Resolution of the more anteriorly positioned psoas muscle following correction of spinal sagittal alignment from spondylolisthesis: case report

Hasan R. Syed, MD,¹ Kurt Yaeger, MD,² and Faheem A. Sandhu, MD, PhD¹

¹Department of Neurosurgery, Medstar Georgetown University Hospital, Washington, DC; and ²Department of Neurosurgery, Mount Sinai Hospital, New York, New York

Several studies have described the radiographic, histological, and morphological changes to the paraspinal muscle in patients with chronic low-back pain due to degenerative diseases of the spine. Gross anatomical illustrations have shown that the psoas muscle lies lateral to the L4–5 vertebrae and subsequently thins and dissociates from the vertebral body at L5–S1 in a ventrolateral course. A “rising psoas” may influence the location of the lumbar plexus and result in transient neurological injury on lateral approach to the spine. It is postulated that axial back pain may be exacerbated by anatomical changes of paraspinal musculature as a direct result of degenerative spine conditions. To their knowledge, the authors present the first reported case of a more anteriorly positioned psoas muscle and its resolution following correction of spondylolisthesis in a 62-year-old woman. This case highlights the dynamic nature of degenerative spinal disorders and illustrates that psoas muscle position can be affected by sagittal balance. Normal anatomical positioning can be restored following correction of spinal alignment.

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KEY WORDS psoas; L4–5; lumbar; spondylolisthesis; lateral interbody fusion; sagittal balance

INTERBODY fusion in the lumbar spine is a well-established strategy for treating degenerative disc disease and correcting spinal sagittal instability.^{8,25} Compared with traditional posterolateral lumbar fusion, interbody approaches are associated with higher rates of fusion in patients with degenerative spondylolisthesis who exhibit preoperative instability.^{9,25,30} The array of surgical approaches for interbody fusions in the lumbar spine allow for diverse therapeutic options, depending on the patient's individual anatomy and pathophysiology.

A lateral approach to lumbar interbody fusion (also described as direct lateral interbody fusion or extreme lateral interbody fusion) allows for the minimally invasive placement of a large intervertebral graft, with minimal destruction of osteoligamentous processes and retraction of neural elements.^{5,6,15,24} Furthermore, the lateral approach obviates the need for an approach surgeon and avoids the potentially morbid complications associated with an anterior approach. With a lower risk of significant bleeding and less damage to structural tissues, procedures in which a lateral exposure is used lead to reduced operation time, less postoperative pain, and shorter hospital stay.^{6,10,20,24}

One potential complication of the transpsoas lateral interbody approach results from the surgical proximity to the psoas muscle and lumbar plexus, specifically at L4–5.^{3,10,12,21,23} It has been reported that injury due to intraoperative traction, mechanical disruption, or thermal injury may contribute to postoperative iliopsoas and quadriceps muscle weakness or groin and thigh paresthesias in 2%–30% of cases, a majority of which resolve over time without additional intervention.^{4,23,24} Several anatomical studies have elucidated safer zones through which to approach the intervertebral space from a lateral perspective in an attempt to minimize lumbar plexus injury.^{1,2,11–13,29} Furthermore, intraoperative electromyography (EMG) and somatosensory evoked potentials are often used to avoid inadvertent nerve damage during the initial surgical approach.^{16,34,35,37}

The psoas muscle originates from the transverse processes of T12–L5, courses ventrolaterally into the pelvis, and inserts into the lesser trochanter of the femur. The psoas muscle belly diameter is largest around L5–S1, and thins substantially as it enters the pelvis, where it dissociates from the vertebral bodies prior to its insertion point

ABBREVIATIONS CSA = cross-sectional area; EMG = electromyography; PLIF = posterior lumbar interbody fusion.

