INTERNATIONAL JOURNAL of SPINE SURGERY

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Int J Spine Surg 2022, 16 (S1) S17-S25
doi: https://doi.org/10.14444/8232
http://ijssurgery.com/content/16/S1/S17

The International Journal of Spine Surgery
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Aurora, IL 60504, Phone: +1-630-375-1432

International Journal of Spine Surgery, Vol. 16, No. S1, 2022, pp. S17–S25
https://doi.org/10.14444/8232

Single-Position Anterior Column Lateral Lumbar Interbody Fusion

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ABSTRACT

Lateral lumbar fusion is a commonly used spinal fusion technique that allows for indirect neural decompression while correcting sagittal malalignment. The lateral position has evolved to include placement of percutaneous pedicle screw fixation, anterior longitudinal ligament release, and approach the L5-S1 segment. This review article focuses on the anatomy and technique of the single-position anterior column spinal fusion and highlights the recent trends, outcomes, and future directions for the approach.

Lumbar Spine

Keywords: LLIF, lumbar fusion, spine surgery

INTRODUCTION

In the ever-changing landscape of identifying optimal approaches to the lumbar spine, lateral access surgery has gained popularity since its introduction in the early 2000s.[1] Accessing the spine from the lateral approach, initially thought of as the direct lateral or transpsoas lumbar interbody fusion (LLIF), offers various advantages. First, avoidance of dissection through the paraspinal muscles minimizes soft tissue trauma and postoperative pain and may hasten recovery.[2] Furthermore, access to the anterior column of the spine allows for interbody support that biomechanically allows for increased surface area for arthrodesis and load sharing when compared to the posterior fusion approaches.[2,3]

In cases of revision surgery, accessing the spine from the lateral approach allows the surgeon to forgo dissection through posterior scar tissue and permits indirect decompression without direct manipulation of the thecal sac or exiting nerve roots. The lateral transpsoas approach has evolved to include patients requiring significant lordosis correction via release of the anterior longitudinal ligament (ALL) with anterior column realignment (ACR) procedures. [4–8]

Historically, patients requiring posterior instrumentation after LLIF would require prone repositioning and increasing operative and anesthesia time. However, recent studies have suggested similar outcomes using a single lateral position approach, whereby minimally invasive posterior instrumentation is performed with the patient in the lateral decubitus position.[9,10]

The lateral single-position approach allows access for a direct anterior retroperitoneal approach to L5-S1 without patient repositioning. Techniques have recently been developed that allow for a direct anterior approach to L5-S1 with the patient in the lateral position following essentially the same procedural steps as are performed with a traditional supine anterior lumbar interbody fusion (ALIF). With this advance, lateral positioned interbody fusion can be performed at all lumbar levels and posterior instrumentation placed in the lateral position without patient repositioning being required.

Single-position prone lateral surgery has increased in popularity in the past few years. The prone lateral approach allows surgeons to perform not only lateral interbody fusions but also posterior techniques, including decompression and fusion. Although it has been shown to be a safe and effective operation, this does not allow for anterior column access of L5-S1.

This article focuses on the anatomy and technique of the single-position anterior column spinal fusion and highlights the recent trends in outcomes and future directions of a powerful approach.

INDICATIONS AND CONTRAINDICATIONS

The ideal candidate has spinal pathology requiring interbody fusions from T12-L1 to L5-S1. Single-position anterior column lateral lumbar interbody fusion is ideal in a patient not requiring direct decompression or visualization of the thecal sac. The disc spaces and/or facet joints should be free of bony ankylosis to allow

Table 1. Single-position lateral lumbar interbody fusion.

Indications
• Spondylolisthesis • Advanced degenerative disc disease • Central or neuroforaminal stenosis • Degenerative scoliosis/kyphosis • Adjacent segment disease • Pseudarthrosis
Relative Contraindications
• Morbid obesity • Previous retroperitoneal surgery or radiation • High-grade spondylolisthesis • Impaired bone mineral density • Severe facet arthrosis

for disc space distraction and indirect decompression. The use of single-position surgery does not allow for posterior facet release or resection that may be required for sagittal alignment correction. For patients requiring larger deformity correction, single-position anterior column lateral surgery is not recommended (Table 1).

