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Research Article

Extreme-Lateral Lumbar Interbody Fusion (XLIF) with Intraoperative Neurophysiological Monitoring - A Safe and Minimally Invasive Surgical Approach to the Anterior Lumbar Spine

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ABSTRACT

Aims: Minimally invasive surgical approaches to the spine continue to evolve. We describe here the technique and the results of a recently developed minimally invasive surgical approach to the lumbar spine, the extreme-lateral lumbar interbody fusion (XLIF) approach.

Methods: The XLIF approach to the anterior lumbar disc space allows for complete discectomy, vertebral body distraction, large graft placement, and disc height restoration. It achieves these goals with minimal trauma to the surrounding tissues. The psoas muscle is traversed with a minimum of trauma, and the lumbosacral plexus is protected by the use of intraoperative real-time electromyography (EMG) neuromonitoring.

Results: A group of 31 patients with degenerative lumbar disease, metastatic tumors to the spine, or with spondylodiscitis have undergone XLIF in combination with percutaneous transpedicular screw fixation. All patients have experienced improvement of low back pain and most have improved neurologically. No procedure-related severe side effects or complications have been encountered. There was no permanent nerve damage to the lumbosacral plexus.

Conclusions: This study demonstrates that the XLIF approach for anterior lumbar fusion is a safe and minimally invasive surgical technique, which avoids significant intraoperative blood loss and has no major intraoperative or postoperative complications and side effects. The XLIF approach allows for a wide and very convenient surgical access to the anterior lumbar disc space without the potential complications of a trans-abdominal procedure.

Keywords: Lumbar spine, Extreme lateral anterior lumbar interbody fusion, Lumbar disc disease, Neuromonitoring

Introduction

Lumbar interbody fusion (LIF) has been well established over the last decades as a surgical treatment for a range of spinal disorders, including degenerative disc disease, traumatic injuries, spondylodiscitis, and primary or metastatic tumors. LIF involves the placement of an implant within the intervertebral space after discectomy and endplate preparation, often combined with posterior transpedicular screw and rod fixation [1]. Currently, LIF is performed using a few main surgical approaches; posterior lumbar interbody fusion (PLIF), transforaminal lumbar interbody fusion (TLIF), oblique lumbar interbody fusion (OLIF), anterior lumbar interbody fusion (ALIF), and extreme lateral lumbar interbody fusion (XLIF). There is no definitive evidence from randomized and controlled studies for one of these approaches being superior to another in terms of fusion or clinical outcomes [2].

The XLIF approach was recently developed in order to allow maximal disc excision and end plate availability for interbody fusion, while providing direct or indirect decompression of the nerve roots and spinal canal. XLIF is able to avoid most of the major visceral and vascular injuries seen with ALIF, and trauma to the nerve structures, paraspinal muscles, and facet joints seen with TLIF or PLIF. Further advantages of the XLIF technique include reduction of operative time and greatly reduced blood loss [3,4].

The XLIF approach was used in the present study to gain wide access to the anterior and anterior-lateral lumbar spine via a 90° lateral approach, passing through the retroperitoneal space and traversing the psoas muscle [3-5]. The nerve roots constituting the lumbosacral plexus were protected by using intraoperative neurophysiological monitoring with real-time electromyography (EMG). With the XLIF approach and intraoperative EMG neuromonitoring, potential complications of the usual anterior retroperitoneal approach to the lumbar spine may be avoided, permanent neurological deficits from traversing the psoas are the exception, major vessels are left ventral to the working area and are not encountered, access to the entire anterior column of the spine is achieved, and the whole procedure can be carried out through a single lateral incision of 5-6 cm length [6-8].

Here we describe our modified surgical technique with the XLIF approach to the lumbar spine, and present preliminary clinical results in a cohort of patients undergone XLIF surgery.

