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ANATOMY

# Anatomic Mapping of Lumbar Nerve Roots During a Direct Lateral Transpsoas Approach to the Spine

*A Cadaveric Study*

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**Study Design.** Cadaveric study.

**Objective.** Identifying anatomic structures at risk for injury during direct lateral transpsoas approach to the spine.

**Summary of Background Data.** Direct lateral transpsoas approach is a novel technique that has been described for anterior lumbar interbody fusion. Potential risks include damage to genitofemoral nerve and lumbar plexus, which are not well visualized during small retroperitoneal exposure. Previous cadaveric studies did not evaluate the direct lateral transpsoas approach, and considering the approach being used in clinical practice, the current study was undertaken in an effort to identify the structures at risk during direct lateral transpsoas approach.

**Methods.** Sixteen dissections were performed on eight fresh-frozen male cadavers. Eight were to localize proximal lumbar nerve roots, ilioinguinal nerves, and genitofemoral nerves and establish their relationship to psoas muscle and disc space. Four simulated direct lateral transpsoas approaches, with K-wire placed into mid-disc space under fluoroscopic guidance, were made. In four dissections, sequential dilators were inserted, disc space was evacuated, and interbody devices were placed. The study was conducted in three phases to identify, in a stepwise progression, which portion of the procedure placed the nerve at greatest risk.

**Results.** With initial dissections, perforating branches of lumbar nerve roots were identified in anterior, middle, and posterior third of psoas muscle. Sympathetic chain was identified in anterior third of psoas over L1–L4. Distance from the middle of the anterior longitudinal ligament at the level of the disc to the sympathetic chain averaged 9.25 mm. The nerve roots and genitofemoral nerve were placed at risk in all dissections in which the approach was recreated. Damage secondary to K-wire placement occurred in 25% of cases at L3–L4 and L4–L5; in one case, L4 nerve root was pierced, and in another, genitofemoral nerve was pierced. K-wire was posterior to the nerve roots in 25% of cases at L3–L4 and in 50% of cases at L4–L5. The lumbar plexus was placed under tension because of sequential dilator placement.

**Conclusion.** On the basis of our results, there is no zone of absolute safety when using the direct lateral transpsoas approach. The potential for nerve injury exists when using this approach, and consequently, we recommend either direct visualization of the nerve roots intraoperatively and/or the use of neuromonitoring. In our opinion, a higher quality, larger clinical study that examines the outcomes and surgical complications of the direct lateral transpsoas approach is warranted.

**Key words:** lumbar nerve roots, direct lateral transpsoas approach, lumbar plexus, anterior third of psoas, anatomic mapping, **Spine 2011;36:E687–E691**

Lumbar fusion is used to treat a variety of indications, including degenerative, neoplastic, developmental, and traumatic conditions of the lumbar spine. Over the years, novel approaches to fusion techniques have been developed in an effort to minimize the trauma associated with the surgical approach. The concept of minimally invasive surgical exposure developed in an effort to decrease the complications associated with open procedures. The open exposures typically used for fusion techniques have been reported to be associated with soft tissue damage, leading to increased morbidity and longer recovery times. The theoretical benefits of minimally invasive spinal surgery include less tissue disruption, decreased injury to the nerve and blood supply of the paraspinous musculature, improvement in postoperative pain, decreased blood loss, shorter hospital stays, and faster recoveries.

One such minimally invasive technique is the direct lateral transpsoas approach. The transpsoas approach to the lumbar spine was first described in 2006 and has been presented as a safe and reproducible technique to reconstruct sagittal balance, correct degenerative scoliosis, and address other degenerative

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disorders of the lumbar spine. The direct lateral transpsoas approach theoretically avoids the risks of conventional "open" surgery and allows for rapid recovery. The technique is performed with the patient in the lateral decubitus position. A lateral bolster is used to open the interval between the 12th rib and iliac crest. A small incision is made directly lateral to the vertebral bodies in the flank, over the psoas muscle, and sequential dilators are inserted through the psoas muscle to the disc level. Electromyographic monitoring is performed as the dilators are passed through the muscle. A diskectomy is then performed, and disc height is restored with indirect foraminal and canal decompression.