Several contraindications exist for single-position lateral lumbar fusion that falls in line with traditional lateral fusion operation. Severe obesity and multiple comorbidities hinders this procedure. Prior surgery, infections, and radiation to the pelvis or retroperitoneal space increase the risk of vascular, bowel, and ureteral injury during exposure. Calcification of the vasculature and abdominal aortic aneurysm also increase the possibility of intraoperative complications.[11–13] Performing an ACR in a patient who does not have a clear hyperintense border around the aorta or vena cava is concerning for possible scarring or adhesions of the blood vessel to the anterior disc space.[14,15] Careful preoperative questioning regarding previous abdominal processes and surgeries and examination of the abdomen for prior incisions are important for careful preoperative patient selection.

PREOPERATIVE SELECTION

Clinical and radiographic preoperative evaluation is critical for operative success. A careful review of standing radiographs and corresponding lumbar magnetic resonance imaging (MRI) scan are imperative.

For single-position surgery that includes the L5-S1 segment, a high sacral slope angle increases difficulty with accessing the disc even from the supine position (Figure 1) and may not allow access in the lateral position.[17] Having the sacral slope be at or above the superior border of the pubic symphysis as seen on radiograph or MRI imaging will allow for increased success

Figure 1. Radiograph demonstrating a patient with a recessed L5-S1 segment. The patient's pubic symphysis is blocking easy entry into the L5-S1 segment, making anterior exposure difficult and especially not recommended for the lateral position.

in accessing the disc space from the lateral position. At L5-S1, the common iliac vein and artery have typically bifurcated above the disc space level allowing for ease in retractor placement (Figure 2). At L4-5, the aorta and vena cava typically have not bifurcated at the level of the disc space, and direct anterior access is achieved with mobilization of the blood vessels. A careful review of the MRI scan prior to surgery will allow for detection of anomalous anatomy that would render the L4-5 or L5-S1 segments inaccessible.[15,16]

If the L4-5 level is unable to be accessed via a direct anterior approach, single-position surgery allows for the transpsoas approach, and access without change in an intraoperative position. Careful evaluation of the lumbar plexus as it courses through the psoas makes preoperative MRI review critical.[17–24] The transpsoas approach is avoided in patients with anteriorly migrated psoas as the lumbar plexus travels with the muscle, decreases the risk of nerve injury, and allows for the safe completion of the operation (Figure 3).[17–24] Cadaveric studies have evaluated the safe working zones for normal psoas morphology for the direct transpsoas approach. For L2-3 and L3-4, the anterior three quarters of the disc space are considered safe from neural elements. At the L4-5 disc space level, only the anterior two-thirds to one-half are considered to be the safe working corridor. Concern

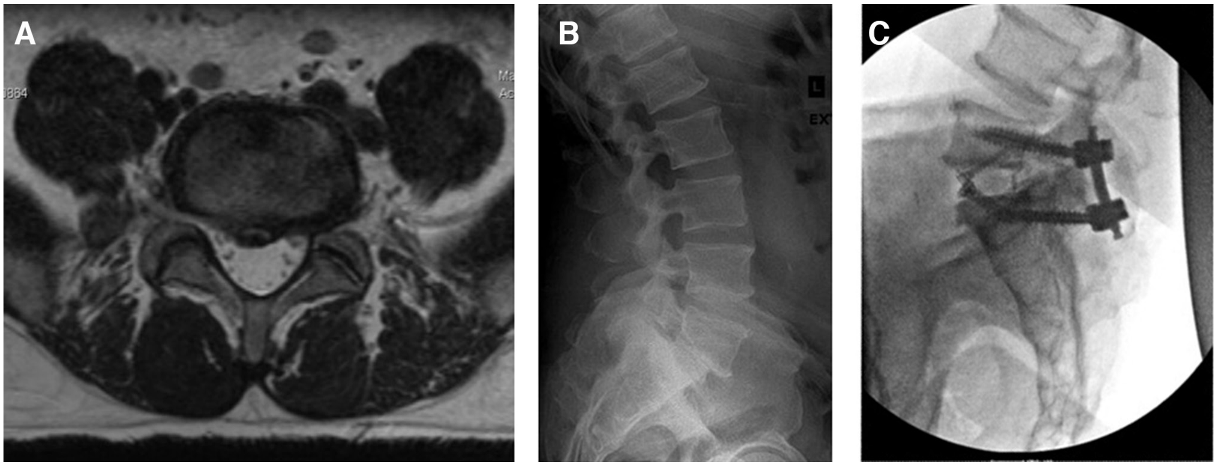

Figure 2. Images depicting a 55-year-old man with a Grade 1 isthmic spondylolisthesis with severe foraminal stenosis (A), (B). The common iliac vessels are on either side of the midline of L5-S1 disc space (A), allowing for adequate lateral anterior lumbar interbody fusion exposure. The postoperative fluoroscopic images (C) demonstrate adequate reduction of the spondylolisthesis.

