Anterior Longitudinal Ligament Release From the Minimally Invasive Lateral Retroperitoneal Transpsoas Approach: Technical Note

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Received, April 23, 2015.
Accepted, December 2, 2015.

BACKGROUND: The technique for minimally invasive anterior longitudinal ligament release is a major advancement in lateral access surgery. This method provides hypermobility of lumbar segments to allow for aggressive lordosis restoration while maintaining the benefits of indirect decompression and minimally invasive access.
OBJECTIVE: To provide video demonstration of the lateral retroperitoneal transpsoas approach with anterior longitudinal ligament sectioning.
METHODS: A detailed surgical technique of the minimally invasive anterior column release is described and illustrated in an elderly patient with adult spinal deformity and low back pain (visual analog scale, 8 of 10) refractory to conservative measures. The 3-foot standing radiographs demonstrated a lumbar lordosis of 54.4°, pelvic incidence of 63.7°, and pelvic tilt of 17.5°. Computed tomography and magnetic resonance imaging showed generalized lumbar spondylosis and degenerative disc changes from L2 to L5.
RESULTS: The patient underwent a multilevel minimally invasive deformity correction with an anterior longitudinal ligament release at the L3/L4 level through the lateral retroperitoneal transpsoas approach. Lumbar lordosis increased from 54.4° to 77° with a global improvement in sagittal vertical axis from 4.37 cm to 0 cm. Total blood loss was less than 25 mL, and there were no major neurological or vascular complications.
CONCLUSION: The anterior longitudinal ligament release using the minimally invasive lateral approach allows for deformity correction without the morbidity and blood loss encountered by traditional open posterior approaches. However, the risk of major vascular/visceral complication warrants only experts in minimally invasive lateral surgery to attempt this technique.

KEY WORDS: Anterior longitudinal ligament, Deformity, Lateral access, Lordosis, Minimally invasive, Scoliosis

Operative Neurosurgery 0:1–8, 2016 DOI: 10.1227/NEU.0000000000001203

Restoration of spinopelvic harmony in adult degenerative deformity is a complex and evolving practice with multiple tools for evaluation and correction. Traditional methods are well established and include posterior column osteotomies. These require aggressive, wide posterior dissection, and although they are time tested, they may be associated with increased morbidity from excessive exposure and significant blood loss with perioperative and postoperative complications ranging from 15.5% to 80%.[1-11]

To circumvent some of these complications, minimally invasive surgery (MIS) techniques have been applied to address spinal deformities.[12-16] Specifically, in short-segment procedures, MIS techniques have resulted in less blood loss, lower infection rates, and faster postoperative mobilization.[13] Extrapolating these benefits to larger constructs could greatly enhance patient outcome. The minimally invasive lateral retroperitoneal transpsoas approach has been heavily investigated as part of this paradigm and been used by multiple groups to

ABBREVIATIONS: ACR, anterior column release; **ALL,** anterior longitudinal ligament; **AP,** anterior-posterior; **EMG,** electromyogram; **MIS,** minimally invasive surgery; **tEMG,** triggered electromyogram

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augment their treatment strategies for adult spinal deformity and degenerative scoliosis.[13,14,17-25]

The lateral retroperitoneal transpsoas approach offers unique access to the anterior spinal column. This access provides a platform for a more substantial correction of coronal, sagittal, and rotary deformities when compared with traditional posterior techniques.[24,26] Recent investigations have demonstrated the feasibility of a new technique of lateral access supplemented with anterior longitudinal ligament (ALL) release and placement of hyperlordotic interbody cages.[9,14,20-22,24] Previously, segmental lordosis was limited by the laxity of the anterior column. However, sectioning of the ALL allows for the vertebrae to *fish mouth* open, which allows for a significant amount of lordosis correction while maintaining indirect decompression that is only limited by the shingling effects of the posterior elements.

