# *eXtreme* Lateral Interbody Fusion (XLIF®)

EDITED BY

J. Allan Goodrich, MD
Associate Clinical Professor,
Department of Orthopaedic Surgery, Medical College of Georgia;
Augusta Orthopaedic Clinic, Augusta, Georgia

Ildemaro J. Volcan, MD
Associate Clinical Professor,
Department of Neurological Surgery, Medical College of Georgia;
West Augusta Spine Specialists, LLC, Augusta, Georgia

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# Basic Concepts: Applied Anatomy of Extreme Lateral Interbody Fusion

J. Allan Goodrich ▪ Ildemaro J. Volcan
Thomas D. Schaffa ▪ David P. Goodrich

Surgical procedures, whether open or minimally invasive, cannot be performed safely or successfully without a thorough knowledge of the relevant anatomy. Specific knowledge of the bony structures, soft tissues, and vascular and neurologic structures is of the utmost importance. Orthopaedic and neurosurgeons are, in general, quite familiar with posterior approaches to the lumbar spine. Anterior access is usually obtained with the assistance of a vascular or general surgeon who is adept at mobilizing the great vessels and protecting these throughout the procedure. With the introduction of the extreme lateral interbody fusion (XLIF®, NuVasive®, Inc., San Diego, CA) approach—a retroperitoneal, transpsoas approach to anterior column stabilization of the thoracolumbar spine (Fig. 2-1)—a review of the contents and boundaries of the retroperitoneal space is appropriate.

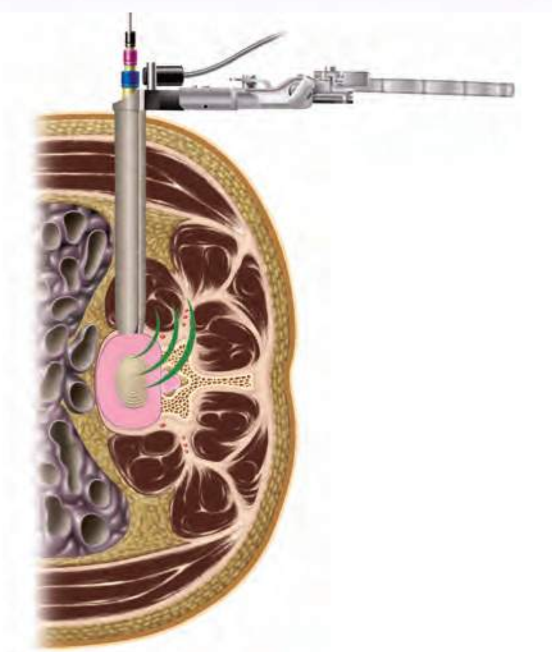


**FIG. 2-1** Axial illustration of XLIF's retroperitoneal, transpsoas access to the lumbar spine using the MaXcess® (NuVasive, Inc.) Retractor.

The retroperitoneal space is the area of the posterior abdominal wall located between the posterior parietal peritoneum and the posterior part of the transversalis fascia. Located within this space are embryologically related organs such as the adrenal glands, kidneys, and ureters, all of which are referred to as the *retroperitoneal viscera.* Also within the retroperitoneal space is the neurovascular apparatus, formed by the aorta and its branches, the inferior vena cava and its tributaries, the lymphatic vessels and the lymph nodes, and the lumbar plexus, with its branches and the sympathetic trunk.

The retroperitoneal space is covered anteriorly by the parietal peritoneum (Fig. 2-2) and posteriorly by the transversalis fascia. The retroperitoneal space extends from the twelfth thoracic vertebra and the twelfth rib cephalad to the base of the sacrum, the iliac crest, and the pelvic diaphragm caudally. The lateral borders extend from an imaginary line from the tip of the twelfth rib down to the junction of the anterior and posterior halves of the iliac crest.