for the genitofemoral nerve is most likely at L2-3 and L3-4 procedures, while the L4 nerve root was at greatest risk at the L4-5 level.[25]

For ACR, identifying the hyperintense signal on an MRI scan between the blood vessels and disc space allows for a safe operating plane and retraction of the great vessels. Also, careful inspection of the segmental anatomy on the sagittal MRI scan confirms that no aberrant vessels are crossing the disc space around the operating location.[14]

For posterior fixation, patient selection does not differ from the prone or lateral position. The pedicle anatomy and trajectory of percutaneous fixation can be measured preoperatively.

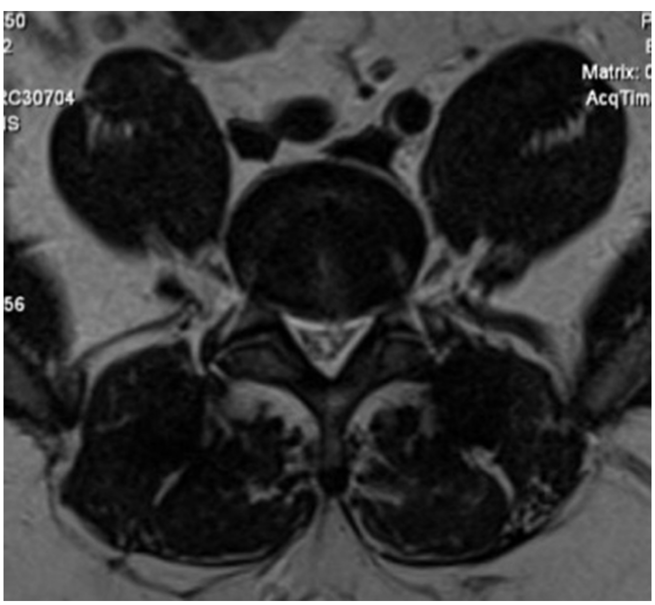

Figure 3. Axial cut T2-magnetic resonance imaging demonstrates anteriorly-migrated psoas, similarly migrating the lumbar plexus and increasing the risk for injury with a direct lateral approach in this patient.

TECHNIQUE

Patient Positioning

The patient is initially placed in the lateral decubitus position on a radiolucent table, padding all bony prominences and placing the iliac crest at the break of the table (Figure 4). In cases of single-level procedures, left- or right-sided approaches are utilized based upon the surgeon's preference. If multiple levels, including L4-L5 and L5-S1, via lateral ALIF approach are planned, a left-sided approach is utilized. The downside hip and knee are gently flexed while the upside leg is extended if a lateral ALIF is being performed to allow for retractor placement and exposure. Posterior patient holders are placed to help maintain patient position as well as counter pressure when trialing and placing anterior interbodies. The patient is set at the posterior edge of the table such that when placing screws, the required screw trajectory can be met.

With the iliac crest placed at the break of the table, the operative table can be gently bent to increase the working space between the iliac crest and the 12th rib.

Fluoroscopy is typically situated posterior to the patient and toward the head. Predraping imaging should be used to ensure that the intervertebral disc of interest is perfectly perpendicular to the floor. The bed can be gently rotated to achieve this. After a perfect anterior-posterior and lateral radiograph is confirmed, the patient should be secured in place, which can be done using hip positioners or tape. The goal is for the fluoroscope

Figure 4. A patient in the lateral decubitus position for single-position lateral surgery is depicted prior to draping. The patient is taped to the bed with the posterior holders in place on the inferior portion of the sacrum and thoracic spine.

to remain in place while rotating the patient to achieve a perfect radiograph such that the surgeon can operate confidently knowing that they are perpendicular to the disc space. It is expected that the patient may need to be subtly rotated if multiple levels are to be operated on.

