showing the transplanted kidney in the left iliac fossa.

In the clinic**Investigation of the urinary tract**

After an appropriate history and examination of the patient, including a digital rectal examination to assess the prostate in men, special investigations are required.

IVU (intravenous urogram)

An IVU is one of the most important and commonly carried out radiological investigations (Fig. 4.149). The

patient is injected with iodinated contrast medium. Most contrast media contain three iodine atoms spaced around a benzene ring. The relatively high atomic number of iodine compared to the atomic number of carbon, hydrogen, and oxygen, attenuates the radiation beam. After intravenous injection, contrast media are excreted predominantly by glomerular filtration, although some are secreted by the renal tubules. This allows visualization of the collecting system as well as the ureters and bladder.

Ultrasound

Ultrasound can be used to assess kidney size and the size of the calices, which may be dilated when obstructed. Although the ureters are poorly visualized using ultrasound, the bladder can be easily seen when full. Ultrasound measurements of bladder volume can be obtained before and after micturition.

Computed tomography

Computed tomography can be used to assess the kidneys, ureters, bladder, and adjacent structures and is a powerful tool for staging primary urinary tract tumors.

Nuclear medicine

Nuclear medicine is an extremely useful tool for investigating the urinary tract because radioisotope compounds can be used to estimate renal cell mass and function and assess the parenchyma for renal scarring. These tests are often very useful in children when renal scarring and reflux disease is suspected.

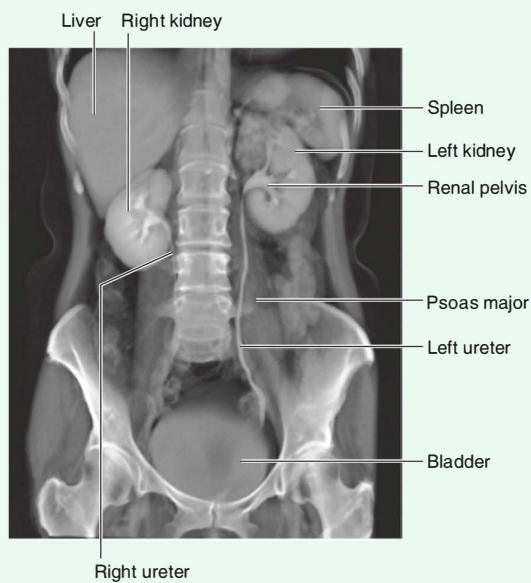


Fig. 4.149 Coronal view of 3-D urogram using multidetector computed tomography.



Abdomen

Suprarenal glands

The suprarenal glands are associated with the superior pole of each kidney (Fig. 4.150). They consist of an outer cortex and an inner medulla. The right gland is shaped like a pyramid, whereas the left gland is semilunar in shape and the larger of the two.

Anterior to the right suprarenal gland is part of the right lobe of the liver and the inferior vena cava, whereas

anterior to the left suprarenal gland is part of the stomach, pancreas, and, on occasion, the spleen. Parts of the diaphragm are posterior to both glands.

The suprarenal glands are surrounded by the perinephric fat and enclosed in the renal fascia, though a thin septum separates each gland from its associated kidney.

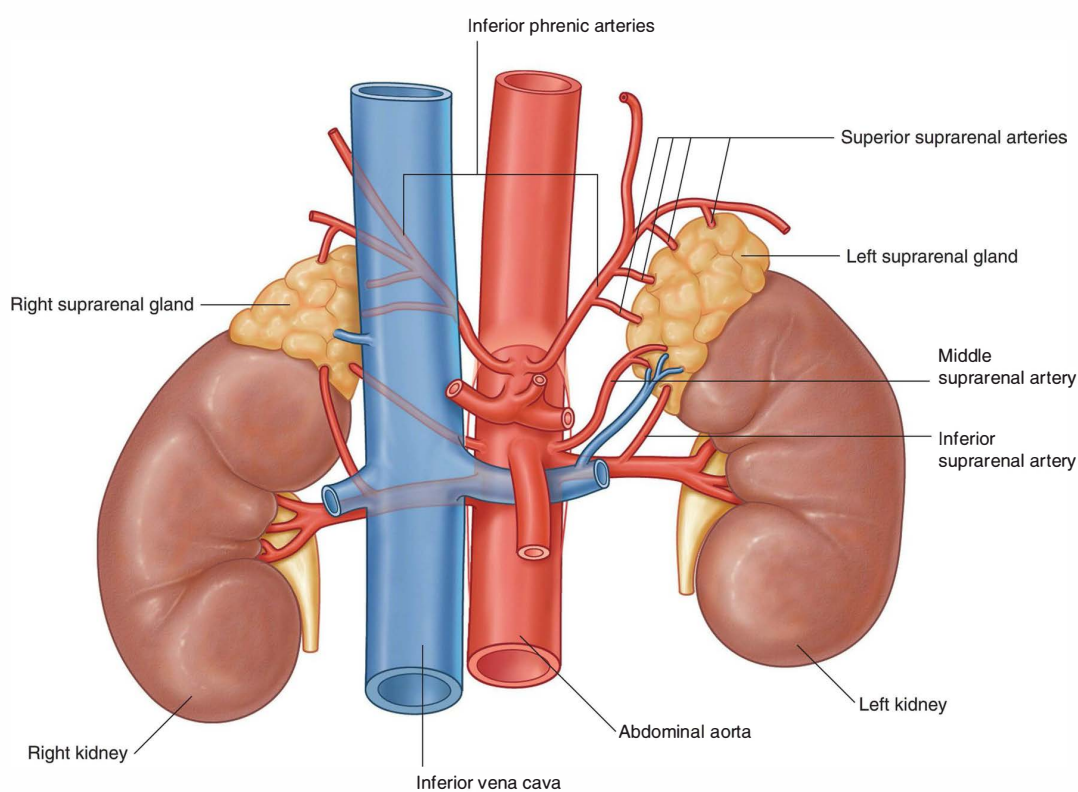


Fig. 4.150 Arterial supply to the suprarenal glands.

Suprarenal vasculature

The arterial supply to the suprarenal glands is extensive and arises from three primary sources (Fig. 4.150):

- As the bilateral inferior phrenic arteries pass upward from the abdominal aorta to the diaphragm, they give off multiple branches (superior suprarenal arteries) to the suprarenal glands.
- A middle branch (middle suprarenal artery) to the suprarenal glands usually arises directly from the abdominal aorta.
- Inferior branches (inferior suprarenal arteries) from the renal arteries pass upward to the suprarenal glands.

In contrast to this multiple arterial supply is the venous drainage, which usually consists of a single vein leaving the hilum of each gland. On the right side, the **right suprarenal vein** is short and almost immediately enters the inferior vena cava, while on the left side, the **left suprarenal vein** passes inferiorly to enter the left renal vein.

Vasculature

Abdominal aorta

The abdominal aorta begins at the aortic hiatus of the diaphragm as a midline structure at approximately the lower level of vertebra TXII (Fig. 4.151). It passes downward on the anterior surface of the bodies of vertebrae LI to LIV, ending just to the left of midline at the lower level of vertebra LIV. At this point, it divides into the **right and left common iliac arteries**. This bifurcation can be visualized on the anterior abdominal wall as a point approximately 2.5 cm below the umbilicus or even with a line extending between the highest points of the iliac crest.

As the abdominal aorta passes through the posterior abdominal region, the prevertebral plexus of nerves and ganglia covers its anterior surface. It is also related to numerous other structures:

- Anterior to the abdominal aorta, as it descends, are the pancreas and splenic vein, the left renal vein, and the inferior part of the duodenum.

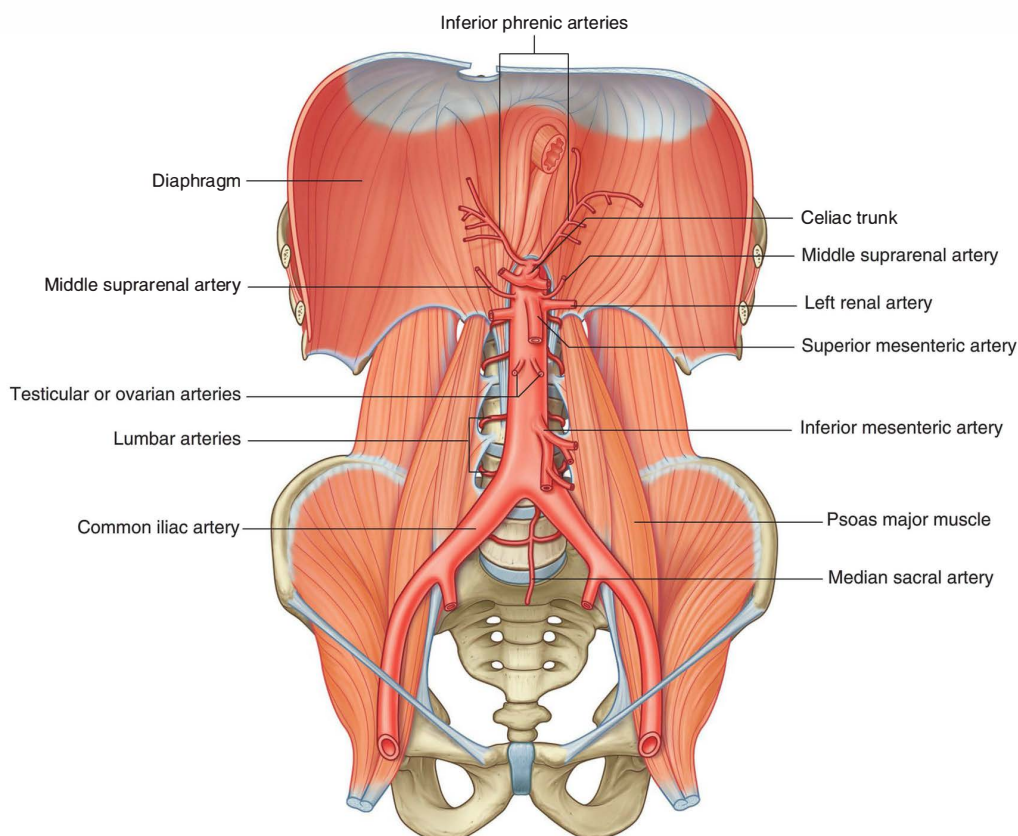


Fig. 4.151 Abdominal aorta.



Abdomen

- Several lumbar veins cross it posteriorly as they pass to the inferior vena cava.
- On its right side are the cisterna chyli, thoracic duct, azygos vein, right crus of the diaphragm, and the inferior vena cava.
- On its left side is the left crus of the diaphragm.

Branches of the abdominal aorta (Table 4.3) can be classified as:

- visceral branches supplying organs,
- posterior branches supplying the diaphragm or body wall, or
- terminal branches.

Visceral branches

The visceral branches are either unpaired or paired vessels.

The three unpaired visceral branches that arise from the anterior surface of the abdominal aorta (Fig. 4.151) are:

- the celiac trunk, which supplies the abdominal foregut,
- the superior mesenteric artery, which supplies the abdominal midgut, and
- the inferior mesenteric artery, which supplies the abdominal hindgut.

The paired visceral branches of the abdominal aorta (Fig. 4.151) include:

- the middle suprarenal arteries—small, lateral branches of the abdominal aorta arising just above the renal

arteries that are part of the multiple vascular supply to the suprarenal gland;

- the renal arteries—lateral branches of the abdominal aorta that arise just inferior to the origin of the superior mesenteric artery between vertebrae LI and LII, and supply the kidneys; and
- the testicular or ovarian arteries—anterior branches of the abdominal aorta that arise below the origin of the renal arteries, and pass downward and laterally on the anterior surface of the psoas major muscle.