Patients and Methods

Patient selection and surgical indications

Patients who presented with low back pain with or without a leg pain component, or patients with neurogenic claudication due to central canal stenosis were considered candidates for surgery if they failed at least 6 months of conservative management. Patients with beginning to moderate spondylolisthesis (up to 2 cm) and corresponding clinical symptoms were considered immediate surgical candidates. Patients with spondylodiscitis and with malignant disease were also included in this series, if there was no major destruction of vertebral bodies. Contraindications included severe scoliosis with a major torsion component.

The selected group of patients was essentially the same as the candidates for a classical anterior lumbar interbody fusion (ALIF) or a posterior lumbar interbody fusion (PLIF) [9].

Surgical technique

Positioning and preoperative preparation: The anesthetized patient is placed in a true 90° left lateral decubitus position with legs flexed 75°-90° in the knees, the right side elevated and iliac crest and chest taped to the operating table in this position with adhesive tape. The iliac crest is positioned exactly at the major joint of the operating table. EMG electrodes attached to selected muscles of the thighs and calves (myotomes L1-L5) are wired and connected to the relay box of the EMG monitoring device (NeuroVision JJB, Nuvasive Inc., S. Diego, USA). The table is then flexed in such a way as to increase the distance between the iliac crest and the rib cage and to tilt the iliac crest away from the L4/5 level. For upper lumbar levels, less flexing of the table is necessary compared with lower lumbar levels (Figure 1A and B). Due to superposition of the iliac crest, the L5/S1 level is not accessible through an XLIF approach. An anterior-posterior (AP) fluoroscopy image helps to confirm the true lateral (90°) position or, if necessary, to restore it by rotating the table along the longitudinal axis and centering the projection of the spinal processes between the pedicles. The C-arm is then rotated to a lateral position and the projection of the respective lumbar level is marked on the skin of the right flank.

Surgical approach and instruments: After aseptic treatment and sterile draping of the operating field, a 5-6 cm skin incision is placed on the mark. After sharp opening of the fascia and the abdominal oblique muscles with scissors, further dissection in the retroperitoneal

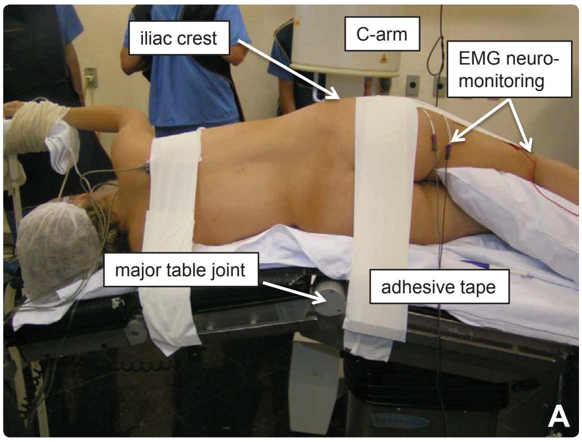

Figure 1A: Positioning of the patient in a true 90° left lateral position. The iliac crest and chest are taped to the operating table with adhesive tape, and the iliac crest is positioned exactly at the major joint of the operating table.

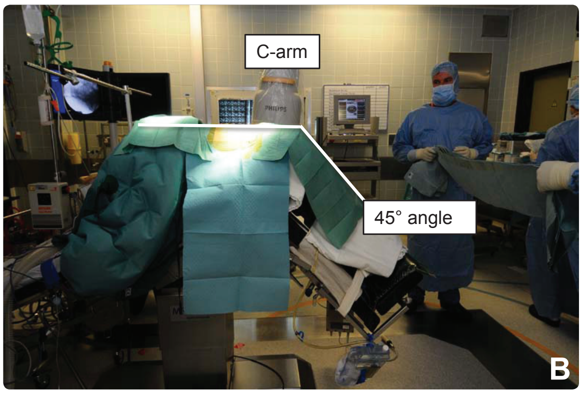

Figure 1B: Final positioning and draping of patient on the operating table. For access to the L4/5 level,the table with the patient is flexed to a maximum of 45° in order to tilt the iliac crest as far away from L4/5 as possible. The C-arm in a lateral position is used to mark the projection of the respective lumbar level on the skin of the right flank.

space is carried out bluntly, with the surgeon's index finger used to penetrate the retroperitoneal fat, to sweep the peritoneum anteriorly and then to palpate down to the psoas muscle. Once the psoas muscle is identified, an atraumatic tissue dilator (MaXcess System, NuVasive Inc.) is introduced to its surface (Figure 1C-E). The auxiliary incision technique (second incision about 10 cm dorsal from the lateral incision) was initially proposed [5], however it was never needed in our hands.