Approach and Instrumentation

For lateral ALIF exposure, the disc space level is localized under fluoroscopy. The iliac crest and the lateral border of the rectus abdominus are palpated and marked. The incision for L5-S1 is centered over the border of the lateral rectus and made in a transverse fashion. The rectus fascia is identified and incised along the incision and the rectus abdominus musculature is mobilized medially. The posterior rectus sheath or transversalis abdominis fascia is incised taking care not to violate the peritoneum. The retroperiteneal layer is followed lateral and posterior and then swept anteriorly until the large blood vessels and ventral spine are visualized. The large vessels are mobilized, and the ventral disc is exposed. At L5-S1, the space between the common iliac artery and vein is typically used for disc space access. The approach, although performed with the patient in the lateral position, follows the same tissue planes and dissection that is used for supine ALIF (Figure 5). At L4-L5, the iliolumbar vein may have to be isolated and transected in order to mobilize the blood vessels for adequate exposure. Fluoroscopy is used for confirmation of adequate exposure, appropriate rotation of the operative segment, and midline marking (Figure 6). An annulotomy, discectomy, and interbody are placed following exposure.

To access L1-L5 via the transpsoas approach, variations of the technique have been readily described. When the transpsoas approach was first gaining popularity, surgeons would use a 2-incision technique. The first incision was a posterior-based incision to allow for finger dissection to ensure correct access into the retroperitoneal space. This 2-cm incision is made just lateral to the paraspinal musculature, and a finger is used to push the retroperitoneal contents anteriorly. Subsequently, a second incision is made laterally (or more anteriorly) for access to the intervertebral disc. This second, lateral, incision is deepened in line with the fibers of the external oblique muscle, and the abdominal muscles are gently spread. At more cephalad levels, the diaphragm may require transaction, which should be tagged with sutures to allow for correct closure after the surgical case.

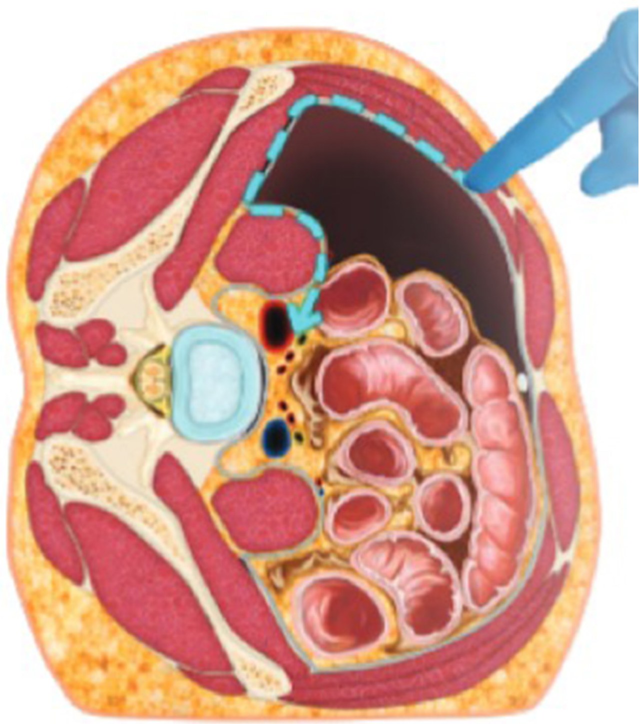

Figure 5. Illustration of the lateral anterior lumbar interbody fusion retroperitoneal exposure.

The first cannulated dilator is gently passed through the psoas muscle from the lateral approach, and direct directional Electromyography (EMG) stimulation is used to ensure there is no contact with the nearby lumbar plexus. Intraoperative fluoroscopy

Figure 6. Intraoperative fluoroscopic image of the L5-S1 segment that allows for analysis of the vertebral body rotation, retractor placement, and assessment of the midline.

is used to confirm the correct placement of the first dilator in the mid-portion of the disc space.

