An anatomical study of the lumbosacral plexus as related to the minimally invasive transpsoas approach to the lumbar spine

Laboratory investigation

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Object. Minimally invasive anterolateral approaches to the lumbar spine are options for the treatment of a number of adult degenerative spinal disorders. Nerve injuries during these surgeries, although rare, can be devastating complications. With an increasing number of spine surgeons utilizing minimal access retroperitoneal surgery to treat lumbar problems, the frequency of complications associated with this approach will likely increase. The authors sought to better understand the location of the lumbar contribution of the lumbosacral plexus relative to the disc spaces encountered when performing the minimally invasive transpsoas approach, also known as extreme lateral interbody fusion or direct lateral interbody fusion.

Methods. Three fresh cadavers were placed lateral, and a total of 3 dissections of the lumbar contribution of the lumbosacral plexus were performed. Radiopaque soldering wire was then laid along the anterior margin of the nerve fibers and the exiting femoral nerve. Markers were placed at the disc spaces and lateral fluoroscopy was used to measure the location of the lumbar plexus along each respective disc space in the lumbar spine (L1–2, L2–3, L3–4, and L4–5).

Results. The lumbosacral plexus was found lying within the substance of the psoas muscle between the junction of the transverse process and vertebral body and exited along the medial edge of the psoas distally. The lumbosacral plexus was most dorsally positioned at the posterior endplate of L1–2. A general trend of progressive ventral migration of the plexus on the disc space was noted at L2–3, L3–4, and L4–5. Average ratios were calculated at each level (location of the plexus from the dorsal endplate to total disc length) and were 0 (L1–2), 0.11 (L2–3), 0.18 (L3–4), and 0.28 (L4–5).

Conclusions. This anatomical study suggests that positioning the dilator and/or retractor in a posterior position of the disc space may result in nerve injury to the lumbosacral plexus, especially at the L4–5 level. The risk of injuring inherent nerve branches directed to the psoas muscle as well as injury to the genitofemoral nerve do still exist.
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Key Words • **direct lateral interbody fusion** • **extreme lateral interbody fusion** • **lumbar spine** • **lumbosacral plexus** • **psoas muscle** • **retroperitoneal approach**

The minimally invasive lateral transpsoas approach to the lumbar spine (such as XLIF and DLIF) exists as an alternative to interbody placement at levels L1–5 in the setting of degenerative disc disease, spondylolisthesis, and scoliotic or kyphotic deformity.[1–4,6,7,11] Due to the location of the lumbar nerve root contributions to the lumbosacral plexus within the psoas muscle, the risk of motor and sensory nerve injury is present when traversing the lumbosacral plexus with the dilator or during retractor positioning over the disc space.[2,5,12] Avoiding complications associated with this approach is dependent on a combination of knowledge from relevant regional anatomy and 2D lateral fluoroscopy. In addition, neural monitoring is believed to be critical in localizing the lumbosacral plexus during positioning of the retractor system. This study was designed with the goal of better delineating the location of the lumbar contribution to the lumbosacral plexus in relation to the respective disc spaces relevant to the transpsoas approach (L1–5).

Methods

Cadaveric Anatomical Dissection

Three adult fresh-frozen cadavers (2 males and 1 female) were used in the current study. Anatomical dissections were performed in a refrigerated mobile lab-truck

Abbreviations used in this paper: DLIF = direct lateral interbody fusion; EMG = electromyographic; XLIF = extreme lateral interbody fusion.