This technique has been shown to increase segmental lordosis by 12° to 13° per level (in both cadaveric and clinic studies) without disruption of posterior elements.[9,21,22,24,27] In comparison, a Smith-Peterson osteotomy only has an expected lumbar lordosis correction of 10° per level.[9-11,27-30] Furthermore, an ALL release complemented with a Ponte osteotomy or Smith-Peterson osteotomy has the potential to achieve the segmental lordosis of a pedicle subtraction osteotomy without the blood loss and spinal shortening nature of the procedure.

In this technical note, the authors describe a minimally invasive technique that can be used in select patients in lieu of the traditional posterior techniques. We describe the lateral retroperitoneal transpsoas approach with anterior longitudinal ligament sectioning known as the anterior column release (ACR). This technique is extremely advanced and should only be performed by surgeons who are experts in both lateral access and deformity surgery.

CASE ILLUSTRATION

Our patient is a 67-year-old woman without significant comorbidity with the primary complaint of lower back pain intermittently radiating to the bilateral posterior thighs. She had no prior surgical intervention. Multiple modalities of conservative therapy have failed for this patient, including at least 6 weeks of physical therapy and pain management for >1 year. Pain is divided into 90% lower back pain and 10% leg pain. Computed tomography (CT) and magnetic resonance imaging revealed generalized lumbar spondylosis with focal collapse and degenerative disc changes from L2 to L5, with areas of lateral recess stenosis. The preoperative spinal parameters were as follows: coronal Cobb angle of 31.0°, sagittal vertical axis of 4.37 cm, lumbar lordosis of 54.4°, pelvic incidence of 63.7°, and pelvic tilt of 17.5°. Preoperative Visual Analog Scale (back/leg) and Oswestry Disability Index scores were 8 back, 5 leg, and 34%, respectively.

The patient subsequently underwent L2-L5 minimally invasive lateral lumbar interbody fusion with L3-L4 anterior column reconstruction, and L2-L5 instrumentation with percutaneous pedicle screws. The patient was ambulatory on postoperative day 2. Minor postoperative complications included ileus and right lateral thigh numbness, which completely resolved. There was no sympathetic dysfunction or major vascular injury.

At 3 months follow-up, postoperative spinal parameters were as follows: coronal Cobb 7.2°, sagittal vertical axis 0 cm, lumbar lordosis 77°, pelvic incidence 66.7°, and pelvic tilt 17.7°.Visual Analog Scale (back/leg) and Oswestry Disability Index scores improved to 4 back, 4 leg, and 24%, respectively (Figures 1-6).

Surgical Technique

This procedure is highly dependent on anterior-posterior (AP), lateral fluoroscopy, and patient positioning. Fluoroscopic guidance is essential for a safe and efficient procedure because it compensates for the reduced visual and tactile cues inherent with minimally invasive approaches to the spine. Furthermore, to help prevent lumbar plexus injury, directional-triggered electromyogram (tEMG) is used to assist placement of the retractor anterior to the lumbar plexus. To facilitate this, electromyogram (EMG) leads are placed in the lower extremities of the patient first, before positioning (see **Video**, **Supplemental Digital Content**, https://youtu.be/oBiKTQPXKns).

The patient is positioned in the lateral decubitus position in the same manner used for a basic lateral transpsoas approach. The table is adjusted accordingly to obtain true AP and lateral views of the desired disc space. With a true lateral view, both end plates are clearly shown, and a vacuum phenomenon will become evident as seen in the video (see **Video**, **Supplemental Digital Content**, https://youtu.be/oBiKTQPXKns). In a true AP view, the spinous process should be equidistant from the pedicles. A previous laminectomy makes this difficult and requires fastidious caution. Minor discrepancies can have exaggerated effects and compromise the surgeon's ability to maintain an appropriate trajectory.