A guidewire is introduced through the dilator and malleted into the disc space, allowing for the introduction of sequentially larger dilators, each being stimulated with EMG during placement. Any concerning EMG findings mandate repositioning of the dilators (typically further anterior) with fluoroscopic confirmation. After the largest dilator is passed (often 22 mm in diameter), retractor blades are placed, and the dilator is removed. An EMG probe can be used to examine the surgical field and any creeping muscle to again confirm the lumbar plexus is securely and safely retracted and out of the field. Despite success using intraoperative neuromonitoring, similar results have been demonstrated without neuromonitoring.[26]

The discectomy and instrumentation are performed in the usual fashion, preserving the ALL and posterior longitudinal ligament. The discectomy is carried to the contralateral annulus, which along with the ALL can be taken down to allow for more mobilization of the spinal segment. Specific paddles, curettes, and rongeurs are used to prepare the endplates, which should be cleaned of any disc material without violating the bone. Trial spacers can be used to further facilitate distraction, and the final cage is then placed using fluoroscopic guidance. The lateral wound is irrigated and closed in layers, ensuring appropriate closure of the transversalis fascia. For an ACR procedure, the ALL is directly visualized with a retractor. Fluoroscopy is used to confirm the placement of the retractor across the disc space protecting the anterior blood vessels. After discectomy is performed, special instruments used for cutting the ALL are used under direct visualization.

Posterior instrumentation can be placed prior to or following interbody placement. If the interbody does not fully reduce the listhesis segment, posterior instrumentation is able to improve segmental reduction (Figure 7). The instrumentation is placed percutaneously from the same lateral position. Fluoroscopic guidance is used to ensure that the spinal segment of interest is clearly visualized. At the level of interest, lateral imaging should demonstrate that each vertebral endplate is a single line. On the anterior-posterior, the spinous process should project directly between the 2 pedicles.

A radiopaque tool can be used to confirm the position of each pedicle, and a small incision is made. Prior to draping, confirming the trajectory of the downside pedicle screw is important, as positioning

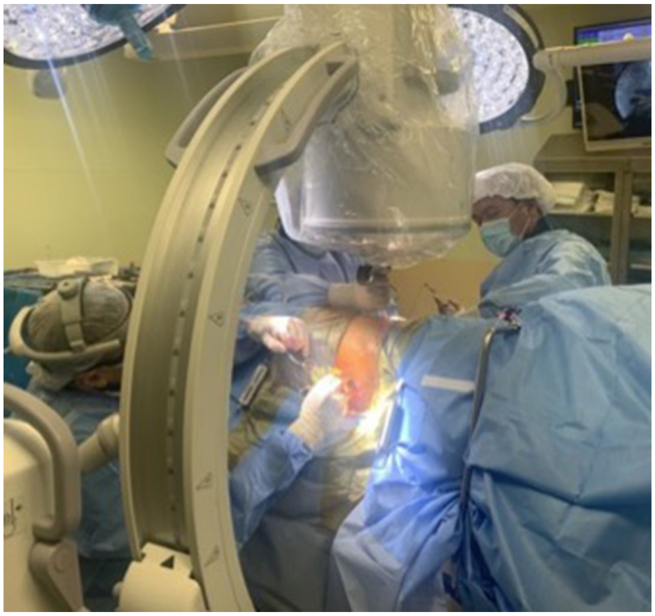

Figure 7. An intraoperative picture depicting simultaneous anterior and posterior manipulation of the spine.

closer to the edge of the bed will allow for ease in placement. Typically, the incision is made 1.5 to 2 cm lateral to the lateral wall of the pedicle on the anterior-posterior view. A Jamshidi or similar cannulated needle is then introduced to the intersection of the transverse process and the superior articular facet, which is again confirmed on fluoroscopy as it passes into the pedicle. A k-wire is then passed and tested with an EMG attachment to ensure no cortical breach. The pedicles are tapped and screws are inserted in standard fashion, both of which can be similarly tested with EMG attachments. Posterior instrumentation is completed with percutaneous placement of a rod and locked in place via torque-limited caps.

While unilateral screws can be placed in cases of more stable spinal segments, bilateral screw placement remains the standard.[27] Similarly, various companies have introduced k-wire-free techniques with positive results.[28]

OUTCOMES AND COMPLICATIONS

ALIF and the transpsoas approaches for lumbar fusion have both demonstrated excellent clinical and radiographic outcomes.[11,29–39] Such approaches allow for powerful correction of sagittal and coronal imbalance (Table 2).

