

Trajectory of the main sensory and motor branches of the lumbar plexus outside the psoas muscle related to the lateral retroperitoneal transpsoas approach

Laboratory investigation

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Object. The minimally invasive lateral retroperitoneal transpsoas approach is increasingly used to treat various spinal disorders. Accessing the retroperitoneal space and traversing the abdominal wall poses a risk of injury to the major nervous structures and adds significant morbidity to the procedure. Most of the current literature focuses on the anatomy of the lumbar plexus within the substance of the psoas muscle. However, there is sparse knowledge regarding the trajectory of the lumbar plexus nerves that travel along the retroperitoneum and abdominal wall muscles in relation to the lateral approach to the spine. The objective of this study is to define the anatomical trajectories of the major motor and sensory branches of the lumbar plexus that are located outside the psoas muscle.

Methods. Six adult fresh frozen cadaveric specimens were dissected and studied (12 sides). The relationship between the retroperitoneum, abdominal wall muscles, and the lumbar plexus nerves was analyzed in reference to the minimally invasive lateral retroperitoneal approach. Special attention was given to the lumbar plexus nerves that run outside of psoas muscle in the retroperitoneal cavity and within the abdominal muscle wall.

Results. The skin and muscles of the abdominal wall and the retroperitoneal cavity were dissected and analyzed with respect to the major motor and sensory branches of the lumbar plexus. The authors identified 4 nerves at risk during the lateral approach to the spine: subcostal, iliohypogastric, ilioinguinal, and lateral femoral cutaneous nerves. The anatomical trajectory of each of these nerves is described starting from the spinal column until their termination or exit from the pelvic cavity.

Conclusions. There is risk of direct injury to the main motor/sensory nerves that supply the anterior abdominal muscles during the early stages of the lateral retroperitoneal transpsoas approach while obtaining access to the retroperitoneum. There is also a risk of injury to the ilioinguinal, iliohypogastric, and lateral femoral cutaneous nerves in the retroperitoneal space where they travel obliquely during the blunt retroperitoneal dissection. Moreover, there is a latent possibility of lesioning these nerves with the retractor blades against the anterior iliac crest. (DOI: 10.3171/2010.10.SPINE10395)

KEY WORDS • transpsoas approach • retroperitoneal approach • extreme lateral interbody fusion • direct lateral interbody fusion • lumbar interbody fusion • anatomy • lateral access

THE minimally invasive lateral retroperitoneal transpsoas approach was first described by Ozgur et al.¹⁵ and is increasingly being used to treat common spinal disorders including degenerative disc disease, spondylolisthesis, traumatic injuries, and spinal deformity. Although the minimally invasive lateral retroperitoneal transpsoas approach avoids many of the disadvantages of the anterior and posterior approaches, it has certain limitations and disadvantages of its own. One of the main limitations is the proximity of the lumbar plexus to the surgical pathway and the resultant risk of injury to nerves.

The addition of intraoperative real-time nerve monitoring to this procedure allows the surgeon to safely traverse the psoas muscle while avoiding the major motor branches of the lumbar plexus. However, this neural monitoring does not help prevent injury to nerves living outside the psoas. A thorough understanding of the anatomical complexity of the lumbar plexus may reduce the risk of injury to the nerves.

The anatomy of the lumbar plexus has been well described.²³ In our previous study, we analyzed the nerves of the lumbar plexus relative to the disc spaces that travel within the substance of the psoas muscle, and we delineated potential safe anatomical zones to prevent direct injury to these nerves.¹⁹ Previous cadaveric and morphometric radiographic studies of the lumbar plexus using endoscopic or minimally invasive approaches to the spine have been done, but they have failed to identify the nerves traveling outside the psoas muscle in the retroperitoneum.^{1,12} The goal of this study is to define the anatomical trajectories of the major motor and sensory branches of the lumbar plexus that are located outside the psoas muscle within the retroperitoneum and abdominal wall.

Methods

Six adult fresh frozen cadaveric specimens without innate or detected abnormalities were used in this study.

