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Anatomy of the Lateral Approach at the Thoracolumbar Junction

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The thoracolumbar junction, encompassing the eleventh thoracic to the second lumbar vertebrae (T11-L2), is a common location for traumatic and nontraumatic pathologies because of the relative rigidity of the thoracic spine (afforded by the ribs and their sternal attachments) superiorly and the mobility of the lumbar region inferiorly.[1-3] Lateral approaches to this junctional area have been described as early as 1925.[4-7] The thoracolumbar junction poses anatomically unique challenges to the spine surgeon during lateral approach procedures, given access challenges introduced by the lower border of the rib cage and the diaphragm. Multiple surgical approaches have been described to access this area, from conventional open to less-invasive exposures, as well as coelomic and extracoelomic approaches. Extracoelomic approaches include both the retropleural and retroperitoneal access corridors, whereas coelomic exposures include transthoracic and transperitoneal approaches.[8-13]

The minimally invasive lateral extracoelomic approach to the thoracolumbar spine has been previously described.[8,14] During the minimally invasive extracoelomic approach, the diaphragm must be mobilized to communicate the thoracic and abdominal cavities at the thoracolumbar junction. An understanding of the anatomy of the diaphragm and its relationship to nearby structures is critical to a successful approach and recovery. In this chapter, we describe the anatomic relationship between the retroperitoneal space, retropleural space, diaphragm, and thoracolumbar spine in reference to the minimally invasive extreme lateral interbody fusion (XLIF®, NuVasive®, Inc., San Diego, CA) approach.

REGIONAL ANATOMY

Chest/Abdominal Wall

When approaching the spine from a 90 degree lateral approach, the relevant muscles of the chest and abdominal wall at the thoracolumbar transitional area include the latissimus dorsi, intercostal, transversus abdominis, and external and internal oblique muscles.[14-16] The latissimus dorsi originates from the six lower thoracic and all the lumbar and sacral spinous processes, as well as a posterior portion of the iliac crest. These fibers then converge to a tendon that inserts into the medial lip of the intertubercular groove of the humerus to facilitate adduction, extension, and internal rotation of the arm. The muscles that pass between adjacent ribs are named intercostal muscles and are arranged into two layers, external and internal. The external and internal intercostal muscles originate from the lower border of each rib and insert into the upper border of the rib below. The external intercostal fibers project downward and forward along the rib, whereas the internal intercostal fibers travel downward and backward. The external oblique muscle originates from the inferior six ribs, runs downward and medially, and inserts on the anterior part of the iliac crest, pubis, and linea alba. The internal oblique muscle originates from the iliopsoas fascia, the anterior part of the iliac crest, and the thoracolumbar fascia before traveling upward and medially to finally insert into the lower borders of the tenth, eleventh, and twelfth ribs and linea alba. The transversus abdominis originates from the thoracolumbar fascia (between the iliac crest and the twelfth rib), iliopsoas fascia, anterior part of the iliac crest, and the internal aspects of the lower six costal cartilages. The muscle is found deep to the external and internal oblique muscles and interdigitates with the diaphragm. It shares a common insertion with the oblique muscles into the linea alba.

Coelomic Cavities (Pleural and Peritoneal Cavities)

The two coelomic cavities relevant to the XLIF approach at the thoracolumbar junction are the pleural and peritoneal cavities, separated by the diaphragm (Fig. 3-1).[8,14-16] The pleura, composed of two layers, is the serous membrane that surrounds the lungs and forms the lining of the pleural cavity. The outer (parietal) pleura attaches to the chest wall; the inner (visceral) pleura encapsulates the lungs and adjoining structures. The potential space between the parietal and visceral pleura is known as the pleural cavity. The peritoneum, also composed of two layers, is a serous membrane that forms the lining of the abdominal cavity. It covers most of the intraabdominal (or coelomic) organs. The outer layer, called the parietal peritoneum, is attached to the abdominal wall. The inner layer, or visceral peritoneum, is wrapped around the internal organs that are located inside the intraperitoneal cavity. The potential space between the parietal and visceral peritoneum is the peritoneal cavity.

