Lumbarized Sacrum as a Relative Contraindication for Lateral Transpsoas Interbody Fusion at L5-6

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Study Design: Retrospective review.

Objective: To determine if lumbarized sacra at the L5-6 level (functional L4-5) are a contraindication to a lateral transpsoas approach.

Summary of background Data: Transitional vertebrae at the lumbosacral junction present mechanical and morphologic changes, though these changes have not been characterized with respect to the feasibility of a lateral transpsoas approach.

Methods: Three hundred fifty-one patients were scheduled for lumbar interbody fusion using a mini-open lateral transpsoas approach (XLIF) at L4-5 from 2004 to 2008 at a single institution. In patients with 6 lumbar vertebrae, accessibility, based on neuromonitoring, of the L5-6 level (functional L4-5) was reviewed. Qualitative assessments using axial magnetic resonance imaging (MRI) were performed and compared with a sample of patients with normal anatomy treated at L4-5.

Results: Of the 351 patients scheduled for treatment at L4-5, 10 (2.8%) were determined to have 6 lumbar vertebrae with the symptomatic level at L5-6. Of those 10, 2 (20%) could be treated using a lateral transpsoas approach, and 8 (80%) were converted to another approach after a corridor through the psoas muscle was not found, based on neuromonitoring feedback. Review of axial MRI showed a teardrop-shaped psoas detached from the lateral border of the disc space in patients with transitional anatomy unapproachable at L5-6, resemblant of L5-S1 in normal anatomy. In the 2 patients who could be safely approached, the psoas anatomy at L5-6 was similar to a normal L4-5 level, with a domed/helmet shape, attached laterally to the disc space.

Conclusions: Treating the L5-6 level using a lateral transpsoas approach in individuals with lumbarized sacra can be challenging due to anatomy more similar to the L5-S1 level in normal patients. Preoperative planning using axial MRI and intraoperative adherence to advanced neuromonitoring can aid in identifying and avoiding injury in these rare patients.

Key Words: sacralization, lumbarization, transitional anatomy, functional L4-5, Bertolloti syndrome, XLIF

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Over the past decade, the lateral transpsoas approach to the lumbar spine for discectomy and interbody fusion has gained popularity as an alternative to anterior and posterior approaches.[1–6] This shift has been driven in part by the lateral approach utility in minimizing the morbidities associated with conventional approaches, but its adoption was made possible by the development of advanced neuromonitoring techniques, which provide a layer of safety during the approach and procedure, where there is a small risk of injury to nerves in and surrounding the psoas muscle, particularly at the L4-5 level.[7–13]

In patients with anatomic anomalies of the lumbar spine, namely transitional vertebrae at the lumbosacral junction, variations in morphology may increase the risk of injury and increase the likelihood for wrong-level surgery.[14–16] Transitional anatomy is a bony abnormality that presents as either an additional lumbar vertebra (lumbarization: 6 lumbar levels) or as 3 or 4 lumbar levels (sacralization) with varying degrees of mobility at the last lumbar segment, from immobile to fully articulating.[17] In those with 6 mobile lumbar vertebrae, the L5-6 disc acts as a functional L4-5, as it most closely resembles in structure and function the L4-5 level in an individual with normal anatomy. Total incidence of lumbarization or sacralization may occur in up to 30% of the normal population,[17–19] although the incidence of patients with 6 completely mobile segments is more realistically between 2% and 5.5%,[20–22] and with 3 or 4 mobile segments, between 1% and 7.5%.[20–23]

Where the bony abnormalities are reasonably apparent on 30 degree cranially angled anterior radiography,[24] changes in surrounding soft-tissue anatomy (neural, connective, muscular, and vascular) are less readily apparent and less well understood, comparatively.[16,22,25,26] Of interest to this study are the clinical implications of the neural anatomy accompanying changes in the mechanics and bony anatomy of the

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lumbar spine, as alterations in the position or distribution of the nerves of the lumbar plexus in the psoas muscle may affect the ability to safely approach the anterior spinal column using a lateral transpsoas approach. Where L5-S1 is typically not approachable from a lateral approach due to the position of the iliac crest, an L5-6 level is generally accessible, as the segment rests approximately where the L4-5 space rests in a normal spine, with adequate trajectory superior to the iliac crest for approach. Although it has been demonstrated that some neural changes occur in transitional vertebrae, most commonly at the last fully mobile lumbar level, the changes have been shown to be highly subject to individual variation in the small series studies that have examined the phenomenon.[21,25]