The lumbar plexus, composed of the anterior rami of the L1, L2, and L3 nerve roots and part of the L4 anterior ramus, is located within the substance of the psoas muscle on the posterior abdominal wall.[1] A documented risk of the direct lateral transpsoas approach is damage to the genitofemoral nerve, which arises from the L1–L2 nerve root and passes over the psoas at the L3–L4 level. Remaining in the anterior third of the psoas muscle and visualizing the nerve are recommended to prevent injury to the nerve. However, groin and thigh paresthesias have been reported to occur after surgery despite the use of neuromonitoring.[2,3] In a recent retrospective clinical trial, Knight *et al*[4] found that 3.4% of patients who had undergone the direct lateral transpsoas approach experienced approach-related nerve injury. Furthermore, our anecdotal experience suggests that a percentage of patients experience thigh pain and groin paresthesias after surgery.

Previous cadaveric studies did not evaluate the direct lateral transpsoas approach, and considering that the approach is being used in clinical practice, the current study was undertaken in an effort to identify the associated structures at risk. Cadaveric dissections were performed in an attempt to localize the lumbar nerve roots and determine their relationship to the psoas muscle and the intervertebral disc. The direct lateral transpsoas approach was then recreated in cadaveric specimens to assess the likelihood of nerve injury.

## MATERIALS AND METHODS

Eight fresh-frozen male cadaveric specimens were dissected bilaterally, for a total of 16 dissections. The dissections were performed in three parts. We conducted the study in three phases to identify, in a stepwise progression, which portion of the procedure placed the nerve at greatest risk. Each part used a unique protocol.

### Part I

Four fresh-frozen male cadaveric specimens were placed in the lateral decubitus position with a bolster to open the interval between the 12th rib and the iliac crest. A lateral incision was then made overlying the psoas muscle and was carried down through the internal and external oblique muscles, the transversalis, and the psoas muscle. The psoas muscle was then divided into anterior, middle, and posterior thirds. Careful attention was given to dissect out any overlying neurovascular structures. Once the psoas was mobilized, the retroperitoneal fat was cleared away from the spine and the L1–L5 vertebral bodies were identified. Each disc space and respective nerve root were also identified, as were the sympathetic chain and lumbar nerve roots. The distance from the anterior longitudinal ligament at the level of the disc to the sympathetic chain was measured in the lateral position. A trajectory from the anterior longitudinal ligament at the level of the disc directly anterior to the position of the chain along the anterior border of the vertebral bodies was measured in all eight specimens. The nerve roots and femoral nerve roots were classified as occupying the space represented by the anterior, middle, or posterior third of the psoas muscle. The dissection was then performed on the contralateral side, for a total of eight dissections.

### Part II

The standard direct lateral transpsoas surgical exposure was performed on two fresh male cadaveric specimens. The cadavers were placed in a lateral decubitus position with a bolster. Fluoroscopic imaging was used to identify the L3–L4 and L4–L5 disc spaces. With the use of lateral fluoroscopy, a K-wire was placed into the midportion of the L3–L4 and L4–L5 disc spaces. An incision was then made overlying the center of the disc space, and the anterior muscle layers were bluntly dissected with the examiner's index finger. Once the retroperitoneal space was identified, the peritoneum was moved anteriorly and the psoas muscle identified. Sequential dilators were then passed through the anterior third of the psoas musculature to the level of the vertebral body.

The dilators were then removed, and dissections were performed with the guidewires in place. Wire placement was evaluated regarding accuracy of placement and proximity to the lumbar nerve roots and genitofemoral nerve. The surgical exposure was then performed on the contralateral side. A total of four dissections were performed.

### Part III

Two male fresh-frozen cadavers were placed in a lateral decubitus position. Guidewire placement and dissection were performed as outlined for part II. After the sequential dilators had been passed, the SynFrame (Synthes Spine, Paoli, PA) retractor was positioned so that direct visualization of the disc space could be achieved. The disc space was evacuated, and a trial spacer that had been molded with methylmethacrylate was placed. The sympathetic chain and lumbar nerve roots were identified, as were any structures that appeared to have been damaged during the approach. The approach and dissection were then performed on the contralateral side for a total of four dissections.