During the XLIF approach in the thoracic spine, either a coelomic (transthoracic) or extracoelomic (retropleural) approach can be used; the lumbar spine requires a retroperitoneal approach.[8-12] Access into these spaces has been previously described, detailing a 90 degree off-midline approach using a mini-open technique either sparing (for discectomy and/or fusion) or resect-

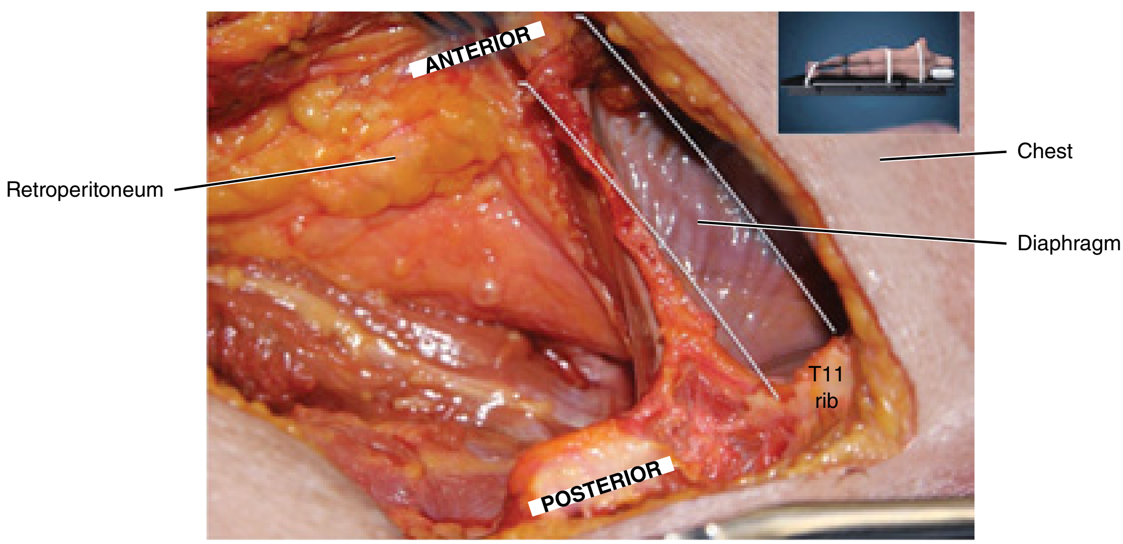

FIG. 3-1 Cadaveric specimen in the right lateral decubitus position with the chest/abdominal wall removed demonstrating how the diaphragm separates the thoracic cavity from the abdomen. The eleventh rib has been resected and is outlined. Image copyright use provided courtesy of the American Association of Neurological Surgeons (AANS).

ing (for corpectomy) ribs in the thoracic spine or at the thoracolumbar junction and traversing the retroperitoneal space and the psoas muscle in the lumbar region to access the lateral aspect of the intervertebral disc.[10,17,18]

Diaphragm

The diaphragm is a musculotendinous sheet that extends between the thoracic and abdominal cavities. Its superior surface is covered by parietal pleura and pericardium, whereas its inferior surface is covered by the diaphragmatic fascia, an extension of the transversalis fascia, and the peritoneum (Fig. 3-2).[14-16] The peritoneum separates from the posterior aspect of the diaphragm because of the intervening fat as well as the cranial portions of the kidneys and related structures. The attachments of the diaphragm can be broadly divided into three main groups: (1) sternal or anterior, (2) costal or lateral, and (3) lumbar or posterior (Table 3-1). The sternal attachments arise from the internal surface of the xiphoid process and aponeurosis of the transversus abdominis and are the least relevant attachments with respect to the XLIF approach at the thoracolumbar junction. The costal attachments arise from the medial aspects of the seventh and eighth ribs anteriorly, the ninth and tenth laterally, and the eleventh and twelfth ribs posterolaterally (Fig. 3-3). Despite the presence of the liver, there are no differences in the sternal or costal attachments between the right and left sides. Posteriorly, the diaphragm forms two arcuate ligaments on each side and two crura. The lateral arcuate ligament spans the quadratus lumborum, whereas the medial arcuate ligament attaches medially to the transverse process of the