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FIG. 1. Standing lateral radiograph showing a Grade 2 L4–5 spondylolisthesis (arrow).

caudally. Although anatomical studies have illustrated relatively safe corridors for lateral transpsoas approaches, these typical surgical strategies may be less valuable in patients with variable or asymmetrical paraspinal musculature, as has been associated with degenerative spinal diseases.^{17–19,31,33,39} A variable psoas muscle anatomy is especially concerning because of the intrinsic relationship between the muscle belly and the lumbar plexus.

The previously reported “rising psoas sign” is a radiological finding in which the psoas muscle is located ventral to the vertebral body, rather than lateral, and may indicate an increased risk of nerve injury with a lateral surgical approach, due to ventral displacement of the lumbar plexus.³⁸ This finding was initially observed retrospectively on MRI in 3 patients undergoing lateral interbody fusion procedures for L4–5 spondylolisthesis whose surgeries were aborted because of robust EMG signals during the initial approach. To our knowledge, we present the first reported case of anatomical resolution of a more anteriorly displaced psoas muscle following correction of spondylolisthesis.

FIG. 2. Sagittal (A) and axial (B) MR images showing a Grade 2 L4–5 spondylolisthesis. The psoas muscle can be seen rising away from vertebral body bilaterally (arrows).

Case Report

History and Examination

A 62-year-old woman presented with several months of progressively worsening low-back pain, with radiation down the right leg that failed to improve with conservative measures. Neurological examination demonstrated mild right extensor hallucis longus weakness (Grade 4+/5). Imaging was significant for Grade 2 spondylolisthesis at L4–5 on lateral radiography (Fig. 1), as well as a broad disc protrusion at L4–5 causing foraminal stenosis and moderate spinal canal compromise on MRI. Bilateral psoas muscles rising ventrally from the vertebral bodies were also noted on preoperative MRI (Fig. 2).

Operation and Technique

The patient underwent an L4–5 lateral interbody fusion (Ravine Lateral Access System, K2M), followed by percutaneous placement of pedicle screws at L4–5 (Romeo 2 K-Wireless, Spineart). Neuromonitoring, including EMG recordings, were planned, and the needles were inserted in the usual fashion. This included monitoring L-2 and L-3 (the rectus femoris muscle), L-3 and L-4 (the vastus medialis muscle), L-4 (the anterior tibialis muscle), L-5 and S-1 (peroneus longus), and S-1 and S-2 (gastrocnemius) for all cases. Baseline measures were obtained, and stimulation was provided multiple times during decompression and insertion of the lateral device. There were no intraoperative complications.

The patient was placed in the standard lateral decubitus position with her left side up. An axillary roll was placed under the right axilla, and all pressure points were padded. The chest and legs were secured to the operating table with tape. The table was subsequently broken at the level of the iliac crest to provide greater access to the level of interest. Fluoroscopy was used to localize the L4–5 level (Fig. 3A). After the area was prepared and draped in the usual fashion, a 2.5-cm skin incision directly over the disc space of interest was made, followed by dissection of the subcutaneous soft tissue. Then, the oblique muscles were split

FIG. 3. Intraoperative lateral fluoroscopic images showing access to the L4–5 disc space. An incision is made, centered at L4–5 level (A). The first dilator is inserted under the guidance of neuromonitoring and docked near the midpoint of the disc space (B). The Ravine Lateral Access Retractor is docked at the center of the L4–5 disc space (C). Final fluoroscopic image showing the dual blade retractor with rigid fixation to the spine and insertion of the lateral interbody cage (D).