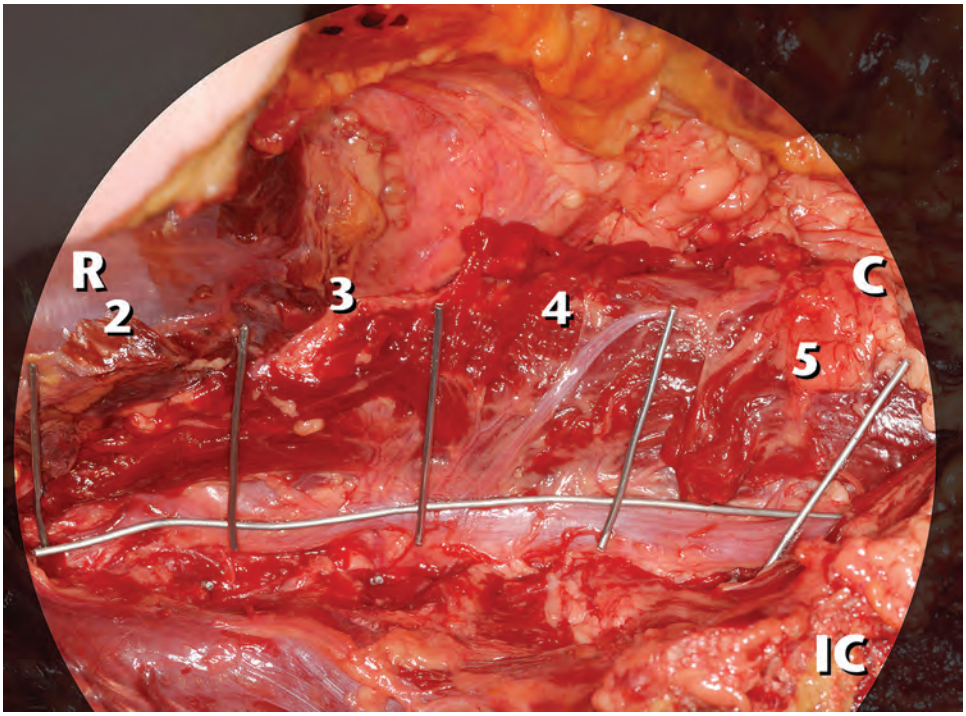

Fig. 1. Photograph of a cadaveric dissection of psoas muscle (reflected ventrally) in the lateral position (right side up) revealing the underlying lumbar plexus. Markers delineate the respective disc spaces and ventral limit of the lumbar contribution of the lumbosacral plexus. Numbers reflect the vertebral bodies (L1–5). C = caudal; IC = iliac crest; R = rostral.

unit provided by Medtronic Spinal and Biologics. The 3 cadavers were placed lateral, and dissections of the lumbar plexus were performed in a total of 12 lumbar levels. An incision was made from the umbilicus ventrally to the midline of the lower thoracic spine dorsally, and the skin was reflected to reveal the abdominal and posterior spinal musculature. The T-11 and T-12 ribs were removed to better expose the L-1 vertebral body, while partial removal of the iliac crest facilitated exposure at the L-5 vertebral body. The abdominal musculature was then incised, and the retroperitoneal space was defined. Abdominal contents of the cadavers were reflected ventrally away from the view of the surgeon. Blunt dissection of the lumbosacral plexus was then performed by first localizing the large femoral nerve outside the psoas muscle on the surface of the iliacus muscle and following it back rostrally within the psoas muscle. Once exposed, the psoas muscle flap was moved ventrally, and radiopaque malleable wire was placed along the anterior margin of the large conjoined nerve roots. These markers were also positioned over the disc spaces from L-1 through L-5 (Fig. 1).

Fluoroscopic Imaging

A lateral fluoroscopic image was obtained for each cadaver with the radiopaque wire in place.

Measurements and Statistical Analysis

Results were reported as the ratio of the location of the plexus from the posterior endplate to the total length of the disc space on the radiographic image (L-1 through L–5). Mean ratios at each disc space ± SDs were then calculated (Fig. 2). The L5–S1 disc space was not included in the study because it is not an option for the XLIF/DLIF approach. Adobe Photoshop and Microsoft Excel software programs were used for length measurements (according to the number of pixels), calculations, and statistical analysis. An overlay of the fluoroscopic image was made on the anatomical image to delineate the location of the plexus in relation to each lumbar vertebral disc space studied.

Results

The plexus was found lying on the dorsal surface of the psoas muscle within a cleft created by the transverse process–vertebral body junction. We noted a general trend of dorsal to ventral migration of the lumbar contribution to the lumbosacral plexus on the lumbar disc spaces from L-2 to L-5. The location of these nerve structures at L1–2 was at the posterior endplate of the disc space. Mean ratios of the location of the plexus to total disc space length were 0 (L1–2), 0.11 ± 0.02 (L2–3), 0.18 ± 0.03 (L3–4), and 0.28 ± 0.005 (L4–5) (Fig. 3). This ventral migration was most impressive at the L4–5 disc space (Fig. 4). The genitofemoral nerve that innervates the skin over the femoral triangle (L1–2) and travels through the psoas muscle piercing it anteriorly was not identified in this study.