Posterior branches

The posterior branches of the abdominal aorta are vessels supplying the diaphragm or body wall. They consist of the inferior phrenic arteries, the lumbar arteries, and the median sacral artery (Fig. 4.151).

Inferior phrenic arteries

The **inferior phrenic arteries** arise immediately inferior to the aortic hiatus of the diaphragm either directly from the abdominal aorta, as a common trunk from the abdominal aorta, or from the base of the celiac trunk (Fig. 4.151). Whatever their origin, they pass upward, provide some arterial supply to the suprarenal gland, and continue onto the inferior surface of the diaphragm.

Lumbar arteries

There are usually four pairs of **lumbar arteries** arising from the posterior surface of the abdominal aorta

Table 4.3 Branches of the abdominal aorta

Artery	Branch	Origin	Parts supplied
Celiac trunk	Anterior	Immediately inferior to the aortic hiatus of the diaphragm	Abdominal foregut
Superior mesenteric artery	Anterior	Immediately inferior to the celiac trunk	Abdominal midgut
Inferior mesenteric artery	Anterior	Inferior to the renal arteries	Abdominal hindgut
Middle suprarenal arteries	Lateral	Immediately superior to the renal arteries	Suprarenal glands
Renal arteries	Lateral	Immediately inferior to the superior mesenteric artery	Kidneys
Testicular or ovarian arteries	Paired anterior	Inferior to the renal arteries	Testes in male and ovaries in female
Inferior phrenic arteries	Lateral	Immediately inferior to the aortic hiatus	Diaphragm
Lumbar arteries	Posterior	Usually four pairs	Posterior abdominal wall and spinal cord
Median sacral artery	Posterior	Just superior to the aortic bifurcation, passes inferiorly across lumbar vertebrae, sacrum, and coccyx	
Common iliac arteries	Terminal	Bifurcation usually occurs at the level of LIV vertebra	

(Fig. 4.151). They run laterally and posteriorly over the bodies of the lumbar vertebrae, continue laterally, passing posterior to the sympathetic trunks and between the transverse processes of adjacent lumbar vertebrae, and reach the abdominal wall. From this point onward, they demonstrate a branching pattern similar to a posterior intercostal artery, which includes providing segmental branches that supply the spinal cord.

Median sacral artery

The final posterior branch is the **median sacral artery** (Fig. 4.151). This vessel arises from the posterior surface of the abdominal aorta just superior to the bifurcation and passes in an inferior direction, first over the anterior surface of the lower lumbar vertebrae and then over the anterior surface of the sacrum and coccyx.

In the clinic

Abdominal aortic stent graft

An abdominal aortic aneurysm is a dilatation of the aorta and generally tends to occur in the infrarenal region (the region at or below the renal arteries). As the aorta expands, the risk of rupture increases, and it is now generally accepted that when an aneurysm reaches 5.5 cm or greater an operation will significantly benefit the patient.

With the aging population, the number of abdominal aortic aneurysms is increasing. Moreover, with the increasing use of imaging techniques a number of abdominal aortic aneurysms are identified in asymptomatic patients.

For many years the standard treatment for repair was an open operative technique, which involved a large incision from the xiphoid process of the sternum to the symphysis pubis and dissection of the aneurysm. The aneurysm was excised and a tubular woven graft was sewn into place. Recovery may take a number of days, even weeks, and most patients would be placed in the intensive care unit after the operation.

Further developments and techniques have led to a new type of procedure being performed to treat

abdominal aortic aneurysms—the endovascular graft. The idea of placing the graft into the aortic aneurysm and lining the dilated vessel is not new and was first described over 10 years ago. Since the original description the devices have been modified on a number of occasions (Fig. 4.152).

The technique involves surgically dissecting the femoral artery below the inguinal ligament. A small incision is made in the femoral artery and the preloaded compressed graft with metal support struts is passed on a large catheter into the abdominal aorta through the femoral artery. Using X-ray for guidance the graft is opened, lining the inside of the aorta. Limb attachments are made to the graft that extend into the common iliac vessels. This bifurcated tube device effectively excludes the abdominal aortic aneurysm.

This type of device is not suitable for all patients. Patients who receive this device do not need to go to the intensive care unit. Many patients leave the hospital within 24 to 48 hours. Importantly, this device can be used for patients who were deemed unfit for open surgical repair.

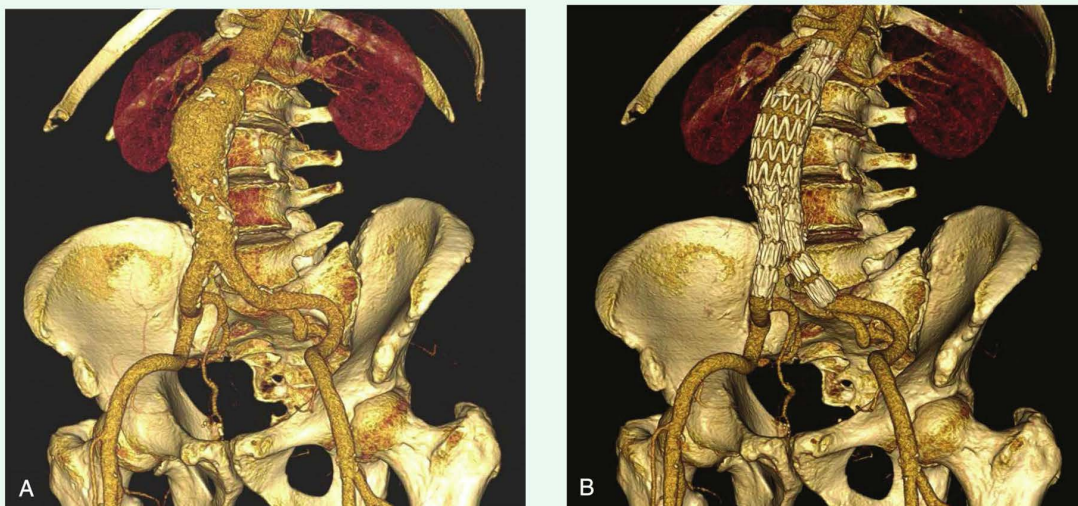


Fig. 4.152 Volume-rendered reconstruction using multidetector computed tomography of patient with an infrarenal abdominal aortic aneurysm before (A) and after (B) endovascular aneurysm repair. Note the image only demonstrates the intraluminal contrast and not the entire vessel. White patches in the aorta represent intramural calcium.



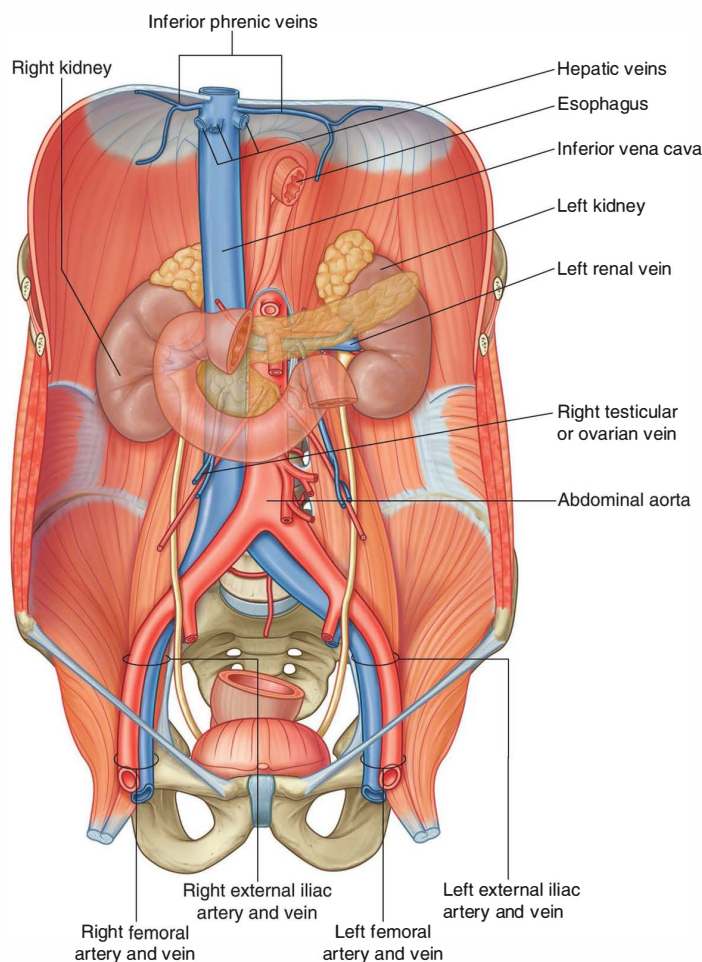
Abdomen

Inferior vena cava

The inferior vena cava returns blood from all structures below the diaphragm to the right atrium of the heart. It is formed when the two common iliac veins come together at the level of vertebra LV, just to the right of midline. It ascends through the posterior abdominal region anterior to the vertebral column immediately to the right of the abdominal aorta (Fig. 4.153), continues in a superior

direction, and leaves the abdomen by piercing the central tendon of the diaphragm at the level of vertebra TVIII.

During its course, the anterior surface of the inferior vena cava is crossed by the right common iliac artery, the root of the mesentery, the right testicular or ovarian artery, the inferior part of the duodenum, the head of the pancreas, the superior part of the duodenum, the bile duct, the portal vein, and the liver, which overlaps and on occasion completely surrounds the vena cava (Fig. 4.153).



Tributaries to the inferior vena cava include the:

- common iliac veins,
- lumbar veins,
- right testicular or ovarian vein,
- renal veins,
- right suprarenal vein,
- inferior phrenic veins, and
- hepatic veins.

There are no tributaries from the abdominal part of the gastrointestinal tract, the spleen, the pancreas, or the gall-bladder, because veins from these structures are components of the portal venous system, which first passes through the liver.

Of the venous tributaries mentioned above, the **lumbar veins** are unique in their connections and deserve special attention. Not all of the lumbar veins drain directly into the inferior vena cava (Fig. 4.154):

- The fifth lumbar vein generally drains into the iliolumbar vein, a tributary of the common iliac vein.
- The third and fourth lumbar veins usually drain into the inferior vena cava.

- The first and second lumbar veins may empty into the ascending lumbar veins.

The **ascending lumbar veins** are long, anastomosing venous channels that connect the common iliac, iliolumbar, and lumbar veins with the azygos and hemi-azygos veins of the thorax (Fig. 4.154).

If the inferior vena cava becomes blocked, the ascending lumbar veins become important collateral channels between the lower and upper parts of the body.

In the clinic

Inferior vena cava filter

Deep vein thrombosis is a potentially fatal condition where a clot (thrombus) is formed in the deep venous system of the legs and the veins of the pelvis. Virchow described the reasons for thrombus formation as decreased blood flow, abnormality of the constituents of blood, and abnormalities of the vessel wall. Common predisposing factors include hospitalization and surgery, the oral contraceptive pill, smoking, and air travel. Other factors include clotting abnormalities (e.g., protein S and protein C deficiency).

The diagnosis of deep vein thrombosis may be difficult to establish, with symptoms including leg swelling and pain and discomfort in the calf. It may also be an incidental finding.

In practice, patients with suspected deep vein thrombosis undergo a D-dimer blood test, which measures levels of a fibrin degradation product. If this is positive there is a high association with deep vein thrombosis.

The consequences of deep vein thrombosis are twofold. Occasionally the clot may dislodge and pass into the venous system through the right side of the heart and into the main pulmonary arteries. If the clots are of significant size they obstruct blood flow to the lung and may produce instantaneous death. Secondary complications include destruction of the normal valvular system in the legs, which may lead to venous incompetency and chronic leg swelling with ulceration.