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They were each systematically evaluated for evidence of previous retroperitoneal, abdominal, or spinal surgeries. Bilateral dissections of the abdominal wall, retroperitoneal cavity, and lumbar plexus were performed, yielding a total of 12 dissections. Dissections were performed at the University of South Florida biomechanical spine laboratory. The relationship between the retroperitoneum, abdominal wall muscles, and the lumbar plexus nerves was analyzed in reference to the minimally invasive lateral retroperitoneal approach. Special attention was given to the lumbar plexus nerves that run outside the psoas muscle in the retroperitoneal cavity and within the abdominal muscle wall.

The cadaveric specimens were placed in the lateral decubitus position similar to the surgical technique. A linear skin incision at the midaxillary line was made from the 12th rib to the anterior iliac crest. The abdominal musculature was carefully and bluntly dissected to identify and isolate the different muscle layers and the nerves traveling within. While protecting the nerves, the muscles were incised to access the retroperitoneal space. The nerves of the lumbar plexus that traverse the retroperitoneal space were dissected from the adipose and connective tissues. Their trajectories were documented, and intraoperative photographs were taken.

Results

Our findings are consistent with previous anatomical descriptions.^{14,23} No anomalies, pathological lesions, or previous incisions were noted for any side, excluding minor degenerative changes to the spine in these adult cadavers. All 12 sides were successfully dissected, analyzed, and photographed. No differences were noted between the left and right sides or when comparing the sex of the cadavers. We identified 4 major nerves of the lumbar plexus traveling outside the psoas in the retroperitoneum (Fig. 1). We describe each nerve individually below.

Subcostal Nerve

The subcostal nerve originates from the T-12 root and accompanies the subcostal vessels along the inferior border of the 12th rib. It passes behind the lateral arcuate ligament and kidney and travels anterior to the upper part of the quadratus lumborum. The subcostal nerve then perforates the aponeurosis of the origin of the transversus abdominis muscle and travels between the transversus abdominis and internal oblique muscles in a medial and inferior course. A lateral cutaneous branch pierces the internal and external obliques before reaching the costal angle. The subcostal nerve continues its course within the abdominal wall medially until it reaches the edge of the rectus abdominis, where it perforates to give rise to the anterior cutaneous branches.

Iliohypogastric Nerve

The iliohypogastric nerve originates from the L-1 root. It emerges from the upper lateral border of the psoas major muscle. It runs obliquely embedded on the retroperitoneal adipose tissue behind the kidney to continue in

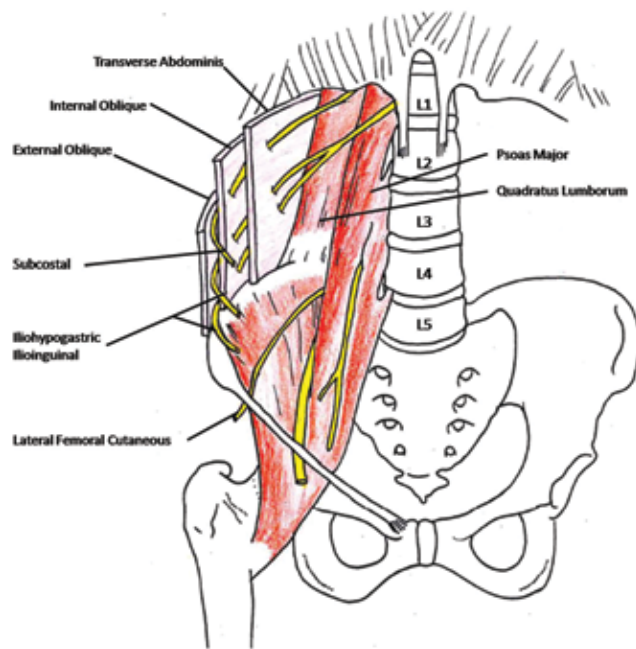


Fig. 1. Illustration demonstrating the trajectory of the 4 main nerves traveling outside the psoas muscle in the retroperitoneum along the posterior abdominal wall and within the abdominal muscles.

front of the quadratus lumborum muscle. Above the iliac crest, it perforates the posterior part of the transversus abdominis and divides into lateral and anterior cutaneous branches. The lateral cutaneous branch pierces the internal and external oblique muscles just above the iliac crest and a little behind the lateral cutaneous branch of the subcostal nerve. The anterior branch runs anteriorly and inferiorly superior to the iliac crest between the transversus abdominis and internal oblique until just medial to the anterior superior iliac spine, where it pierces the internal and external obliques (Figs. 2 and 3).