## RESULTS

### Part I

The structures that were consistently identified during the initial eight dissections were the perforating branches of the lumbar nerve roots. Perforating branches of the lumbar nerve roots were identified in the anterior, middle, and posterior third of the psoas musculature in all eight initial dissections. When the branches were dissected to their origins, it was found that the nerves originated from the L2–L4 foramen.

In all specimens, the sympathetic chain was identified overlying the disc space of the L1–L5 vertebral bodies in the anterior third of the psoas muscle (Figure 1). The distance from the mid-disc space to the sympathetic chain was measured with the specimen in the lateral position. A trajectory from the mid-disc space directly anterior to the position of the chain along the anterior border of the vertebral bodies was measured in all eight specimens (Figure 2). The distance range was 8 to 12 mm, with an average distance of 9.25 mm.

The genitofemoral nerve was often difficult to identify unless it was traced from its origin at the L1 and L2 nerve roots. In all instances, it was identified overlying the middle third of the psoas (Figure 3).

### Part II

Direct nerve damage occurred secondary to fluoroscopic K-wire placement in 25% of cases. In one instance, the L4 nerve root was pierced (Figure 4), and in another instance, the genitofemoral nerve was pierced (Figure 5). At the L3–L4 level, the guidewire was posterior to the nerve roots in 25% of cases. At the L4–L5 level, the guidewire was posterior to the nerve roots in 50% of cases (Figure 6).

### Part III

With the eight dissections that included placement of sequential dilators, displacement of the lumbar plexus by the dilators was visible. As the dilators were placed in the substance of the psoas musculature, the lumbar nerve roots were subjected to stretch.

## DISCUSSION

In 2006, the direct lateral transpsoas approach was described as a novel technique for anterior lumbar interbody fusion. Ozgur *et al*[3] described the operative procedure and the results achieved for the first 13 patients treated. The reported advantages of the procedure were avoidance of the complications associated with anterior transperitoneal approaches to the lumbar spine, avoidance of the major vessels, and no need for an access surgeon. According to Ozgur *et al*, damage to the genitofemoral nerve during the direct lateral transpsoas approach is unlikely because the approach does not require retraction of the psoas or significant dilation of the dissection site in the psoas. In the initial cohort presented, no evidence of trauma to the psoas muscle or nerves was shown. The authors asserted that the descending nerves of the lumbar plexus lie in the posterior third of the psoas muscle and should thus be avoided by remaining in the anterior portion of the muscle.

However, a review of the literature and the anatomy of the lumbar plexus revealed that the plexus and the nerve roots might not be confined to the anterior portion of the psoas musculature. The lumbosacral plexus is composed of the ventral divisions of the lumbar and sacral spinal

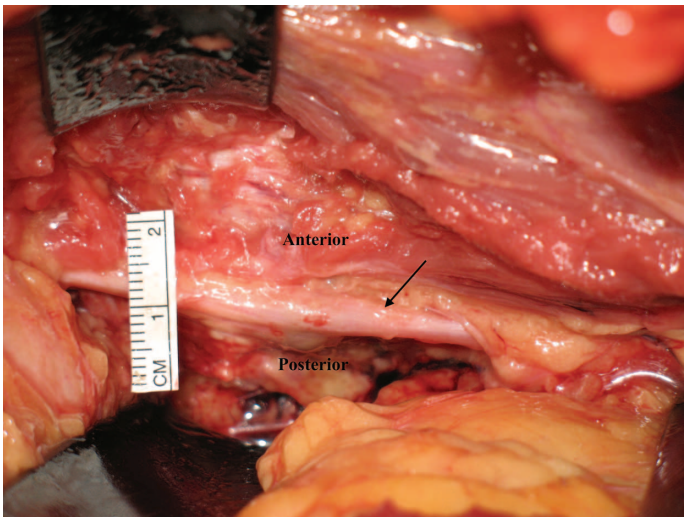



**Figure 2.** Measurements were taken to determine the average distance between the disc space and the sympathetic chain; a trajectory from the mid-disc space directly anterior to the position of the sympathetic chain along the anterior border of the vertebral bodies was measured. *Arrow*, Sympathetic chain.