The treatment for deep vein thrombosis is prevention. In order to prevent deep vein thrombosis, patients are optimized by removing all potential risk factors. Subcutaneous heparin may be injected and the patient wears compression stockings to prevent venous stasis while in the hospital.

In certain situations it is not possible to optimize the patient with prophylactic treatment, and it may be necessary to insert a filter into the inferior vena cava that traps any large clots. It may be removed after the risk period has ended.

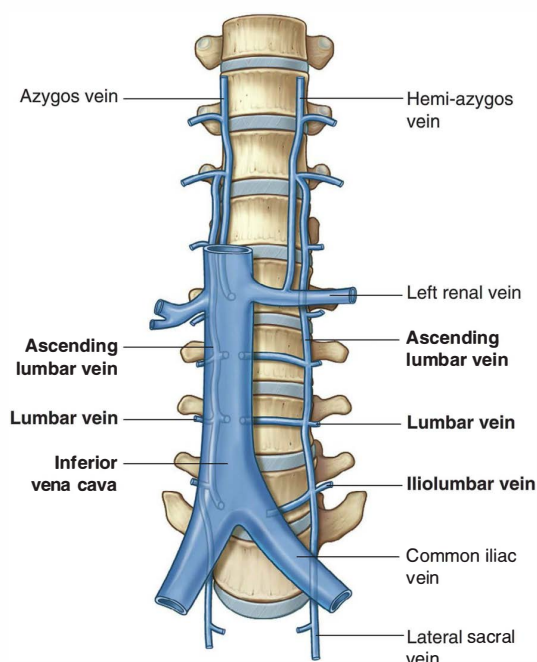


Fig. 4.154 Lumbar veins.



Abdomen

Lymphatic system

Lymphatic drainage from most deep structures and regions of the body below the diaphragm converges mainly on collections of lymph nodes and vessels associated with the major blood vessels of the posterior abdominal region (Fig. 4.155). The lymph then predominantly drains into the thoracic duct. Major lymphatic channels that drain different regions of the body as a whole are summarized in

Table 4.4 (also see Chapter 1, pp. 29-30, for discussion of lymphatics in general).

Pre-aortic and lateral aortic or lumbar nodes (para-aortic nodes)

Approaching the aortic bifurcation, the collections of lymphatics associated with the two common iliac arteries and veins merge, and multiple groups of lymphatic vessels and nodes associated with the abdominal aorta and

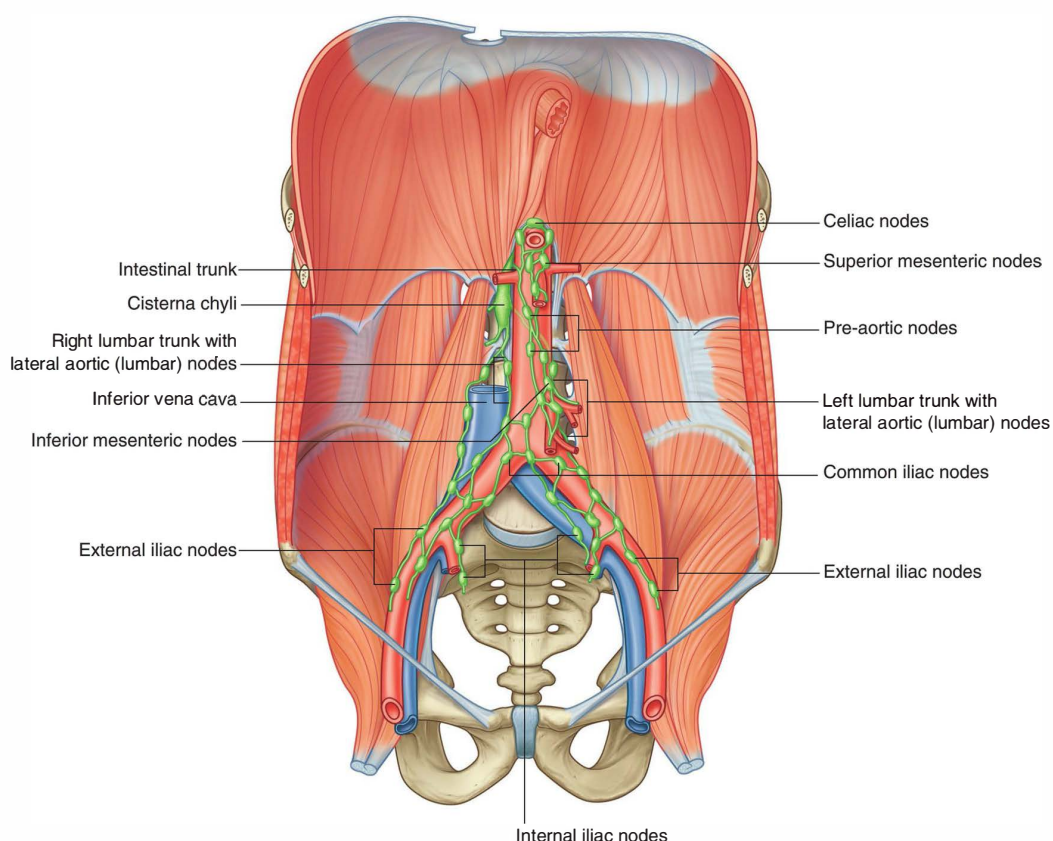


Fig. 4.155 Abdominal lymphatics.

Table 4.4 Lymphatic drainage

Lymphatic vessel	Area drained
Right jugular trunk	Right side of head and neck
Left jugular trunk	Left side of head and neck
Right subclavian trunk	Right upper limb, superficial regions of thoracic and upper abdominal walls
Left subclavian trunk	Left upper limb, superficial regions of thoracic and upper abdominal walls
Right bronchomediastinal trunk	Right lung and bronchi, mediastinal structures, thoracic wall
Left bronchomediastinal trunk	Left lung and bronchi, mediastinal structures, thoracic wall
Thoracic duct	Lower limbs, abdominal walls and viscera, pelvic walls and viscera, thoracic wall

inferior vena cava pass superiorly. These collections may be subdivided into **pre-aortic nodes**, which are anterior to the abdominal aorta, and **right and left lateral aortic or lumbar nodes (para-aortic nodes)**, which are positioned on either side of the abdominal aorta (Fig. 4.155).

As these collections of lymphatics pass through the posterior abdominal region, they continue to collect lymph from a variety of structures. The lateral aortic or lumbar lymph nodes (para-aortic nodes) receive lymphatics from the body wall, the kidneys, the suprarenal glands, and the testes or ovaries.

The pre-aortic nodes are organized around the three anterior branches of the abdominal aorta that supply the

abdominal part of the gastrointestinal tract, as well as the spleen, pancreas, gallbladder, and liver. They are divided into celiac, superior mesenteric, and inferior mesenteric nodes, and receive lymph from the organs supplied by the similarly named arteries.

Finally, the lateral aortic or lumbar nodes form the right and left lumbar trunks, whereas the pre-aortic nodes form the intestinal trunk (Fig. 4.155). These trunks come together and form a confluence that, at times, appears as a saccular dilation (the cisterna chyli). This confluence of lymph trunks is posterior to the right side of the abdominal aorta and anterior to the bodies of vertebrae LI and LII. It marks the beginning of the thoracic duct.

In the clinic

Retroperitoneal lymph node surgery

From a clinical perspective, retroperitoneal lymph nodes are arranged in two groups. The pre-aortic lymph node group drains lymph from the embryological midline structures, such as the liver, bowel, and pancreas. The para-aortic lymph node group (the lateral aortic or lumbar nodes), on either side of the aorta, drain lymph from bilateral structures, such as the kidneys and adrenal glands. Organs embryologically derived from the posterior abdominal wall also drain lymph to these nodes. These organs include the ovaries and the testes (importantly, the testes do not drain lymph to the inguinal regions).

In general, lymphatic drainage follows standard predictable routes; however, in the presence of disease, alternate routes of lymphatic drainage will occur.

There are a number of causes for enlarged retroperitoneal lymph nodes. In the adult, massively enlarged lymph nodes are a feature of lymphoma, and smaller lymph node enlargement is observed in the presence of infection and metastatic malignant spread of disease (e.g., colon cancer).

The treatment for malignant lymph node disease is based upon a number of factors, including the site of the primary tumor (e.g., bowel) and its histological cell type. Normally, the primary tumor is surgically removed and the lymph node spread and metastatic organ spread (e.g., to the liver and the lungs) are often treated with chemotherapy and radiotherapy.

In certain instances it may be considered appropriate to resect the lymph nodes in the retroperitoneum (e.g., for testicular cancer).

The surgical approach to retroperitoneal lymph node resection involves a lateral paramedian incision in the midclavicular line. The three layers of the anterolateral abdominal wall (external oblique, internal oblique, and transversus abdominis) are opened and the transversalis fascia is divided. The next structure the surgeon sees is the parietal peritoneum. Instead of entering the parietal peritoneum, which is standard procedure for most intraabdominal operations, the surgeon gently pushes the parietal peritoneum toward the midline, which moves the intraabdominal contents and allows a clear view of the retroperitoneal structures. On the left, the para-aortic lymph node group is easily demonstrated, with a clear view of the abdominal aorta and kidney. On the right the inferior vena cava is demonstrated and has to be retracted to access the right para-aortic lymph node chain.

The procedure of retroperitoneal lymph node dissection is extremely well tolerated and lacks the problems of entering the peritoneal cavity (e.g., paralytic ileus). Unfortunately, a complication of a vertical incision in the midclavicular line is division of the segmental nerve supply to the rectus abdominis muscle. This produces muscle atrophy and asymmetrical proportions of the anterior abdominal wall.



Abdomen

Nervous system in the posterior abdominal region

Several important components of the nervous system are in the posterior abdominal region. These include the sympathetic trunks and associated splanchnic nerves, the plexus of nerves and ganglia associated with the abdominal aorta, and the lumbar plexus of nerves.

Sympathetic trunks and splanchnic nerves

The sympathetic trunks pass through the posterior abdominal region anterolateral to the lumbar vertebral bodies, before continuing across the sacral promontory and into

the pelvic cavity (Fig. 4.156). Along their course, small raised areas are visible. These represent collections of neuronal cell bodies—primarily postganglionic neuronal cell bodies—which are located outside the central nervous system. They are sympathetic paravertebral ganglia. There are usually four ganglia along the sympathetic trunks in the posterior abdominal region.

Also associated with the sympathetic trunks in the posterior abdominal region are the lumbar splanchnic nerves (Fig. 4.156). These components of the nervous system pass from the sympathetic trunks to the plexus of nerves and ganglia associated with the abdominal aorta. Usually two to four lumbar splanchnic nerves carry preganglionic sympathetic fibers and visceral afferent fibers.