The desired disc space is marked from the lateral view with an approximate 4-cm line along the disc space and a vertical line denoting working zone 3 or the posterior third of the disc space.[31] (For multilevel procedures, our institution will mark each disc level and then create a vertical incision for better cosmesis). A 4-cm horizontal skin incision is made along the disc space mark, and monopolar cautery is used to dissect the adipose tissue down to the external oblique fascia. The fascia is opened with monopolar cautery and the muscle fibers are dissected bluntly with 2 Kelly instruments. It is imperative to maintain a strict vertical trajectory during blunt dissection because a fading anterior can increase your risk of violating the peritoneal cavity. The first muscular layer encountered is the external oblique, followed by the internal oblique, and finally the transversalis muscle and fascia (each with distinctly oriented fibers).

Bright adipose tissue will then come into view denoting the retroperitoneal space. If this is not seen, then the patient may have had previous retroperitoneal surgery, and the surgeon should ensure that the trajectory is accurate with lateral fluoroscopy. Next, blunt finger dissection is used to further dilate the abdominal

FIGURE 1. *Preoperative midsagittal computed tomographic (CT) scan.*

FIGURE 2. *Preoperative coronal computed tomographic (CT) scan.*

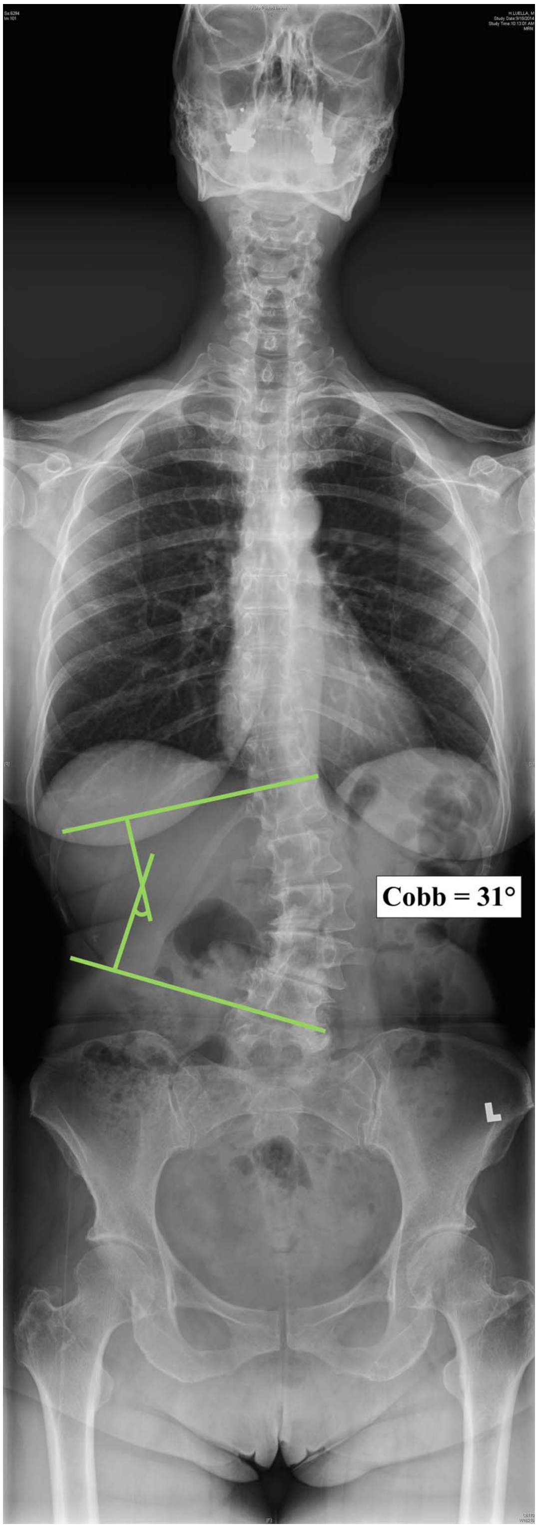

FIGURE 3. *Preoperative 36-inch anterior-posterior (AP) radiograph with spinal parameters. Color version available online only.*