Ilioinguinal Nerve

Similar to the iliohypogastric nerve, the ilioinguinal nerve arises from L-1 and emerges from the lateral border of the psoas major just caudal to the iliohypogastric nerve. It then passes obliquely across the quadratus lumborum and the upper part of the iliacus in the retroperitoneal space. Near the anterior portion of the iliac crest, it pierces the transversus abdominis muscle and courses anteriorly and inferiorly parallel to the iliohypogastric nerve. Medial to the anterior iliac spine, it pierces the internal oblique muscle to travel within the inguinal canal, and it emerges from the superficial inguinal ring (Figs. 2 and 3).

Lateral Femoral Cutaneous Nerve

The lateral femoral cutaneous nerve originates from the L-2 and L-3 roots. It emerges from the lateral border of the psoas major muscle at approximately L-4 and courses obliquely across the iliacus muscle toward the anterior superior iliac spine. Within the iliac fossa, the right nerve passes posterolateral to the cecum and the left passes be-

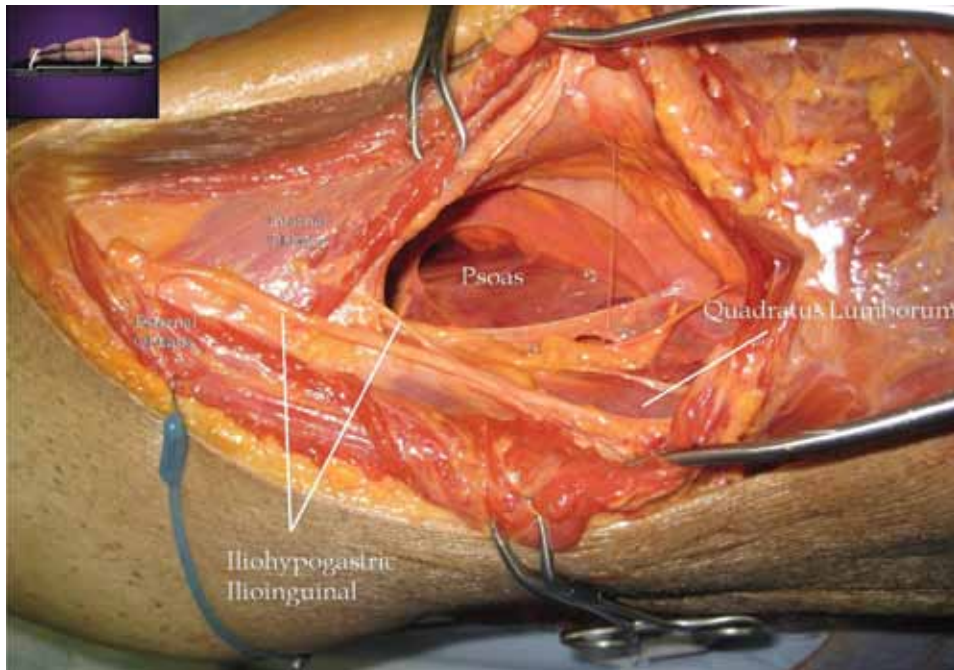


FIG. 2. From the lateral view, one can appreciate the ilioinguinal and iliohypogastric nerves coursing along the posterior abdominal wall and crossing obliquely within the abdominal muscle wall.

hind the descending colon. Both sides then course either through or below the inguinal ligament approximately 1 cm medial to the anterior superior iliac spine. The lateral femoral cutaneous nerve will ultimately divide into anterior and posterior branches (Fig. 3).