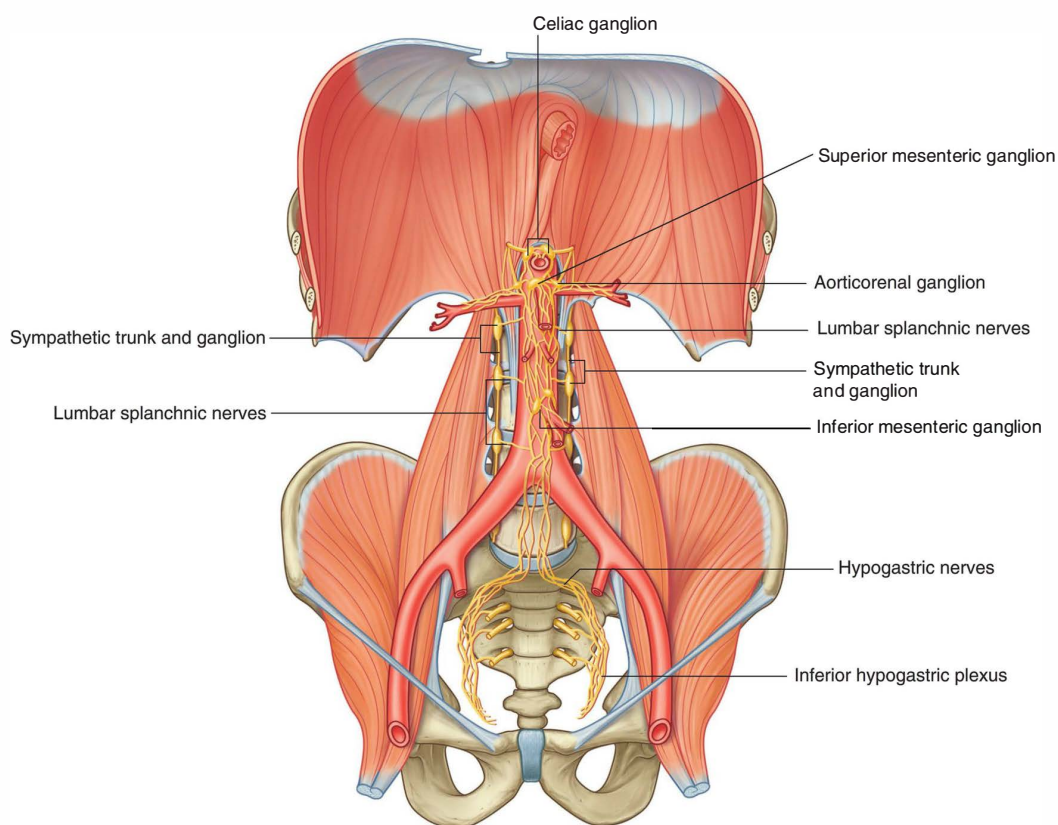


Fig. 4.156 Sympathetic trunks passing through the posterior abdominal region.

Abdominal prevertebral plexus and ganglia

The abdominal prevertebral plexus is a network of nerve fibers surrounding the abdominal aorta. It extends from the aortic hiatus of the diaphragm to the bifurcation of the aorta into the right and left common iliac arteries. Along its route, it is subdivided into smaller, named plexuses (Fig. 4.157):

- Beginning at the diaphragm and moving inferiorly, the initial accumulation of nerve fibers is referred to as the

celiac plexus—this subdivision includes nerve fibers associated with the roots of the celiac trunk and superior mesenteric artery.

- Continuing inferiorly, the plexus of nerve fibers extending from just below the superior mesenteric artery to the aortic bifurcation is the abdominal aortic plexus (Fig. 4.157).
- At the bifurcation of the abdominal aorta, the abdominal prevertebral plexus continues inferiorly as the superior hypogastric plexus.

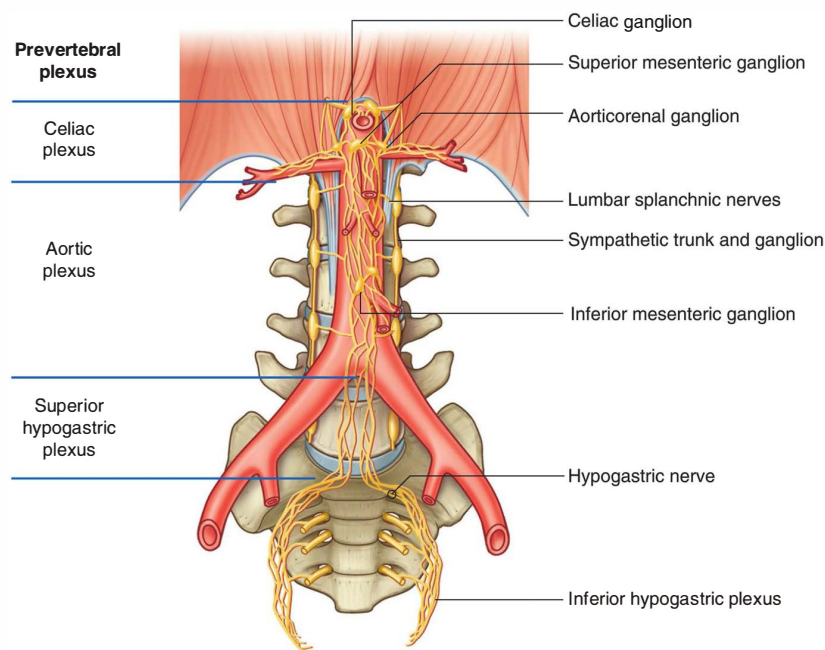


Fig. 4.157 Prevertebral plexus and ganglia in the posterior abdominal region.



Abdomen

Throughout its length, the abdominal prevertebral plexus is a conduit for:

- preganglionic sympathetic and visceral afferent fibers from the thoracic and lumbar splanchnic nerves,
- preganglionic parasympathetic and visceral afferent fibers from the vagus nerves [X], and
- preganglionic parasympathetic fibers from the pelvic splanchnic nerves (Fig. 4.158).

Associated with the abdominal prevertebral plexus are clumps of nervous tissue (the **prevertebral ganglia**),

which are collections of postganglionic sympathetic neuronal cell bodies in recognizable aggregations along the abdominal prevertebral plexus; they are usually named after the nearest branch of the abdominal aorta. They are therefore referred to as **celiac**, **superior mesenteric**, **aorticorenal**, and **inferior mesenteric ganglia** (Fig. 4.159). These structures, along with the abdominal prevertebral plexus, play a critical role in the innervation of the abdominal viscera.

Common sites for pain referred from the abdominal viscera and from the heart are given in Table 4.5.

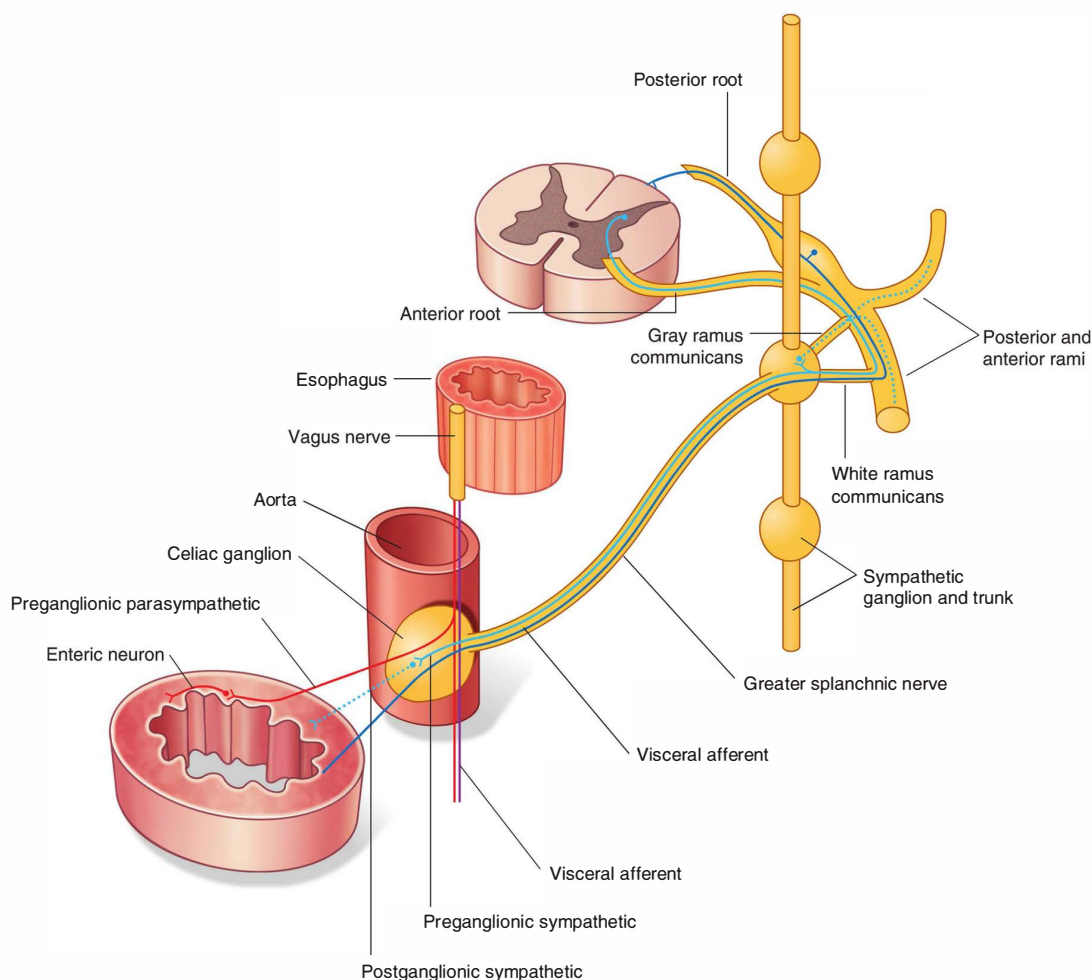


Fig. 4.158 Nerve fibers passing through the abdominal prevertebral plexus and ganglia.

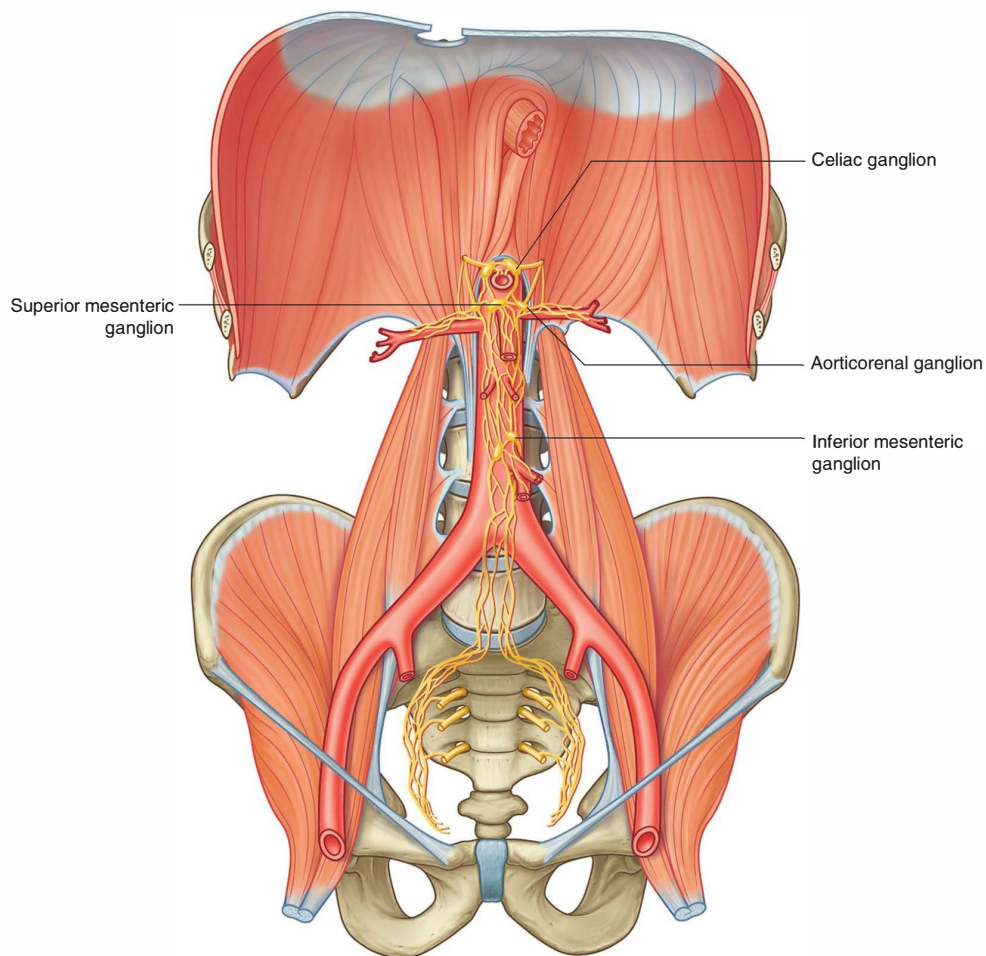


Fig. 4.159 Prevertebral ganglia associated with the prevertebral plexus.