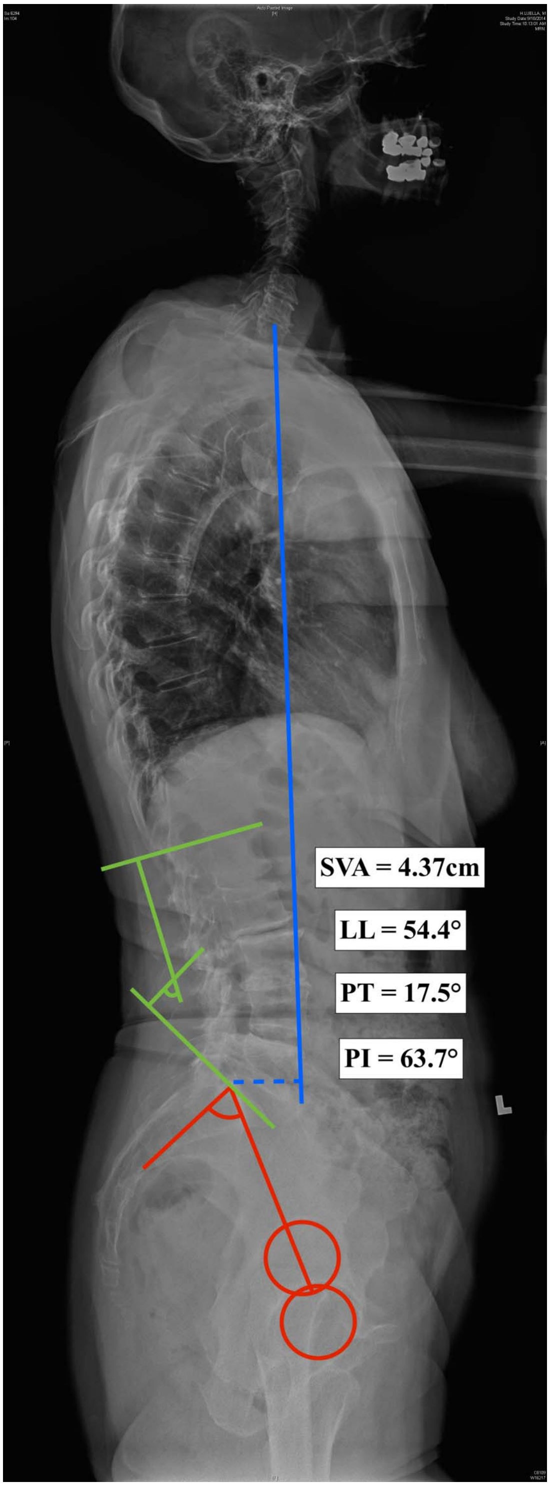

FIGURE 4. *Preoperative 36-inch lateral radiograph with spinal parameters. LL, lumbar lordosis; PI, pelvic incidence; PT, pelvic tilt; SVA, sagittal vertical axis. Color version available online only.*