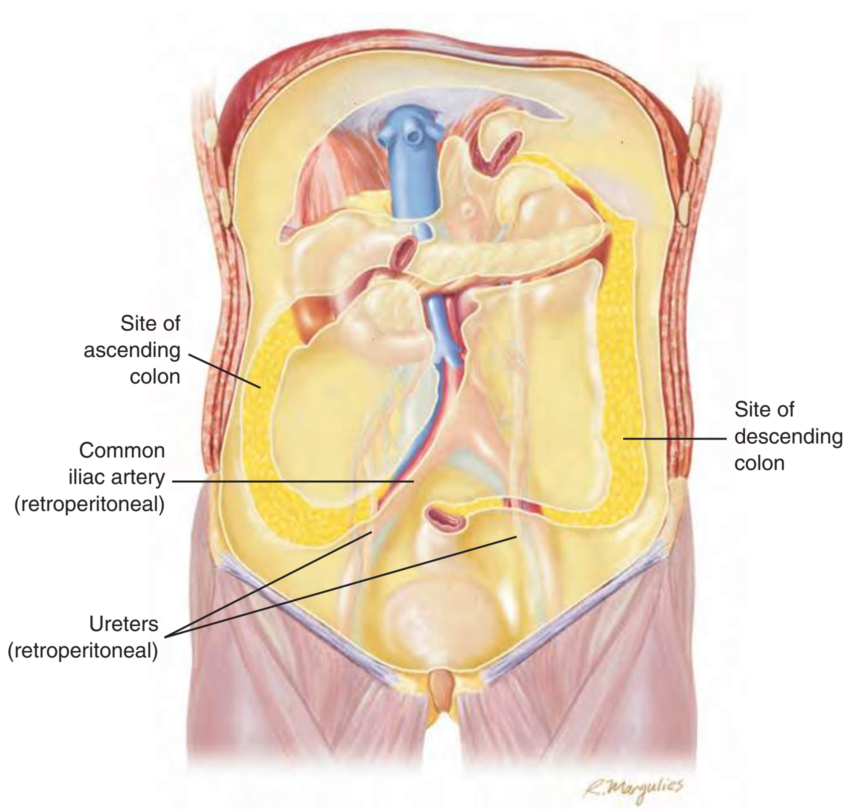



**FIG. 2-2** The peritoneum.

# Muscular Anatomy

The anterior lateral abdominal muscles include the external oblique, internal oblique, transversus abdominis, and rectus abdominis. The XLIF approach involves careful dissection through the oblique muscles—the most superficial of these is the external oblique, which arises from eight fleshy digitations of the external surface and lower borders of the eight inferior ribs. From these attachments, the muscular fibers pass in various directions. Those from the lowest ribs pass nearly vertically to insert into the anterior half of the outer lip of the iliac crest. The middle and upper fibers are directed downward and forward to terminate in tendinous fibers that spread out into a broad aponeurosis joining the opposite side.

The internal oblique is smaller and lies beneath the external oblique. It is irregularly quadrilateral and situated at the anterior, lateral, and posterior part of the abdomen. It arises from the outer half of Poupart's ligament, from the anterior two thirds of the middle tip of the crest of the ileum, and from the lumbar fascia. From this origin, fibers diverge in different directions. From Poupart's ligament, fibers arch downward and anteriorly across the spermatic cord, inserting conjointly with the transversus abdominis into the crest of the pubis and pectineal line. Fibers from the anterior superior iliac spine are horizontal in direction, and those from the anterior portion of the iliac crest pass obliquely upward and inward, terminating in an aponeurosis that continues forward to the linea alba. The posterior fibers ascend almost vertically, inserting into the lower borders of the lower four rib cartilages.

The only two structures that pass between the external and internal oblique muscles are the iliohypogastric and ilioinguinal branches of the first lumbar nerve root, which are pure sensory fibers. The transversalis muscle is so named because of the direction of its fibers. It lies immediately beneath the internal oblique and arises from the outer third of Poupart's ligament, the inner lip (anterior two thirds) of the iliac crest, and the inner suture of the six lower rib cartilages, interdigitating with the diaphragm and a broad aponeurosis from the spinous and transverse processes of the lumbar vertebrae.[1] All three of these abdominal muscles are traversed with the lateral dissection in the XLIF approach to the lumbar spine.

The psoas major muscle is the key muscle dissected during the XLIF approach. It functions as a hip flexor, abductor, and lateral rotator. It extends from the posterior mediastinum to the thigh on either side of the lumbosacral spine and arises from the sides of the vertebral bodies, intervertebral discs, and anterior base of the transverse processes of the last thoracic and all lumbar vertebrae (see Fig. 2-3). The muscle originates from tendinous arches between vertebrae and travels across the pelvic brim, diminishing in size as it passes beneath

Poupart's ligament, where it terminates in a tendon joined by fibers of the iliacus muscle to insert into the lesser trochanter of the femur. Within the substance of the psoas major lies the lumbar plexus, which receives contributions from T12 to L5. The genitofemoral nerve pierces the psoas and can be visualized on the anterior surface of the muscle. The sympathetic chain can be identified along the lateral surface of the vertebral body, just anterior to the tendinous origin of the psoas. Anterior to this muscle are the peritoneum, kidneys, renal vessels, ureters, spermatic vessels, and the colon. The medial border of the psoas muscle encompasses the lumbar vertebrae, the lumbar arteries, and the sympathetic ganglia with communicating branches with the spinal nerves.

## Applied Neuroanatomy

The union of neuromonitoring with the XLIF approach made lateral access spine surgery possible. The ability to locate the neural elements allows repositioning of the approach dilator and the subsequent docking of the retractor system. However, there is no substitute for a thorough knowledge of the normal location of the neural elements within the spinal canal, as well as their exit zones and paths through the psoas muscle. A review of the pertinent anatomy is extremely warranted.