bluntly, and the retroperitoneal space was entered. Under direct visualization, the preperitoneal fat was swept forward, uncovering the psoas muscle. At this point, the first dilator was placed on the surface of the psoas muscle and passed through using continuous neuromonitoring with the aim of docking in the midpoint of the disc space (Fig. 3B). No EMG activity was noted, and a guidewire was placed through the dilator to secure the position to the disc space. Two sequential oblong dissectors were then passed over the guidewire in line with the psoas muscle fibers and rotated circumferentially to help release the psoas muscle from the annulus of the disc. Continuous EMG monitoring stimulated throughout the base of both dissectors was performed to ensure protection of the lumbar plexus. The Ravine Lateral Access retractor was passed over the guidewire in line with the psoas muscle fibers, turned 90°, expended, and secured to the vertebral bodies with fixation screws. Proper positioning of the retractor was confirmed on fluoroscopic imaging (Fig. 3C). Direct monopolar stimulation of the exposed disc area with a minimal stimulation threshold further confirmed a safe working zone. A thorough discectomy was then performed in the traditional manner, and the contralateral annulus was released. After appropriate endplate preparation, an interbody cage was then packed with bone graft material (bone morphogenetic protein; Infuse, Medtronic) and inserted into the disc space. Satisfactory placement of the cage was confirmed using anteroposterior and lateral fluoroscopy (Fig. 3D). The working channel was then removed, and the incision was closed in the standard manner.

FIG. 4. Postoperative anteroposterior (A) and lateral (B) radiographs, demonstrating L4–5 lateral interbody fusion with percutaneous pedicle screws.

Postoperative Course

The patient recovered well from her procedure, with immediate resolution of her radicular symptoms. She was discharged from the hospital on postoperative Day 2. She experienced complete resolution of her back and leg symptoms by 3 months. Postoperative radiography demonstrated anatomical reduction of L4–5 spondylolisthesis (Fig. 4). Follow-up MR imaging at 3 months showed resolution of foraminal and central canal stenosis caused by indirect decompression. Upon review of the paraspinal musculature, the psoas muscles were observed in their anatomical position, lateral to the lumbar vertebral bodies, in contrast to their preoperative ventral location (Fig. 5).

Discussion

Minimally invasive lumbar interbody fusion is a safe, effective alternative to open methods of lumbar fusion, and is currently used to treat a wide variety of lumbar spinal pathology, including degenerative disc disease, spondylolisthesis, and scoliosis.^{9,15,20,32} Clinical outcomes following interbody fusion are comparable to traditional procedures, yet these minimally invasive operations allow for smaller incisions and minimal muscle dissection, leading to less postoperative pain, fewer surgical site infections, and decreased muscle denervation.⁶

Several approaches are commonly used to access the intervertebral space, each with varying indications depending on individual patient anatomy and pathology, as well as surgeon experience and preference. The lateral approach, commonly performed as either the direct or ex-

FIG. 5. Comparison of preoperative sagittal (A) and axial (B) MR images and follow-up postoperative sagittal (C) and axial (D) MR images demonstrating a reduction of spondylolisthesis. The psoas muscle can be seen lying lateral to the vertebra at L4–5 in its normally described anatomical position in contrast to the preoperative images (arrows).

treme lateral interbody fusion, allows for the placement of a large intervertebral graft with relative preservation of spinal osteoligamentous integrity.^{5,15,24,27} By using a lateral, retroperitoneal, transpsoas trajectory, the anterior and posterior spinal elements are conserved. One significant consequence of traversing this anatomical corridor is potential injury to nerves of the lumbar plexus, which lies ventral to the psoas muscle most significantly at L4–5.¹ Iatrogenic lumbar nerve injury, caused by initial dilator placement or subsequent manipulation of the retractor, may contribute to motor weakness in the hip flexors or knee extensors, or sensory deficits, including paresthesias, numbness, or radicular pain, throughout the thigh. Although complication rates vary depending on the individual study, between 0.7% and 54.9% for muscle weakness and 12% and 25% for sensory deficits, most postoperative deficits are transitory, resolving within weeks to months.^{6,20,21,32}

Since the course of the lumbar plexus is inexorably linked to psoas muscle anatomy, any variation to the paraspinal musculature may lead to inadvertent nerve injury, despite utilizing commonly practiced surgical approaches. Several studies have investigated the relationship between anatomical variations in paraspinal musculature and spinal balance in patients with degenerative lumbosacral diseases, including scoliosis and spondylolisthesis.