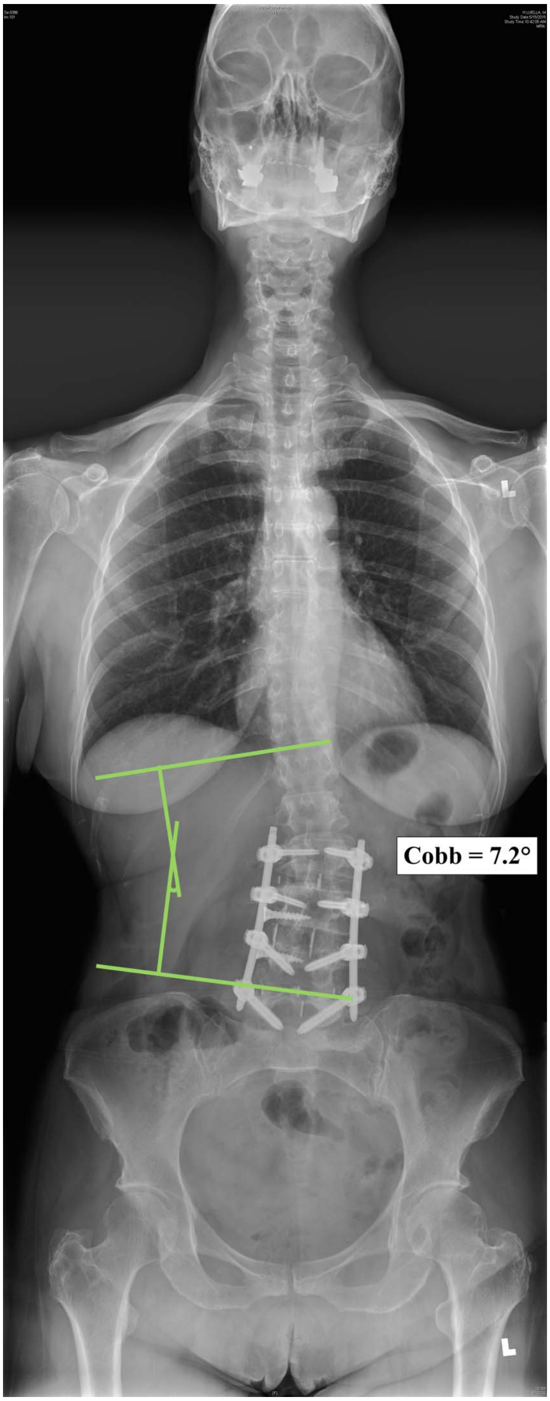

FIGURE 5. *Postoperative 36-inch anterior-posterior (AP) radiograph with spinal parameters. Color version available online only.*

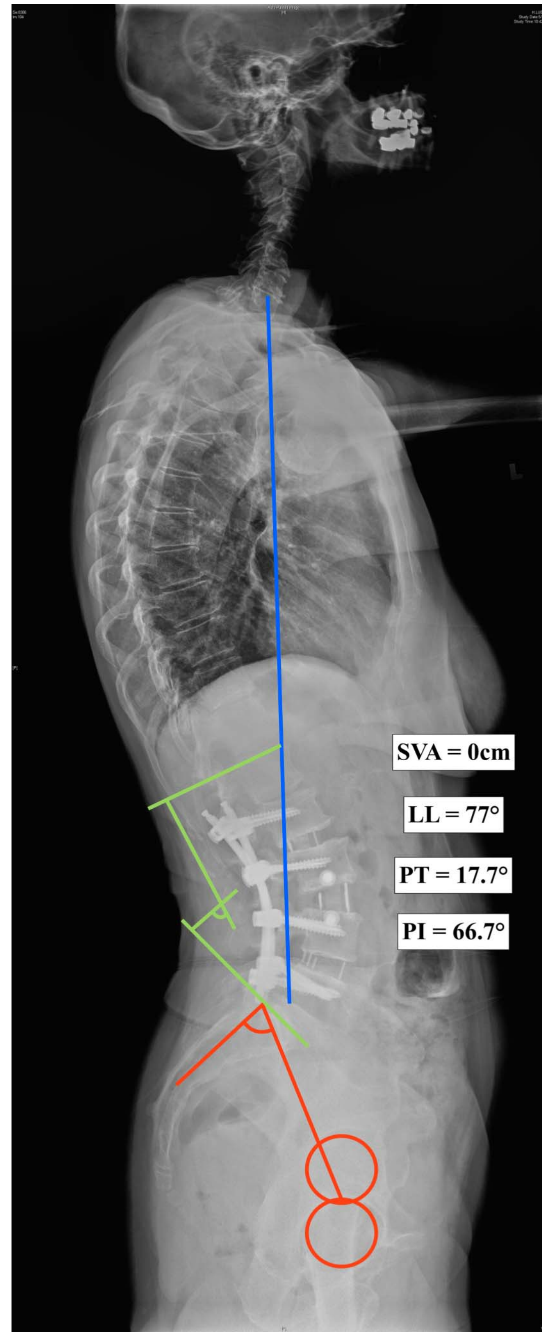

FIGURE 6. *Postoperative 36-inch lateral radiograph with spinal parameters. LL, lumbar lordosis; PI, pelvic incidence; PT, pelvic tilt; SVA, sagittal vertical axis. Color version available online only.*

musculature and palpate the posteriorly oriented transverse process and quadratus lumborum. The finger is then swept anteriorly to feel the round psoas muscle.