Table 4.5 Referred pain pathways (visceral afferents)

Organ	Afferent pathway	Spinal cord level	Referral area
Heart	Thoracic splanchnic nerves	T1 to T4	Upper thorax and medial arm
Foregut (organs supplied by celiac trunk)	Greater splanchnic nerve	T5 to T9 (or T10)	Lower thorax and epigastric region
Midgut (organs supplied by superior mesenteric artery)	Lesser splanchnic nerve	T9, T10 (or T10, T11)	Umbilical region
Kidneys and upper ureter	Least splanchnic nerve	T12	Flanks (lateral regions)
Hindgut (organs supplied by inferior mesenteric artery) and lower ureter	Lumbar splanchnic nerves	L1, L2	Pubic region, lateral and anterior thighs, and groin



Abdomen

Lumbar plexus

The lumbar plexus is formed by the anterior rami of nerves L1 to L3 and most of the anterior ramus of L4 (Fig. 4.160 and Table 4.6). It also receives a contribution from the T12 (subcostal) nerve.

Branches of the lumbar plexus include the iliohypogastric, ilio-inguinal and genitofemoral nerves lateral cutaneous nerve of the thigh (lateral femoral cutaneous) and femoral and obturator nerves. The lumbar plexus forms in the substance of the psoas major muscle anterior to its attachment to the transverse processes of the lumbar vertebrae (Fig. 4.161). Therefore, relative to the psoas major muscle, the various branches emerge either:

- anterior—genitofemoral nerve,
- medial—obturator nerve, or
- lateral—iliohypogastric, ilio-inguinal, and femoral nerves and the lateral cutaneous nerve of the thigh.

Iliohypogastric and ilio-inguinal nerves (L1)

The iliohypogastric and ilio-inguinal nerves arise as a single trunk from the anterior ramus of nerve L1 (Fig. 4.160). Either before or soon after emerging from the lateral border of the psoas major muscle, this single trunk divides into the iliohypogastric and the ilio-inguinal nerves.

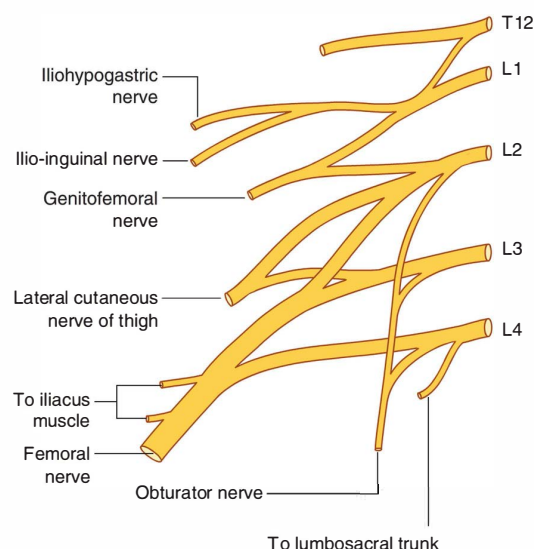


Fig. 4.160 Lumbar plexus.

Table 4.6 Branches of the lumbar plexus

Branch	Origin	Spinal segments	Function: motor	Function: sensory
Iliohypogastric	Anterior ramus L1	L1	Internal oblique and transversus abdominis	Posterolateral gluteal skin and skin in pubic region
Ilio-inguinal	Anterior ramus L1	L1	Internal oblique and transversus abdominis	Skin in the upper medial thigh, and either the skin over the root of the penis and anterior scrotum or the mons pubis and labium majus
Genitofemoral	Anterior rami L1 and L2	L1, L2	Genital branch—male cremasteric muscle	Genital branch—skin of anterior scrotum or skin of mons pubis and labium majus; femoral branch—skin of upper anterior thigh
Lateral cutaneous nerve of thigh	Anterior rami L2 and L3	L2, L3		Skin on anterior and lateral thigh to the knee
Obturator	Anterior rami L2 to L4	L2 to L4	Obturator externus, pectineus, and muscles in medial compartment of thigh	Skin on medial aspect of the thigh
Femoral	Anterior rami L2 to L4	L2 to L4	Iliacus, pectineus, and muscles in anterior compartment of thigh	Skin on anterior thigh and medial surface of leg

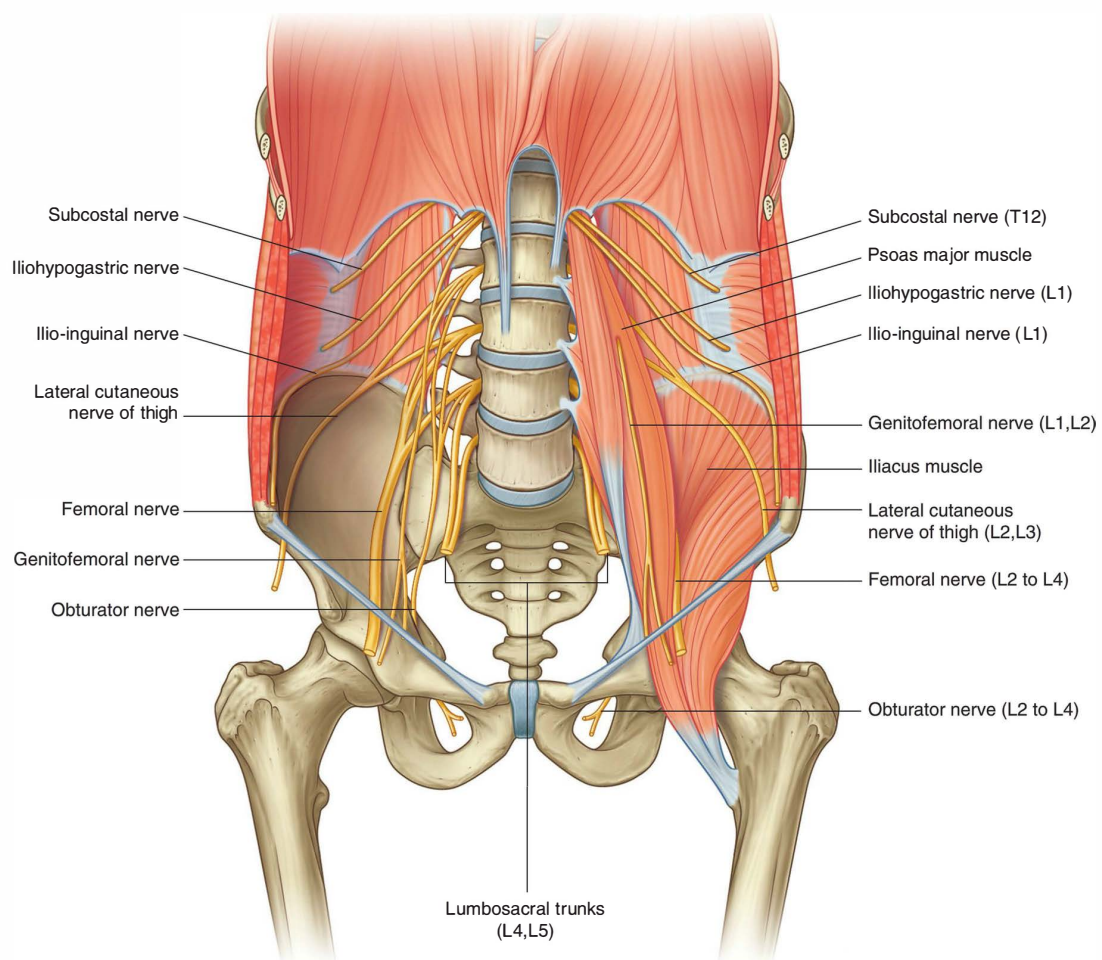


Fig. 4.161 Lumbar plexus in the posterior abdominal region.



Abdomen

Iliohypogastric nerve

The **iliohypogastric nerve** passes across the anterior surface of the quadratus lumborum muscle, posterior to the kidney. It pierces the transversus abdominis muscle and continues anteriorly around the body between the transversus abdominis and internal oblique muscles. Above the iliac crest, a **lateral cutaneous branch** pierces the internal and external oblique muscles to supply the posterolateral gluteal skin (Fig. 4.162).

The remaining part of the iliohypogastric nerve (the **anterior cutaneous branch**) continues in an anterior

direction, piercing the internal oblique just medial to the anterior superior iliac spine as it continues in an obliquely downward and medial direction. Becoming cutaneous, just above the superficial inguinal ring, after piercing the aponeurosis of the external oblique, it distributes to the skin in the pubic region (Fig. 4.162). Throughout its course, it also supplies branches to the abdominal musculature.

Ilio-inguinal nerve

The ilio-inguinal nerve is smaller than, and inferior to, the iliohypogastric nerve as it crosses the quadratus lumborum

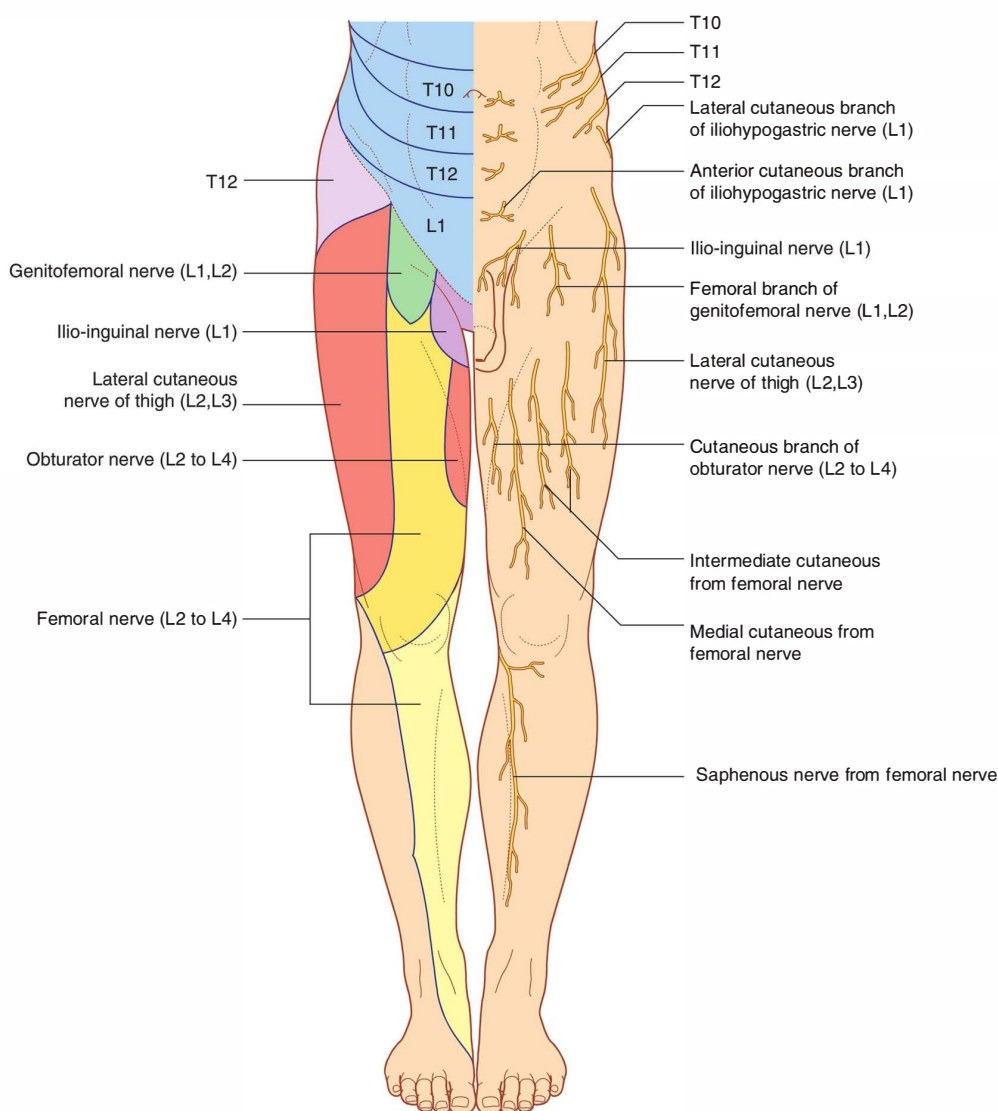


Fig. 4.162 Cutaneous distribution of the nerves from the lumbar plexus.

muscle. Its course is more oblique than that of the iliohypogastric nerve, and it usually crosses part of the iliacus muscle on its way to the iliac crest. Near the anterior end of the iliac crest, it pierces the transversus abdominis muscle, and then pierces the internal oblique muscle and enters the inguinal canal.