The role of paraspinal muscle asymmetry as a cause of, or a compensatory mechanism for, degenerative spinal imbalance remains incompletely clarified. In the case

of degenerative scoliosis, progressive coronal instability may be theorized to cause stretching and thinning of the paraspinal muscles on the convex side, and consequent shortening and thickening of the concave musculature. However, in a retrospective study of the cross-sectional area (CSA) of paravertebral musculature in patients with degenerative scoliosis, Kim and coauthors observed that the CSAs of the psoas and multifidus muscles were significantly greater on the convex side of the deformity, compared with the concave side, whereas the degree of muscle atrophy, as indicated by fatty infiltration, was consistent bilaterally.¹⁹ These findings allude to compensatory paraspinal muscle hypertrophy as a consequence of progressive coronal imbalance, a conclusion that fits with the long-standing theory that the psoas and paraspinal muscles are dynamic stabilizers of the spinal column.^{26,28} Another retrospective cohort of patients with degenerative lumbar scoliosis and spinal stenosis was similarly observed by Shafaq et al. to have asymmetric paravertebral muscles, with smaller CSAs and greater fatty infiltration in muscles along the concavity.³³ These atrophic concave muscles appeared to be histologically denervated, with decreased fiber sizes and fewer nuclei, and suggest a possible role of lumbar radiculopathy, as a consequence of spinal imbalance, in the mechanism of asymmetrical paraspinal muscle degeneration. This pathophysiological response has been shown to occur similarly in patients with unilateral back pain and monosegmental degenerative disc disease, in whom the paraspinal muscle CSA is significantly smaller on the symptomatic side.³¹ The fact that this finding can occur without structural deformity (i.e., scoliosis or spondylolisthesis), indicates the secondary, rather than causative, nature of asymmetrical muscle atrophy on spinal imbalance.

Paraspinal muscle asymmetry has also been investigated in patients with spinal sagittal imbalance. When comparing 108 patients with either lumbar degenerative kyphosis or chronic low-back pain, Kang and colleagues observed a significant reduction in the cross-sectional area of the psoas, erector spinae, and multifidus in patients with a kyphotic deformity.¹⁷ Furthermore, the paraspinal musculature in patients with structural disease was associated with a greater degree of fatty infiltration, an indicator of severe muscular atrophy, occurring in 54% of patients (compared with 7% of patients without structural deformity). These data were echoed by a comparable study by Lee and coauthors, again illustrating a decreased CSA and greater fat infiltration of the paraspinal muscles in patients with degenerative lumbar kyphosis than in healthy controls.²² Hyun et al. observed similar atrophic muscular changes, both in terms of reduced CSA and enhanced fatty infiltration in patients with degenerative lumbar kyphosis, most significantly within the multifidus and erector spinae at the levels of L-4 and L-5.¹⁴ The selective atrophy of these posterior muscle groups in association with lumbar kyphosis highlights the importance of paraspinal muscles in maintaining sagittal balance. Wang and colleagues examined 149 patients with degenerative spondylolisthesis and similarly observed a greater degree of multifidus muscle atrophy compared with controls.³⁹ In contrast, however, the erector spinae muscles were significantly larger in

patients with sagittal imbalance than in patients without deformity, possibly representing a compensatory mechanism to maintain sagittal stability.

