Anatomy of the abdominal wall

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INTRODUCTION

Incision and closure of the abdominal wall is among the most frequently performed surgical procedures. The abdominal wall is defined cranially by the xiphoid process of the sternum and the costal margins and caudally by the iliac and pubic bones of the pelvis. It extends to the lumbar spine, which joins the thorax and pelvis and is a point of attachment for some abdominal wall structures [1].

Integrity of the anterior abdominal wall is primarily dependent upon the abdominal muscles and their conjoined tendons. These muscles assist with respiration and control the expulsive efforts of urination, defecation, coughing, and parturition. They also work with the back muscles to flex and extend the trunk at the hips, rotate the trunk at the waist, and protect viscera by becoming rigid.

The contour of the abdomen is dependent upon age, muscle mass, muscle tone, obesity, intra-abdominal pathology, parity, and posture. These factors may significantly alter topography and become a major obstacle to proper incision selection and placement [2].

Knowledge of the layered structure of the abdominal wall permits efficient and safe entry into the peritoneal cavity. There are nine layers to the abdominal wall: skin, subcutaneous tissue, superficial fascia, external oblique muscle, internal oblique muscle, transversus abdominis muscle, transversalis fascia, preperitoneal adipose and areolar tissue, and peritoneum. Nerves, blood vessels, and lymphatics are present throughout.

Abdominal wall anatomy that is clinically pertinent to the surgeon, focusing primarily on the structures of the anterior abdominal wall, will be reviewed. Common incisions and closure

techniques, and prevention and management of wound complications, are discussed elsewhere. (See "Incisions for open abdominal surgery" and "Principles of abdominal wall closure" and "Complications of abdominal surgical incisions".)

SKIN AND SUBCUTANEOUS TISSUE

The skin is the largest organ of the human body. It has numerous functions, including protection against mechanical injury, prevention of bacterial invasion, and protection from the effects of ultraviolet light. Skin is loosely attached to the underlying structures of the abdomen, with the exception of the umbilicus, where the skin is tethered firmly to underlying tissue.

Skin lines of approximately equal tension are known as Langer's lines (figure 1) [3]. Across the abdomen, these lines are oriented in a predominately transverse direction with a gentle curvature. Langer's lines are associated with the distribution of collagen and elastic fibers in the skin [4]. Thus, transverse incisions heal with a narrower, more cosmetic scar because they are parallel to Langer's lines and have less tension, while longitudinal or oblique incisions, which traverse these lines, may heal with a broader scar.

The subcutaneous tissue is comprised of deep and superficial adipose tissue layers separated by weak, poorly defined fibrous tissue matrices. Camper's fascia is superficial and Scarpa's fascia is deep [5]. Camper's fascia is the superficial fatty layer that is continuous with superficial adipose and may vary in thickness, depending upon the patient's body habitus. Scarpa's fascia is a more membranous layer that will eventually become contiguous with the superficial fascia of the back, thorax, and fascia lata of the thigh. Inferiorly, this membranous layer also fuses in the midline and forms a tubular sheath for the penis or clitoris.

MUSCLES

The anterior abdominal wall consists primarily of the rectus muscles and associated fascia (figure 2A). The posterolateral, lateral, and remaining anterior portions of the abdominal wall are composed of three paired, broad, flat muscles, each with an aponeurosis or tendon including the external oblique, internal oblique, and transversus abdominis muscles (figure 2B). The rectus muscles are responsible for abdominal wall flexion, while the oblique muscles rotate the torso. The internal oblique and transversus abdominis muscles support and compress the abdominal contents.

Rectus abdominis — The rectus abdominis consists of a pair of strap muscles that extend the length of the anterior abdominal wall and are separated by the linea alba (figure 2A).

These muscles arise from the symphysis pubis and the pubic crest with insertion into the fifth, sixth, and seventh costal cartilages and the xiphoid process. The rectus sheath has variable contributions from the oblique and transversus muscles. (See 'Rectus sheath' below.)

External oblique — The external oblique muscle is a broad, thin muscle that arises from the surfaces of the lower eight ribs, fanning out downward to insert medially into the xiphoid process, the linea alba, and the anterior portion of the iliac crest (figure 2A-B). Its aponeurotic sheet contributes to the anterior sheath of the rectus abdominis, then fuses at the linea alba in the midline with the contralateral counterpart (figure 3). The remainder of the aponeurosis extends from the iliac spine to the pubic tubercle, where it becomes the inguinal ligament.

Internal oblique — The internal oblique muscle is a broad, thin muscle that lies deep to the external oblique, with its origins from the thoracolumbar fascia, the anterior two-thirds of the iliac crest, and the lateral two-thirds of the inguinal ligament (figure 2A-B). The muscle fibers travel upward and forward to insert into the lower borders of the lower three ribs and their costal cartilages, the xiphoid process, the linea alba, and the symphysis pubis. Above the arcuate line, its aponeurotic sheet contributes to both the anterior and posterior sheath of the rectus abdominis, then fuses at the linea alba in the midline with the contralateral counterpart (figure 3). Below the arcuate line, the aponeurosis of the internal oblique muscle courses only anteriorly to the rectus abdominis muscle as part of the anterior rectus sheath.

Transversus abdominis — The transversus abdominis muscle is a thin muscle sheet that lies deep to the internal oblique muscle. It arises from the deep surface of the lower six costal cartilages, lumbar fascia, iliac crest, and lateral third of the inguinal ligament and inserts into the xiphoid process, linea alba, and symphysis pubis (figure 2A-B). The fibers of this muscle sheet run horizontally and forward. Its aponeurotic sheet contributes to the posterior rectus sheath above the arcuate line and the anterior rectus sheath below the arcuate line (figure 3). It then fuses at the linea alba in the midline with the contralateral counterpart.

Pyramidalis — The pyramidalis muscle is a flat, triangular muscle at the inferior margin of the anterior abdominal wall. It originates from the superior pubic ramus, between the symphysis pubis and the pubic tubercle, and runs superomedially inserting into the linea alba. Most of the existing literature regarding this muscle focuses on whether or not it actually exists [6].

FASCIA

Rectus sheath — The rectus sheath is composed of the broad, sheet-like aponeuroses of the flank muscles that enclose the rectus abdominis (and pyramidalis muscle, if present). Lateral to the rectus abdominis, the aponeuroses can be separated, but they fuse as they reach the midline (figure 3).

The external oblique muscle, the most superficial of the flank muscles, has a broad aponeurosis that passes anteriorly over the rectus abdominis. Beneath the external oblique, the internal oblique has a bilaminar aponeurosis that passes anterior and posterior to the rectus abdominis above the arcuate line, but only anterior to the rectus below the arcuate line. The innermost abdominal muscle is the transversus abdominis. Its aponeurosis is posterior to the rectus abdominis above the arcuate line and anterior to the rectus abdominis below the arcuate line where it fuses with the aponeurosis of the internal oblique.

Inferior to the arcuate line, the aponeuroses of all three muscles form the anterior sheath. The posterior sheath is absent, and the rectus lies directly on top of the transversalis fascia (figure 3). The arcuate line is the site where the inferior epigastric vessels enter the rectus sheath, travel superiorly, and converge with the superior epigastric vessels (figure 4). The arcuate line is absent in as many as 30 percent of individuals [7].