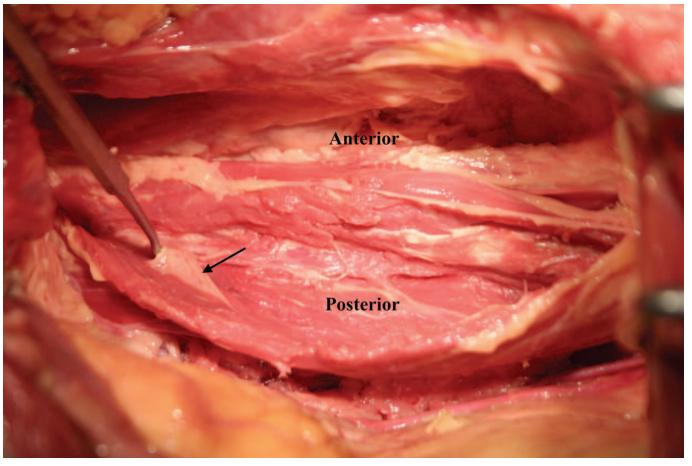



**Figure 1.** Perforating branches of the lumbar plexus identified coursing throughout the anterior, middle, and posterior third of the psoas musculature. *Arrow*, Perforating branch of the lumbar plexus.

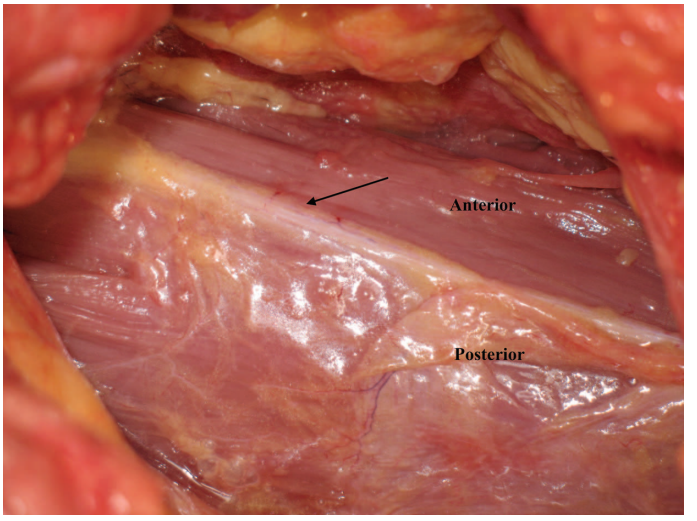
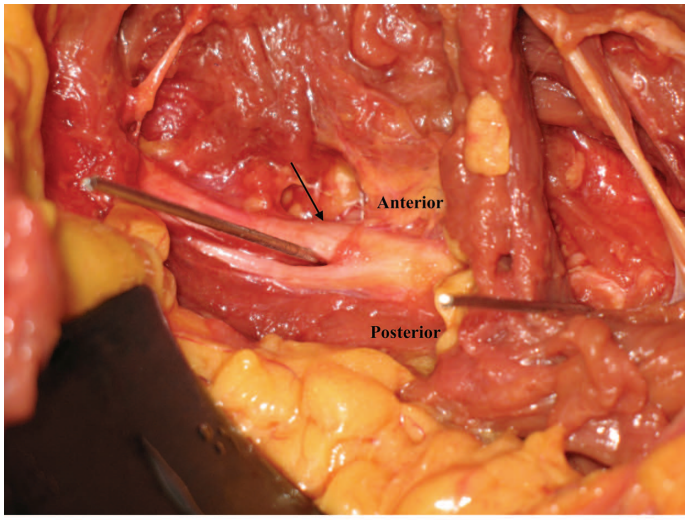



**Figure 3.** Genitofemoral nerve identified overlying the anterior third of the psoas musculature. *Arrow*, Genitofemoral nerve.




(A)