Discussion

The aim of this study was to identify the location of the lumbar contribution to the lumbosacral plexus in rela-

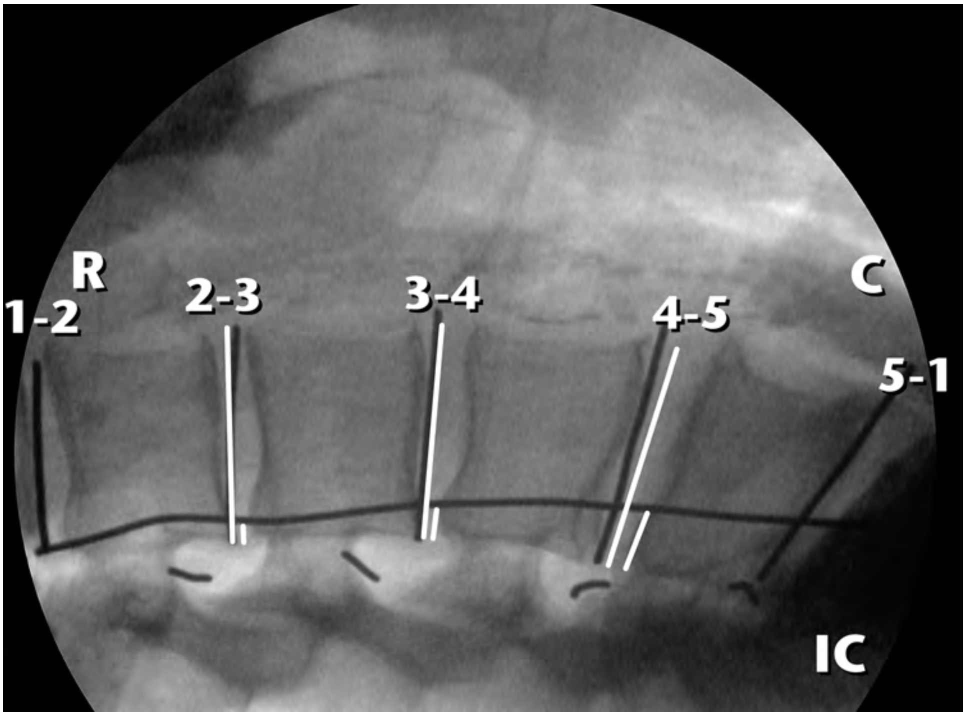

Fig. 2. Fluoroscopic image of Fig. 1 with disc spaces numbered. White lines are representative of the ratios calculated at the respective disc spaces (ratio of the location of the plexus from the posterior endplate *[short line]* to the total length of the disc space *[long line]*).

tion to the relevant disc spaces for the minimally invasive transpsoas approach to better understand areas for future complication avoidance. Previous documentation of adverse events associated with minimally invasive retroperitoneal spine surgery has been reported in the literature. Tonetti and colleagues[12] described 3 cases of femoral nerve injury following a miniopen retroperitoneal approach, in which they attributed the problem to stretching of the nerve during retraction of the psoas muscle. Bergey and colleagues[2] listed a number of patients with transient sensory abnormalities (30%) following an endoscopic transpsoas approach. Manzano and colleagues[5] reported transient, anterolateral, lower extremity thigh numbness and dysesthesias located on the side of the transpsoas minimally invasive approach. Our results are similar to a previous study conducted in relation to an endoscopic retroperitoneal approach. Moro et al.[8] analyzed the distribution of the lumbosacral plexus in the axial plane and concluded that there were certain "safe zones" at particular lumbar levels where important nerve structures were unlikely to be located.

Electrophysiological Monitoring and Stimulation

Electrophysiological monitoring is reported to be useful in the prevention of femoral nerve injury while traversing the psoas muscle with the dilator instrument. Ozgur et al.[9] have reported that threshold stimulation values > 10 mA are safe for advancement toward the disc space of interest. To further delineate which nerve fibers can cause distal activation of monitored muscles, the senior author has stimulated both the lumbar plexus and the large and small intrinsic nerve fibers to the psoas muscle during open retroperitoneal surgery. Not surprisingly, EMG stimulation of the lumbar plexus causes activation of distally monitored muscles such as the quadriceps. Interestingly, this phenomenon is also observed with stimulation (at 1–2 mA) of the large intrinsic branches to the psoas muscle (potentially by retrograde activation),