Transversalis fascia — The transversalis fascia is a weak fibrous layer covering the inner surface of the transversus abdominis muscles and is separated from the peritoneum by a layer of fat, commonly known as the preperitoneal fat layer. It is frequently incised off the bladder when the peritoneal cavity is opened. This layer of connective tissue forms a continuous lining for the abdominal and pelvic cavities and is continuous with the diaphragmatic fascia, the iliacus fascia, and the pelvic fascia (figure 3).

Linea alba — The linea alba stretches from the xiphoid process to the pubic symphysis. It is defined as the fusion of the aponeuroses of the external oblique, internal oblique, and transversus abdominis muscles (figure 3). It maintains the abdominal musculature at a certain proximity to each other. The linea tends to have its widest margin approximately 3 cm superior to the umbilicus and has varying distances depending upon the point of reference along the abdominal wall [8].

PERITONEUM

The peritoneum is a single layer of serosa supported by a thin layer of connective tissue that lines the abdominal cavity. Five vertical folds are formed by underlying ligaments or vessels that converge at the umbilicus: the abdominal wall reflection of the bladder, which fuses with the urachus; the single middle umbilical ligament (the obliterated urachus); the paired medial umbilical ligaments (remnants of the obliterated umbilical arteries); and the lateral umbilical ligaments associated with the deep inferior epigastric vessels.

VASCULATURE

The blood supply of the abdominal wall is comprised of superficial and deep vascular supplies (figure 4) [9]. These named vessels run primarily longitudinally and may provide collateral flow channels between the subclavian artery and femoral artery when significant aortic or bilateral iliac artery obstruction is present. The superficial vasculature is located in the subcutaneous tissues and supplies the tissues superficial to the external oblique aponeurosis and the anterior rectus sheath. The muscles and tissues below these layers are supplied by the deep vessels that are located in the musculofascial layers.

Deep arteries

Inferior epigastric arteries — The inferior epigastric artery is thought to be the dominant vascular supply to the anterior abdominal wall (figure 4) [9]. It branches from the external iliac artery passing medially adjacent to the inguinal ligament. It ascends medial to the internal (deep) inguinal ring and superficial to the transversalis fascia. It then proceeds toward the umbilicus and crosses the lateral border of the rectus muscle at the arcuate line where it enters the posterior rectus sheath (figure 5). Once the artery enters the sheath, it branches extensively. It ascends within the rectus sheath to communicate with the superior epigastric artery. The angle between the vessels and lateral border of the rectus forms the apex of the inguinal (Hesselbach's) triangle, the base of which is the inguinal ligament.

The musculocutaneous perforating vessels of the inferior epigastric artery reach and supply deeper tissue as well as the integument of the anterior abdominal wall. These perforators are particularly relevant in reconstructive surgery as an important supply for abdominal tissue flaps used [9]. The number, location, and course of these perforators are highly variable.

The inferior epigastric vessels are bounded only by loose areolar tissue below the arcuate line. Trauma to this portion of the inferior deep epigastric artery may result in considerable hemorrhage. Because hematomas commonly dissect into the retroperitoneal space, large quantities of blood may be lost before outward evidence of hematoma is detectable.

Superior epigastric arteries — The superior epigastric artery is a terminal branch of the internal thoracic artery (figure 4). It enters the rectus sheath at the seventh costal cartilage and descends on the posterior surface of the rectus muscle (figure 5). The superior and inferior epigastric arteries freely anastomose with one another at the level of the umbilicus to provide a generous collateral circulation between the subclavian and external iliac arteries. These vessels communicate laterally with the intercostals and subcostal and lumbar arteries, as well as the ascending branch of the deep circumflex iliac artery [9]. Deep branches of this vessel supply the posterior rectus sheath and the

peritoneum with muscular branches and anterior perforating branches supplying skin and subcutaneous tissues.

Deep circumflex iliac arteries — The deep circumflex iliac artery also branches from the external iliac artery or, less frequently, from a common origin that includes the inferior epigastric artery (figure 4). Its course is lateral and vertical behind the inguinal ligament. It then turns medially at the iliac crest, where it pierces the transversus abdominis muscle. Between the transversus abdominis and internal oblique muscles, numerous connecting branches supply the lower and lateral abdominal wall. Anastomoses with the intercostal and lumbar vessels supply branches to all the flank muscles.

Musculophrenic arteries — The musculophrenic artery is also a branch of the internal thoracic artery (figure 4). It lies behind the costal cartilage to supply the intercostal spaces and upper abdominal wall. Anastomoses from intercostal and subcostal vessels to the deep circumflex iliac vessels occur in the deep layer.

Superficial arteries — The superficial vasculature of the abdominal wall is located in the subcutaneous tissues and consists of branches of the femoral artery, including the superficial epigastric (or superficial inferior epigastric), superficial external pudendal, and superficial circumflex arteries.

The superficial epigastric vessels run diagonally in the subcutaneous tissues from the femoral artery toward the umbilicus (figure 4). They can be identified on a line between the palpable femoral pulse and umbilicus just superficial to Scarpa's fascia. As they approach the umbilicus, the arteries branch extensively.

The external pudendal arteries have a medial and diagonal course from the femoral artery and supply the region of the mons pubis. These vessels branch extensively as they approach the midline. Following incision, bleeding is typically heavier here than in other subcutaneous areas of the abdomen.

The superficial circumflex iliac vessels proceed from the femoral vessels to the flank. The superficial vessels follow the general pattern of the deep vessels and arise from the iliac or femoral vessels. The exception is that the superficial inferior epigastric vessels have no superior counterparts.

Veins — Venous drainage of the anterior abdominal wall tends to be more variable than arterial pathways; however, veins typically follow the course of arteries (figure 4). A better understanding of venous drainage systems of the anterior abdominal wall is needed for better management of abdominal flaps [9]. Above the umbilicus, they drain to the subclavian vessels, and below the umbilicus, they drain to the external iliac vessels. Veins may be dilated

in patients with obstructed blood flow through the liver and porta hepatis. They may also be engorged in patients with large pelvic masses.

Collateral flow channels — Several patterns of collateral flow exist in the abdominal wall due to the extensive network of vessels supplying it. The principle blood vessels involved in this collateral circulation are the internal mammary, superior epigastric, intercostals, inferior epigastric, and external iliac (figure 4). This network allows blood to bypass the occlusion of the aorta or iliac vessels and thus restore blood flow to the lower extremities. Case reports have described worsening of lower extremity ischemia when transverse incisions of the abdomen disrupt the abdominal wall vessels [10].

LYMPHATIC CHANNELS

Abdominal lymphatics generally follow the course of the abdominal veins. As a general rule, the channels of the upper abdominal wall, above the level of the umbilicus, drain primarily to the anterior axillary (ie, pectoral) lymph nodes and, to a lesser extent, to the internal mammary chain (figure 6). Those of the lower abdomen, below the level of the umbilicus, drain to the inguinal nodes and then to the iliac chain of nodes. Lymphatics adjacent to the umbilicus drain toward the liver through the falciform ligament. Transverse incisions are likely to disrupt lymphatic drainage to some degree. This disruption may lead to tissue swelling in the abdominal wall until collateral lymphatic drainage can be established.