Outcomes following single-position anterior column lateral lumbar surgery have been promising. Hiyama et al reviewed 45 patients undergoing 1- to 4-level single-position or dual position LLIF. Single-position LLIF allowed for faster operative time and similar improvement in radiographic parameters and complications.[40] Pedicle screw placement from the lateral position has also been well described, and when compared to prone instrumentation, results demonstrate equivalent fluoroscopy use, operative time, breech rates, and complications, while maintaining improved lordosis.[9] Malham et al detailed their technique for lateral ALIF at various levels and also reported an increased complication rate of 23% in the obese population.[43] However, even this obese population had maintained positive outcomes at final follow-up. At the time of publication, data involving single-position surgery with ACR have not been described.

Like it's supine counterpart, preoperative imaging should be closely scrutinized for nearby neurovascular structures that can contribute to perioperative complications with lumbar interbody fusion. Furthermore, the limitations of the procedure cannot be ignored. In cases of central stenosis involving significant bony and/or soft tissue components, indirect decompression may remain inadequate for symptom resolution. Regardless, lateral

Table 2. Single-position lateral lumbar interbody fusion: outcomes and complications.

Study	Key Findings
Hiyama et al, 2019[40]	• Operative time 31 min longer in dual-positioned group (129.7 vs 98.4 min) • No significant difference in lumbar lordosis, segmental lordosis, or disc height between single-position and flip procedures • Central canal diameter increased in both single-position and flip procedure groups, with no significant difference
Buckland et al, 2021[10]	Single-position cohort characterized by significantly reduced operative time (103 vs 306 min), EBL (97 vs 313 mL), fluoroscopy usage (32 vs 88 mGy), and postoperative length of stay (1.7 vs 4.1 d)
Ziino et al, 2018[41]	Dual-position operative time was significantly longer (226 vs 128 min), with no difference in immediate postoperative outcomes or lumbar lordosis
Ashayeri et al, 2022[42]	• Single-position group had a significant reduction in OR time (132 vs 261 min), EBL (120 vs 224 mL), and rate of ileus postoperatively (0% vs 6%) • No differences in fluoroscopy use or perioperative complications, including vascular injury, retrograde ejaculation, abdominal injury, neuropraxia, wound complications, or VTE, were noted

Abbreviations: EBL, estimated blood loss; VTE, venous thromboembolism.

lumbar surgery offers unique benefits in appropriately indicated patients.

Future Directions

Further advancements in medical technology have allowed for the expansion of various tools into the realm of spine surgery. Robotics and navigation have been successfully implemented in prone spine surgery, minimizing radiation exposure while maintaining accuracy, albeit at a higher overall cost.[44] Similar technology has improved 3D imaging, allowing surgeons to plan optimal pedicle screw angle and trajectories, as well as appropriate implant diameter and length.[45,46] 3D printing and modeling technology may improve surgeon interpretation of local anatomy and has promising results, suggesting lower surgical time, blood loss, and radiation exposure.[47] Expansion of the field of imaging and preoperative imaging may allow the addition of single-position lateral surgery to include management of spine tumors.[44]

Lateral single-position surgery does have drawbacks, including the inability to decompress neural elements. Increasing segmental lordosis via facet release or patient positioning in the prone position are also not utilized in the single-position lateral approach. These deficiencies are addressed with the use of the transpsoas lateral fusion technique in the prone position. Early data suggest that the prone transpsoas approach is safe and as effective as the lateral position; however, the prone lateral approach allows surgeons to perform not only lateral interbody fusions but also posterior techniques, including decompression and fusion. There have been concerns about the associated learning curve.[48,49] The main drawback of prone lateral surgery is the inability to access L5-S1 without patient repositioning.

CONCLUSION

Single-position lateral anterior column fusion offers a powerful approach to coronal and sagittal imbalance correction, treatment of degenerative disc disease, and other cases in which patients do not require direct neural decompression. The combination of ALIF with LLIF while maintaining the patient in a single position allows for full access to the anterior column without repositioning in conjunction with posterior fixation. The single-position LLIF allows for improved operating room efficiency, less anesthesia dosing, and less blood loss. Although fluoroscopic-guided pedicle screw placement is reasonable in the single position, surgeons may find robotics or navigation a useful adjunct to ease the learning curve. As other modifications of the single-position LLIF are published in the literature, this technique will become more readily used.

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Funding: The author(s) received no financial support for the research, authorship, and/or publication of this article.

Declaration of Conflicting Interests: The authors report no conflicts of interest related to this work.

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Published 05 April 2022