Surgical Anatomy and Approaches to the Anterior Thoracolumbar Spine Region

Anatomia cirúrgica e abordagens para a coluna tóraco-lombar

Andrei F. Joaquim
Leonardo Giacomini
Enrico Ghizoni
Fábio Araújo Fernandes
Marcelo L. Mudo
Helder Tedeschi

1Neurosurgeon. Neurosurgery Division, State University of Campinas (UNICAMP), Campinas-SP, Brazil.
2Neurosurgery Resident. Neurosurgery Division, State University of Campinas (UNICAMP), Campinas-SP, Brazil.
3Orthopaedic surgeon, Spine Surgeon – Irmandade da Santa Casa de Misericórdia de São Paulo, São Paulo-SP.
4Neurosurgeon. Head, Neurosurgery Division, Hospital Estadual de Sorocaba. Sorocaba-SP.
5Neurosurgeon. Head of the Neurosurgery Division, State University of Campinas (UNICAMP), Campinas-SP.

RESUMO
A anatomia cirúrgica da região tóraco-lombar da coluna vertebral (T11-L2) é revisada. As características principais dos grupos musculares, vascularização e estruturas neurais são descritas em detalhes. Apresentamos também uma discussão técnica dos acessos anterior a essa região, como o transtorácico retroperitoneal e o retropleural lateral. Concluímos que o conhecimento anatômico é fundamental para se obter resultados mais seguros e eficazes em cirurgias desta região.

Palavras Chave: junção tóraco-lombar, transtorácico retroperitoneal, retropleural lateral, anotma

ABSTRACT
We review the surgical anatomy of the thoraco-lumbar spine region located between the eleventh thoracic and the second lumbar vertebrae (T11-L2). Anatomical features of muscular, vascular and neural structures important to surgical approaches are described in details. We also discuss surgical nuances of the transthoracic retroperitoneal and the lateral retropleural approaches. We conclude that anatomical knowledge is important to improve the efficacy and safety of surgical procedures in the thoraco-lumbar spine region.

Keywords: thoraco-lumbar junction, transthoracic retroperitoneal, retropleural lateral, anatomy
INTRODUCTION

The thoraco-lumbar spine comprises the region located between the eleventh thoracic and the second lumbar vertebrae (T11-L2). The thoraco-lumbar region is one of the most common sites for spinal fractures, once it constitutes a transitional zone between the rigid thoracic spine and the relative mobile lumbar spine. This region is also affected by other diseases, such as infections, neoplastic and degenerative lesions.

Many surgical routes have been described to approach this region. Anterior approaches may provide a wide anterior decompression with grafting and instrumentation and also restore the anterior column support, whereas posteriorly based approaches are used for stabilization with pedicle screws, with or without decompression. Posterior approaches include standard laminectomy, transpedicular decompressions, posterolateral costotransversectomy and the lateral extracavitary approach.

The main anterior-based approaches to the thoracolumbar junction are performed antero-laterally, which can be performed via a thoracotomy or, more recently, by thoracoscopy. These transthoracic approaches can be performed together with retroperitoneal approaches. A recently described technique for this region is the lateral retropleural approach that avoids entering into the chest cavity. In a general view, the approach is chosen based on the surgeon’s experience and preference, patient’s clinical condition and body habitus and also according to the characteristics of the disease. However, regardless the chosen surgical route, anatomical knowledge is still the cornerstone to achieve a good surgical result.

In this paper, we review the main anatomical features of the anterior thoracolumbar spine region, from a spinal surgeon’s perspective, discussing anatomical nuances of the anterior-based approaches to this area.

ANATOMY

The anatomy of the thoracolumbar spine requires the understanding of the relationship between the ribs, the muscles, the regional vessels and the neural structures of this region.

Ribs

Usually the ribs have two articular facets – one articulates with the vertebral body of the same level and the other with the vertebra above - covering the disc on its posterolateral aspect. As an example, the seventh rib articulates with the body and transverse process of T7, but also with the body of T6, covering the disk space of T6-7. Exceptions are the first, eleventh and twelfth ribs that articulate only with the same level vertebra.

There are four ligaments attached to the ribs: 1) The radiate ligament that spans out from the ventral portion of the proximal rib head and attach to the adjacent vertebra and intervertebral disc; 2) The costotransverse ligament attaching the neck of the rib to the articulating transverse process; 3) The intertransverse ligament which connects the transverse processes and 4) The capsular ligaments which span from the ventral transverse process to the dorsal portion of the articulating rib.

Also important, the thoracic vertebral body has a unique anatomy, with a concavity relative to the spinal canal in the axial plan. The pedicles arise in the superior portion of the body, higher than in the cervical or lumbar vertebrae. The disc space is narrower than in the lumbar spine.