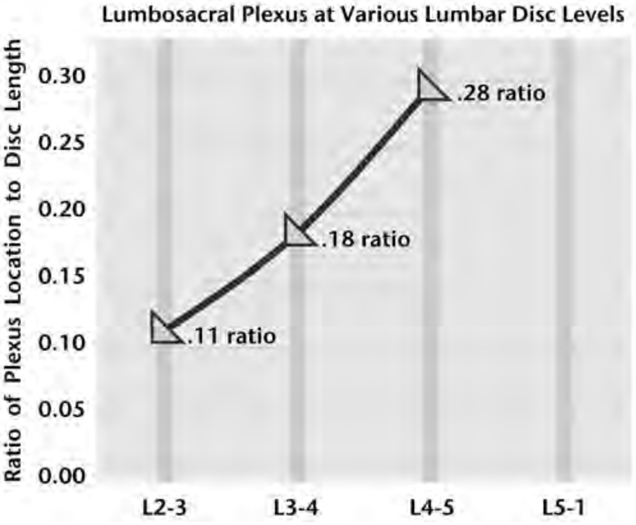

Fig. 3. Graph of the ratio of plexus location to disc length at lumbar disc levels L2–5. The L1–2 level was not plotted because the value was 0.

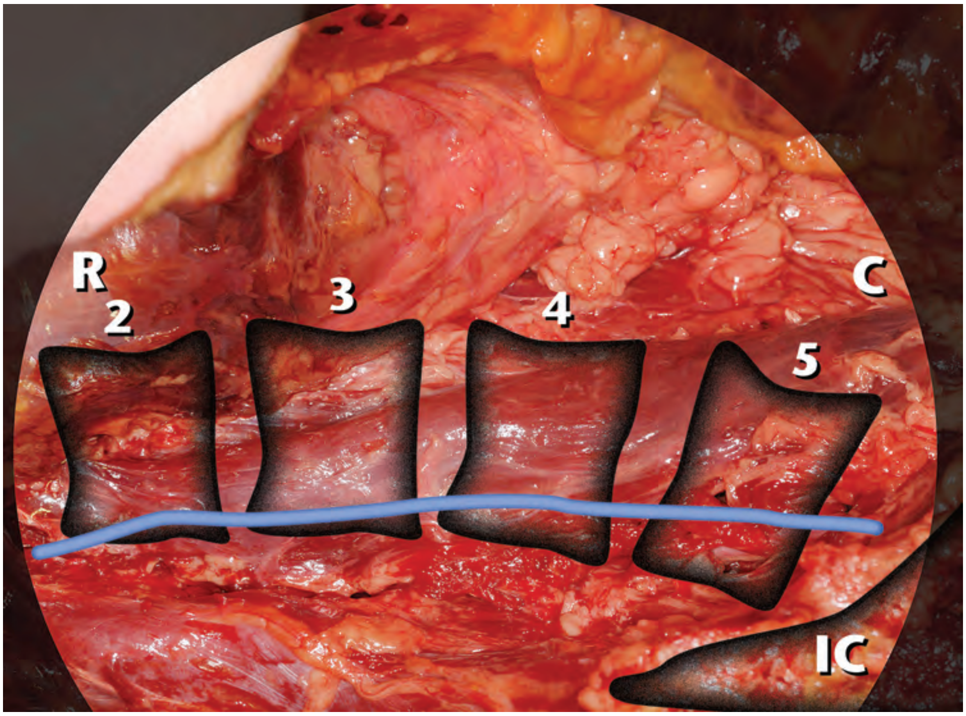

FIG. 4. Cadaveric photograph with overlay of the vertebral bodies and disc spaces as related to the psoas muscle. The blue line represents the lumbar contribution of the lumbosacral plexus that continues distally as the femoral nerve; note its more ventral location at L4–5.