NERVES

The intercostal and lumbar nerves enter the abdominal wall between the transversus abdominis and internal oblique muscles and run in a generally caudal and medial direction. Each nerve innervates a dermatome, but some overlapping innervation occurs. Longitudinal incisions (except at the midline) can be expected to lead to sensory impairment inferior and medial to the level of the transected nerves.

Although technically not nerves of the abdominal wall, the femoral nerve, the lateral femoral cutaneous nerve, and the genitofemoral nerve can also be damaged during abdominal surgery, especially with inguinal and femoral hernia repair (figure 7). The prevention of neurologic complications during the course of hernia and pelvic surgery is reviewed separately. (See "Nerve injury associated with pelvic surgery" and "Open surgical repair of inguinal and femoral hernia in adults", section on 'Minimizing post-herniorrhaphy neuralgia'.)

Intercostal nerves — The 7^{th} to 12^{th} intercostal nerves innervate the abdominal wall (figure 8B). Because of overlapping dermatomes, the fifth and sixth intercostal nerves can

also contribute. The intercostal nerves divide into lateral cutaneous branches and anterior and posterior branches. The 10th nerve supplies the region of the umbilicus. Postoperative bulge is related to intercostal nerve injury with subsequent paralysis of abdominal wall musculature. Intercostal nerve injury can be reduced by avoiding extension of the incision into the 11th intercostal space [11].

Iliohypogastric nerves — The 12th intercostal and the first lumbar nerves form the iliohypogastric nerve, which passes medial to the anterior superior iliac spine (figure 8A-B). The iliohypogastric nerve enters the abdominal wall at the transversus abdominis muscle and courses, on average, 2 cm medial and 1 cm inferior to the anterior superior iliac spine, following a linear course to terminate approximately 4 cm lateral to the midline and 5 cm superior to the pubic symphysis [12]. The terminal branch courses medial and parallel to the inguinal ligament. It provides motor fibers to the external oblique, internal oblique, and transversus abdominis muscles and provides sensory fibers to the skin of the mons pubis. The anterior cutaneous branch of the iliohypogastric nerve provides sensory innervation to the skin of the upper and lateral thigh [13]. It communicates with the ilioinguinal nerve and provides sensory fibers to the skin overlying the external inguinal ring and symphysis. Measures to avoid nerve injury during the course of open hernia repair are discussed elsewhere. (See "Open surgical repair of inguinal and femoral hernia in adults", section on 'Minimizing post-herniorrhaphy neuralgia'.)

Ilioinguinal nerve — The ilioinguinal nerve is formed by the combination of the first and second lumbar nerves and passes medial to the superior anterior iliac spine to supply the lower abdominal wall (figure 8A-B). On average, the proximal end of the ilioinguinal nerve enters the abdominal wall 3 cm medial and 4 cm inferior to the anterior superior iliac spine, then follows a linear course to terminate 3 cm lateral to the midline and 2 cm superior to pubic symphysis [12]. The ilioinguinal nerve generally follows a course with the iliohypogastric nerve, running medially at the inguinal ligament between the transversus abdominis and internal oblique muscles. A branch of the ilioinguinal nerve accompanies the round ligament as it passes through the inguinal canal. It exits the canal at the external inguinal ring and provides sensory fibers to the labia majora and the upper aspect of the medial thigh [13]. Measures to avoid nerve injury during the course of open hernia are discussed elsewhere. (See "Open surgical repair of inguinal and femoral hernia in adults", section on 'Minimizing post-herniorrhaphy neuralgia'.)

Genitofemoral nerve — The genitofemoral nerve has fibers from the first and second lumbar nerves and rests on the psoas muscle lateral to the external iliac artery (figure 8A and figure 8B). The genital branch provides sensation to the mons pubis and labia majora. The femoral branch provides sensation to the femoral triangle [14]. The genital branch passes within the cremasteric muscle fibers in men and in the round ligament in women and

may be encountered during open hernia surgery. (See "Open surgical repair of inguinal and femoral hernia in adults", section on 'Minimizing post-herniorrhaphy neuralgia'.)

Lateral femoral cutaneous nerve — The second and third lumbar roots give rise to this nerve (figure 8A-B), which crosses the psoas muscle slightly above the femoral nerve and provides sensory innervation to the anterior and lateral thigh [15]. It runs inferiorly and laterally toward the anterior superior iliac spine, exiting the pelvis through the lateral lacuna musculorum. It pierces the fascia approximately 2 to 3 cm below the anterior superior iliac spine. Entrapment of the lateral femoral cutaneous nerve can occur, leading to numbness; paresthesias; and pain in the anterolateral thigh, a condition known as meralgia paresthetica. (See "Meralgia paresthetica (lateral femoral cutaneous nerve entrapment)".)

SUMMARY AND RECOMMENDATIONS

- **Significance of abdominal wall anatomy –** Knowledge of the anatomy of the abdominal wall is important to properly perform an abdominal incision and closure in a manner that is secure and minimizes the risk of complications such as abdominal wall hernia, bleeding, and nerve injury. (See 'Introduction' above.)

- **Abdominal wall layers –** The structures comprising the abdominal wall include the skin, subcutaneous tissue, abdominal wall musculature and associated aponeuroses, preperitoneal fat, and peritoneum. The specific anatomy of the abdominal wall depends upon the location in the abdominal wall. (See 'Introduction' above.)

- **Abdominal wall muscles –** The anterior abdominal wall is composed of four muscles, including the rectus muscles positioned anteriorly, and the oblique (external, internal) muscles and transversus abdominis muscle located anterior and posterolaterally. The rectus abdominis muscle is responsible for abdominal wall flexion. The oblique muscles provide abdominal wall rotation. (See 'Muscles' above.)

- **Abdominal wall fascia –** The fascial layers of the abdominal wall vary above and below the arcuate ligament. Superior to the arcuate line, the aponeuroses of the rectus, external oblique, and anterior portion of the internal oblique aponeurosis form the anterior rectus sheath, and the posterior portion of the internal oblique aponeurosis, transversus abdominis muscle, and transversalis fascia form the posterior sheath. Inferior to the arcuate ligament, the aponeuroses of the rectus, external oblique, and internal oblique muscles form the anterior rectus sheath; the posterior rectus sheath is absent. (See 'Fascia' above.)

- **Abdominal wall vasculature –** The blood vessels supplying the abdominal wall originate from the internal thoracic arteries, thoracic and lumbar intercostals, external

and internal iliac arteries, and common femoral arteries. Collateral flow channels may develop between the subclavian and femoral arteries when significant aortic or bilateral iliac artery obstruction is present. Venous drainage from the abdominal wall parallels the arterial supply. (See 'Vasculature' above.)

