Lumbar Plexus Anatomy within the Psoas Muscle: Implications for the Transpsoas Lateral Approach to the L4-L5 Disc

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Background: The transpsoas lateral surgical approach has been advocated as an alternative to direct anterior approaches for less invasive or minimally invasive access to the spine. Postoperative thigh pain, paresthesia, and/or weakness have been described after the use of this surgical approach. The purpose of this cadaveric anatomic study is to provide a description of the lumbar plexus as it relates to the transpsoas lateral surgical approach.

Methods: Dissection of the lumbar plexus was performed in eighteen cadaveric specimens. Needle markers were placed in the L2-L3, L3-L4, and L4-L5 discs in the midcoronal plane. The anatomic structures were surveyed, and the proximity of the needle to the neural structures was observed.

Results: In thirteen of the eighteen specimens, the femoral nerve received its contributions from the L2 to L4 nerve roots and was formed at the L4-L5 disc space. In all specimens, the femoral nerve passed dorsal to or directly at the midpoint of the disc. In three specimens, the needle displaced or was immediately adjacent to the femoral nerve. The femoral nerve was found between the needle and the posterior aspect of the L4-L5 disc space in thirteen of the eighteen specimens.

Conclusions: Because of the proximity of the neural elements, in particular the femoral nerve, to the center of the disc space, the transpsoas lateral surgical approach to the L4-L5 disc space will likely cause intraoperative displacement of neural structures from their anatomic course during retractor dilation. Careful attention should be paid to retractor placement and dilation time during transpsoas lateral access surgery, particularly at the L4-L5 disc.

Clinical Relevance: During the transpsoas lateral surgical approach to the L4-L5 disc space, the femoral nerve should be considered to be at risk intraoperatively because of the position and size of currently available retractors.

Surgical exposure of the lumbar intervertebral disc space with use of minimally invasive techniques via a transpsoas lateral retroperitoneal approach has been developed and advocated. The approach has been reported to be suitable for anterior spinal arthrodesis procedures involving the disc spaces cephalad to L5-S1[1,2]. Advocates of the transpsoas lateral

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A commentary by Michael J. Bolesta, MD, is linked to the online version of this article at jbjs.org.

approach have described its potential benefits when compared with traditional anterior exposures, including less postoperative pain and reduced manipulation of the aorta and inferior vena cava[3-5]. A variety of specialized retractor systems utilizing this approach have been developed to allow surgeons access to the disc space in a minimally invasive fashion.

The reported rate of neurologic complications following this surgical approach has ranged from 8% to 30%, and the neurologic complications have ranged in severity from paresthesias to femoral nerve palsy[2,5]. Despite the introduction of tools to facilitate surgical access via the transpsoas lateral approach and to avoid nerve injury, the current understanding of the relevant anatomy is based on few studies[6]. Previous anatomic studies were based on dissections performed with cadavers in the supine position and concentrated on the locations where nerves exited out of the psoas muscle rather than on their locations within the psoas muscle[7,8]. There is a paucity of information on the neural anatomy of the lumbar plexus that is specifically relevant to the transpsoas lateral approach, which may contribute to the occurrence of neural complications.

The purpose of the present cadaveric anatomic study was to provide a description of the lumbar plexus relevant to the transpsoas lateral surgical approach. Emphasis was placed on the anatomy involved with surgery at the L4-L5 disc space.

Materials and Methods

Eighteen fresh-frozen cadavers were studied. Dissection was performed with the specimen in the lateral decubitus position in a manner relevant to the recommended surgical technique for currently available retractor systems that are used with the transpsoas lateral approach. A rectangular full-thickness flap was formed, bordered by the L1 spinous process cranially, the S1 spinous process caudally, the posterior spinous processes medially, and the midaxillary line laterally. The latissimus dorsi, serratus posterior, portions of the gluteus maximus and gluteus medius, external oblique, internal oblique, and transversus abdominis muscles were sequentially detached from their osseous origins and insertions and were removed. The multifidus muscles were removed to expose the lamina and transverse processes of the lumbar spine from L1 to S1. The quadratus lumborum muscle was detached from the inferior rib, transverse processes, and iliac crest to expose the dorsal boundary of the peritoneum.