The position of the dilator over the psoas and the lateral disc space is confirmed by AP and lateral fluoroscopy. The fibers of the psoas muscle are then gently separated with the initial dilator attached to the EMG monitoring system (NeuroVision, NuVasive Inc.) to assess distance of the lumbar nerve roots to the advancing dilator. The NeuroVision system performs evoked real-time EMG monitoring and will continuously search for the stimulus threshold that elicits an EMG response on the myotomes monitored, and audibly and visually report the thresholds.

Besides lumbar nerve avoidance, further care should be taken to minimize trauma to the psoas muscle, which should be parted between the middle and anterior third (in antero-posterior direction). The nerves of the lumbar plexus are located posteriorly and remain outside of the surgical approach [10]. The nerves are not visualized, and the size of the psoas muscle does not seem to be a factor in this technique. An additional benefit of the direct lateral trajectory through the psoas is the fact that the great vessels remain far anterior to the working area.

After fully traversing the psoas muscle with the first dilator attached to the NeuroVision system, subsequent larger dilators are introduced, gradually spreading the psoas muscle under EMG monitoring until the MaXcess retractor is inserted over the third and final dilator. Antero-posterior and lateral fluoroscopy is used to confirm the position of the retractor blades over the disc space. A rigid articulated arm attached to the surgical table is used to hold the retractor in place. The retractor blades are expanded in a cranio-caudal and antero-posterior direction to the desired width. The dorsal blade of the retractor is then anchored in the disc space with a shim. The size of the exposure is customizable as needed and can be varied intraoperatively. A xenon light source with a light cable is attached to the cranial and caudal retractor blades and used to illuminate the surgical area (Figure 1E). Bipolar electrocoagulation of the psoas should be avoided and is usually not necessary, as no major bleeding is occurring.

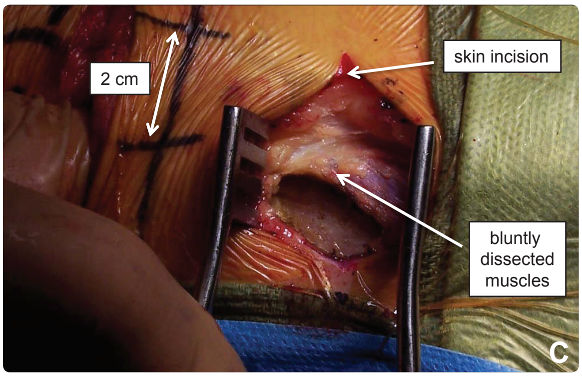

Figure 1C: Skin incision of 4 cm length over the L3/4 level, and blunt dissection of muscles to access retroperitoneal space and psoas muscle.

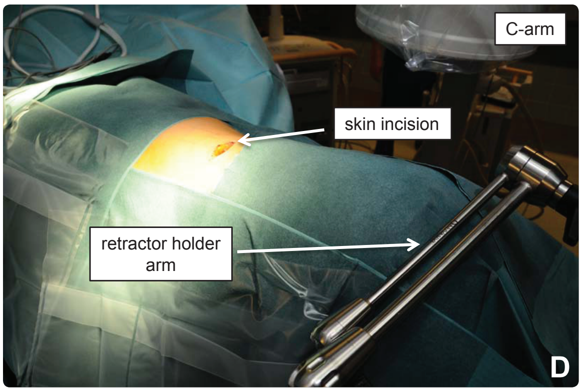

Figure 1D: Overview of a typical surgical approach with skin incision on the right flank over marked spinal level L3/4, articulated retractor holder arm attached to the operating table, and C-arm in a 90° lateral position.