The objective of this study was to examine the incidence of transitional anatomy in a large series of patients undergoing a lateral transpsoas approach for interbody fusion at the functional L4-5 level (L4-5 in patients with normal anatomy, L5-6 in patients with lumbarized sacra), where the potential effects of transitional anatomy would be most apparent with respect to the approach, and to determine whether the approach or procedure were affected by the presence of the abnormality. The hypothesis of this study was that patients with lumbarization of their highest sacral segment would be more likely to have neural abnormalities, which would affect the ability to safely approach the functional L4-5 disc space using a lateral transpsoas approach.

MATERIALS AND METHODS

Three hundred fifty-one patients were scheduled to undergo lumbar interbody fusion at L4-5 using extreme lateral interbody fusion (XLIF, NuVasive, Inc. San Diego, CA) from 2004 through 2008 for degenerative conditions of the lumbar spine. The XLIF approach has been previously described in detail,[3,27] though the general technique involves making a small (2 to 4 cm) incision 90 degrees off midline and performing blunt dissection through the retroperitoneal space to the psoas muscle. Sequential dilators with integrated, directional, triggered electromyographic (EMG) surfaces are then carefully passed through the psoas muscle with EMG stimulation (NV JJB™/M5® neuromonitoring system, NuVasive, Inc.) to provide information on the location and proximity of the nerve trunks and roots exiting the cauda equina. Once the lateral disc space has been exposed, discectomy and interbody fusion is performed using standard techniques and instrumentation under direct illuminated visualization, with both stimulated and free-run EMG used throughout the procedure. A rectangular interbody spacer is positioned with the outer margins bilaterally over the posterolateral aspects of the apophyseal ring.

Patients with transitional anatomy were identified prospectively, with chart review performed to characterize the effects the anatomy had on the approach and procedure. Of note were the occurrences of any approach-related complications and/or the conversion from a lateral transpsoas approach to an alternative approach due to the lack of availability of a passage to the anterior spine without interference from lumbar nerve roots or trunks. Review of available imaging studies was performed on patients diagnosed with transitional anatomy. Transitional anatomy was determined by the counting of complete vertebral segments from the last spinal level with attached ribs (T12) to the last fully mobile segment (no adherence of transverse processes to the sacrum).[24] In lumbarized patients, axial magnetic resonance imaging (MRI) was reviewed with qualitative assessments made of the position and morphology of the psoas muscle for each L4-5 and L5-6/L5-S1 disc space. The films of a random sample of 10 patients treated at L4-5 with XLIF without transitional anatomy were reviewed in the same manner to assist in qualifying changes. These qualitative findings were correlated with clinical findings during the surgery, including if any anatomic variations resulted in changes in the ability to perform the approach or procedure.

Statistical analysis, including frequency and χ^2 statistics were performed using IBM SPSS Statistics version 19.0 (Chicago, IL). Statistical significance was determined at $P < 0.05$.

RESULTS

Of the 351 patients scheduled for treatment with XLIF at L4-5, 10 patients (2.8%) exhibited complete lumbarization of their highest sacral segment. Of these 10 patients, 8 were converted to an alternative approach after a safe corridor around the nerves within the psoas muscle could not be found, whereas the remaining 2 patients could be treated as intended, with an XLIF procedure at the functional L4-5 (L5-6) segment. Of the 8 patients converted to alternative techniques, 1 (12.5%) was treated with open posterior lumbar interbody fusion and 7 (87.5%) were treated with a minimally invasive presacral approach for interbody fusion (AxiaLIF, TranS1, Inc. Wilmington, NC) at L5-6 and L6-S1 (Fig. 1). The remaining 343 (97.7%) patients were treated at L4-5 by XLIF after a corridor through the psoas muscle was found, based on the feedback of intraoperative neuromonitoring. A comparison of the frequency of accessibility at the functional L4-5 level and the incidence of lumbarization revealed a statistically significant effect of transitional anatomy at L5-6 on the accessibility of the segment, $P < 0.001$.