Eighteen-gauge spinal needles were then placed in the midcoronal plane at a midpoint between the anterior and posterior aspects of the disc spaces of L2-L3, L3-L4, and L4-L5. This location was selected because it is the recommended insertion point for many currently available retractor systems. The needles were placed with use of fluoroscopy in the lateral view and were advanced across the disc space to maintain position. Care was taken to avoid piercing the peritoneum. The needles remained in position for the remainder of the dissection to allow visualization of the lumbar plexus in relation to the midcoronal plane of the disc.

The iliolumbar ligaments were transected, and a portion of the superior iliac crest as well as the two lower ribs were removed with use of an oscillating saw. Meticulous care was taken to avoid disruption of the iliacus muscle, which would result in displacement of the plexus. Gentle blunt dissection with gauze was used to separate the fascicles of the psoas muscle and the perineural adipose tissue. The femoral nerve was identified, and its distance from the previously placed needle at the L4-L5 disc was recorded. Its width was measured where the L2 and L3 nerve roots and trunk combine with the L4 nerve root. Following identification of the femoral nerve, the psoas muscle was detached from the ventral aspects of the transverse processes and the neural contributions to the femoral nerve were exposed in retrograde fashion to the level of the foramina of the spine (Fig. 1).

Statistical Methods

Descriptive statistics were used to characterize femoral nerve size and location and anatomic variations. The location of the femoral nerve was

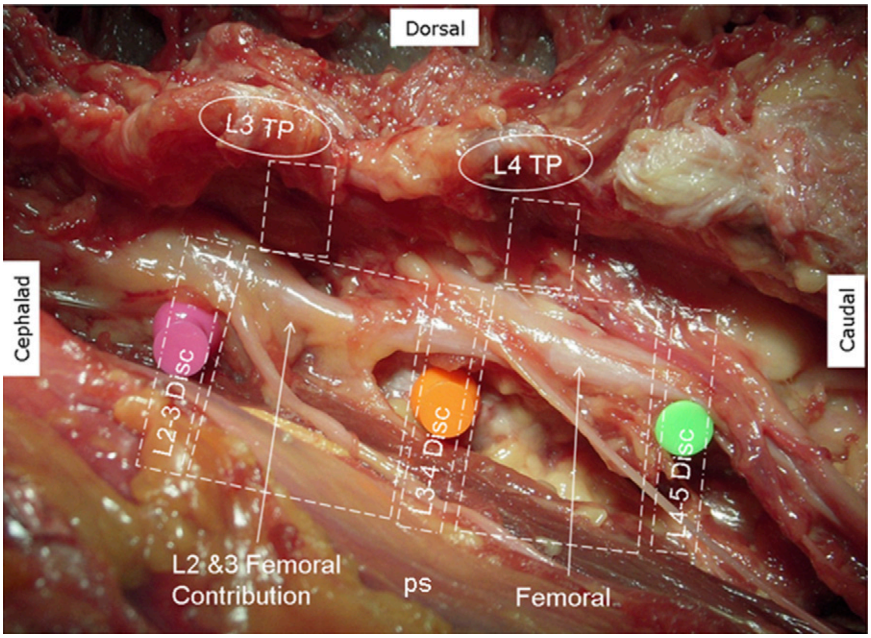

Fig. 1

Left lateral view of a left-sided specimen, made after dissection of the psoas muscle (ps). The spinous processes would be at the top of the image (not visible). Outlines show the approximate locations of the vertebral bodies, disc spaces, and pedicles. Transverse processes (TP) are also outlined. Note the close proximity of the L4-L5 needle and the trunk of the femoral nerve.