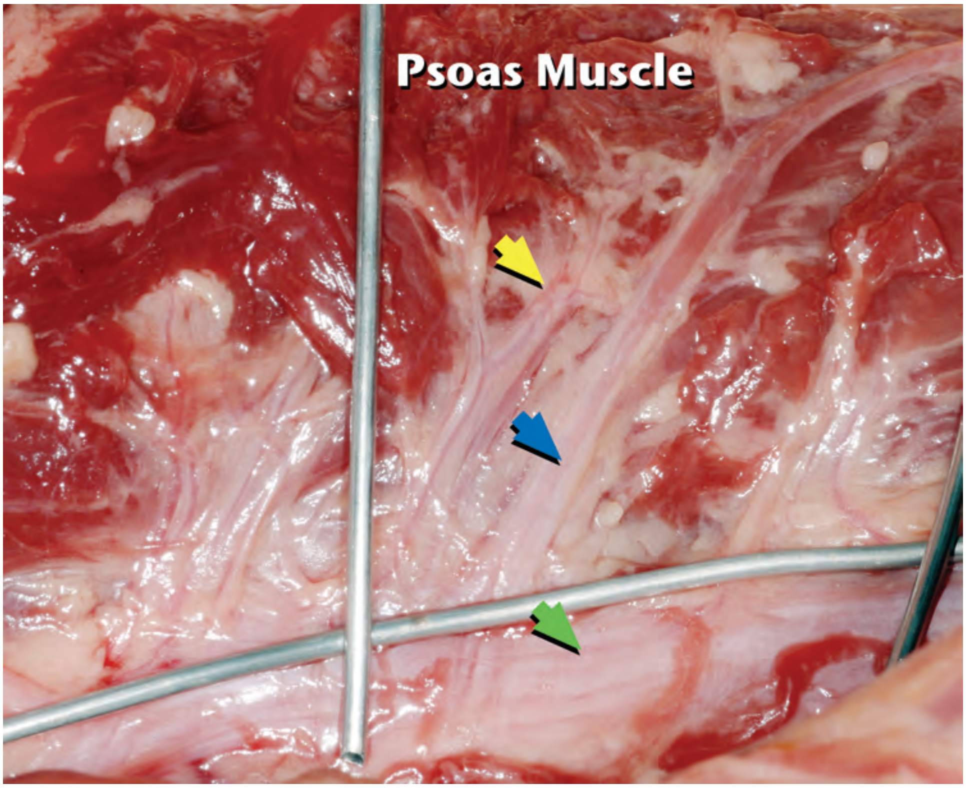

FIG. 5. Magnified cadaveric photograph of the plexus *(green arrow)*, larger proximal psoas *(blue arrow)*, and smaller distal psoas *(yellow arrow)* nerve fibers.