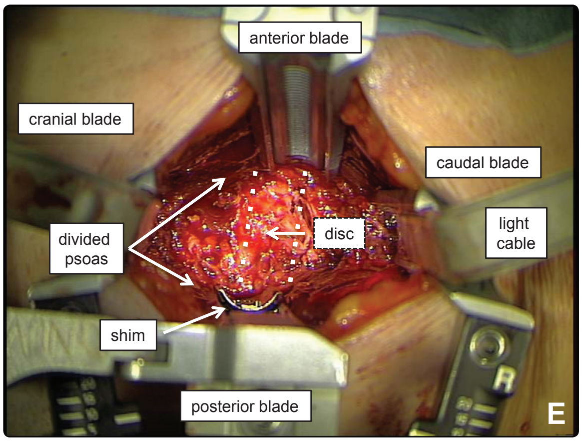

Figure 1E: Operating microscope view of the illuminated MaXcess surgical retractor with anterior blade in place. Note the bluntly parted psoas muscle and the broad exposure of the right lateral disc space at the L3/4 level. Major vessels remain further anterior to the anterior retractor blade, beyond the reach of discectomy instruments.

Implants and fusion technique: Discectomy is performed under direct visualization using standard instruments such as an up-biting curette, long rongeurs, and various scrapers and shavers. The posterior and anterior parts of the annulus are left intact, with the annulotomy centered over the middle part of the disc space. Disc removal and release of the contralateral annulus using a Cobb dissector allows the placement of a long implant that will rest on both lateral margins of the apophyseal ring, maximizing end plate support. Interbody distraction and implant placement in this position provide strong support for disc height restoration and sagittal and coronal plane imbalance correction. In most cases, PEEK cage implants (CoRoent, NuVasive Inc.) are used. To avoid additional tissue trauma and incision connected with harvesting autologous bone from the posterior iliac crest to fill the cage, in most cases the InductOs® kit

(Medtronic Inc., Minneapolis, MN) containing a collagen sponge and BMP2 recombinant bone morphogenetic protein is used.

After finalizing placement of the cage and controlling its position in two planes by fluoroscopy, the retractor is removed slowly and a gelatin hemostatic sponge is left within the psoas muscle. The wound is closed in layers, and the skin is sutured with a continuous suture. No drains are required.

The patient is then placed prone for percutaneous placement of pedicle screws. Alternatively, this is done later in a second session, or in some cases has been done prior to the XLIF procedure. In our group of patients, all XLIF procedures were supplemented with percutaneous dorsal pedicle screw fixation (either immediate or staged), and some underwent posterior decompression of the spinal canal for relief of central or recessal stenosis.

Results

A group of 31 patients was treated surgically using the XLIF technique. Eighteen of these were females (age range 53-85 years, median 74 years) and 13 were males (age range 58-79 years, median 69 years) (Table 1). A total of 50 spinal levels (from L1 to L5) were fused. In 15 cases one spinal level was fused, in 13 2 levels, and in 3 cases 3 levels. All patients had degenerative disc disease with narrowing of the spinal canal and lateral recess and were symptomatic with pain, neurogenic claudication, and radicular syndrome in one or more levels (**Figure 2A-C**). Three patients were diagnosed with destructive disc and endplate changes suggestive of spondylodiscitis, however no infectious agent could be demonstrated microbiologically.

Table 1: Demographics.

	number of patients	age range (median) in years
Female	18	53-85 (74)
Male	13	58-79 (69)
Total	**31**	**53-85 (71)**

Bone mass densitometry was not performed routinely, as it was not deemed crucial to the success of the XLIF procedure. Occasional presence of advanced osteoporosis was not linked to any intra- or postoperative complications. The intervertebral cages had an exceptionally large footprint and were designed to use the apophyseal ring of each vertebral body as the main supporting structure (Figure 3A-D), thus completely avoiding cage subsidence and break-ins.