TABLE 3-1 Summary of Attachments of the Diaphragm

Location	Attachments
Anterior (sternal)	Xiphoid process, aponeurosis of the transversus abdominis
Lateral (costal)	Medial aspects of the seventh and eighth ribs anteriorly, ninth and tenth ribs laterally, and eleventh and twelfth ribs posterolaterally
Posterior (lumbar)	Medial and lateral arcuate ligaments, left and right crura

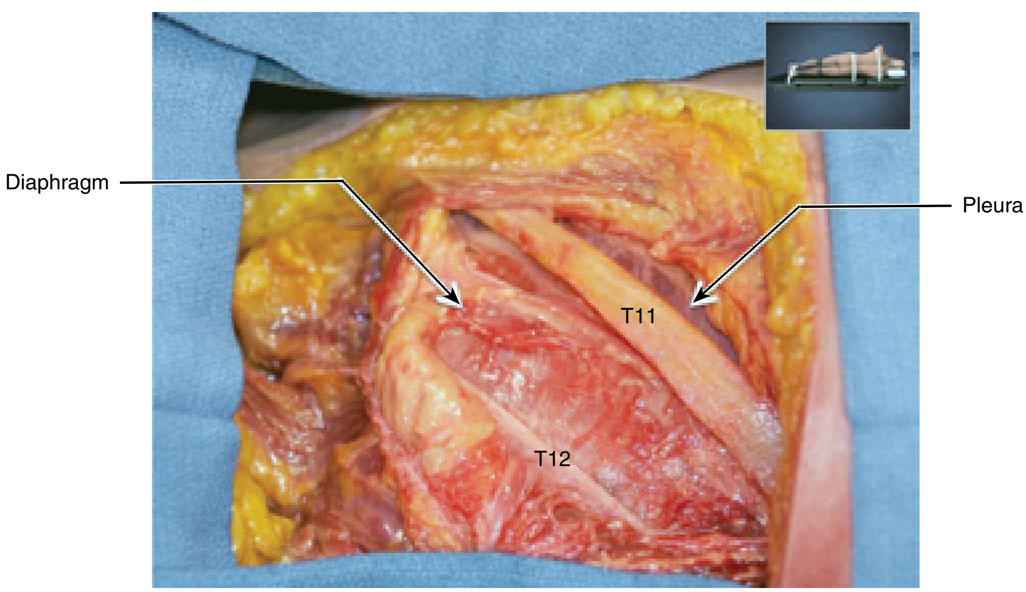

FIG. 3-2 Cadaveric specimen in the right lateral decubitus position demonstrating the relative relationship of the diaphragm and pleural cavity to the eleventh and twelfth ribs. Image copyright use provided courtesy of the American Association of Neurological Surgeons (AANS).

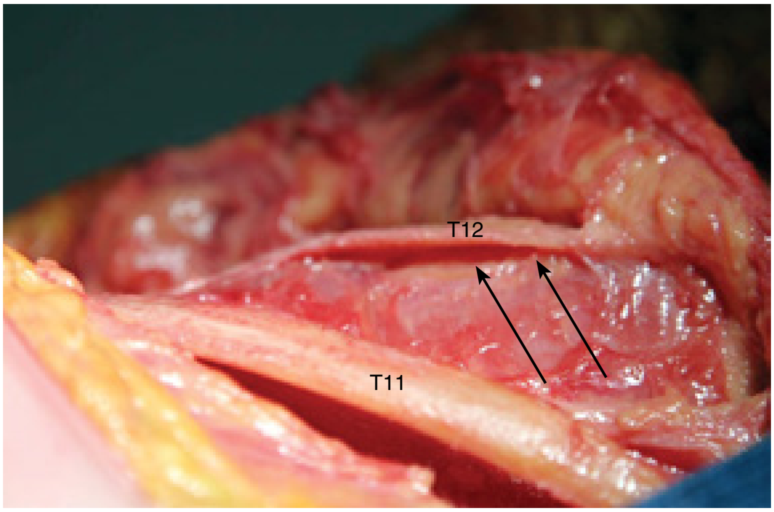

FIG. 3-3 Cadaveric specimen demonstrating the costal attachments *(arrows)* of the diaphragm to the medial surface of the twelfth rib when looking from cranially to caudally. Image copyright use provided courtesy of the American Association of Neurological Surgeons (AANS).