Qualitative assessment showed that patients with lumbarization tended to have psoas muscle orientation more similar to the anatomic segment, rather than the functional segment. On axial MRI or computed tomography, the psoas muscle at L5-6 (functional L4-5) presented as laterally detached from the bony vertebral segment, in a teardrop shape, similar to the L5-S1 orientation in normal anatomy. The L4-5 level in lumbarized patients (functional L3-4) more closely resembled the normal L4-5 level, with the psoas muscle having a domed/helmeted appearance, positioned directly

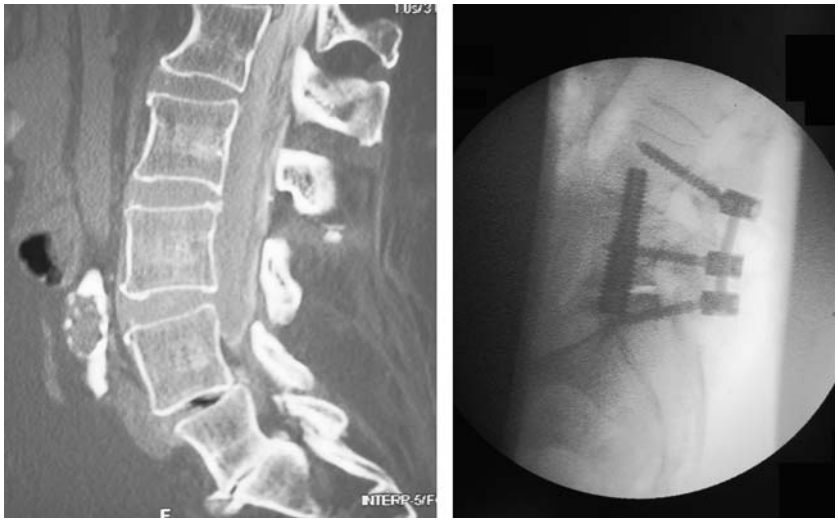


FIGURE 1. Intraoperative fluoroscopy of a 2-level presacral approach for interbody fusion (AxiaLIF) at L5-6 and L6-S1 after an aborted XLIF approach at L5-6.

against the lateral wall of the vertebral segment. The later orientation was seen, in our series, as a predictor of the ability to successfully approach the segment. The 2 patients with transitional anatomy who could be treated at the functional L4-5 level exhibited characteristics of psoas muscle orientation more similar to normal anatomy. Three columns of images of axial MRI or computed tomography studies comparing normal L4-5, normal L5-S1, and lumbarized L5-6 anatomy are shown in Figure 2. The images of a case where 6 lumbar vertebrae were present yet a lateral transpsoas approach at L5-6 was performed without complication or abnormal intraoperative EMG findings are shown in Figure 3.