In the adult, the spinal cord generally terminates at the L1-2 level. The spinal nerve is formed by ventral (motor) and dorsal (sensory) roots, which pierce the dura separately as they exit through the intervertebral foramen. The dorsal root is thicker and larger than the ventral root and has a bulbous enlargement within the neuroforamen, the dorsal root ganglion. After uniting as the spinal nerve, both ventral and dorsal branches form. Sympathetic fibers from the lateral columns of the lower thoracic and lumbar cord travel along the ventral branch. The dorsal primary rami divide into medial and lateral branches. The medial branch descends posteriorly at the back of the transverse and superior articular processes to supply sensory fibers to two facet joint levels. Therefore each facet receives sensory innervation from two different spinal nerve segments. The medial branch continues posteriorly to innervate the dorsal muscles of the back (such as multifidus and interspinalis). Medial branches also supply the interspinous and supraspinous ligaments. The lateral branches of the dorsal primary rami supply small branches to the sacrospinal muscles and cutaneous structures in the lumbar area. Although the nucleus pulposus of the disc is devoid of nerve endings, the posterior anulus fibrosus shares free nerve endings with the fibrous tissue that binds to the posterior longitudinal ligament.

The lumbar plexus is formed by the ventral rami of the first three lumbar nerves and part of the fourth lumbar nerve (Fig. 2-3). It is narrow above and broad below, and it is generally situated in the posterior substance of the psoas muscle.[2] The first lumbar spinal nerve (L1) gives off the iliohypogastric and ilioinguinal nerves, which travel superficially to the retroperitoneal space and provide sensory innervation to the area of the groin. The genitofemoral nerve—formed from the L1 and L2 spinal nerves—penetrates the lateral border of the psoas to lie on its anterior fascia and sends branches to the genital and femoral areas. The lateral cutaneous nerve of the thigh is formed from the L2 and L3 spinal nerves and innervates the skin of the anterolateral and lateral surfaces of the thigh. The femoral nerve is formed by the L2, L3, and L4 spinal nerves, exits in the angle between the iliacus and psoas muscles, and travels to the thigh to innervate the quadriceps. The obturator nerve comprises branches of the L2, L3, and L4 spinal nerves, which, together with a branch of L4 that joins L5 to form the lumbosacral trunk, appear at the medial border of the psoas muscle and cross the ala of the sacrum. The obturator nerve provides motor innervation to the adductor muscles of the thigh and cutaneous sensory innervation of the inner thigh. The sympathetic trunk enters the abdomen with the psoas, behind the medial crural ligament. The trunk is closely attached to the medial psoas muscle as it descends along the vertebral bodies and intervertebral discs to enter the abdomen.

The lumbar plexus nerves are often encountered in the posterior psoas when approaching the L4-5 disc. Care should be taken to use NeuroVision® dynamic EMG (NuVasive, Inc.) guidance through the muscle; this system allows the surgeon to locate and avoid neural structures in the path of the approach by entering slightly anterior to the identified locations of nerves, thereby achieving a safe and effective access channel.