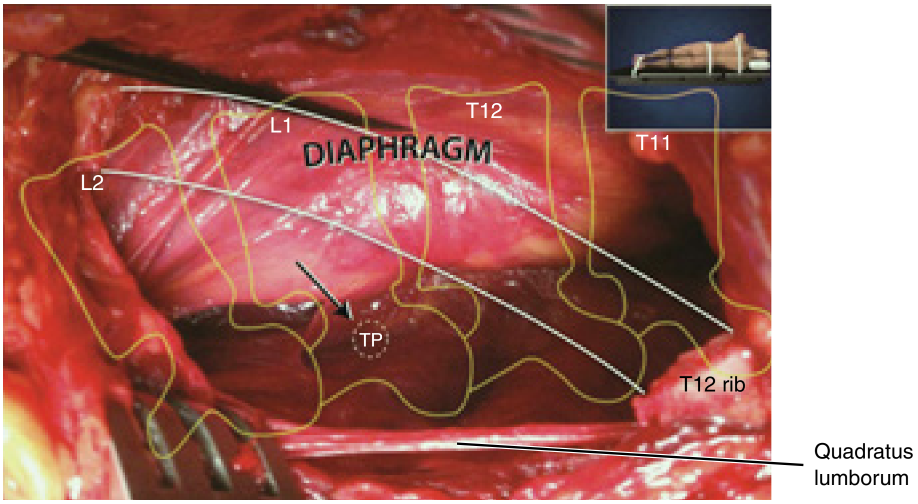

FIG. 3-4 Cadaveric specimen in the right lateral decubitus position demonstrating the posterior or lumbar attachments of the diaphragm to the transverse process of L1. The resected rib has been outlined in *white lines,* and the *arrow* is indicating the intervening point between the medial and lateral arcuate ligaments. *TP,* Transverse process. Image copyright use provided courtesy of the American Association of Neurological Surgeons (AANS).

first lumbar vertebra (L1) and laterally to the inferior border of the twelfth rib. The medial arcuate ligament attaches laterally to the transverse process of L1 and medially to the corresponding crus. The intervening point of attachment is on the transverse process of L1 (Fig. 3-4).The crura of the diaphragm extend along the anterolateral lumbar spine on their respective sides. The right crus typically arises from the ventral surfaces of the superior three lumbar vertebrae, whereas the left crus extends only to the second lumbar vertebra. This is the only major difference between the left and right side attachments of the diaphragm.

SURGICAL SIGNIFICANCE

The complex relationship between the diaphragm, ribs, pleura, and peritoneum poses a notable challenge when surgically approaching the lower thoracic and upper lumbar vertebrae. Because of this unique transitional anatomy, the approach to the spine when using the XLIF

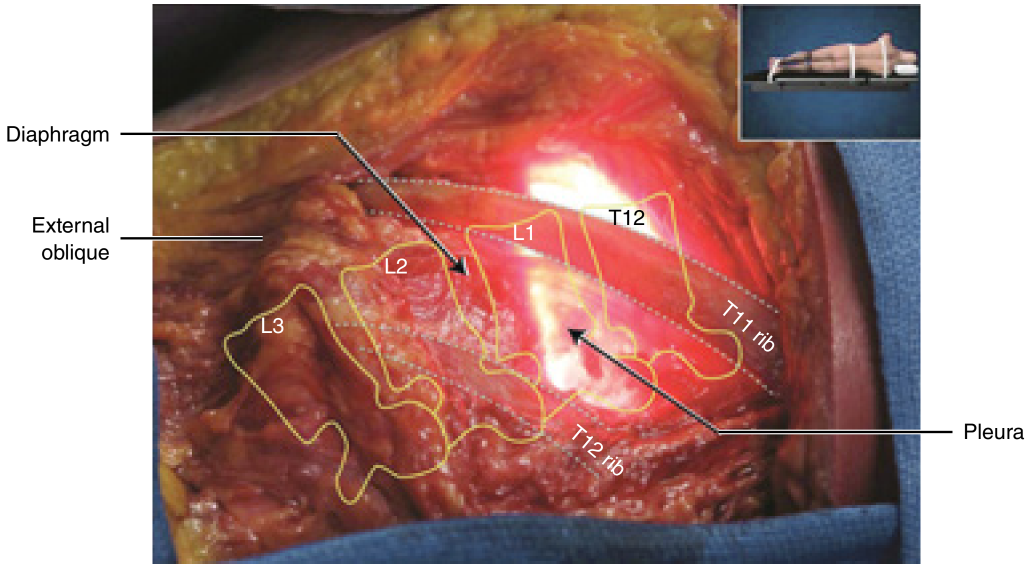

FIG. 3-5 Cadaveric specimen in the right lateral decubitus position demonstrating the relative relationship of the diaphragm and illuminated pleural cavity to the eleventh and twelfth ribs. Image copyright use provided courtesy of the American Association of Neurological Surgeons (AANS).