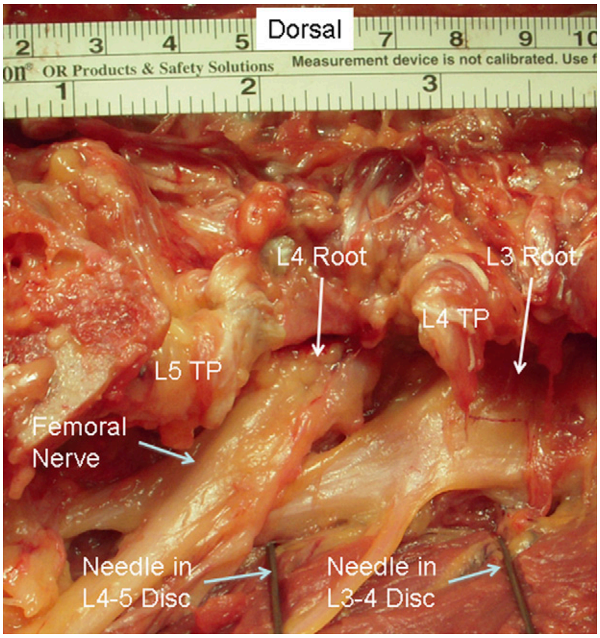

Fig. 2

Right lateral view of right-sided specimen, showing the needle placed in the midcoronal plane and contacting the ventral aspect of the femoral nerve. Part of the iliac crest (left side of image) has been removed for better visualization. Note the substantial size of the femoral nerve and the presence of the right L5 transverse process (TP) posteriorly.

categorized as one of six zones (1 through 4, A, P), as previously defined: 1 through 4 denote the disc space divided into quartiles from anterior to posterior, A denotes anterior to the disc space, and P denotes posterior to the disc space[9].

Source of Funding

There was no external funding source for this investigation.

Results

The course of the L2 and L3 nerve roots after exiting the neural foramina was immediately adjacent to the lateral aspect of the pedicle of the vertebral level below and dorsolateral to the vertebral body of the level below. The lateral femoral cutaneous nerve branched off the lumbar plexus at the level of the L3-L4 foramen. The lateral femoral cutaneous nerve was identified anterior to the transverse process of L4 and anterior and lateral to the lateral tip of the L5 transverse process.

In thirteen of the eighteen specimens, the femoral nerve received its contributions from the L2 to L4 nerve roots and was formed at the L4-L5 disc space. In the remaining five specimens, the L2 and L3 contributions passed dorsal to the L4-L5 disc space and joined with the L4 root so that the femoral nerve was formed caudal to the L4-L5 disc space.

The femoral nerve was largest at the level of the L4-L5 disc space. The mean diameter was 13 mm (range, 8 to 17 mm), most often being measured at the L4-L5 disc level, but occasionally more distal. In three specimens, the femoral nerve was displaced by the needle placed in the midcoronal plane of the L4-L5 disc (Fig. 2). In ten specimens, the femoral nerve was dorsal to the needle and ventral to the posterior aspect of the L4-L5 disc. Therefore, in thirteen of the eighteen specimens, the femoral nerve was located ventral to the posterior border of the disc space. In the remaining five specimens, the femoral nerve was dorsal to the posterior aspect of the L4-L5 disc (zone P).

The locations of the femoral nerve at the L4-L5 disc were as follows: zone A (zero specimens), zone 1 (zero specimens),