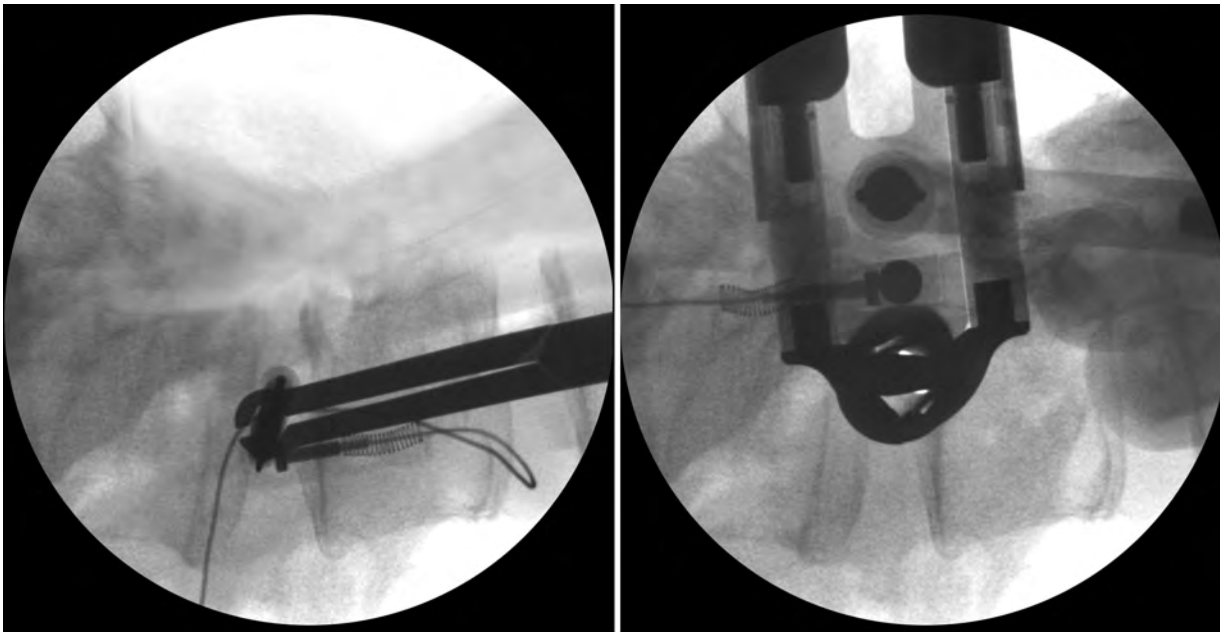

FIG. 6. Anteroposterior fluoroscopic images of the patient in the lateral position while XLIF is performed at L4–5. *Left:* Initial dilator placed into the disc space. *Right:* Final retractor position at the posterior endplate.

whereas stimulation of smaller psoas muscle branches does not (Levi, unpublished data, 2008; Fig. 5). Further analysis is needed to define whether differences exist in stimulation intensities of these large intrinsic branches to the psoas muscle versus the lumbar plexus. Nevertheless, because these large intrinsic branches to the psoas muscle are proximal to the lumbar plexus, stimulation of distal muscles regardless of nerve fiber source should prompt the surgeon to change dilator positioning to a more anterior trajectory.

Illustrative Case

Knowledge of the regional anatomy applicable to the transpsoas approach is a useful adjunct to electrophysiological monitoring in potentially preventing nerve injury. As in the following case, neurological sequelae can occur even in the absence of EMG abnormalities.

A 65-year-old male presented with a chief complaint of progressive axial back pain since 2005 with failure of conservative treatment measures. Imaging studies revealed a degenerated disc at L4–5 without spinal stenosis. The patient had a positive discogram, with concordant pain at this level as well. On preoperative physical examination he was neurologically intact. We performed a minimally invasive, left-sided, transpsoas lumbar interbody fusion at L4–5. During the operation, no EMG activity was noted while traversing the psoas muscle. In addition, only direct electrical stimulation posterior to the final retractor position yielded EMG activity in the monitored distal muscles, indicating that the surgeon's direct view was outside yet near a component of the lumbar plexus (Fig. 6). Following the procedure, the patient awoke with significant left-sided hip flexor and quadriceps weakness (rated 2/5 on the Manual Muscle Test scale), as well as patchy areas of sensory paresthesias over the anterior thigh. At discharge, the patient showed slight improvement of his antigravity strength (3/5 on the Manual Muscle Test scale). We propose that opening of the posteriorly placed retractor may have placed compression on these nerve fibers, ultimately causing the patient to have a neurological deficit.

Limitations of the Study

Limitations of the current study include a small sample size and the inability to identify nerves as being either motor or sensory in origin. Although our study defines where the bulk of the plexus lies, locations of important nerve branches that branch off the lumbosacral plexus were not identified. Therefore, we can only make recommendations for prevention of nerve injury to the large conjoined nerve roots lying in this dorsal cleft. The anatomical location of the genitofemoral nerve in this study was not identified nor were other sensory branches of the plexus including the ilioinguinal, iliohypogastric, or lateral femoral cutaneous nerve. There is a continued risk of sensory nerve injuries when placing a retractor in the anterior portion of the disc space, especially because the intraoperative EMG monitoring will not detect these nerves.[5] The typical symptoms of genitofemoral nerve injury are sensory disturbances on the skin of the medial thigh, scrotum/labia majora, and the abdominal wall below the inguinal ligament. The cremasteric reflex may also be absent in males due to damage to the motor branch.[10]

Conclusions

This anatomical study suggests that the lumbosacral plexus migrates from a dorsal to a ventral location from the L-1 through the L-5 disc spaces. These nerve structures are at greatest risk of injury during the minimally invasive transpsoas approach at the L4–5 level with a posteriorly positioned dilator or retractor. The risks of injuring inherent motor nerve branches directed to the psoas muscle still exist, as well as injury to the genitofemoral nerve, which pierces the psoas muscle and travels caudally on its ventral surface (for example at L1–2, supplying sensory innervation to the femoral triangle and cremaster muscle in males).

Disclosure

Medtronic Spinal and Biologics provided an educational grant to offset cadaver costs for this study and provided the refrigerated mobile lab-truck unit in which the anatomical dissections were performed.

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