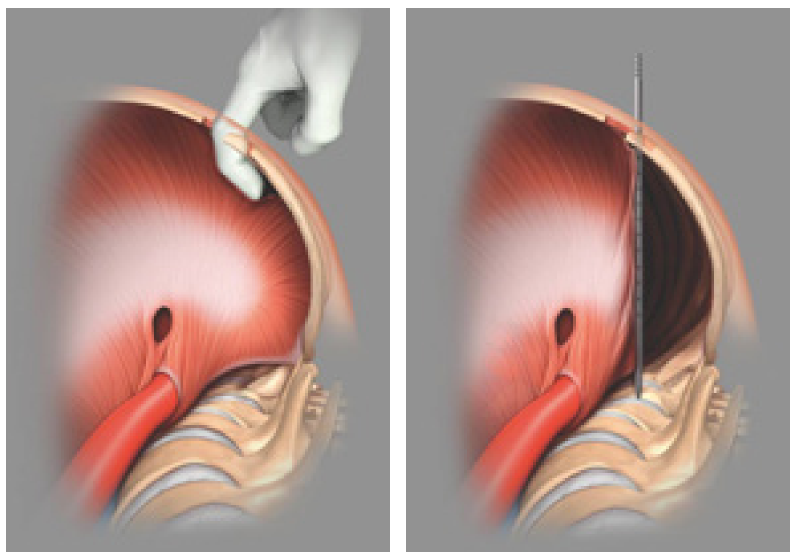

FIG. 3-6 Schematic representations of the diaphragm looking from caudal to cranial demonstrating blunt dissection with the aid of a finger to develop the extracoelomic space *(left)*. The diaphragm is retracted anteriorly once the costal and lumbar attachments have been mobilized *(right)*. Image copyright use provided courtesy of the American Association of Neurological Surgeons (AANS).

or any anterolateral approach is similarly made more complex.[8,14] The diaphragm muscle and its maintenance during the XLIF approach is the most relevant anatomic structure in this area, as it separates the thoracic cavity from the abdominal cavity (Fig. 3-5). As such, mobilization of the diaphragm is necessary when developing the extracoelomic approach to minimize diaphragmatic morbidity. Knowledge of the regional anatomy, with special attention to the attachments of the diaphragm, is essential to successfully navigating the surgical corridor during the XLIF approach.[8,14]

As previously mentioned, the costal and lumbar attachments of the diaphragm are those most relevant in the XLIF approach to these transitional spinal levels. During the early stages of the XLIF exposure, subperiosteal dissection and excision of the rib overlying the target spinal level mobilizes the diaphragm from its costal attachments (Fig. 3-6). The challenge of dissecting the costal attachments is the delineation of tissue planes, as the transversus abdominis interdigitates with the muscle of the diaphragm with no clear plane of dissection. By excising a portion of the rib, an extracoelomic plane is better identified. The lumbar portion (arcuate ligaments and crura) is exposed after detaching the costal portion as described previously and by bluntly mobilizing the diaphragm anteriorly along with the pleural and peritoneal contents. The medial attachment of the lateral arcuate ligament and the lateral attachment of the medial arcuate ligament to the L1 transverse process are then visualized and should be sharply cut to facilitate the exposure.[8,14] In addition to these attachments, the arcuate ligaments also fuse posteriorly to the thoracolumbar fascia. This is the last structure that should be detached before completing the surgical corridor, exposing the thoracolumbar spine from the lateral approach. If further anterior exposure of the vertebral body is required, the ipsilateral crus may be sectioned and mobilized.