- **Abdominal wall lymphatics** – The lymphatics of the abdominal wall follow the course of the abdominal veins. The channels of the upper abdominal wall above the umbilicus drain primarily to the anterior axillary nodes while those below the umbilicus drain to the inguinal nodes. Transverse incisions may disrupt lymphatic drainage. (See 'Lymphatic channels' above.)

- **Abdominal wall nerves** – The abdominal wall is innervated by the thoracic intercostal nerves and contributions from nerves of the lumbar plexus (L2, L3, L4), including the iliohypogastric, ilioinguinal, genitofemoral, and lateral femoral cutaneous nerves. The nerves run in a predominantly transverse direction. Vertical incisions (except at the midline) can be expected to lead to sensory impairment inferior and medial to the level of the transected nerves. (See 'Nerves' above.)

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Topic 3 Version 19.0

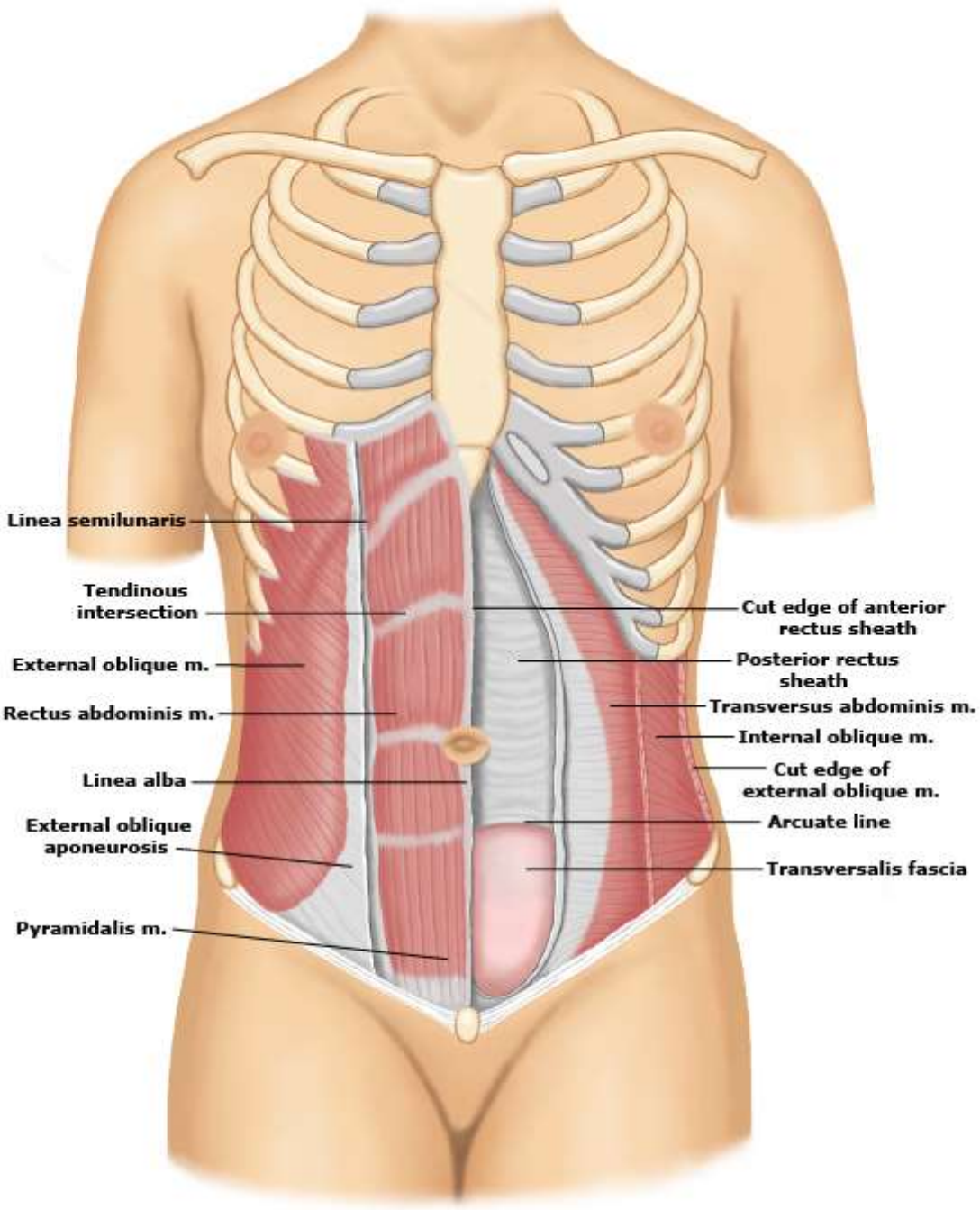
GRAPHICS

Langer's lines of the abdomen

Langer's lines are lines of skin tension. Because these lines are predominantly horizontal in the abdomen, transverse incisions generate less tension in the skin.