After a generous path has been created with finger dilation, the first dilator is positioned directly on the disc space in working zone 3.[31] When placing any instrument into the retroperitoneal space, the surgeon's finger should always position his finger anterior to the instrument and guide it down to the psoas muscle. This prevents peritoneal contents from getting trapped under the dilators/retractor potentially causing visceral injury. The first dilator is only positioned on top of the psoas at this point (not through it). Lateral fluoroscopy is used to confirm the appropriate location on the disc space (typically posterior third or working zone 3). The dilator is spun directly downward through the psoas muscle onto the disc space. (Do not sweep the dilator through the psoas because this can denervate the psoas muscle or cause a lumbar plexus injury). The dilator position is checked once again with lateral fluoroscopy. Minor movements within the psoas muscle in the craniocaudal direction are acceptable, but movements in the AP direction require the dilator to be completely withdrawn from the psoas muscle and then reinserted in the desired position (intrapsoas adjustments in the AP direction simply move the psoas and lumbar plexus with the dilator. The goal is to be in an intrapsoas position that is anterior to the lumbar plexus). Use the tactile feedback of your finger to ensure that the dilator has split the psoas muscle rather than just compressing it. Once the desired intrapsoas location is confirmed with lateral fluoroscopy, directional-triggered EMG is used to determine the location of the femoral nerve in relation to the dilator. The optimal position is anterior to the lumbar plexus so that the opening of the retractor blades does not distract the lumbar plexus from its origin. Discrete threshold tEMG recordings of the lower extremities are taken as the dilator is rotated 360° within the psoas muscle providing real-time feedback for both the relative position and approximate distance of the dilator with respect to the femoral nerve (see as follows, and see dilator placement in **Video**, **Supplemental Digital Content**, https://youtu.be/oBiKTQPXKns).

Triggered EMG recordings are measured by the lowest electrical threshold necessary to depolarize a motor unit and elicit a downstream response.[32] Thus, lower thresholds (tEMG recordings) imply closer proximity of motor nerves to the dilator and higher thresholds imply increased distance from the dilator. In general, thresholds >11 mA suggest a safe distance, responses between 5 and 10 mA suggest close proximity to the nerve, and recordings <5 mA indicate direct contact with the dilator.[32] The most important data are not so much the numbers, but the overall trend, specifically the trend from anterior to posterior. The optimal trend is high numbers anteriorly (denoting increased distance from the nerves) and low numbers posteriorly, which suggests the retractor/dilator is anterior to the lumbar plexus.

The guidewire is then gently tapped into the disc space to hold the dilator in position. With each sequential dilation, directional tEMG is used to determine the proximity of the femoral nerve. The retractor is slid over the last dilator and connected to the surgical bed arm and locked into position. After visual and electrical inspection of the posterior dilator blades (to ensure that lumbar nerves are not in the field), a shim is placed down the posterior blade into the disc space to prevent posterior migration of the retractor into the spinal canal or femoral nerve anterior migration. The retractor blades are opened anteriorly and laterally by approximately 16×22 to 26 mm, respectively.

An annulotomy is performed and a Cobb is slid down each end plate to free the contralateral annulus under AP fluoroscopy (see **Video**, **Supplemental Digital Content**, https://youtu.be/oBiKTQPXKns). A box-cutter disc shaving instrument is used to perform the discectomy and further disrupt the contralateral annulus. This should be performed under AP fluoroscopy to prevent end plate damage. The disc space is then further prepared with angled curettes and a rasp.