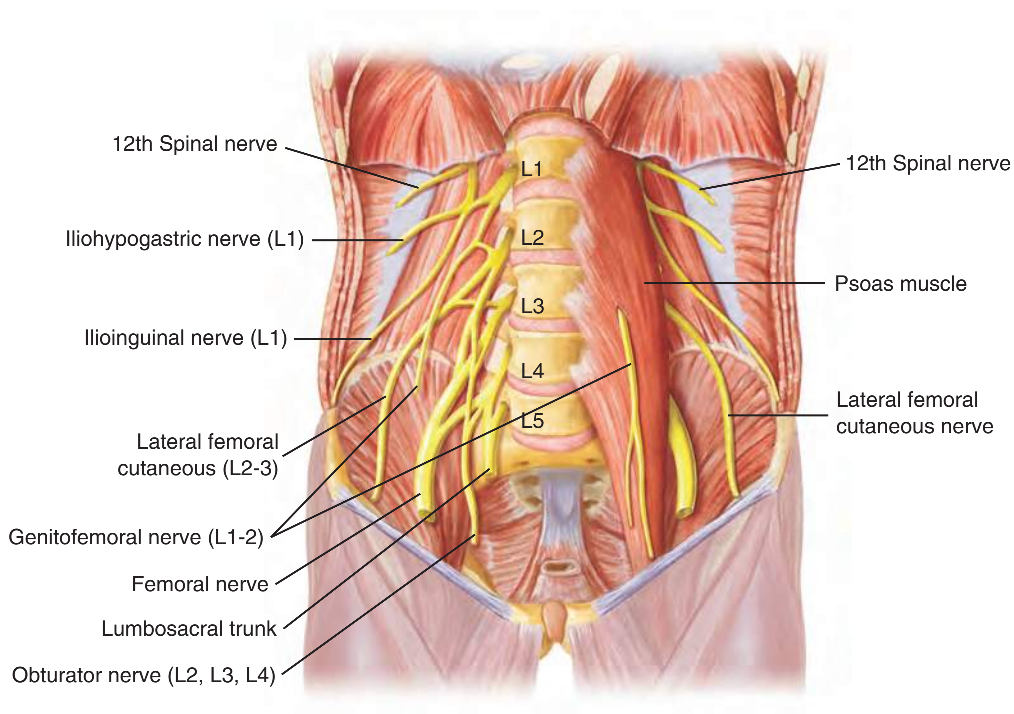



**FIG. 2-3** The psoas muscle and lumbar plexus.

# Vascular Anatomy

The arterial supply in the lumbar spine arises directly from the aorta. Four paired lumbar arteries emerge directly from the posterior aspect of the aorta, anterior to the bodies of the upper four lumbar vertebrae. The venous supply matches the arterial pattern, draining internal and external venous tributaries into the inferior vena cava. These segmental vessels curve posteriorly around the spine in the valley or midportion of the vertebral bodies, supplying the vertebrae and ligaments (Fig. 2-4, *A*).[3] Lateral access to the lumbar disc spaces need not approach the location of the segmental vessels, but care should be taken to ensure that the disc exposure is not exaggerated unnecessarily.