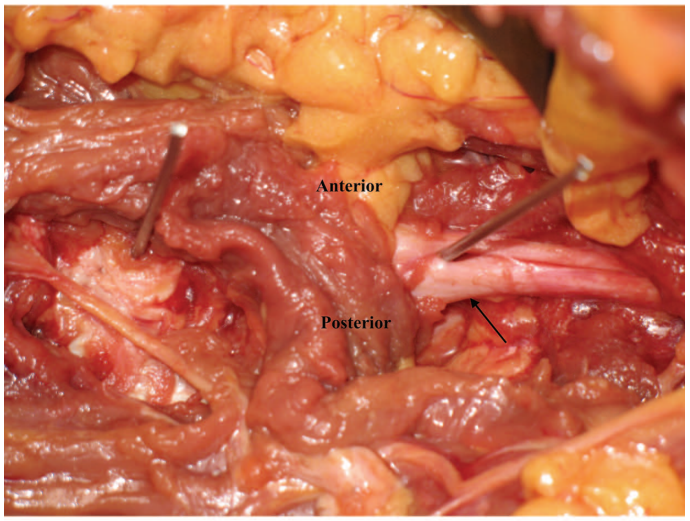



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**Figure 4. A** and **B**, Two views of the K-wire piercing the L4 nerve root. *Arrows*, L4 nerve root.

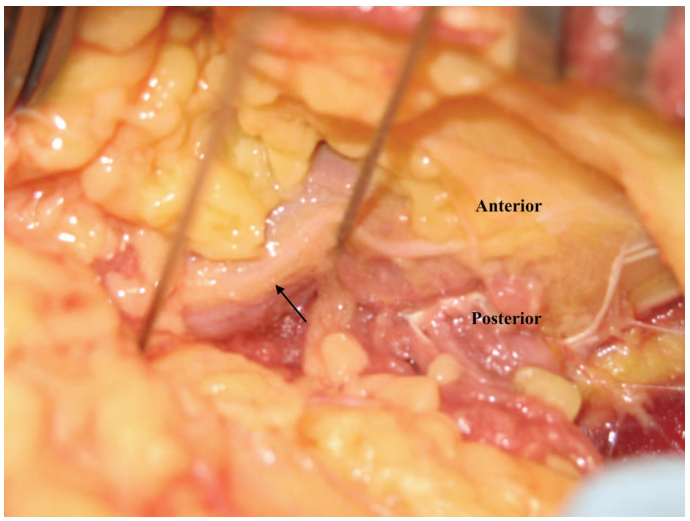
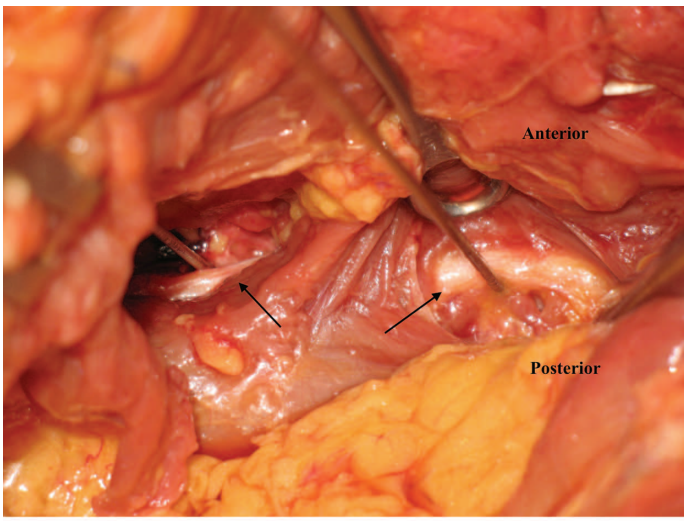