In the present case, preoperative images in a 62-year-old patient with L4–5 spondylolisthesis and progressive low-back pain highlighted the so-called “rising psoas sign,” an imaging finding that has been associated with intraoperative EMG disturbances, and a theoretical risk of nerve damage when proceeding with a lateral transpsoas lumbar interbody fusion procedure. We believe that the risk of nerve injury can be mitigated by using the aforementioned technique. The Ravine Lateral Access System uses dual flat blades instead of the standard tubular retractor with 3 channels in the blades to help with ideal positioning of the retractor over the guidewire (Fig. 6). For example, the guidewire can be placed very anteriorly on the disc space (just behind the anterior longitudinal ligament), and, using the anterior-most channel on the retractor blade, it can still provide excellent exposure of the disc space of interest. The advantages of this technique include a reproducible working corridor at the level of interest that respects psoas muscle anatomy. Three critical steps help provide the surgeon with the safest and most optimal positioning for the retractor system. First, the psoas muscle is split longitudinally, which is in line with the direction of the muscle fibers, using serial oblong dissectors and the dual blades of the retractor. Second, neuromonitoring with EMG during initial dilation and subsequent dissection steps helps avoid the lumbar plexus and safely place the retractor. Unlike tubular retractor systems that need to be placed more posteriorly on the disc space to allow adequate room to open the retractor to complete the discectomy, the Ravine dual blade system may be deployed after placing the initial guidewire anywhere on the disc space that is free and clear of the lumbar plexus. The nerve and muscle are swept away by the retractor to provide a safe working corridor. Finally, after placement of the dual-blade retractor system over the level of interest and opening it to expose the disc space, the position is maintained by affixing the retractor to the vertebral bodies with screws. Then, direct monopolar stimulation with minimal triggered EMG activity allows further confirmation of a safe entry zone. Consequently, despite the abnormal psoas anatomy, the rationale to pursue the lateral transpsoas approach in this case was based on our experience that the risk of nerve injury is low with this retractor system. After undergoing correction of sagittal imbalance via an L4–5 lateral interbody fusion and transcuteaneous pedicle screw placement at L-4 and L-5 bilaterally, the patient’s symptoms resolved, and the aberrant psoas muscle anatomy returned to a normal position directly lateral to the spinal column.

Patients with degenerative spinal deformity who have undergone corrective surgery may experience postoperative changes in paravertebral musculature. In a comparison of minimally invasive versus conventional, open posterior interbody fusion, atrophy of the multifidus muscle was observed in all patients, as indicated by the muscle CSAs and T2 signal intensity (fatty infiltration).⁷ However, less multifidus atrophy occurred in patients undergoing minimally invasive posterior lumbar interbody fusion (PLIF). These data were confirmed by a similar study that com-

FIG. 6. The Ravine Lateral Access Retractor uses dual flat blades with options for a third and fourth blade. Three channels in each blade allow for adjustment on retractor position depending on the initial docking point. The advantages of this system include dissection and retraction of the psoas muscle in a more anatomical manner and optimum adaptability to the patient’s anatomy. Copyright K2M. Published with permission. Figure is available in color online only.

pared patients undergoing open PLIF versus a mini-open PLIF, in which the more minimally invasive procedure allowed better preservation of the multifidus muscle.³⁶

Conclusions

We describe the first case in the literature of a patient with spinal sagittal deformity and aberrant paravertebral musculature on preoperative imaging who experienced resolution of both symptoms and anomalous musculature after correction of the spondylolisthesis. This observation highlights the association between the psoas and other paravertebral muscles and spinal balance. Whether a causative or compensatory mechanism, this relationship remains to be clarified. This case highlights the dynamic nature of degenerative spinal disorders and illustrates that psoas muscle position can be affected by sagittal balance. Normal anatomical positioning can be restored following correction of spinal alignment.

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Disclosures

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Author Contributions

Conception and design: Sandhu, Syed. Acquisition of data: Sandhu, Syed. Analysis and interpretation of data: Sandhu, Syed. Drafting the article: all authors. Critically revising the article: Sandhu, Syed. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Sandhu. Administrative/technical/material support: Sandhu, Syed. Study supervision: Sandhu, Syed.

Correspondence

Faheem A. Sandhu, Department of Neurosurgery, Medstar Georgetown University Hospital, Pasquerilla Healthcare Center, Seventh Fl., 3800 Reservoir Rd. NW, Washington, DC 20007. email: fasandhu@aol.com.