DISCUSSION

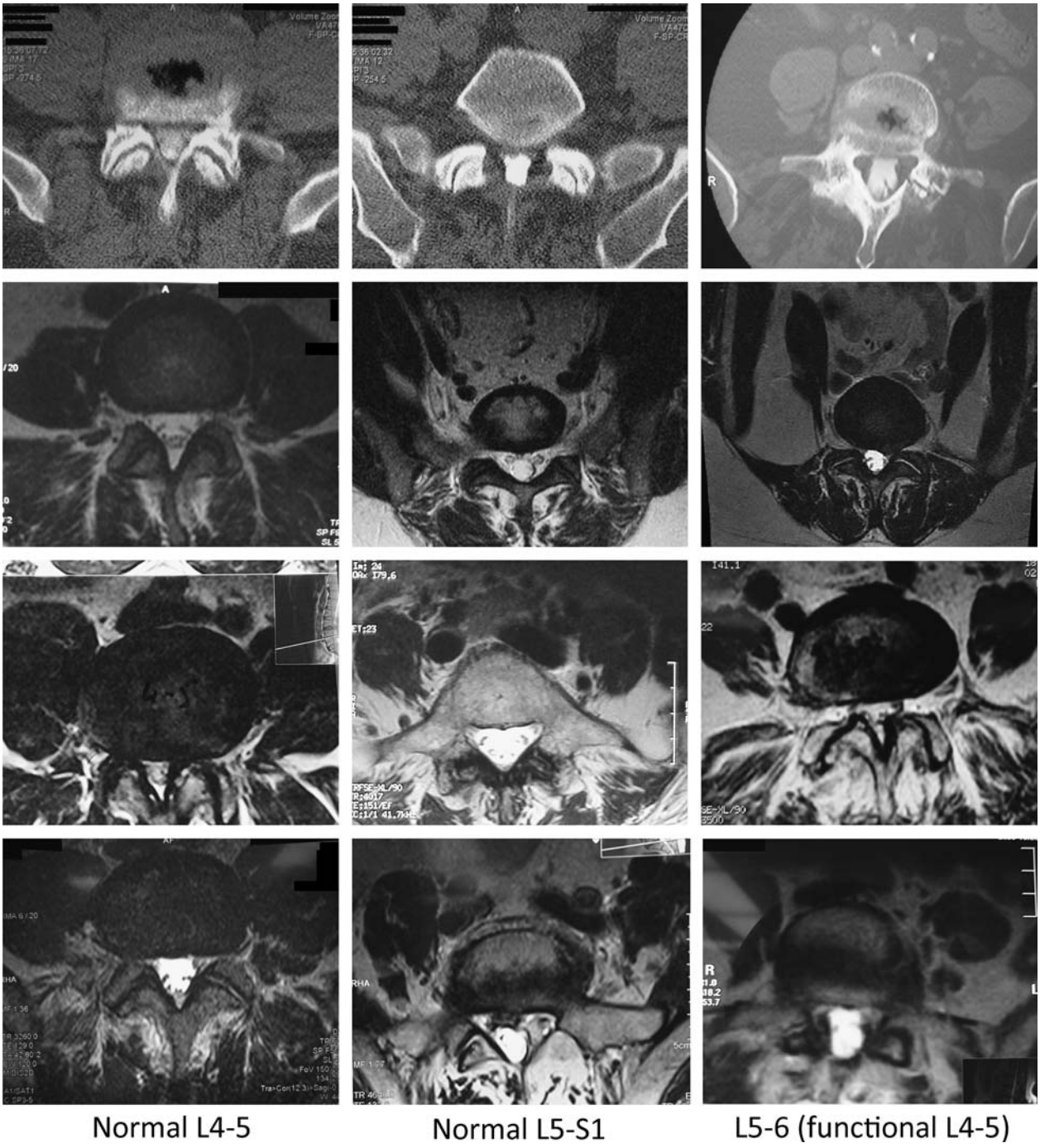
The clinical effects of transitional anatomy have been debated since at least 1917 when Bertolloti described a relationship between sacralization or lumbarization of the lowest lumbar segment and increased incidence of lower back pain.[28] Subsequent work on Bertolloti syndrome (as it has since been named) has found that the incidence of lumbar disc herniation in individuals with transitional levels is no greater than in the general population, but the location of herniation is significantly more frequent at the level above the transitional segment.[17,29,30] As the incidence of clinical symptoms in the transitional anatomy population seems to be no different than in the general population, a major function of transitional anatomy understanding is to increase proper identification of symptomatic levels and to avoid wrong-level surgeries.[14,15] In a case consistent with the results presented here, in 2000 Hsieh et al[22] described a patient who presented with lower extremity radiculopathy in an L5-S1 distribution, but on MRI review, the functional L5-S1 level (actual L6-S1) was shown to have no neural impingement. Rather, a 6 mm posterior disc bulge was present at the L5-6 segment (functional L4-5)—the patient having a lumbarized sacrum.

The current study found a 2.8% (10 patients) incidence of lumbarized sacra out of 351 patients, which is similar to other reports of lumbarization prevalence.[20,21] Of these, 80% were unapproachable at the L5-6 level using a lateral transpsoas approach due to unfavorable neuromonitoring results. The results of this study suggest that the presence of transitional anatomy at the functional equivalents of lower lumbar levels has the potential to exhibit abnormal soft-tissue anatomy, specifically nervous, vascular, and muscular tissue. These abnormalities generally decrease the ability to approach the level using a lateral transpsoas approach, though the changes are not seen in every patient. Instead, the muscular and nervous tissue anatomy at lumbar levels seem to follow normal anatomy, with the anatomic L4-5 segments relatively similar in both normal and lumbarized individuals, and at L5-S1 and L5-L6. Such anatomic similarity is likely attributed to the unchanged insertion of the iliopsoas muscle into the lesser trochanter of the femur in patients both with and without transitional lumbosacral anatomy.