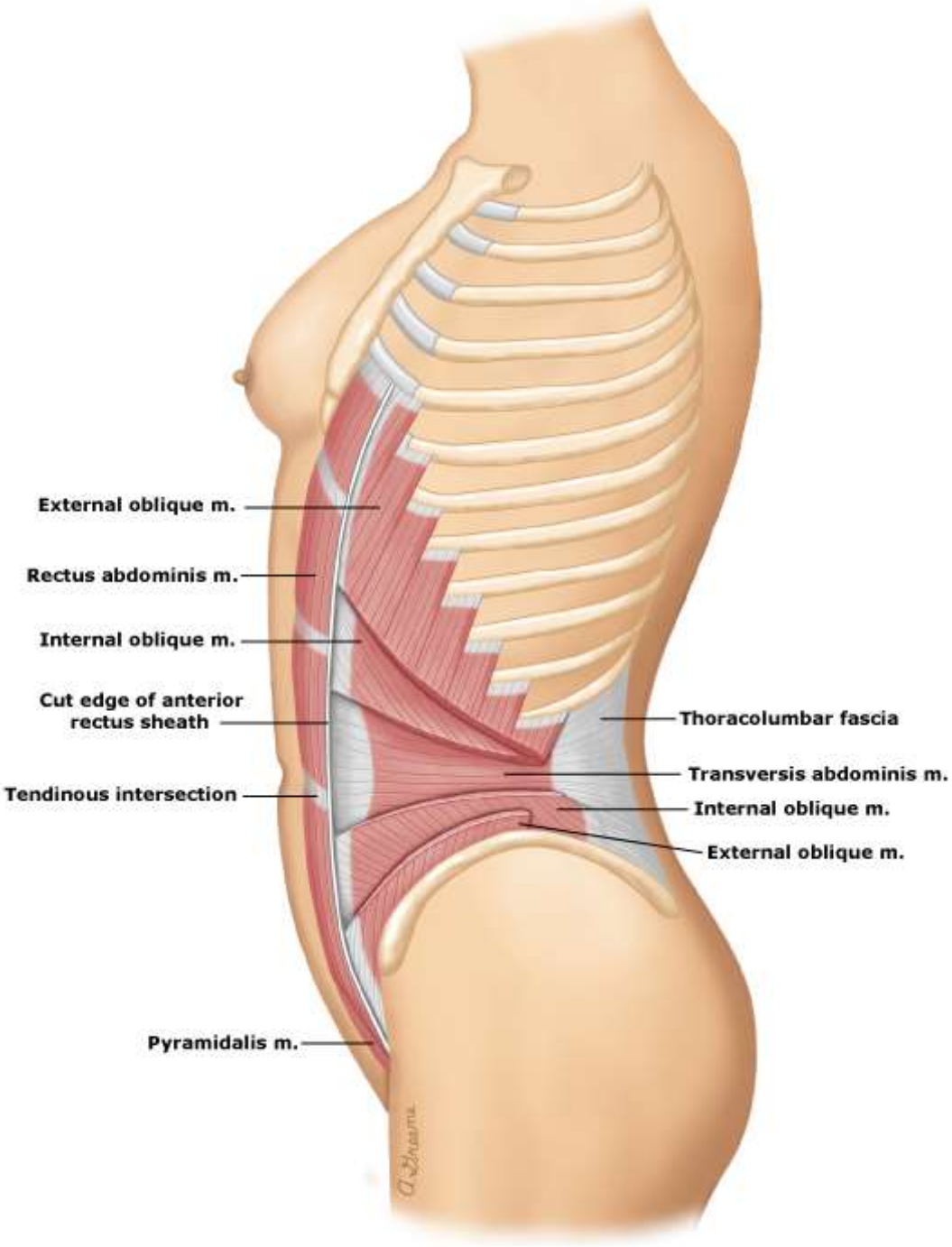
Graphic 76685 Version 3.0

Muscles of the anterior abdominal wall



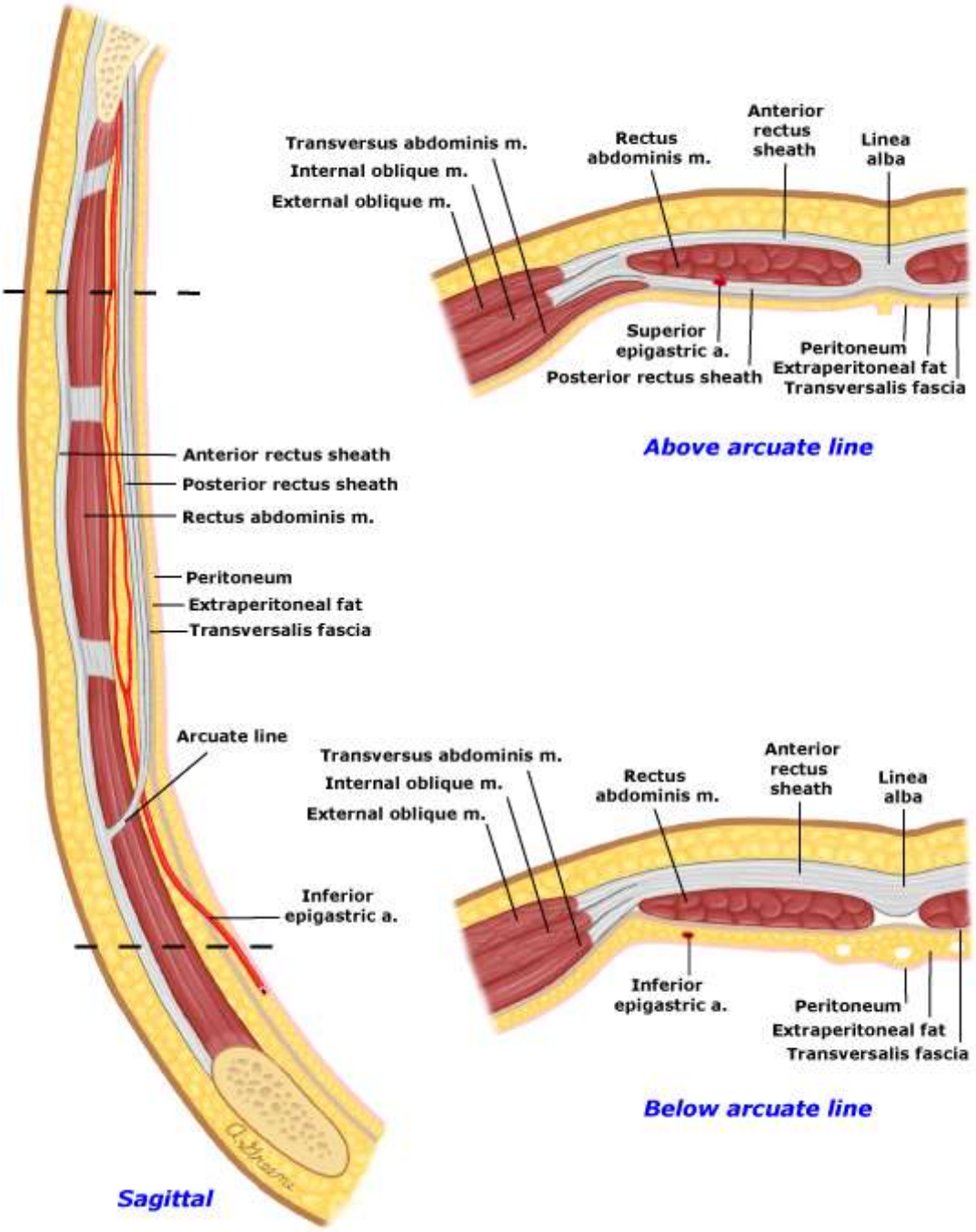
Graphic 72219 Version 5.0

Muscles of the lateral abdominal wall



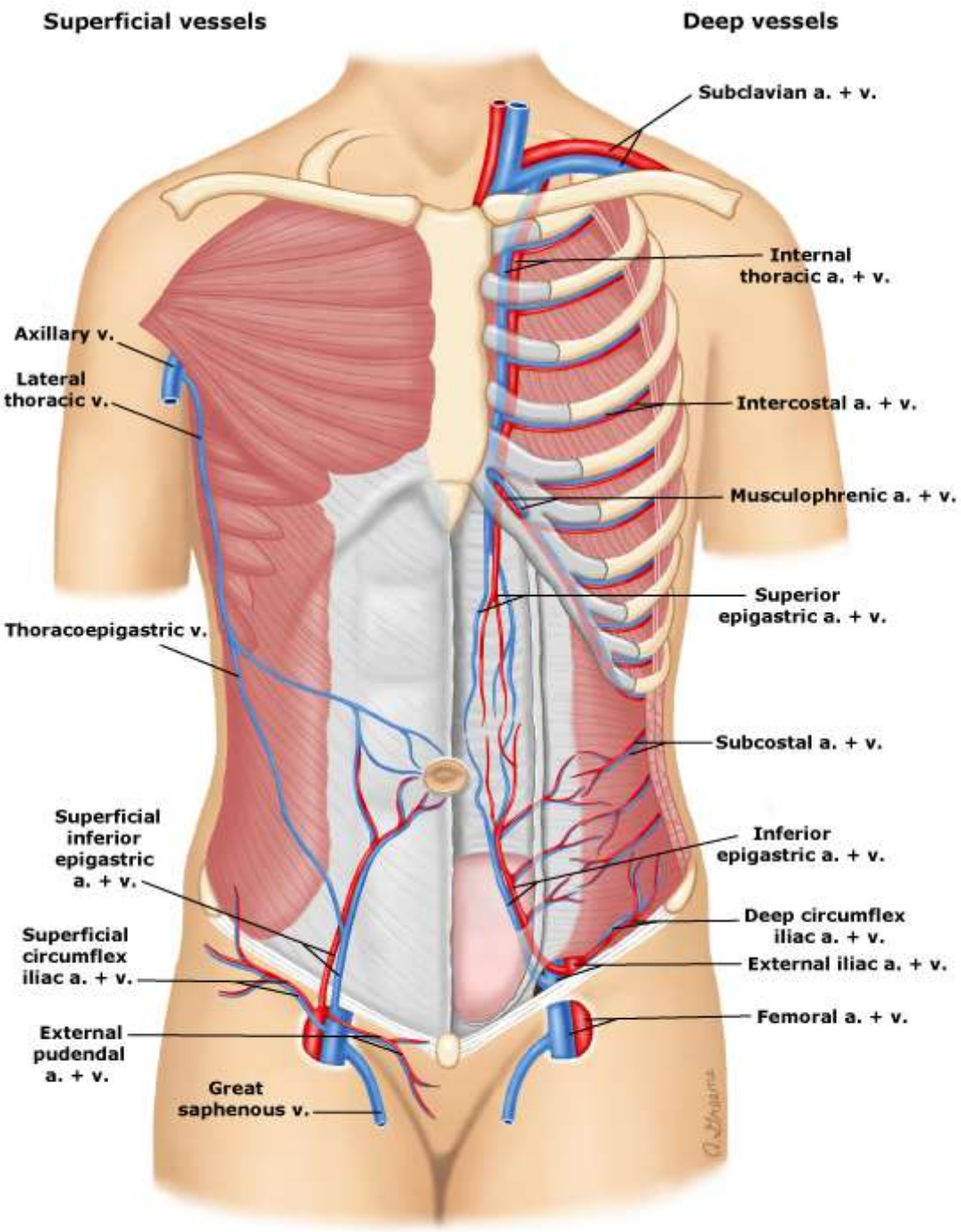
Graphic 66280 Version 3.0

Sectional view of the abdominal wall musculature



Graphic 77053 Version 4.0

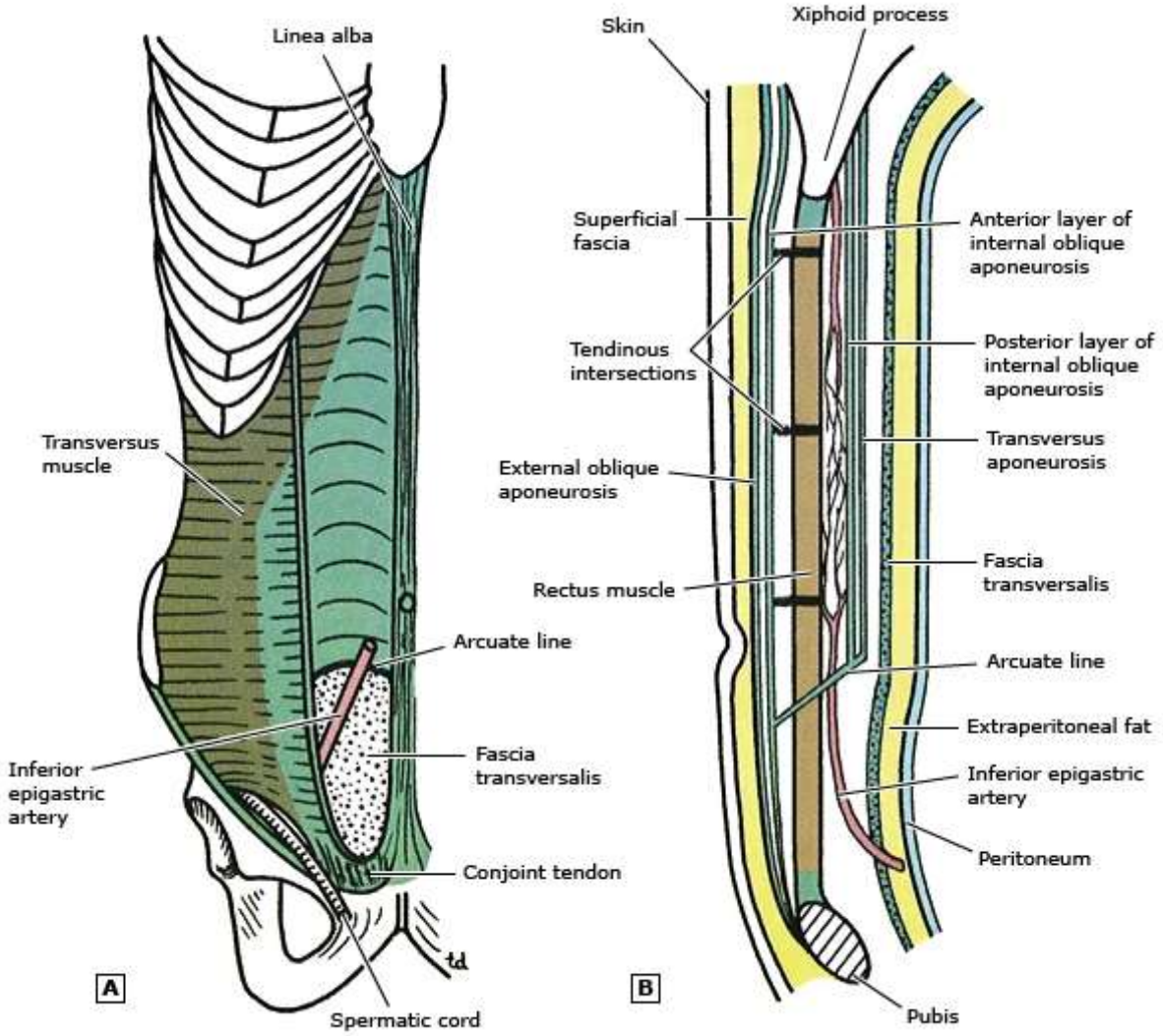
Blood vessels of the anterior abdominal wall



The superior and inferior epigastric arteries provide a rich arcade arising from the internal thoracic artery superiorly and the external iliac artery inferiorly. The musculophrenic artery, deep circumflex iliac artery, and subcostal arteries supply the lateral abdominal wall. The superficial epigastric veins and the superficial iliac veins can arise from the great saphenous vein.