The ilio-inguinal nerve emerges through the superficial inguinal ring, along with the spermatic cord, and provides cutaneous innervation to the upper medial thigh, the root of the penis, and the anterior surface of the scrotum in men, or the mons pubis and labium majus in women (Fig. 4.162). Throughout its course, it also supplies branches to the abdominal musculature.

Genitofemoral nerve (L1 and L2)

The genitofemoral nerve arises from the anterior rami of nerves L1 and L2 (Fig. 4.160). It passes downward in the substance of the psoas major muscle until it emerges on the anterior surface of the psoas major. It then descends on the surface of the muscle, in a retroperitoneal position, passing posterior to the ureter. It eventually divides into genital and femoral branches.

The **genital branch** continues downward and enters the inguinal canal through the deep inguinal ring. It continues through the canal and:

- in men, innervates the cremasteric muscle and terminates on the skin in the upper anterior part of the scrotum, and
- in women, accompanies the round ligament of the uterus and terminates on the skin of the mons pubis and labium majus.

The **femoral branch** descends on the lateral side of the external iliac artery and passes posterior to the inguinal ligament, entering the femoral sheath lateral to the femoral artery. It pierces the anterior layer of the femoral sheath and the fascia lata to supply the skin of the upper anterior thigh (Fig. 4.162).

Lateral cutaneous nerve of thigh (L2 and L3)

The lateral cutaneous nerve of the thigh arises from the anterior rami of nerves L2 and L3 (Fig. 4.160). It emerges from the lateral border of the psoas major muscle, passing obliquely downward across the iliacus muscle toward the anterior superior iliac spine (Fig. 4.162). It passes posterior to the inguinal ligament and enters the thigh.

The lateral cutaneous nerve of the thigh supplies the skin on the anterior and lateral thigh to the level of the knee (Fig. 4.162).

Obturator nerve (L2 to L4)

The obturator nerve arises from the anterior rami of nerves L2 to L4 (Fig. 4.160). It descends in the psoas major muscle, emerging from its medial side near the pelvic brim (Fig. 4.161).

The obturator nerve continues posterior to the common iliac vessels, passes across the lateral wall of the pelvic cavity, and enters the obturator canal, through which the obturator nerve gains access to the medial compartment of the thigh.

In the area of the obturator canal, the obturator nerve divides into **anterior** and **posterior branches**. On entering the medial compartment of the thigh, the two branches are separated by the obturator externus and adductor brevis muscles. Throughout their course through the medial compartment, these two branches supply:

- articular branches to the hip joint,
- muscular branches to the obturator externus, pectineus, adductor longus, gracilis, adductor brevis, and adductor magnus muscles,
- cutaneous branches to the medial aspect of the thigh, and
- in association with the saphenous nerve, cutaneous branches to the medial aspect of the upper part of the leg and articular branches to the knee joint (Fig. 4.162).

Femoral nerve (L2 to L4)

The femoral nerve arises from the anterior rami of nerves L2 to L4 (Fig. 4.160). It descends through the substance of the psoas major muscle, emerging from the lower lateral border of the psoas major (Fig. 4.161). Continuing its descent, the femoral nerve lies between the lateral border of the psoas major and the anterior surface of the iliacus muscle. It is deep to the iliacus fascia and lateral to the femoral artery as it passes posterior to the inguinal ligament and enters the anterior compartment of the thigh. Upon entering the thigh, it immediately divides into multiple branches.

Cutaneous branches of the femoral nerve include:

- medial and intermediate cutaneous nerves supplying the skin on the anterior surface of the thigh, and
- the saphenous nerve supplying the skin on the medial surface of the leg (Fig. 4.162).

Muscular branches innervate the iliacus, pectineus, sartorius, rectus femoris, vastus medialis, vastus intermedius, and vastus lateralis muscles. Articular branches supply the hip and knee joints.



Abdomen

Surface anatomy

Abdomen surface anatomy

Visualization of the position of abdominal viscera is fundamental to a physical examination. Some of these viscera or their parts can be felt by palpating through the abdominal wall. Surface features can be used to establish the positions of deep structures.

Defining the surface projection of the abdomen

Palpable landmarks can be used to delineate the extent of the abdomen on the surface of the body. These landmarks are:

- the costal margin above and
- the pubic tubercle, anterior superior iliac spine, and iliac crest below (Fig. 4.163).

The costal margin is readily palpable and separates the abdominal wall from the thoracic wall.

A line between the anterior superior iliac spine and the pubic tubercle marks the position of the inguinal ligament, which separates the anterior abdominal wall above from the thigh of the lower limb below.

The iliac crest separates the posterolateral abdominal wall from the gluteal region of the lower limb.

The upper part of the abdominal cavity projects above the costal margin to the diaphragm, and therefore abdominal viscera in this region of the abdomen are protected by the thoracic wall.

The level of the diaphragm varies during the breathing cycle. The dome of the diaphragm on the right can reach as high as the fourth costal cartilage during forced expiration.

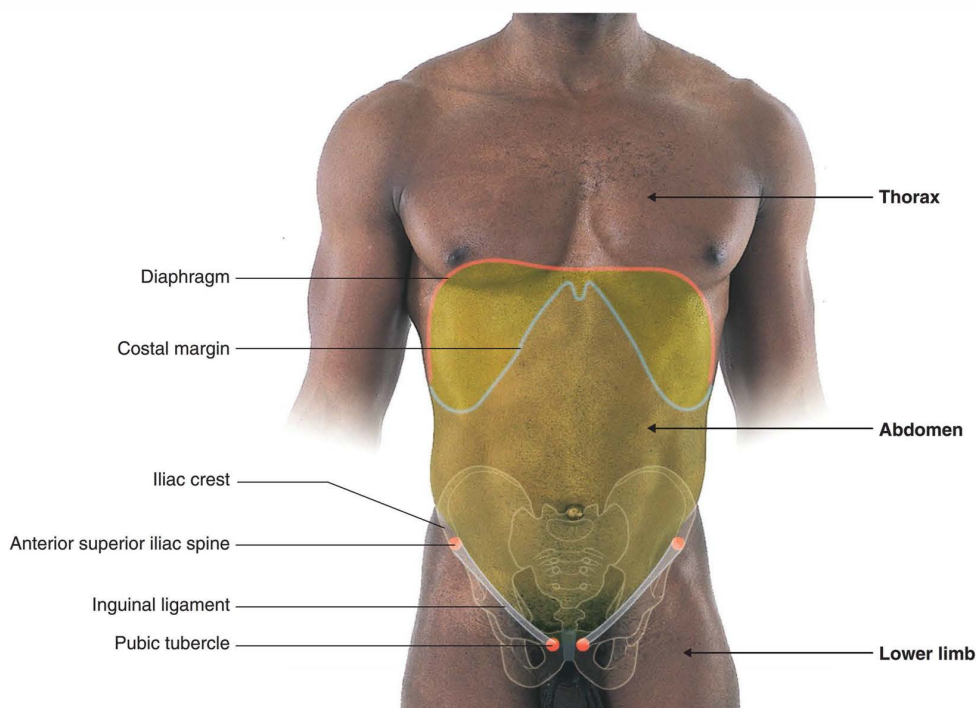


Fig. 4.163 Interior view of the abdominal region of a man. Palpable bony landmarks, the inguinal ligament, and the position of the diaphragm are indicated.

How to find the superficial inguinal ring

The superficial inguinal ring is an elongate triangular defect in the aponeurosis of the external oblique (Fig. 4.164). It lies in the lower medial aspect of the anterior abdominal wall and is the external opening of the inguinal

canal. The inguinal canal and superficial ring are larger in men than in women:

- In men, structures that pass between the abdomen and the testis pass through the inguinal canal and superficial inguinal ring.

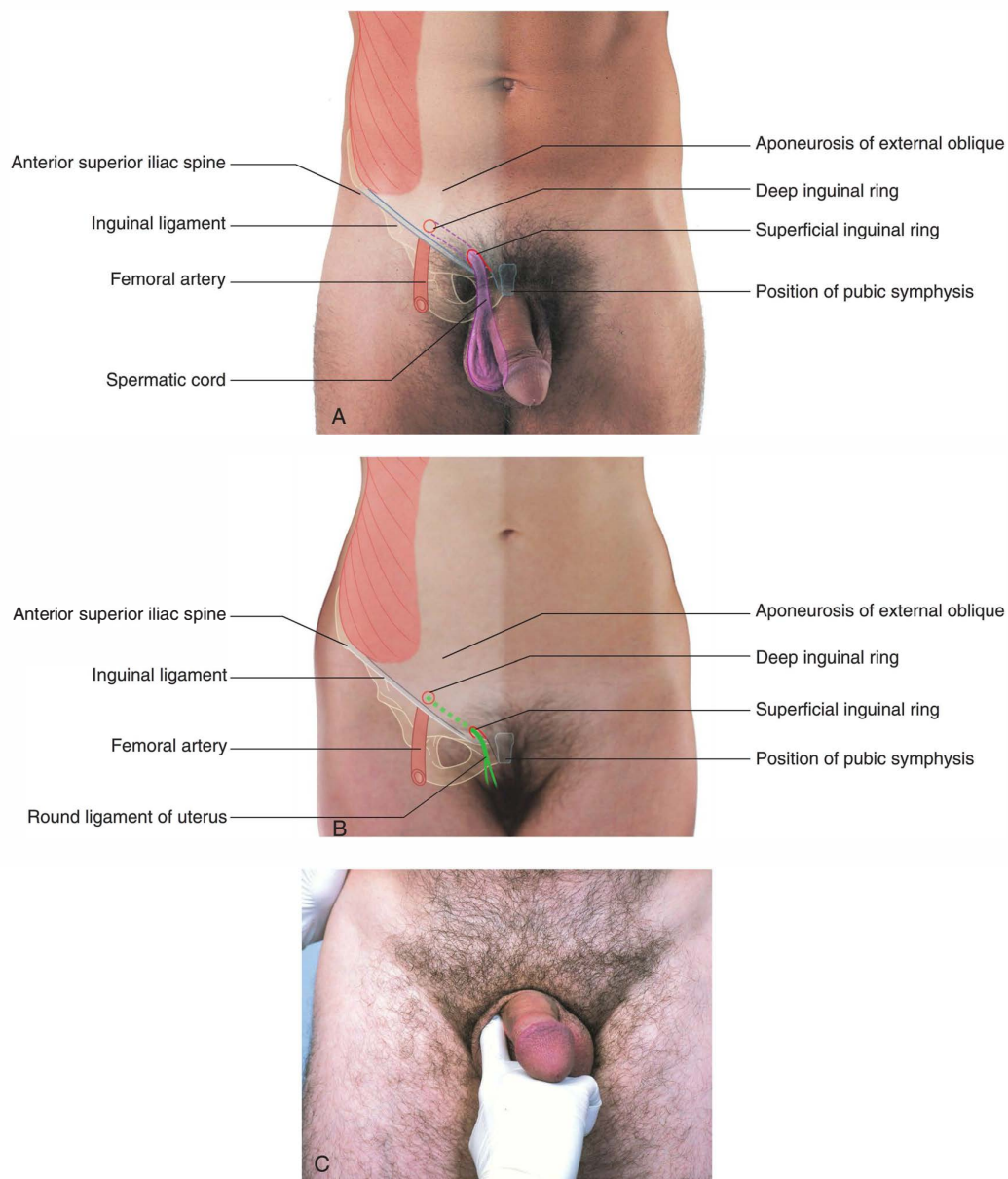


Fig. 4.164 Groin. **A.** In a man. **B.** In a woman. **C.** Examination of the superficial inguinal ring and related regions of the inguinal canal in a man.