Diaphragm

The diaphragm is a dome-shaped muscle that separates the thoracic from the abdominal cavity at the level of T12 to L1. Its convex superior surface forms the floor of the thoracic cavity, and its concave inferior surface forms the roof of the abdominal cavity. Its peripheral part consists of muscular fibers that originate from the circumference of the inferior thoracic aperture and converge to be inserted into a strong aponeurosis, the central tendon. Its muscular fibers can be grouped according to their origin in: 1) sternal (origin from the xiphoid process), 2) costal (attached to the six costal cartilages and the four lower ribs).
and 3) lumbar (in the anterolateral aspect of the upper lumbar spine, the most significantly manipulated region during anterior thoracolumbar junction surgeries). The lumbar portion has two origins: one from the medial and lateral arcuate ligaments (two fibrous arches over the psoas and quadrates muscles) and another from the crura\(^1,\,2\).

The crura are musculotendinous bands of the diaphragm that extend along the anterolateral lumbar spine on each side. The left crus extends to L2, whereas the right crus extends to L3, blending with the anterior longitudinal ligament of the vertebral columns. The aortic hiatus is located between them, at the level of T12\(^10\).

The posterior portion of the diaphragm is separated from the peritoneum by a fat layer and by the superior aspect of the kidneys and adjacent structures. In this posterior portion, the diaphragm forms two ligamentous bands, on either side: the medial and lateral arcuate ligament. The lateral arcuate ligament arises from the tip of the twelfth rib and spans around the quadratus lumborum and the medial arcuate ligament spans across the psoas muscles. The common intervening point between them is on the transverse process of L1\(^18\).

There are three large openings in the diaphragm: the aortic hiatus (contains the aorta, the azygos vein, the thoracic duct, between the left and the right crura), the esophageal hiatus (esophagus, anterior and posterior vagal trunks) and the vena cava hiatus (inferior vena cava and branches of the right phrenic nerve). Small apertures also are present, especially near the crura (containing the splanchnic nerves and the hemiazygos veins)\(^12\).

The phrenic nerve supplies the diaphragm, entering medially toward the periphery, formed by the C3-4-5 cervical nerves, more intense in its central portion. The peripheral portions of the diaphragm have sensorial afferents from the intercostals nerves (T5-11) and the subcostal nerve (T12)\(^12\).

Injuries to the diaphragm can lead to atelectasis, reduced vital capacity and hypoxemia.

### Psoas Muscle

The psoas major is a long muscle that originates from the transverse processes of the lumbar vertebrae (deep portion) and from the lateral surface of the lower thoracic and lumbar vertebrae (superficial portion). It is located in the anterolateral aspect of the lumbar spine (between the lateral portion of the vertebral bodies and the transverse process). It has two portions: 1) the anterior and lower edges of the lumbar transverse processes, 2) the lateral bodies and intervertebral discs of the last thoracic and all the lumbar vertebrae. The lumbar plexus lies between the two psoas layers, whose anterior rami of L1 to L4 are responsible for its innervations. Sometimes, a psoas minor muscle accompanies the psoas major. It joins with the iliacus muscles, forming the iliopsoas, passing beneath the inguinal ligament and anterior to the hip joint capsule, inserting onto the lesser trochanter of the femur. The function of the psoas is flexing the thigh at the hip joint and assist in maintaining an erect posture, avoiding hyperextension at the hip. During surgery, the thigh must be slightly flexed to relax the psoas and avoid excessive traction at the lumbar plexus\(^12\).

### Quadratus Lumborum

The quadratus lumborum arises from the aponeurotic fascia from the iliolumbar ligament and the adjacent portion of the iliac crest, inserting into the lower border of the last rib and in the small tendons into the apices of the transverse processes of the upper four lumbar vertebrae. This muscle is responsible for lateral flexion and extension of the vertebral column.

### Lumbar Plexus

The lumbar plexus is formed by the ventral branches of the spinal lumbar nerves from L1 to L4, sometimes for branches of the subcostal nerve from T12. It is located inside the psoas muscle. The main nerves are the iliohypogastric, ilioinguinal, lateral cutaneous nerve of the thigh and femoral nerves, emerging laterally to the lateral edge of the muscle, and the genitofemoral and obturator nerves, emerging medially to the medial edge of the psoas major muscle. The nerves emerging from the lumbar plexus are responsible for the innervation of the anterior region of the thigh, differently from the nerves from the sacral plexus that are responsible for the posterior portion of the inferior limbs, especially the leg and foot\(^5\).

The lumbar nerve roots are situated in the posterior third portion of the psoas muscle, most of them running under the surface of the lumbar pedicle and across the transverse process ligament. In the transpsoas approaches, to access the disc space and vertebral body, nerve injury can be avoided by incising the ventral 2/3 of the muscles\(^5\).
Vascular Structures

The segmental vessels originate from the aorta and need to be occluded before retraction of the artery to exposure the spine vertebrae. The most important point is to consider that some arterial branches can irrigate the spinal cord. The artery of Adamkiewicz is the most important radiculomedullary artery. It generally originates from the left side of the aorta at any point from the mid-thoracic to the upper lumbar region, and its injury is associated with paraplegia after aortic or spine surgery.