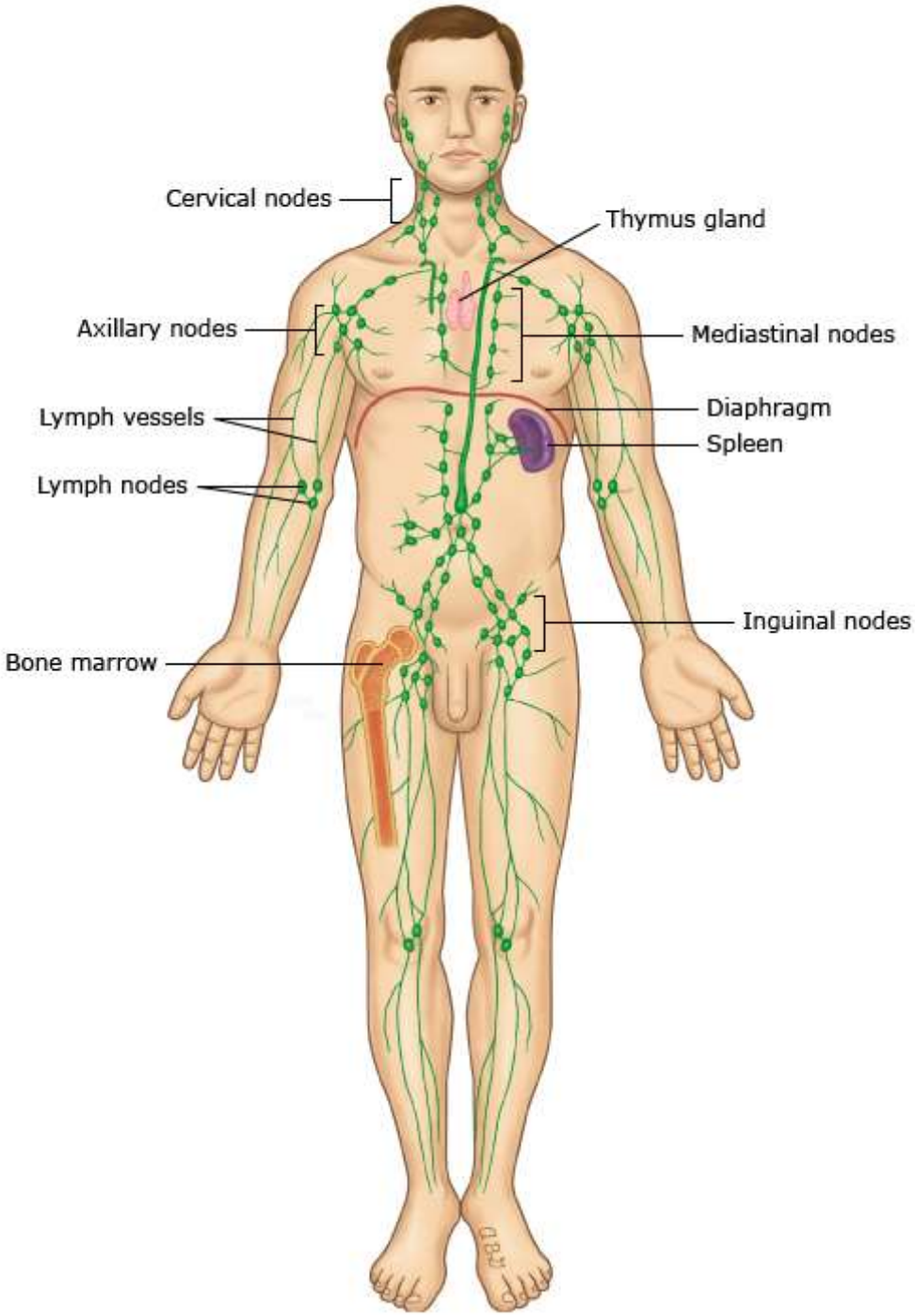
Graphic 81343 Version 6.0

Sagittal view of the layers of the abdominal wall



Graphic 51036 Version 12.0

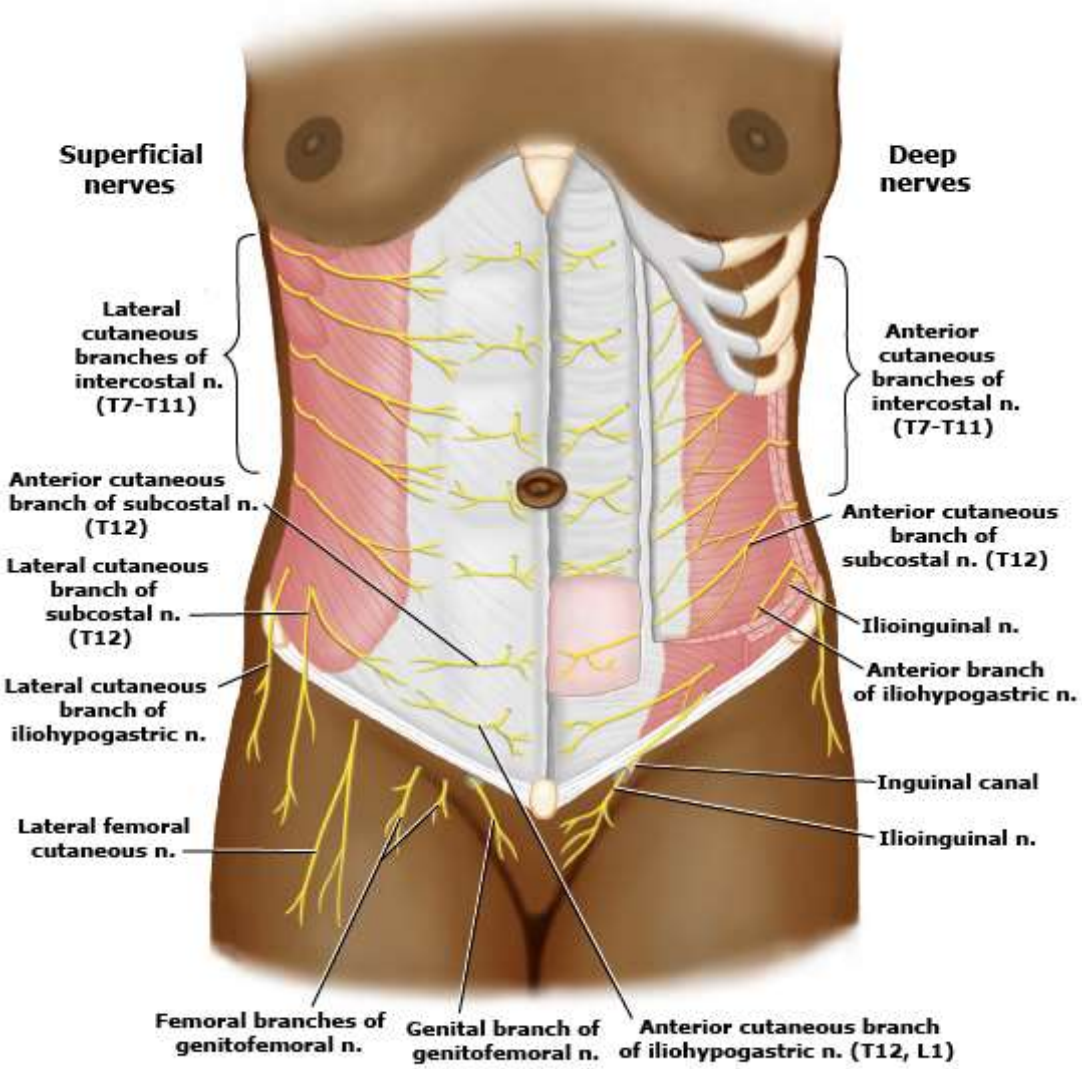
Lymphatic system



This figure shows the organs of the lymphatic system, which include the bone marrow, thymus, spleen, and lymph nodes. These organs are connected by lymph vessels.