Discussion

The minimally invasive lateral retroperitoneal transpsoas approach allows for anterior access to the disc space without mobilization of the great vessels or sympathetic

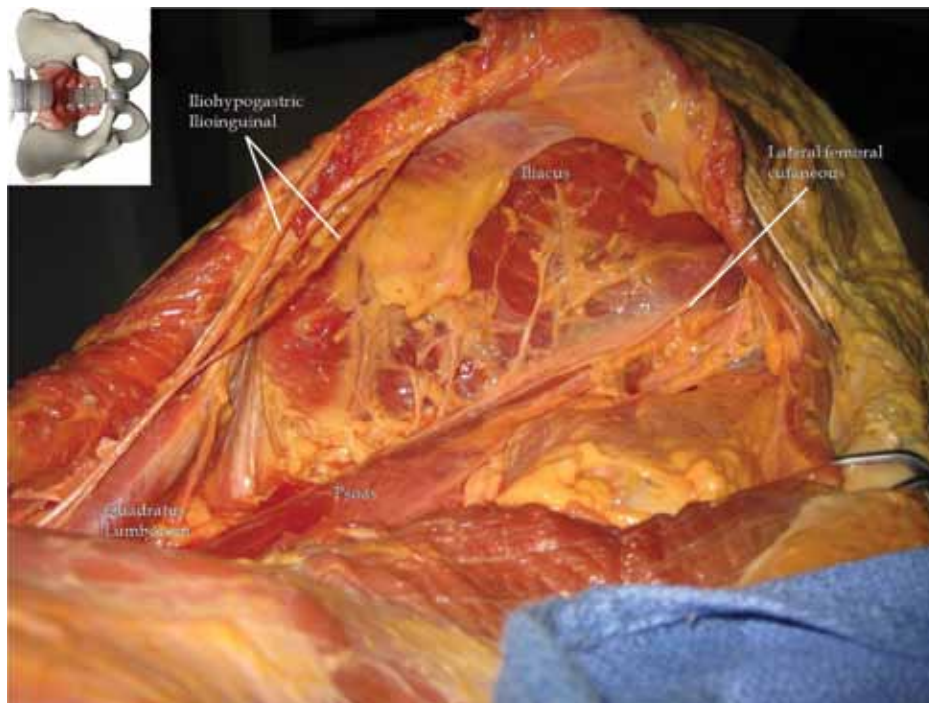


FIG. 3. From the anterior view, one can see the ilioinguinal and iliohypogastric nerves travel along the quadratus lumborum and cross obliquely superior to the iliac crest. The lateral femoral cutaneous nerve is seen emerging posterior to the psoas and crossing the iliacus.

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plexus and without the complications associated with a transabdominal procedure.¹⁵ However, approach-related neural complications have been reported.^{4,6,17,21} Despite the use of proper patient positioning, adequate biplanar fluoroscopy, and nerve monitoring, these complications still exist. The majority of the nerve-related complications occur to the lumbar plexus nerves while traversing the psoas muscle with the dilators and placing the retractor. However, potential injuries to nerves of the lumbar plexus that are located outside the psoas can occur during the early stages of the approach while accessing and dissecting the retroperitoneum. We believe that a thorough knowledge of the regional anatomy of the lumbar plexus with relation to the psoas muscle, retroperitoneum, abdominal wall, and lumbar spine are critical to prevent these complications.