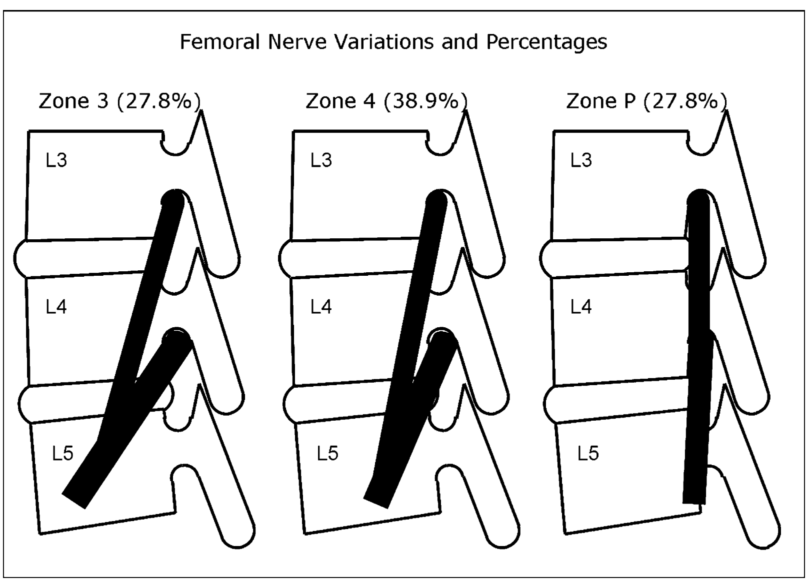

Fig. 3

Schematic diagrams depicting the anteroposterior location of the nervous tissue making up the femoral nerve at the L4-L5 disc space; in one specimen (not shown), the femoral nerve was identified in Zone 2. In thirteen of eighteen specimens, the femoral nerve received its nerve root contributions at the L4-L5 disc space (as depicted here). The course of the femoral nerve remained posterior to the disc space in only five specimens.

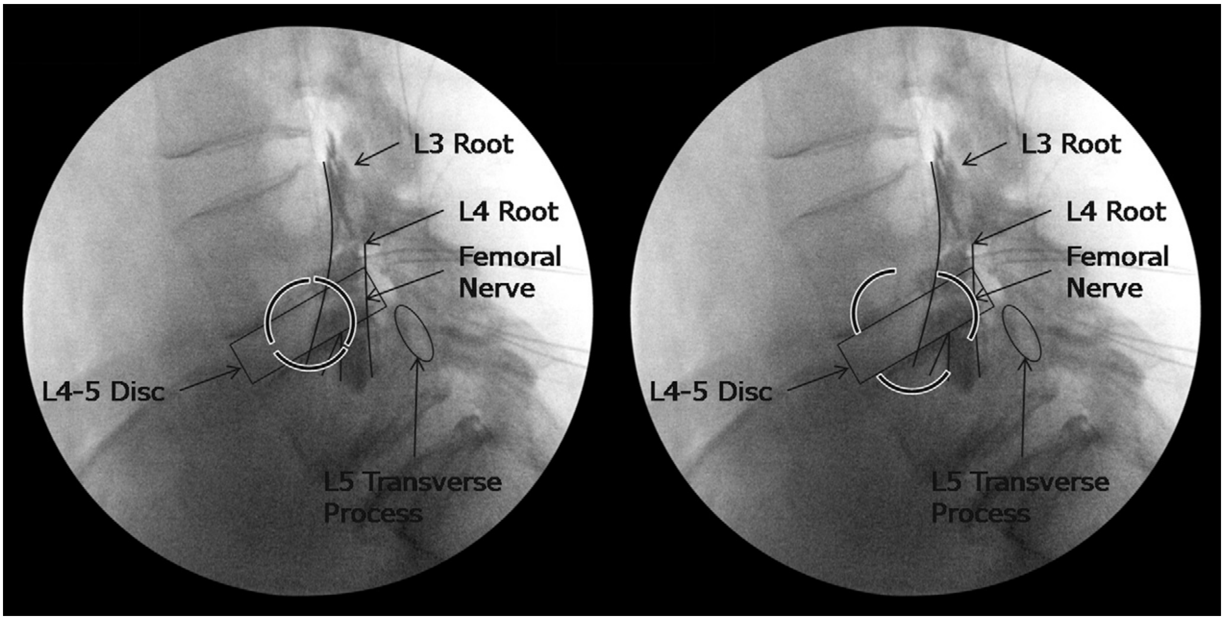

Fig. 4

Lateral fluoroscopic view and neurogram of the femoral nerve following injection of contrast agent during a transforaminal steroid injection of the L4 nerve root. Theoretical placement of a three-blade retractor system is depicted on the basis of the average size of the L4 vertebral body and the actual size of the retractor system. Although initial positioning dilators may avoid the femoral nerve, dilation of the retractor will likely subject it to traction as well as possible compression against the L5 transverse process.

zone 2 (one specimen), zone 3 (five specimens), zone 4 (seven specimens), zone P (five specimens) (Fig. 3).