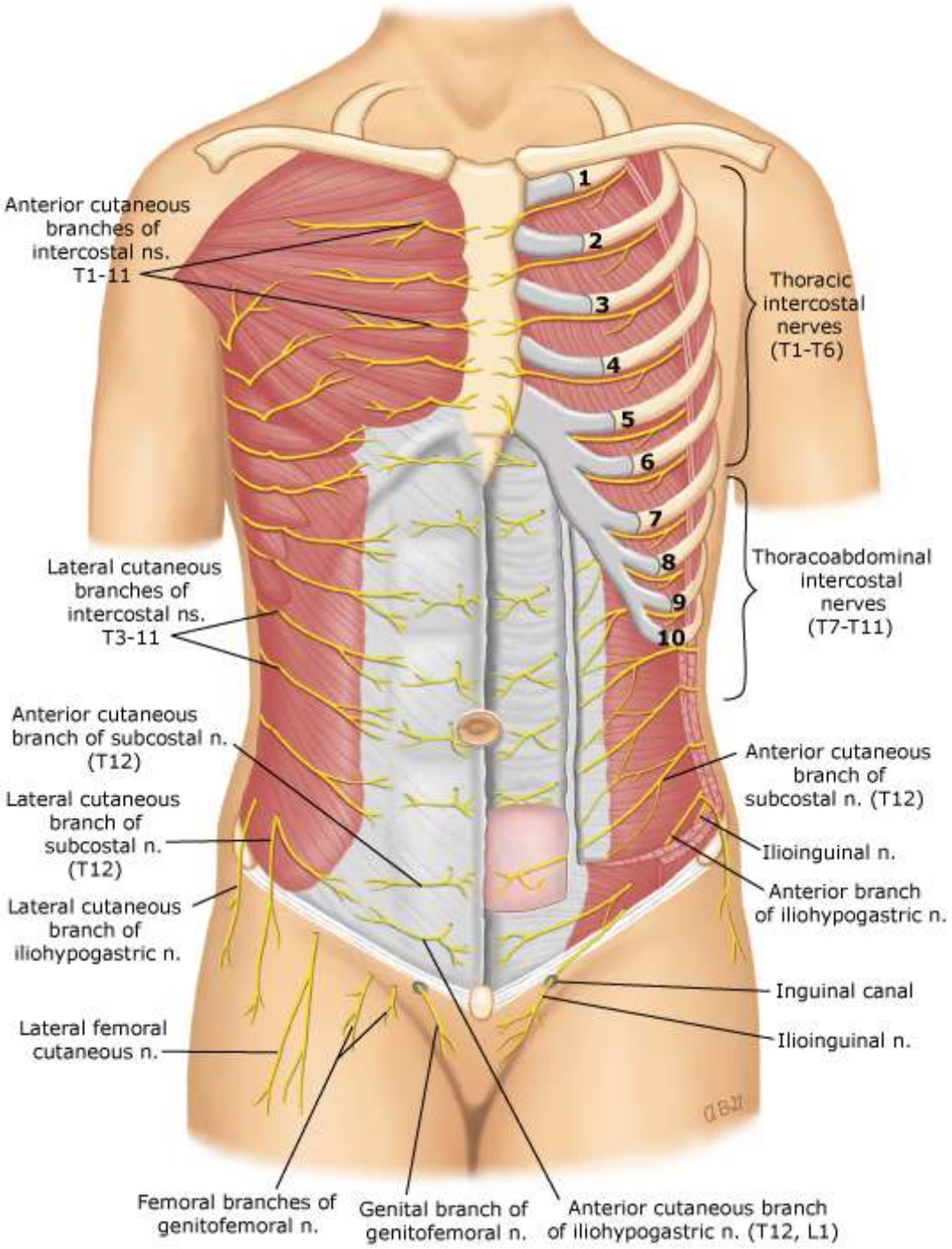
Graphic 63854 Version 5.0

Nerves of the abdominal wall



Graphic 71423 Version 4.0

Nerves of the anterior chest and abdomen



The chest and abdominal walls are supplied by the thoracic and thoracoabdominal intercostal nerves, as well as nerves from the lumbar plexus. The intercostal nerves arise from the ventral rami of the thoracic spinal nerves from T1 to T11. The corresponding nerve associated with T12 is the subcostal nerve.

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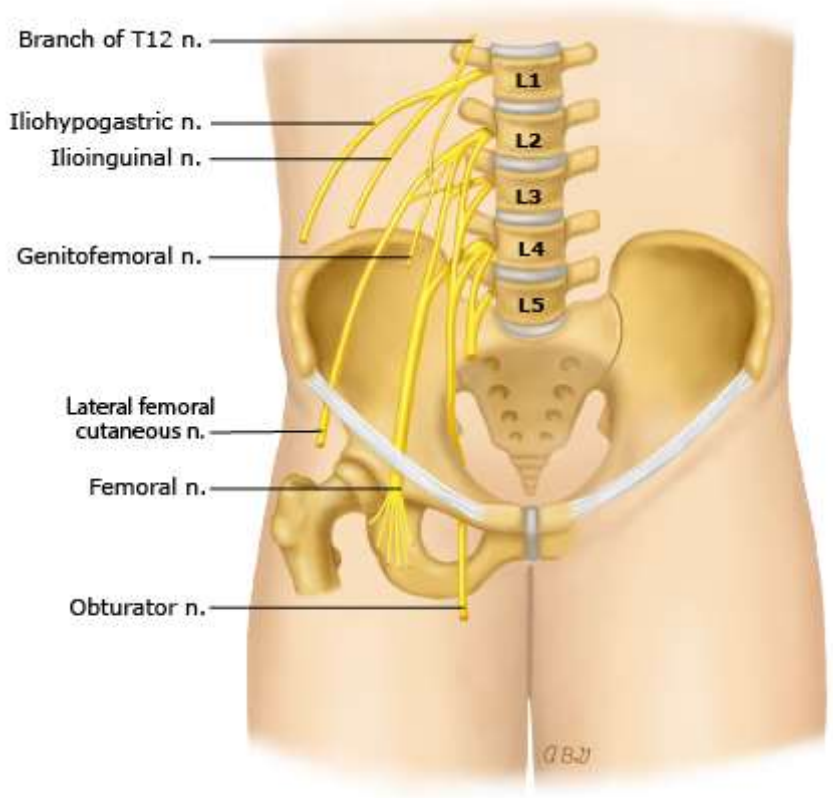
n.: nerve; ns.: nerves.

Graphic 79068 Version 3.0

Lumbar plexus



The lumbar plexus is formed by the ventral rami of the lumbar nerve roots and supplies the muscular and cutaneous innervation to the lower extremity.

Graphic 76701 Version 4.0

Contributor Disclosures

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