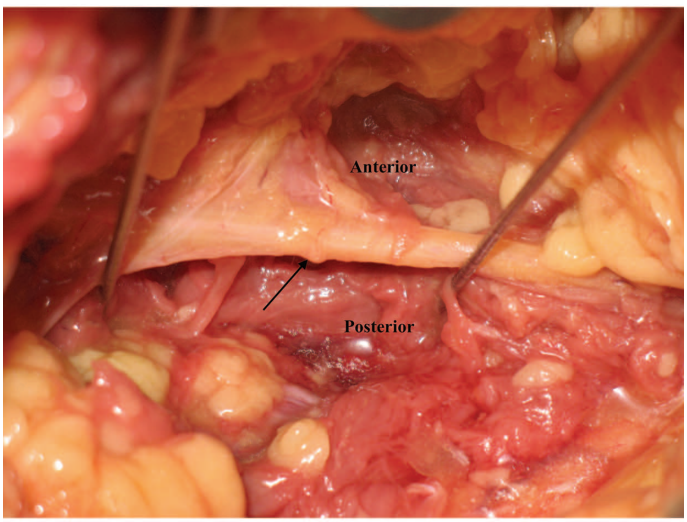

**Figure 5.** K-wire piercing the genitofemoral nerve. *Arrow*, Genitofemoral nerve.

nerves and a contribution from T12.[5] Typically, the L1–L3 nerve roots are distributed to the lumbar plexus, and L4 is divided between the lumbar and sacral plexuses and is termed the *furcal nerve*. If L3 gives a branch to the furcal nerve, the plexus is prefixed; if L5 gives a branch to the furcal nerve, the plexus is postfixed.[1] The lumbar portion of the plexus lies on the ventral surface of the posterior abdominal wall. The nerves exit through the foramina and course through the psoas musculature and between the psoas and iliacus muscles,[5] thus implying that the nerve roots might be at risk even in the anterior third of the psoas musculature.

Our study provides evidence that dissection through the anterior portion of the psoas muscle also poses significant risk to the lumbar plexus and the genitofemoral nerve. Our finding is supported by similar results presented by Samudrala *et al*.[2] The group conducted an anatomic study to identify the critical abdominal and retroperitoneal structures at risk during anterior surgical decompression and fusion. The




(A)




(B)

**Figure 6. A** and **B**, Two views of K-wire placement relative to the lumbar nerve roots. *Arrows*, Lumbar nerve roots.

group found that the lumbosacral plexus arises from the T12–S4 ventral rami, courses to penetrate the psoas posteromedially, and then courses anterolaterally to form discrete nerves. Moro *et al*[6] also conducted an anatomic study in an effort to identify the zone of safety within the psoas major during retroperitoneal surgery. The group reported that the lumbar plexus and nerve roots are contained throughout the psoas major muscle. They therefore recommended that the psoas not be dissected but rather that the dissection should be performed in the interval between the psoas and the vertebral body. Moro *et al* showed that the nerves were found more anteriorly in more distal segments and that they were at little risk proximally.

Our findings were consistent with those reported by Moro *et al*.[6] However, in the present study, the lumbar plexus roots were at risk even at L3–L4, an interspace that seemed to be safe in previous studies. The risk is especially high during percutaneous dilation performed blindly through the psoas muscle body. In all 16 dissections, the lumbar nerve roots were found to course throughout the substance of the psoas musculature. Direct nerve damage by K-wire placement occurred in 25% of the specimens, and lumbar nerve roots were found anterior to the guidewire in 37.5% of the specimens. We therefore conclude that dissection through the anterior portion of the psoas poses significant risk to the lumbar plexus and genitofemoral nerves.

The risk to the lumbar plexus roots is further substantiated by a recent clinical study by Knight *et al*.[4] The authors conducted a retrospective study of patients who had undergone the direct lateral transpsoas approach and found major adverse events in 8.6% and approach-related complaints of nerve injury in 3.4% of the patients.

On the basis of our findings, the lumbar plexus is placed at risk during the currently described technique for the direct lateral transpsoas approach. There is no zone of absolute safety. Even in the anterior third of the psoas, the plexus is vulnerable to injury. Consequently, we recommend the following modifications to avoid damage to the lumbar nerve roots: (1) when possible, dissection should be carried out in a plane as anterior to the psoas as possible; and (2) that dissection should be carried out under direct visualization of the psoas to identify and protect the nerve roots. Intraoperative neuromonitoring with either spontaneous or triggered electromyographic recording from the lower extremity might also play a role in providing an additional source of protection from nerve damage. At our institute, we currently monitor free-running electromyography from all four heads of the quadriceps muscle. We recognize that this study involved recreation of the surgical technique in cadaveric specimens and that obvious differences exist between the tissue planes and flexibility of a cadaveric specimen *versus* a live patient. Consequently, further study is needed to determine the safest method to perform the direct lateral transpsoas approach for anterior fusion and to compare treatment outcomes and complication rates between the direct lateral transpsoas approach and standard surgical approaches.

## ➢ Key Points

- ❑ There is no safe zone for the lumbar nerve roots during direct lateral transpsoas approach.
- ❑ Even in the anterior third of the psoas, the plexus is vulnerable to injury.
- ❑ Dissection should be performed in an interval as anterior to the psoas as possible, with the use of direct visualization of the lumbar nerve roots and/or neuromonitoring.

### Acknowledgment

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