Discussion

In the majority of specimens studied, the femoral nerve was formed from the L2 to L4 nerve roots at the level of the L4-L5 disc space and lay ventral to its posterior aspect. Surgeons should be aware that they are likely to encounter the trunk of the femoral nerve, not the nerve root contributions, at the L4-L5 disc space. In three of eighteen specimens, the femoral nerve was displaced or was immediately adjacent to a needle placed in the midcoronal plane. Direct trauma to the nerve should be avoidable with proper technique, consisting of sequentially larger dilators, mobilization of neural structures without splitting them, and avoidance of cutting instruments until full visualization of the disc space is achieved. However, our findings suggest that injury may occur as the result of a less-recognized mechanism of traction and compression caused by the lateral approach retractor system.

The intended entry point for these systems is ventral to the obturator and femoral nerves and avoids a so-called "danger zone" 25 mm anterior to the foramen[10]. Current commercially available retractor systems expand to a diameter of approximately 20 to 30 mm or greater (Fig. 4). Given the mean femoral nerve diameter of 12.9 mm[10], consistent with previous studies, and the mean anterior-to-posterior diameter of L4, reported as 34 mm[11,12], opening of the retractor to the posterior border of the disc space likely will result in compression and/or tension on the femoral nerve from the retractor blade. The transverse processes create a posterior barrier that can exacerbate compression on the nerve. Compared with the other lumbar vertebrae[13], the L5 transverse process is located in a relatively ventral position. This may lead to the scenario in which dilator tubes and retractors positioned over the L4-L5 disc space compress soft tissue containing the obturator nerve, the femoral nerve, and the L4 contribution to the sciatic trunk against the L5 transverse process[14,15] (Fig. 5).

The exact amount of compression that is created is unclear. The threshold for neurologic injury is also unclear. Previous studies have shown acute neural compressive forces to cause a number of structural and physiologic changes that can equate to variable degrees of functional deficit[16-19]. Stretch injuries in animal models have shown complete intraneural ischemia with a 15% increase of in vivo length[20]. Because nerve roots lack an epineurium and perineurium, even small forces may cause mechanical damage to nerve roots and nerve root attachments[21].

As procedures utilizing the transpsoas lateral surgical approach are performed with increasing frequency, there has been renewed interest in the anatomy of the lumbar plexus within the psoas muscle. In a cadaveric study, Moro et al. and other investigators described the concept of a "safety zone," in which areas void of branches of the lumbar plexus were present[4,8,9]. A recent anatomic study based on magnetic resonance imaging concluded that the transpsoas lateral safe corridor, which theoretically avoids the lumbar plexus, narrows considerably as one moves distally from L1-L2 to L4-L5[22]. Neither study considered the location, diameter, and effect on the lumbar plexus of a dilated retractor. Two recently published studies had objectives and methods highly similar to those in the current study and deserve comment. In a study of ten specimens, Park et al. reported results strikingly similar to ours: a guidewire placed in the center of the L4-L5 disc space penetrated nervous tissue in 15% of