Previous anatomical and radiographic studies have attempted to identify the location of the lumbar contributions of the lumbar plexus coursing within the psoas major in relation to the minimally invasive retroperitoneal approaches to the spine.^{1,12,19} However, they did not reliably describe the important motor and sensory nerve branches that are mainly located outside the psoas muscle. In this study, we describe 4 nerves vulnerable to injury during the minimally invasive lateral retroperitoneal transpsoas approach that travel embedded in the adipose tissue of the retroperitoneal space and outside the substance of the psoas major. They are the subcostal, iliohypogastric, ilioinguinal, and lateral femoral cutaneous nerves. Injury to these nerves may lead to previously well-described clinical syndromes and can account for significant morbidity in patients.^{3,7,10,16}

Anatomy of the Lumbar Plexus and Retroperitoneum

The lumbar plexus is formed in the retroperitoneal abdomen by the ventral rami of the L1–4 branches of nerves plus a branch of T-12.¹¹ Although anatomical variations have been reported in the literature, our specimens did not exhibit any pre- or postfixed plexuses.⁹ Most of the branches are related to the psoas major muscle, passing thorough it or behind it or being formed within it. The nerves of the plexus that course free in the retroperitoneum and are vulnerable during the early stages of the minimally invasive lateral retroperitoneal transpsoas approach are the subcostal, iliohypogastric, ilioinguinal, and lateral femoral cutaneous nerves. When approaching the retroperitoneal space from the lateral decubitus position, a generous amount of adipose tissue fills the space above the psoas muscle bounded anteriorly by the abdominal peritoneal structures, posteriorly by the quadratus lumborum and the iliacus muscles, superiorly by the diaphragm, and inferiorly by the retroperitoneal pelvic space.²³ The innervation and origins of these nerves are described in Table 1. To understand the potential implications of injuring these nerves, we need to review their clinical relevance.

Surgical Anatomy and Clinical Significance

Subcostal Nerve (T-12). The subcostal nerve has a motor and a sensory component. It supplies the muscles of the anterior abdominal wall, especially the external

TABLE 1: Summary of nerves

Nerve	Roots	Muscles Innervated
subcostal	T-12	rectus abdominis, external oblique
iliohypogastric	T12–L1	transversus abdominis, internal oblique
ilioinguinal	L-1	transversus abdominis, internal oblique
lat femoral cutaneous	L-2, L-3	none

oblique, and provides sensation to the anterior gluteal skin. It also occasionally communicates with the iliohypogastric nerve to give off a branch to the pyramidalis muscle. If injury occurs at the level of the spinal rami or near the origin, pain is referred to the area of peripheral distribution. If the dorsal cutaneous branch becomes injured or entrapped, this produces a posterior area of numbness with painful paresthesias known as nostalgia paresthetica. When the anterior cutaneous branch is involved, this leads to an anterior area of numbness with painful paresthesias on the abdomen known as rectus abdominis syndrome.²³ Injury to the motor portion of the nerve paralyzes the muscle fibers supplied by it, thereby weakening the anterior abdominal wall. Chou et al.³ reported that the subcostal nerve is very vulnerable to injury when harvesting bone from the anterior iliac crest.

Iliohypogastric (T12–L1) and Ilioinguinal (L-1) Nerves. After the subcostal nerve, the iliohypogastric and the ilioinguinal (usually smaller than the iliohypogastric) nerves are the first nerves of the lumbar plexus. They have motor and sensory components. The lateral cutaneous branch of the iliohypogastric nerve provides sensation to the posterolateral gluteal skin, whereas its anterior cutaneous branch innervates the suprapubic skin. The ilioinguinal nerve supplies the medial skin of the thigh and either the root of the penis and upper part of the scrotum in men or the mons pubis and labia majoris in women. The iliohypogastric and ilioinguinal nerves supply the muscles of the anterior abdominal walls, especially the transversus abdominis and internal oblique muscles. The ilioinguinal and iliohypogastric nerves are usually reciprocal in size.²³

Injury to these nerves during conventional abdominal surgery is a well-known complication that results in chronic pain syndromes and paresis of the abdominal wall.^{2,8,10,16} This may lead to a bulge in the abdomen or even a direct inguinal hernia. This complication has also been reported during laparoscopic procedures.^{7,20} Damage to the ilioinguinal nerve is a well-known complication of inguinal hernia repair.^{10,16} Whiteside et al.²² stated that the second most common neuropathy following gynecological surgery involves the ilioinguinal and iliohypogastric nerves, with a reported incidence of 3.7%. Nephrectomy is also a common cause of injury to these 2 nerves.¹⁸

Lateral Femoral Cutaneous Nerve (L2–3). The lateral femoral cutaneous nerve comes from the dorsal branches of the ventral rami of L-2 and L-3. It is a purely sensory nerve with no somatic motor component. It supplies sensation to the anterior and lateral area of the thigh. The most common area of injury is at the inguinal ligament.