These clinical implications confirmed the hypothesis in this series of patients, where all patients without transitional anatomy were approachable at their lowest lumbar segment, but only 20% of those with a lumbarized sacrum could be treated.

The effect of sex on the ability to access lumbosacral transitional segments using a lateral transpsoas approach is unclear, based on this series; however, the variability in iliac crest morphology is more varied (typically lower) in females, and may be less obstructing to lower lumbar approaches.

Differences on MRI between patients who could and those who could not be approached using a lateral transpsoas approach suggested that a preoperative indicator of approach feasibility includes the classification



FIGIRE 2. Axial computed tomography (top row) and magnetic resonance imaging (bottom 3 rows) of the disc spaces of L4-5 (left column) and L5-S1 (center column) in individuals with normal anatomy and L5-6 in those with lumbarized sacra, who could not be treated with a lateral transpsoas approach, based on the feedback of advanced neuromonitoring systems (right column).

of psoas anatomy at the operative level using axial MRI, where a helmet/dome-shaped psoas muscle directly attached to the lateral aspect of the disc space is approachable, and a detached, teardrop-shaped psoas muscle at the functional L4-5 level may be unapproachable. The determination of whether or not a level was approachable was made using the feedback of advanced neuromonitoring techniques. The presence of a working corridor was assessed using approach instrumentation with integrated, surgeon-controlled, directional EMG stimulation with discrete threshold responses, which provided information on both the position and distance of motor nerves with respect to the instrument. Ideal placement of the sequential dilators and subsequent

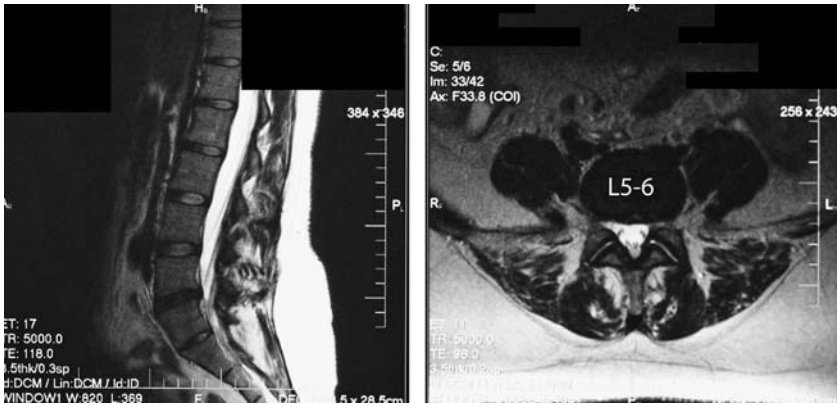


FIGURE 3. Sagittal (left) and axial (right) magnetic resonance imaging of a patient with lumbarization who was treated without complication using a lateral transpsoas approach with advanced neuromonitoring techniques. Note the orientation and shape of the psoas muscle resembles a normal L4-5 segment.

instrumentation is anterior to the lumbar plexus.[3,8,13] In the case where nerve trunks migrate substantially anterior over the lateral disc space, as indicated by the directionality of elicited responses during EMG stimulation or by free-run EMG responses, a sufficient area of the disc space may not be accessible to adequately perform the procedure.

In addition, if the posterior quadrant(s) of the disc space on lateral approach is (are) unapproachable due to the anterior migration of the lumbar plexus, docking more anterior to avoid nerves at the lower lumbar segments may approach the more posterior/lateral position of the iliac vessels inferior to their bifurcation.[12] In normal anatomy, the percentage of vertebral diameter obstructed by iliac vessels may be as high as 36.5% at L4-5 and 62.2% at L5-S1.[12] Reports in the literature of alterations in vascular anatomy, secondary to a transitional lumbosacral junction, show that such anomalies regularly complicate a safe anterior approach using anterior lumbar interbody fusion.[16,31] However, inferior to the aortic and caval bifurcation, the vessels travel lateral and more posterior, with respect to the anterior margin of the vertebral bodies, which could interfere with a safe lateral approach.[12] Vascular variations in lumbarization should be an additional element of observation, alongside the morphology of psoas major, on axial MRI. In all patients in this series, lumbarized and normal anatomy, no injuries to aorta, vena cava, or iliac vessels were observed.