Bifurcation of the aorta and vena cava into the left and right common iliac vessels generally occurs at the L4-5 disc level, but this may vary with more caudal bifurcations (Fig. 2-4, *B*). To avoid injury on either the ipsilateral or contralateral side of the approach, the surgeon should always keep the location of these vessels in mind when he or she approaches the disc laterally. Targeting the lateral center of the disc space in an XLIF approach generally avoids an encounter with the anterior vasculature. Exceptions include the presence of anomalous vasculature and procedures in patients who have undergone previous surgeries. The locations of the blood vessels are shown in the MRIs and axial illustrations on pages 24 through 26.

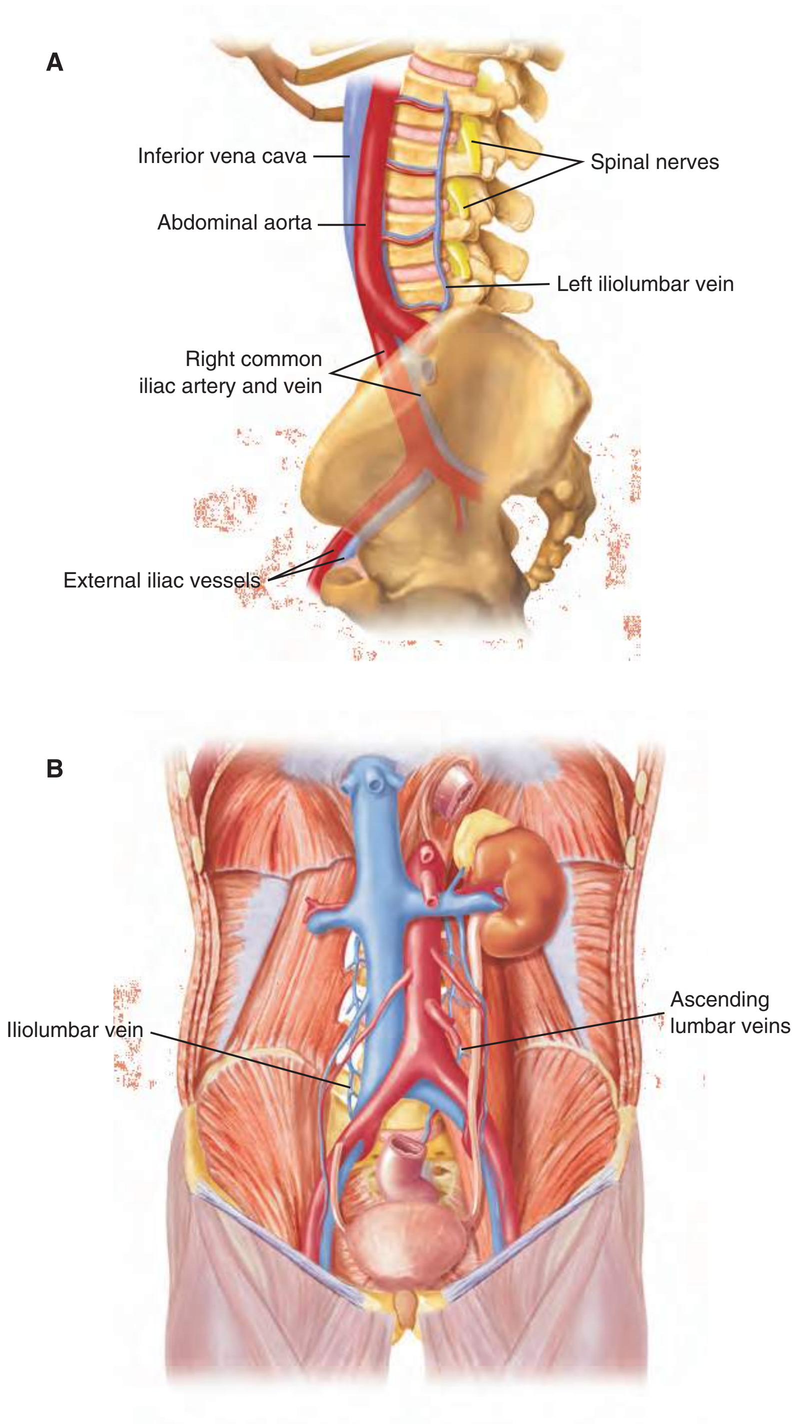
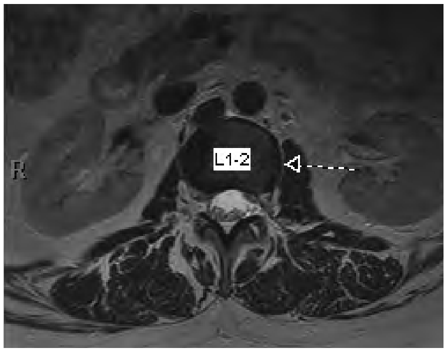
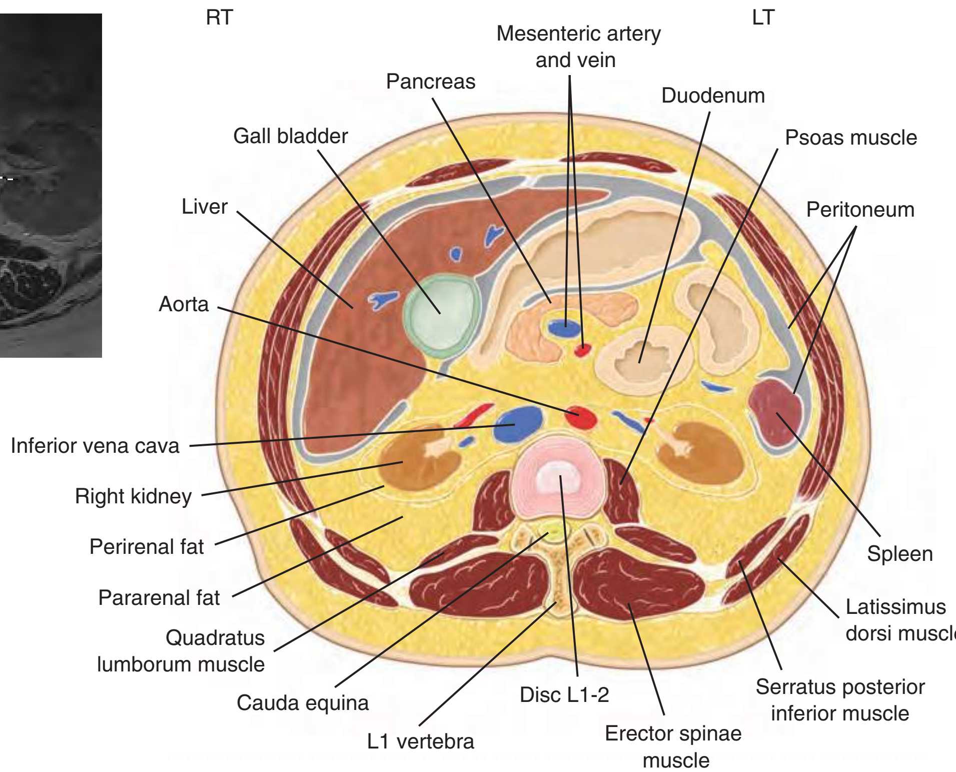