Next, the anterior longitudinal ligament is identified. This is shown with the endoscopic view in the video (see **Video**, **Supplemental Digital Content**, https://youtu.be/oBiKTQPXKns). Special care must be taken to ensure that the correct plane is entered. Deukmedjian et al[22] show a detailed schematic of the ligamental anatomy in their cadaveric feasibility study. AP fluoroscopy should be used generously because major vessel damage can occur at this stage. A recent article outlined major vascular injury that ensued from a standard lateral approach (not an ACR) that ultimately progressed to a fatality.[33] The dissector should be placed in the plane just anterior to the ligament and posterior to the sympathetic autonomic plexus and major vessels. As can be seen in the video (see **Video**, **Supplemental Digital Content**, https://youtu.be/oBiKTQPXKns), this anatomical plane is difficult to visualize. Therefore, the dissector is placed directly on the anterior aspect of the ALL with slight posterior pressure to ensure that the correct plane is entered. The dissector is then advanced while applying this slight posterior pressure against the ALL. The surgeon should use tactile response and encounter very little resistance as the dissector is advanced. We do not recommend advancement across the entire vertebral body for safety reasons.

The next step is sectioning of the ALL. Bipolar cautery is used to coagulate the ligament because it can sometimes bleed. An annulotomy blade is slid down the dissector and cuts are made from an anterior to posterior direction, never cutting in a downward manner. Once again, for safety reasons, only the first two-thirds of the ligament need to be sectioned. The remaining component is broken with a distractor. The distractor is inserted into the disc space under fluoroscopic guidance and opened in a gradual manner to break the final third of the ligament.

A hyperlordotic cage is trialed and then placed into the disc space under lateral fluoroscopic guidance, preventing anterior displacement. Unicortical lateral screws are used to ensure that there is no cage migration. Hemostasis is achieved by using hemostatic agents and pressure. The retractor is then removed under direct vision to ensure there are no areas of significant hemorrhage. The psoas and abdominal muscles should easily collapse back into position as the retractor is withdrawn. Final AP and lateral fluoroscopic images are obtained to ensure proper graft alignment. The abdominal fascia is closed with interrupted 0 sutures (prevents abdominal wall herniation) and the subcutaneous layer is closed with inverted 3-0 sutures followed by a 4-0 subcuticular suture.

The Role of ACR and Our Clinical Experience

In this study, we outline the technique for minimally invasive ACR in deformity surgery. The role of this technique, however, or other MIS procedures in adult spinal deformity has yet to be defined and is beyond the scope of this article. Because this is a relatively new technique, we can only rely on our own clinical experience and evaluation. In 2012, our group reported the first case study regarding this method.[21,22] In 2014, Manwaring et al[27] published our first 9 cases demonstrating the utility of ACR in augmenting lumbar lordosis and sagittal vertical axis. We have completed a total of 53 cases at our institution with satisfactory results, without any major complications. The complete analysis of these results and complications is currently in the process of publication.

For this case presentation, we present a patient with mild sagittal imbalance and clinical symptoms refractory to conservative measures with a primary complaint of axial back pain. The authors' initial clinical experience in MIS deformity correction without the use of ACR in patients with mild sagittal imbalance has led to suboptimal spinopelvic parameters and subsequent poorer clinical outcomes.[20] Therefore, we have supplemented this technique in patients whom we believed would have shortcomings if we did not additionally perform ACR.

CONCLUSION

This case illustrates a technically challenging, but feasible, technique for MIS lateral segmental lordosis restoration. This procedure was performed with no minor or major complications and a positive patient outcome. The minimally invasive lateral retroperitoneal transpsoas approach for ALL section may provide an alternative option to anterior lumbar interbody fusions and posterior osteotomies in select deformity cases. The extent of its use has yet to be determined and will be better understood as deformity and MIS experts gain experience through further clinical application.

Disclosures

No funding was received for this study. Dr Uribe is a paid consultant and receives research grants from NuVasive, LLC. The authors have no personal, financial, or institutional interest in any of the drugs, materials, or devices described in this article.

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