The clinical presentation, termed meralgia paresthetica, results in impaired sensation, pain, and paresthesias along the anterolateral aspect of the thigh.²³ The lateral femoral cutaneous nerve has been reported to be injured during harvesting of autologous iliac bone graft.¹³

Complication Avoidance and Recommendations

The 4 main nerves of the lumbar plexus that travel outside the psoas in the retroperitoneum are the subcostal, iliohypogastric, ilioinguinal, and lateral femoral cutaneous nerves. Nerve injury of the abdominal wall or retroperitoneum is one of the many complications of abdominal surgery, especially herniorrhaphy. The lateral femoral cutaneous, subcostal, and ilioinguinal nerves have also been reported to be vulnerable during iliac crest harvest.^{3,5,13} The clinical significance of these injuries is represented with abdominal wall paresis and a full spectrum of sensory deficits (analgesia, paresthesias, and dysesthesia) at the corresponding dermatome. Of the 4 nerves that we describe, the lateral femoral cutaneous nerve is the only one reported in the literature to be injured after a minimally invasive lateral retroperitoneal transpsoas approach.⁶ However, in our clinical experience, we have seen injuries to all 4 of these nerves after minimally invasive lateral transpsoas procedures.

The location and trajectories of these nerves places them at significant risk during the early stages of the minimally invasive lateral retroperitoneal transpsoas approach. They can be directly injured while accessing the retroperitoneum during the flank or lateral incision, or just above the iliac crest. While dissecting the abdominal muscle wall or while performing blunt digital dissection of the retroperitoneal cavity, these nerves are vulnerable to injury. From the lateral view, these nerves run along the posterior abdominal wall and then course obliquely across the surgical corridor within the abdominal muscles.

In addition to a thorough understanding of the regional anatomy, we advocate a combination of useful adjuncts to minimize nerve injuries directly or indirectly during the minimally invasive retroperitoneal transpsoas approach. During the early stages of the approach once the external oblique muscle fascia is sharply dissected, the dissection of the abdominal wall muscles requires special care. We suggest sequential and gentle muscle dilation with blunt instruments (hemostat forceps) until the retroperitoneal cavity is identified. If a nerve branch is found during the dissection, it is possible to dissect it and mobilize it without causing direct injury.

Once the retroperitoneal space is accessed, the blunt dissection of the retroperitoneal space requires special care. We suggest early identification of the posterior wall of the retroperitoneum (quadratus lumborum muscle) and gentle dissection of the space from posterior to anterior and superior to inferior until the transverse process and the psoas muscle are identified at the target level, to avoid injury to the main nerves that run freely in the retroperitoneal cavity. While dissecting the retroperitoneum bluntly with the finger, one must be careful not to confuse a free running nerve in the retroperitoneal fat for an adhesion and avulse or injure it.

Conclusions

There is risk of direct injury to the main motor/sensory nerves that supply the anterior abdominal muscles and the thigh during the early stages of the lateral retroperitoneal transpsoas approach. Iatrogenic injury to these nerves during abdominal muscle wall and retroperitoneal dissection can result in significant postoperative morbidity. A thorough understanding of the regional anatomy and meticulous surgical technique can potentially minimize nerve injuries.

Disclosure

Dr. Uribe is a consultant for Nuvasive, Inc.

Author contributions to the study and manuscript preparation include the following. Conception and design: Dakwar. Acquisition of data: Dakwar. Analysis and interpretation of data: Dakwar, Vale. Drafting the article: Dakwar. Critically revising the article: Dakwar, Vale. Reviewed final version of the manuscript and approved it for submission: all authors. Study supervision: Uribe.

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