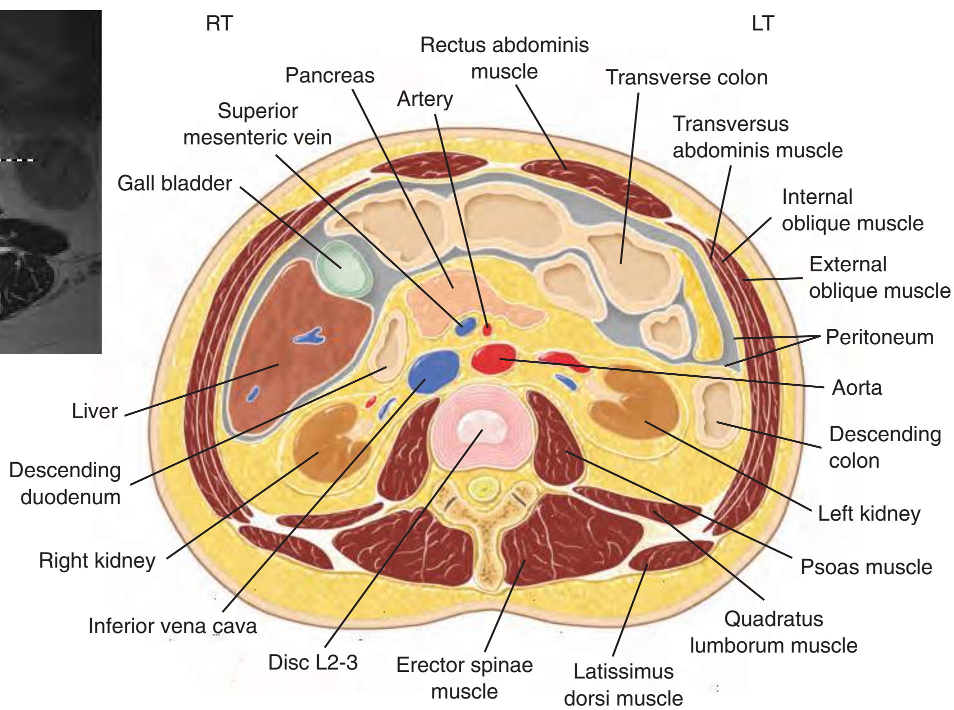

**FIG. 2-4** **A** and **B,** The major lumbar vasculature.

# L1-2 BLOOD VESSEL LOCATIONS

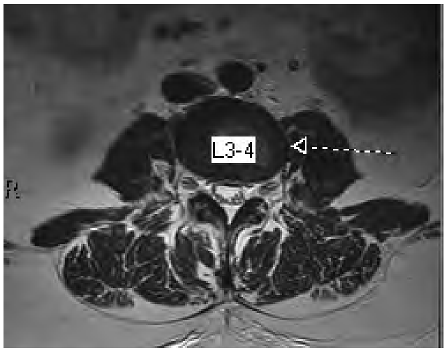


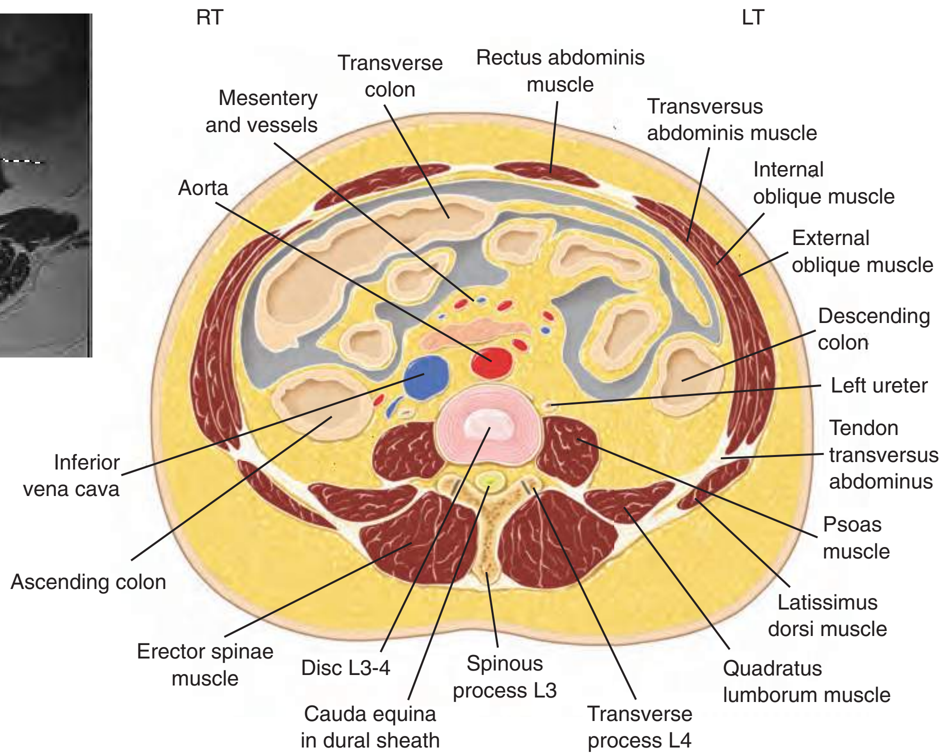




# L2-3 BLOOD VESSEL LOCATIONS

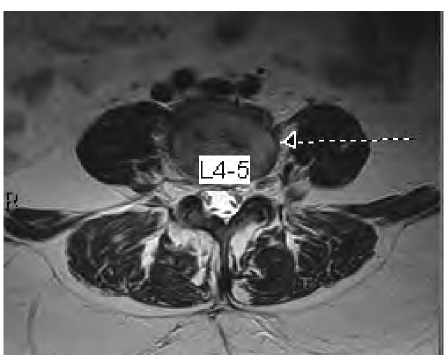



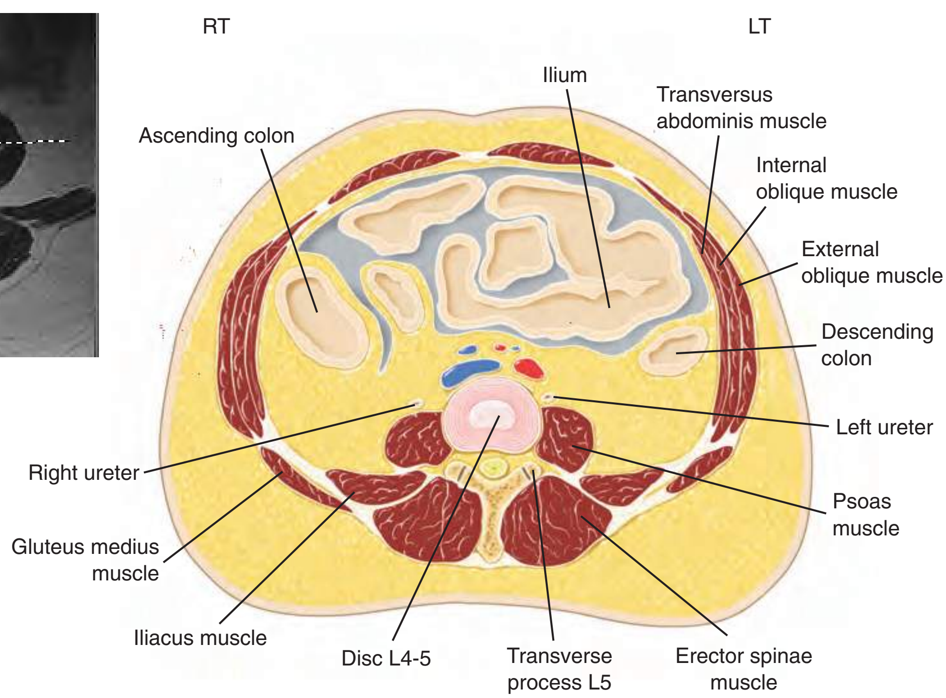
# L3-4 BLOOD VESSEL LOCATIONS



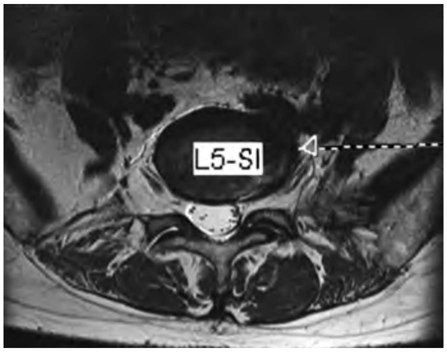



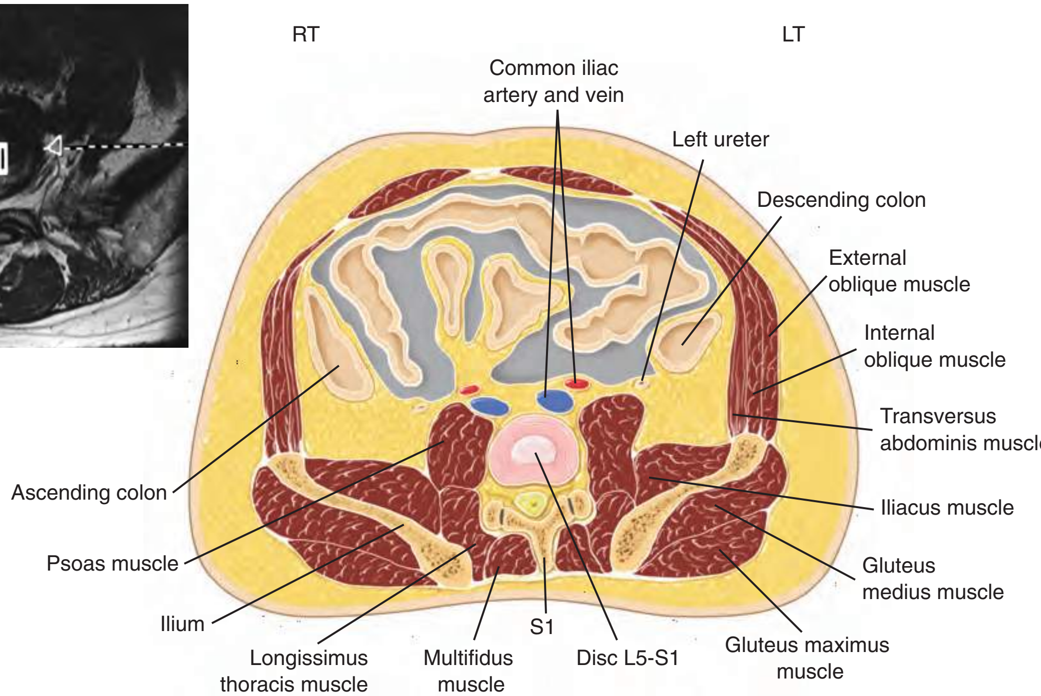

# L4-5 BLOOD VESSEL LOCATIONS



# L5-S1 BLOOD VESSEL LOCATIONS




## OSTEOLOGY

There are five vertebrae in the lumbar spine. The anterior portions—or vertebral bodies—are the primary load-bearing structures, and the posterior features—including the pedicles, facet joints, and spinous and transverse processes—protect the neural elements and act as the origins and insertions of muscle groups. The superior and inferior articular processes are connected by an isthmus called the *pars interarticularis.* The facet joints are true synovial joints, with superior and inferior portions projecting from adjacent vertebrae. They function to stabilize motion between vertebral segments. Each joint is enclosed by a capsule that consists of both an outer, dense connective tissue and an inner layer of elastic fiber, similar to ligamentum flavum.