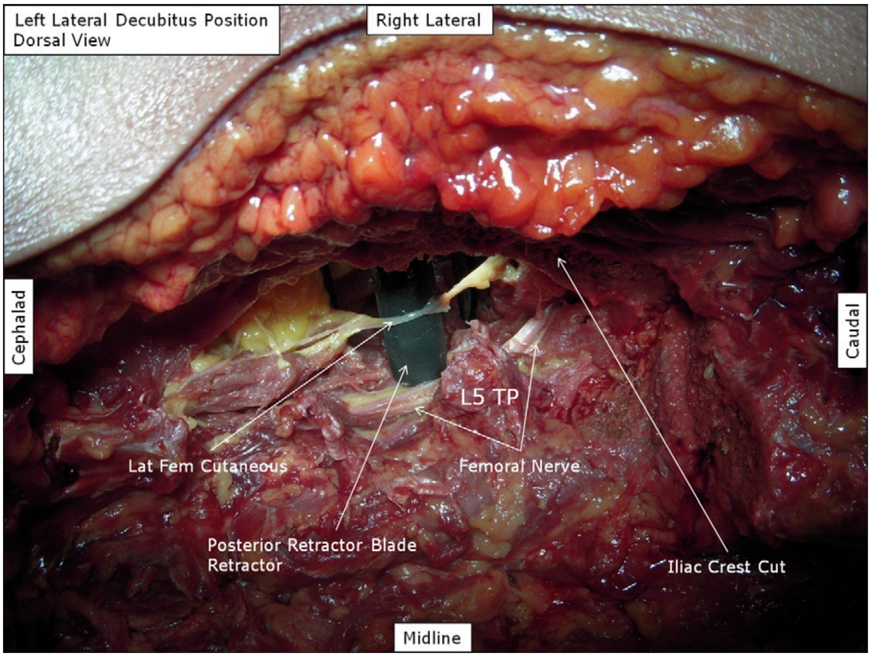

Fig. 5
Dorsal view photograph, with the cadaver in the left lateral decubitus position, made after a right-sided transpsoas lateral approach with a currently commercially available retractor. Dissection was performed after placement of the retractor, which was maintained in place. The spinous processes are located along the bottom border of the figure and are pointing toward the reader. The retractor has been dilated, causing traction of the femoral nerve, as well as the lateral femoral cutaneous nerve, and compression of the femoral nerve against the L5 transverse process (TP).

specimens and was within 8 mm of nervous tissue in 25%[23]. Although that study was designed to be applicable for a lateral approach retractor system, the authors did not clearly identify the nervous structure at risk as the femoral nerve, nor was the diameter of this structure measured. Uribe et al. reported that the genitofemoral nerve was at risk at the L2-L3 disc space if the approach was anterior to the center of the disc space[24]. In the five specimens in that study, the femoral nerve trunk was not identified as being at risk at L4-L5, likely because of the small sample size.

The possible impact of dissection technique and positioning on the location of neural elements is worth noting. One concern is that detaching the psoas muscle from its origins on the transverse processes may have resulted in anterior migration of the nerve roots. In order to minimize these risks, dissection was performed with the specimen in the lateral decubitus position to decrease the effect of gravity, and needles were placed into the disc space before dissection. No attempt was made to alter the sagittal alignment of the lumbar spine, mimicking the clinical situation, and lateral fluoroscopy did not reveal gross flexion of the lumbar spine that would displace the psoas and nerves anteriorly. Park et al. also studied the effect of hip flexion and extension and detected no change in nerve position[23].

Incomplete understanding of the relevant lumbar plexus anatomy may contribute to iatrogenic nerve injuries due to traction and compression. Compounding factors are lack of visualization of these structures and reliance on intraoperative neuromonitoring techniques that may be only marginally effective. Current neuromonitoring methods utilize triggered electromyography with use of an insulated probe to identify neural structures[25]. This modality may help to avoid direct spearing of the neural motor structures but does little thereafter. It does not reliably assess the integrity of nerves transversing the surgical site because stimulation of retractor blades typically occurs distal to the site of traction or compression. Monitoring of somatosensory evoked potentials (SSEP) is an additional modality that tests the sensory tracts but has limited usefulness because detection of nerve root injury is difficult with this modality and because the posterior tibial and peroneal nerves that are monitored are not the neural structures that are at risk during the transpsoas lateral approach.

Because of the anatomy at the L4-L5 disc space, the risk of traction or compression on the femoral nerve is high. Surgeons must have a comprehensive understanding not only of the neural anatomy but also of the effect of dilators and retractor blades on the neural structures. Careful visualization of the L4-L5 surgical site to identify neural structures is recommended. The time of retractor expansion should be monitored closely and limited. Postoperative examinations should include testing of the adductor and quadriceps muscle groups to identify obturator or femoral nerve injury. However, these muscle groups are large enough that injury may only be apparent on repetitive quadriceps testing or stair climbing. ■

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