Abdomen

- In women, the round ligament of the uterus passes through the inguinal canal and superficial inguinal ring to merge with connective tissue of the labium majus.

The superficial inguinal ring is superior to the pubic crest and tubercle and to the medial end of the inguinal ligament:

- In men, the superficial inguinal ring can be easily located by following the spermatic cord superiorly to the lower abdominal wall—the external spermatic fascia of the spermatic cord is continuous with the margins of the superficial inguinal ring.
- In women, the pubic tubercle can be palpated and the ring is superior and lateral to it.

The deep inguinal ring, which is the internal opening to the inguinal canal, lies superior to the inguinal ligament, midway between the anterior superior iliac spine and pubic

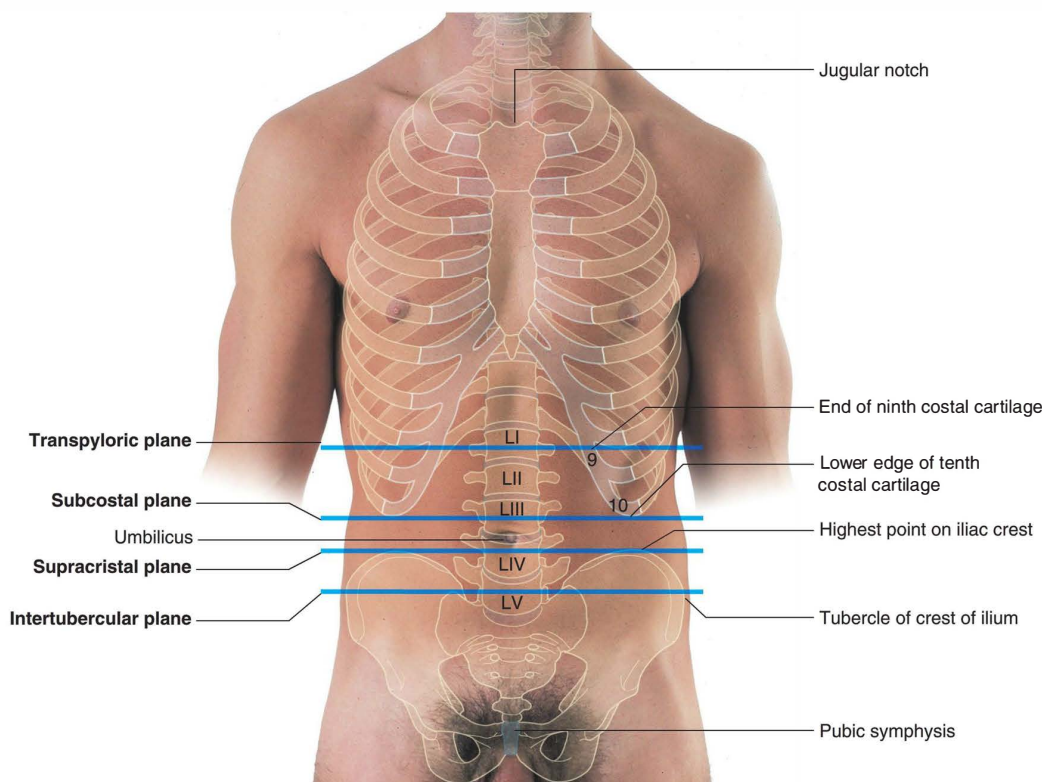
symphysis. The pulse of the femoral artery can be felt in the same position but below the inguinal ligament.

Because the superficial inguinal ring is the site where inguinal hernias appear, particularly in men, the ring and related parts of the inguinal canal are often evaluated during physical examination.

How to determine lumbar vertebral levels

Lumbar vertebral levels are useful for visualizing the positions of viscera and major blood vessels. The approximate positions of the lumbar vertebrae can be established using palpable or visible landmarks (Fig. 4.165):

- A horizontal plane passes through the medial ends of the ninth costal cartilages and the body of the L1 vertebra—this transpyloric plane cuts through the body midway between the suprasternal (jugular) notch and the pubic symphysis.



- A horizontal plane passes through the lower edge of the costal margin (tenth costal cartilage) and the body of the LIII vertebra—the umbilicus is normally on a horizontal plane that passes through the disc between the LIII and LIV vertebrae.
- A horizontal plane (supracristal plane) through the highest point on the iliac crest passes through the spine and body of the LIV vertebra;
- A plane through the tubercles of the crest of the ilium passes through the body of the LV vertebra.

Visualizing structures at the L1 vertebral level

The L1 vertebral level is marked by the transpyloric plane, which cuts transversely through the body midway between

the jugular notch and pubic symphysis, and through the ends of the ninth costal cartilages (Fig. 4.166). At this level are:

- the beginning and upper limit of the end of the duodenum,
- the hila of the kidneys,
- the neck of the pancreas, and
- the origin of the superior mesenteric artery from the aorta.

The left and right colic flexures also are close to this level.

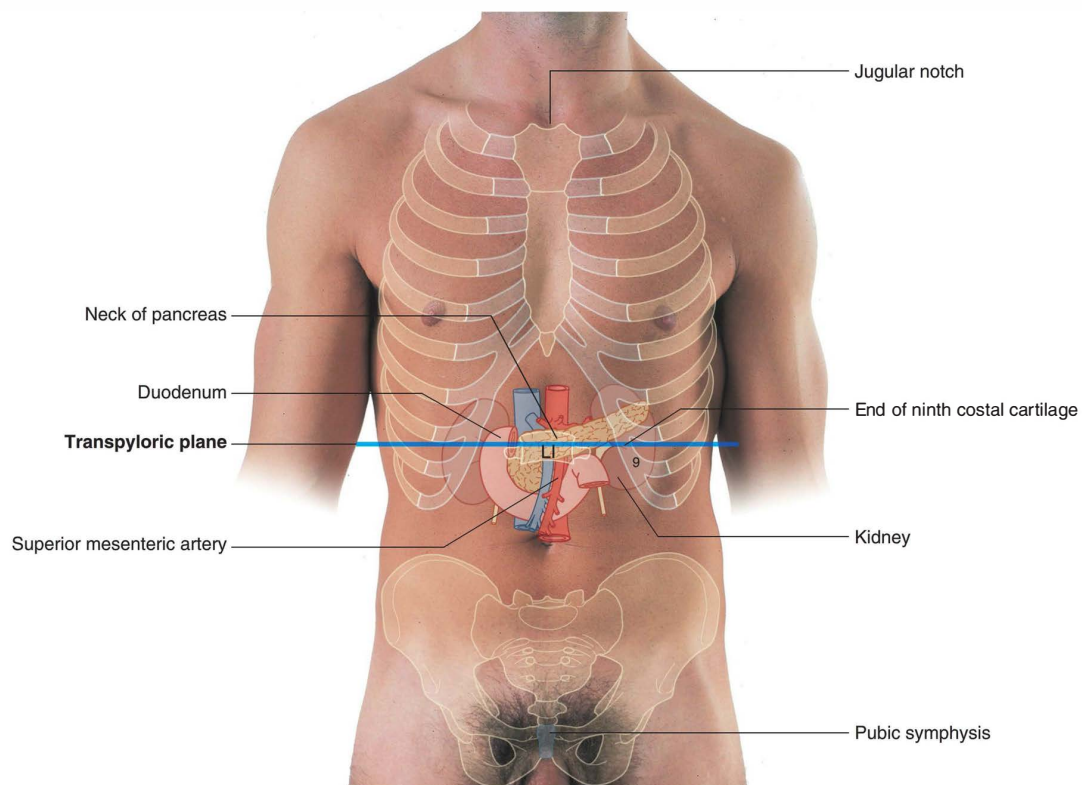


Fig. 4.166 L1 vertebral level and the important viscera associated with this level. Anterior view of the abdominal region of a man.



Abdomen

Visualizing the position of major blood vessels

Each of the vertebral levels in the abdomen is related to the origin of major blood vessels (Fig. 4.167):

- The celiac trunk originates from the aorta at the upper border of the LI vertebra.
- The superior mesenteric artery originates at the lower border of the LI vertebra.
- The renal arteries originate at approximately the LII vertebra.
- The inferior mesenteric artery originates at the LIII vertebra.
- The aorta bifurcates into the right and left common iliac arteries at the level of the LIV vertebra.
- The left and right common iliac veins join to form the inferior vena cava at the LV vertebral level.

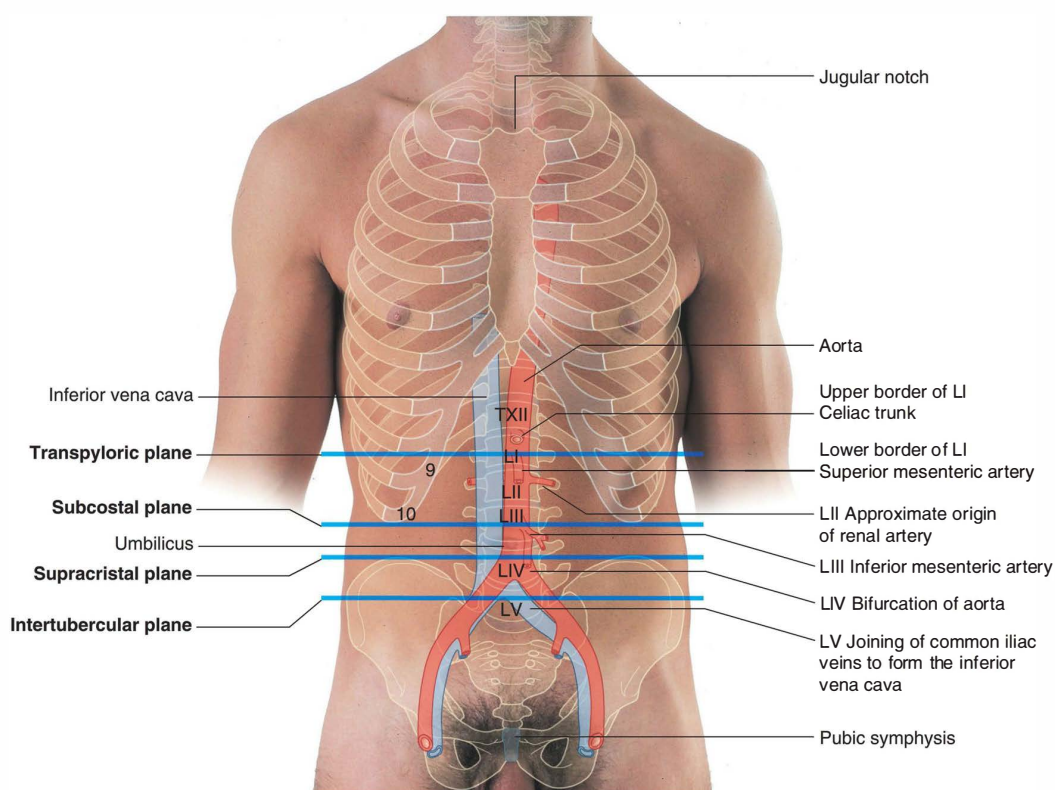


Fig. 4.167 Major vessels projected onto the body's surface. Anterior view of the abdominal region of a man.