The transverse process projects laterally from the junction of the facet and lamina, which provides a good landmark for the surgeon when he or she enters the retroperitoneal space.

The intervertebral foramina provide passages for each exiting nerve root and are bordered by the pedicles superiorly and inferiorly, the disc and body anteriorly, and the lamina and anterior facet joint posteriorly. They are longer in a vertical direction and are largest at L1-2; the overall configuration resembles an inverted teardrop.

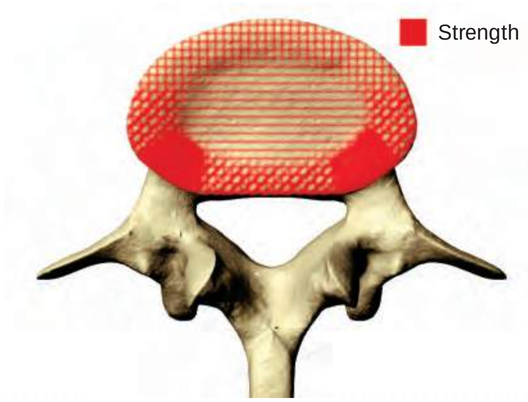



**FIG. 2-5** The endplate and areas of relative strength. The red areas indicate the strongest regions.

Lumbosacral transitional vertebrae are commonly encountered radiographically. In a study by Eyo et al,[4] 37% of the radiographs reviewed demonstrated transitional changes. Sacralization or incorporation of the fifth lumbar vertebra was more common than lumbarization of the first sacral vertebra, by a 2:1 ratio. In the Eyo et al[4] study, these changes were found more often in males (46%) than in females (29%). Transitional changes may affect the ability to access the L4-5 interspace for XLIF procedures, as may advanced degenerative collapse of L5-S1.

The vertebral body itself is covered by a thick cortex that is at its thickest posteriorly and peripherally, which creates a solid base of support for cages. In addition, the trabecular pattern of the central cancellous portion tends to follow the lines of force that these cages place on the spine.

## ENDPLATE ANATOMY (RING APOPHYSIS)

The vertebral endplates in the lumbar spine contain two separate anatomic elements: a slightly depressed, flat, or slightly concave plateau of a highly specialized, condensed cancellous bone and the ring apophysis that surrounds it. This cancellous bony layer is not very thick, but is extremely strong in normal vertebrae. A rich vascular supply is found underlying the bony endplate. The ring apophysis is likewise composed of a rather thin, but extremely strong, layer of dense, woven bone, and it serves as the attachment site for the anulus fibrosus. This peripheral rim provides more strength than the central regions of the endplate (Fig. 2-5).[5] The configuration of the apophyseal ring can be used to its greatest advantage in a lateral approach surgery, because an implant can be positioned on this dense area, which provides much support.

# Ligaments

The six major ligaments of the spine are the anterior longitudinal ligament (ALL), posterior longitudinal ligament (PLL), ligamentum flavum, interspinous ligament, supraspinous ligament, and the intertransverse ligament. The ALL, PLL, and supraspinous ligament are intersegmental, whereas the others are intrasegmental.

The ALL runs along the ventral and ventrolateral surfaces of the vertebral column, from the sacrum to C2. It continues proximally as the atlantooccipital ligament. The ALL has attachments to the vertebral bodies and discs. There are also superficial fibers that span several vertebral segments and deep fibers that run between adjacent vertebrae. The deep fibers blend with the ventral anulus of the disc and reinforce the intervertebral discs. The ALL demonstrates its greatest tensile strength in the lumbar region. In general, the ALL is approximately twice as strong as the PLL. The ALL is usually ventral to the instantaneous axis of rotation and therefore provides resistance to extension.

The XLIF approach to anterior column stabilization preserves the ALL, thereby maintaining significant, inherent spinal stability. Retaining the anterior and posterior anulus and ligaments fosters a stable alignment correction using ligamentotaxis.

# Conclusion

The XLIF approach to the anterior spinal column has some advantages over traditional anterior or posterior approaches, with respect to avoiding anatomic risks and morbidity and maintaining structural integrity (Box 2-1). A surgeon should attempt to perform a new procedure only after he or she has carefully reviewed the anatomy and appropriate surgical technique; XLIF is no exception. The topics discussed within this chapter offer only an introduction to this important procedure.

**BOX 2-1** Advantages of the XLIF Approach

- Disruption of tissues is minimal, resulting in lower blood loss, less postoperative pain, and a shorter recovery time
- Avoids destruction and denervation of the posterior musculature
- Avoids dural retraction and the associated epidural scarring
- Avoids destabilization caused by resection of the posterior arch
- Minimizes the risk of vascular injury, compared with anterior approaches
- Retains all stabilizing ligamentous structures, thus facilitating alignment correction by ligamentotaxis
- Allows access to a large area for disc removal and endplate preparation for fusion
- Allows a spacer with a large surface area to be placed for load distribution
- Maximizes the strongest areas of the endplate with implant placement spanning the ring apophysis, thus supporting axial and coronal alignment restoration

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