ANTERIOR-BASED APPROACHES TO THE THORACOLUMBAR JUNCTION

We describe two anterior-based approaches to the thoracolumbar junction: the traditional transthoracic/retroperitoneal approach and the lateral retropleural approach, emphasizing anatomical nuances.

1. Transthoracic Retroperitoneal approach

Used for thoracolumbar junction access (T11-L1), the side of approach depends on the pathology characteristics: some authors, including us, suggest that the left side is the best side to surgery, because the mobilization of the aorta is easier and safer than the vena cava, as well as the spleen is easier to be retracted than the liver.

Most of the time, release of the diaphragm is necessary to work properly in the thoracolumbar junction, especially above L1. Patient positioning is primordial to achieve the surgical goals – the spine must be perfectly perpendicular to the room floor, improving surgeon’s orientation to insert the screws and decompress the spinal canal. The patient must be centralized in the table, once the surgeon can work in his back or in his front, changing his angle of view. We put a small pad roll just below the approached level to elevate the spine and make the approach easier. The incision is generally placed over the tenth rib, or sometimes the eleventh, with subperiosteal dissection for further resection, but the incision is centered on the approached level based on fluoroscopy image - not in the rib (Fig. 1 and 2). The incision is extended to the oblique external and anterior serrate muscles, and then the transversal abdominal muscle, avoiding entering the transversalis fascia. The adipose tissue is then visualized, indicating the entrance of the retroperitoneal space, whose dissection is easily started supero-posteriorly. The peritoneal sac can be retracted forward, protected with moist sponges. The quadratus lumborum is identified, as well as the psoas. The retropsoas space should not be violated. The medial portion of the quadratus is palpated, identifying the transverse process of L1. When necessary, to access the body of T11 and T12, opening the pleura allows entry into the thoracic cavity, with visualization of the diaphragm and its costal attachment. The lung is retracted and the diaphragm is divided in its peripheral portion, to avoid extensive denervation. The attachment of the lateral arcuate ligament in the twelfth rib and in the transverse process of L1 is divided. The ipsilateral crus is also divided to improve the exposure, in its supratendinous portion.

The kidney and the ureter are located anterior to the psoas and are usually retracted medially in retroperitoneal approaches. Ureter lies anterior to the psoas muscle and then courses anterior to the iliac vessels.

The psoas muscle can obscure the access to the spine in its posterolateral aspect. The muscle is generally retracted towards the incision and lateral to the spine or even incised (but this maneuver may lead to a high risk for lumbosacral plexus injury). The anterior surface of the psoas insertions are exposed, dissecting the muscle from its anterolateral surfaces of the vertebrae. The segmental vessels are ligated, and the periosteum is exposed.

Segmental vessels are ligated and retracted – they should be ligated far from their origin once their retraction can lead to difficult location in case of bleeding. Some segmental vessels, besides the spine elements, can nourish the spinal cord in its anterior portion – the anterior segmental medullary arteries (see above - the artery of Adamkiewicz, at the thoracolumbar junction level). The ligation of the segmental vessel that originates the Adamkiewicz artery can lead to spinal cord infarction and paraplegia.

The rib head and the costovertebral ligaments are then removed (at T11 or T12). The pedicle can be removed using a high speed drill, with exposure of the anterior dural sac. The vertebral body can be assessed and removed if necessary, trying to preserve its anterior portion to avoid injury to soft structures in non-neoplastic diseases. Interbody fusion with graft or titanium mesh cages followed by plate and screws can then be performed.

Of note, the isolated retroperitoneal approach without diaphragm release and thoracotomy is used to approach L1-2 to...
L4-5. Sometimes, we can also approach T12 without opening the pleura. To access the L5-S1 level, it is better to use a midline transperitoneal or retroperitoneal approach. Access to L2-4 space generally does not require crura incision.

2. Lateral Retropleural Approach

The patient is positioned in lateral decubitus, with the side of approach chosen according to the location of the main compression. An oblique incision is performed in the rib trajectory of the level to be approached, with subperiosteal dissection, showing the underlying pleura and neurovascular bundle. The rib is stored as a bone graft and once the parietal pleura is exposed, a plane between the endothoracic fascia is found with blunt dissection. Pleura is retracted anteriorly along with the diaphragm, until exposing the lateral vertebral body and its adjacent disks. The great vessels are also anteriorly retracted. At this point, similarly to the transthoracic/retroperitoneal approach, the rib head and the costovertebral ligaments are then removed, with ligation of the segmental vessels. The pedicle can be removed using a high speed drill, with exposure of the anterior dural sac. The vertebral body can be assessed and removed if necessary, trying to preserve its anterior portion to avoid injury to soft structures. Further instrumentation with titanium plates and screws can be performed.
CONCLUSION

The anterior-based approaches to the thoracolumbar junction are useful alternatives to spine surgeons, when accessing ventral pathologies of the thoracolumbar junction. Accurate anatomical knowledge leads to better surgical results, decreasing complications of unnecessary and potentially catastrophic injuries.

REFERENCES


CORRESPONDING AUTHOR

Dr. Andrei F. Joaquim
e-mail: andjoaquim@yahoo.com