Using abdominal quadrants to locate major viscera

The abdomen can be divided into quadrants by a vertical median plane and a horizontal transumbilical plane, which passes through the umbilicus (Fig. 4.168):

- The liver and gallbladder are in the right upper quadrant.
- The stomach and spleen are in the left upper quadrant.
- The cecum and appendix are in the right lower quadrant.
- The end of the descending colon and sigmoid colon are in the left lower quadrant.

Most of the liver is under the right dome of the diaphragm and is deep to the lower thoracic wall. The inferior margin of the liver can be palpated descending below the right costal margin when a patient is asked to inhale deeply. On deep inspiration, the edge of the liver can be felt “slipping” under the palpating fingers placed under the costal margin.

A common surface projection of the appendix is McBurney’s point, which is one-third of the way up along a line from the right anterior superior iliac spine to the umbilicus.

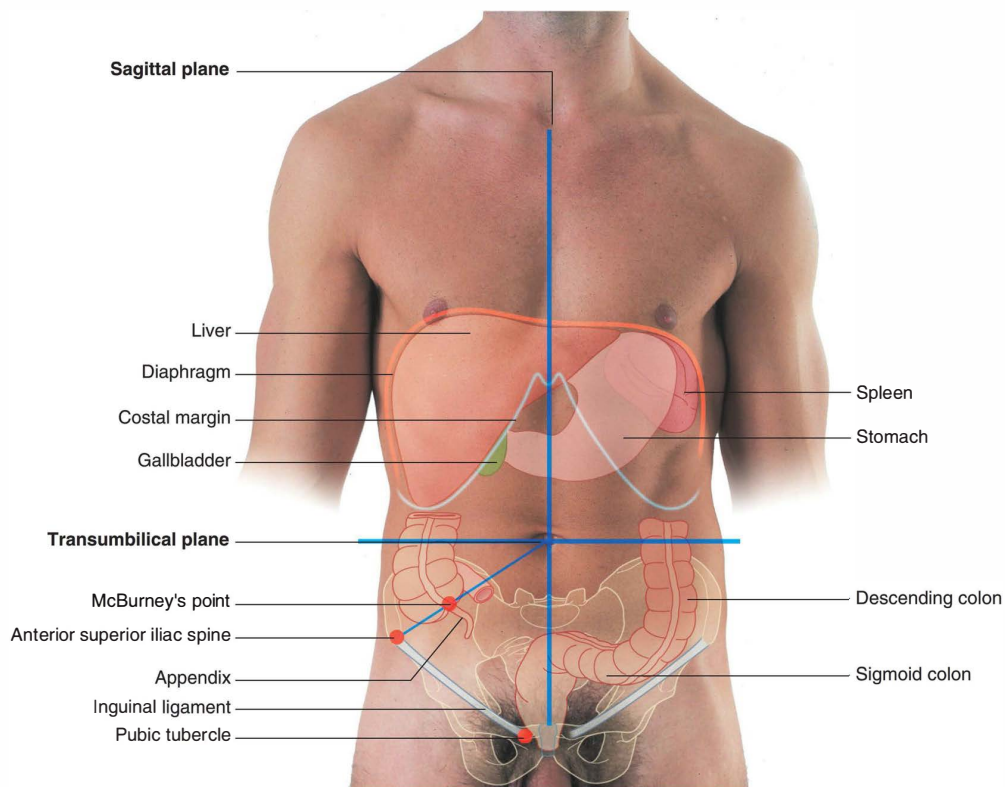


Fig. 4.168 Abdominal quadrants and the positions of major viscera. Anterior view of a man.



Abdomen

Defining surface regions to which pain from the gut is referred

The abdomen can be divided into nine regions by a midclavicular sagittal plane on each side and by the subcostal and intertubercular planes, which pass through the body transversely (Fig. 4.169). These planes separate the abdomen into:

- three central regions (epigastric, umbilical, pubic), and
- three regions on each side (hypochondrium, flank, groin).

Pain from the abdominal part of the foregut is referred to the epigastric region, pain from the midgut is referred to the umbilical region, and pain from the hindgut is referred to the pubic region.

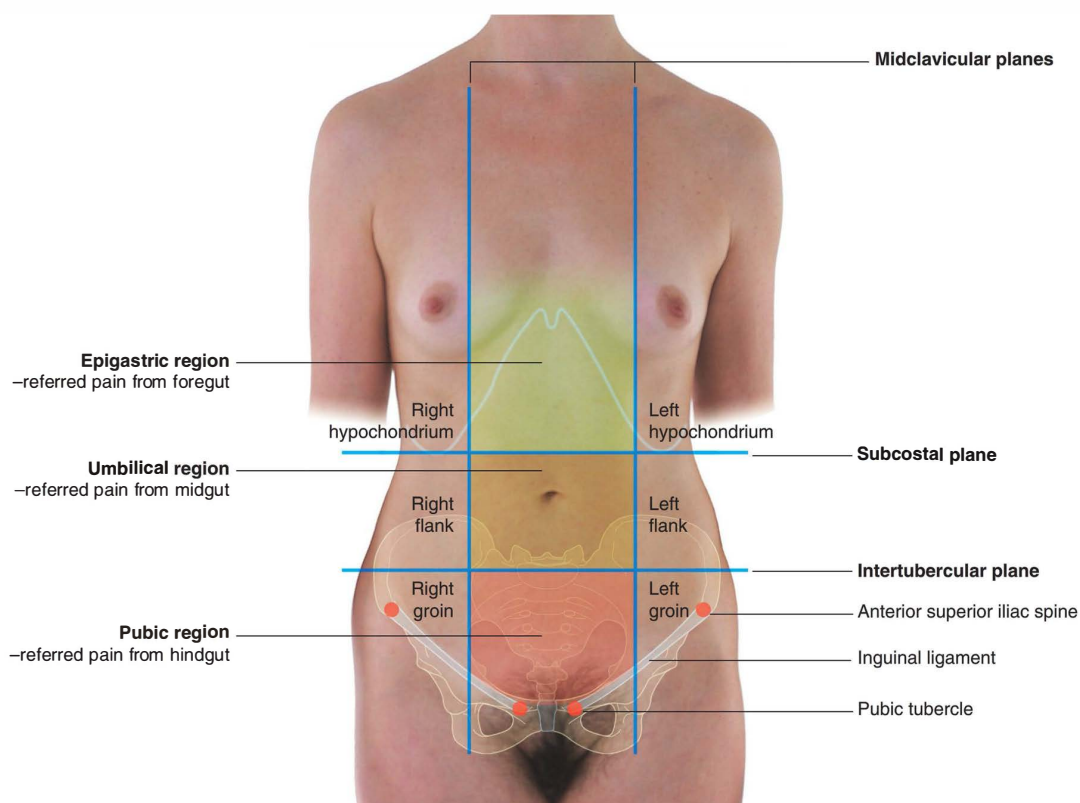


Fig. 4.169 The nine regions of the abdomen. Anterior view of a woman.

Where to find the kidneys

The kidneys project onto the back on either side of the midline and are related to the lower ribs (Fig. 4.170):

- The left kidney is a little higher than the right and reaches as high as rib XI.
- The superior pole of the right kidney reaches only as high as rib XII.

The lower poles of the kidneys occur around the level of the disc between the LIII and LIV vertebrae. The hila of the

kidneys and the beginnings of the ureters are at approximately the LI vertebra.

The ureters descend vertically anterior to the tips of the transverse processes of the lower lumbar vertebrae and enter the pelvis.

Where to find the spleen

The spleen projects onto the left side and back in the area of ribs IX to XI (Fig. 4.171). The spleen follows the contour of rib X and extends from the superior pole of the left kidney to just posterior to the midaxillary line.

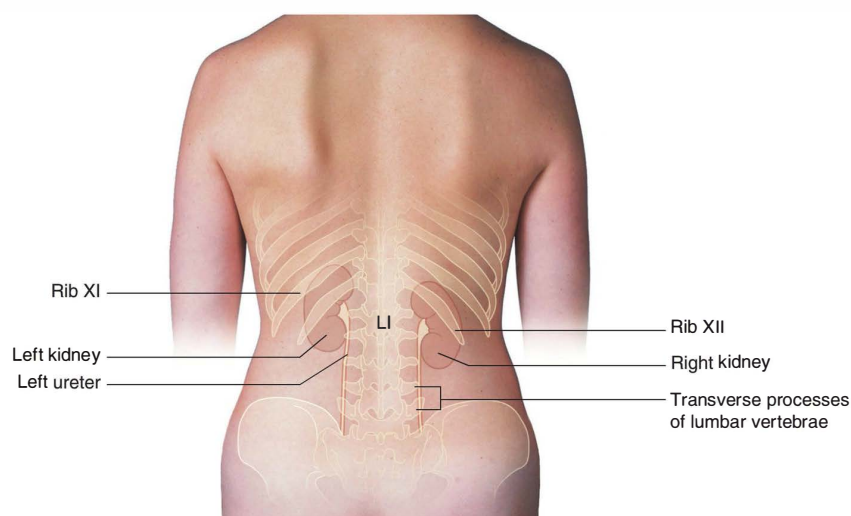


Fig. 4.170 Surface projection of the kidneys and ureters. Posterior view of the abdominal region of a woman.

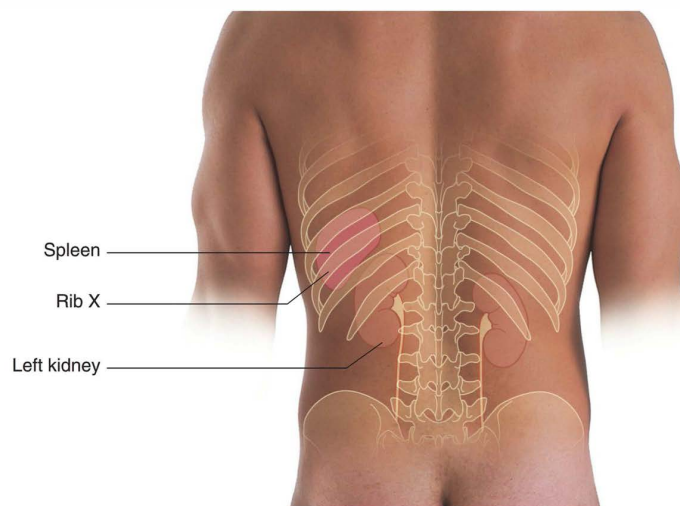


Fig. 4.171 Surface projection of the spleen. Posterior view of a man.