TABLE 1. Review of Anatomic Studies on the Position of Nerve Trunks of the Lumbar Plexus With Respect to Their Location at the Disc Space for Performing a Lateral Transpsoas Approach to the Anterior Spine

						Motor Nerve Safe Zones					Converted Safe Zones*				
Author	Patients	Levels	Study Type	Measurement Type	Measurement Definition	L1-2	L2-3	L3-4	L4-5	L5-S1	L1-2	L2-3	L3-4	L4-5	L5-S1
Park et al[11]	10	40	Cadaver	Direct (mm)	Plexus distance from disc center (mm)	—	16.4	14.9	10.6	—	—	—	—	—	—
Regev et al[12]	100	247	In vivo	MRI (95% CI)	Percentage of disc space from anterior to nerve	89.4%	84.5%	83.6%	74.1%	51.0%	I-III	I-III	I-III	I-II	I-II
Uribe et al[13]	5	20	Cadaver	Direct (mm)	I-IV safe zones, nerves	I-III	I-III	I-III	I-II	—	I-III	I-III	I-III	I-II	—
Moro et al[10]	30	120	Cadaver	Direct (mm)	I-IV safe zones, nerves	—	I-III	I-II	I-II	None	—	I-III	I-II	I-II	None
Benglis et al[7]	3	12	Cadaver	Direct (%)	Percentage of disc space from anterior to nerve	100.0%	89.0%	82.0%	72.0%	—	I-IV	I-III	I-III	I-II	—
Hu et al[8]	48	192	In vivo	MRI (Zones)	I-IV safe zones, nerves	I-IV	I-III	I-II	I-II	—	I-IV	I-III	I-II	I-II	—

I, II, III, and IV refer to the quadrants of the spine on lateral view, where the anterior 25% is represented by quadrant I, the next 25% is quadrant II, the third 25% is quadrant III, and the posterior-most is quadrant IV.

*Where percentages of disc space available anterior to nerve trunks were reported, conservative conversions to quadrants, where if any percentage of a quadrant was occupied in the study by a nerve, the quadrant was not included as a safe zone.

CI indicates confidence interval; mm, millimeters; MRI, magnetic resonance imaging.

Several anatomic studies in normal individuals have been performed to describe the location of neural elements within the psoas muscle at the lumbar levels, to better characterize potential risks of the lateral transpsoas approach.[7–13] Despite some differences in methodology, the findings of 6 anatomic/morphometric studies consistently found that a majority of the lateral disc space at each of the levels from L1-2 to L4-5 is free of motor nerve roots and trunks.[7,8,10–13] Of those that reported percentages of the lateral disc space surface available anterior to motor nerve trunks at L4-5, 1 found an average of 74.1% and the other 72.0% of disc space without neural elements.[10,12] However, of the 2 reports that studied L5-S1, 1 found only 51.0% of the disc space[12] and the other found no quadrant to be free of motor nerve trunks.[10] These findings suggest that inferior to the L4-5 segment in normal individuals the migration of the lumbar trunks continues anteriorly.[10,12] A summary of the findings of these anatomic studies is shown in Table 1. Other reports have confirmed this migration, showing either functional L4-5 bony anatomy in individuals with normal L5-S1 distribution neural architecture,[22] or neural elements that vary significantly in lumbarization, mostly increasing the presence and anterior migration of nerve trunks at the lower lumbar segments,[21,25] though none have considered the clinical implications in performing the lateral transpsoas approach.

CONCLUSION

In patients with lumbarized sacra, a lateral transpsoas approach to the L5-6 disc space is made difficult by anterior migration of neural anatomy within the psoas muscle in a majority of patients with this relatively infrequent variation. Careful examination of the shape and position of the psoas muscle on axial MRI imaging reveals that a laterally detached, teardrop-shaped psoas at the L5-6 level indicates a relative contraindication to the approach. The mere presence of a lumbarized sacrum, however, does not present a contraindication for use at L5-6, as several patients with lumbarized sacra have been safely approached (Fig. 3). In addition, for these and all other cases using a lateral transpsoas approach, the use and adherence to advanced neuromonitoring techniques is essential to identify and mitigate the risk of neural injury.

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