When all of the costal and lumbar attachments of the diaphragm are mobilized, the retropleural and retroperitoneal spaces are communicated into a single plane. Because this approach remains in the retroperitoneal/retropleural space, it can be performed from the right or left side depending on surgeon preference or location of the pathology without interference by the liver, spleen, or other peritoneal structures. Because the approach remains in the extracoelomic space and the diaphragm is not incised, there is no need for any repair of the diaphragm (Fig. 3-7).

Several studies have reported descriptions and outcomes of these various, yet similar XLIF approaches at the thoracolumbar junction (retroperitoneal, coelomic, or extracoelomic).[8,10-12,14,17,18] Of note, Dakwar et al[14] reported anatomic descriptions of the diaphragm and thoracolumbar junction as it relates to the minimally invasive lateral approach in nine cadaveric specimens (18 sides), while Uribe et al[8] described the retropleural XLIF approach in a cadaveric study with four case examples. Clinical examples continue to emerge and have shown generally favorable clinical results with either coelomic or extracoelomic approaches to the thoracolumbar junction and thoracic spine, and substantially decreased morbidity compared with open approaches,

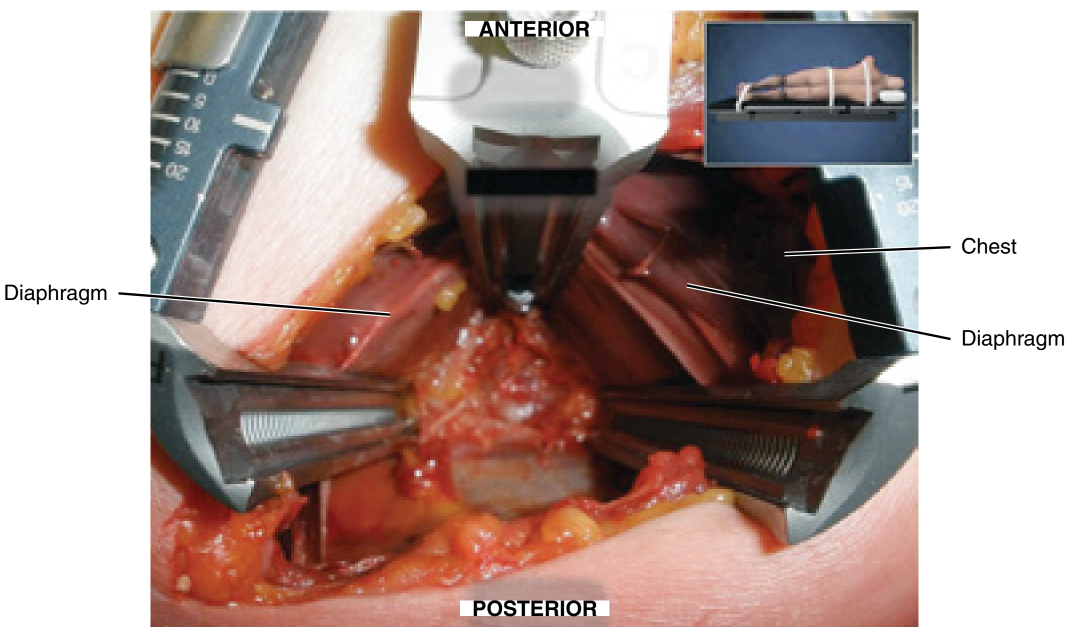

FIG. 3-7 Cadaveric specimen in the right lateral decubitus position demonstrating the view through the split-blade MaXcess® (NuVasive, Inc.) retractor when placed in the extracoelomic space. Image copyright use provided courtesy of the American Association of Neurological Surgeons (AANS).

often without the necessity to place postoperative chest tubes.[8,10,12,17,18]

CONCLUSION

In summary, the retropleural and retroperitoneal cavities are extracoelomic spaces that provide anatomic corridors to the thoracolumbar spine. The diaphragm, which separates the thoracic and abdominal cavities, has multiple attachments that can be categorized as anterior, lateral, and posterior. In reference to the minimally invasive lateral extracoelomic approach to the thoracolumbar junction, the surgically significant attachments are primarily to the twelfth rib and transverse process of L1. Knowledge of these structures in general, and specifically their role in the XLIF approach, will contribute to the effective treatment of patients at these challenging levels.

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