All XLIF procedures were carried out without any serious intraoperative or early postoperative complications. No postoperative intensive care unit stay or blood transfusions were required. In fact, blood loss during the XLIF procedure was minimal and below 100 ml on average. The majority of patients needed opioids and non-steroidal anti-inflammatory drugs for postoperative analgesia, and were mobilized on the first postoperative day. The duration of inpatient treatment depended not only on the surgical procedure, but also more importantly on comorbidity and preoperative condition.

No permanent neurological deficits due to intraoperative lesions of the lumbosacral plexus were encountered. However, 9 of the 31 patients (29.4%) showed slight and reversible weakness of the ipsilateral (right) thigh flexion for a few days to a few weeks after surgery, due to mechanical irritation of the psoas muscle.

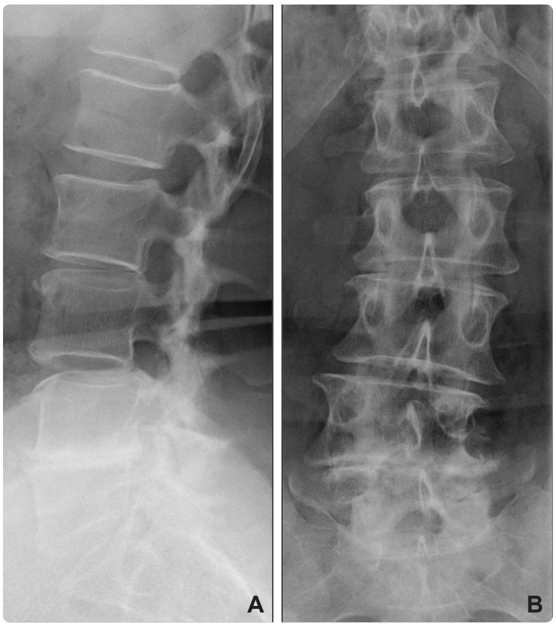

Figure 2A,B: Preoperative X-rays of the lumbar spine in a 76-years old female patient with low back and leg pain, showing degenerative scoliosis, spondylolisthesis, advanced osteochondrosis with neuroforaminal stenosis, and flattened lordosis in the lumbar spine.

Figure 2C: Sagittal CT-scan reconstruction in the same patient showing the degree of spondylolisthesis L3/4 and osteochondrosis and neuroforaminal stenosis L2/3 and L4/5. There are disc herniations with stenosis of the spinal canal in all three segments. The sagittal alignment of the lumbar spine is greatly affected.

Thigh numbness on the ipsilateral side of the surgical approach was encountered in 4 cases (12.9%), and resolved within 4 weeks after surgery. Only one patient (3.2%) experienced prolonged thigh pain and disesthesia, which resolved within 3 months. The main duration of inpatient treatment was 6,8 days (range 4 -22 days).

Initial VAS score for overall back and leg pain dropped from a mean of 6,8 (standard deviation, SD:+1.2) preoperatively to 2,8 (SD: ± 0.45) at 6 months after surgery. Patients were followed for 6 months after surgery.

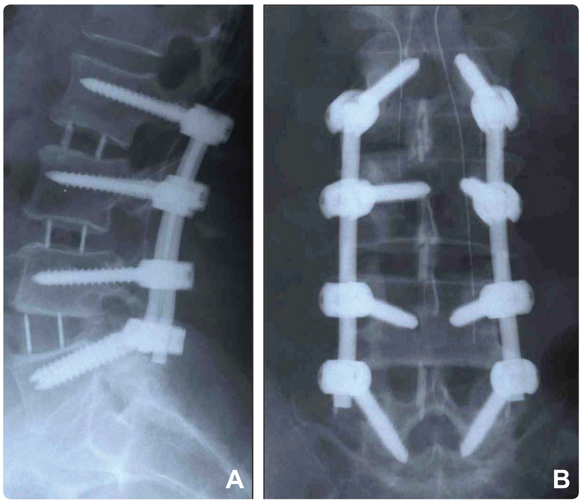

Figure 3A,B: Postoperative X-rays of the lumbar spine of the same patient demonstrating reposition of spondylolisthesis L3/4, straightening of scoliosis, and restoration of height of intervertebral space in the L2/3, L3/4, and L4/5 levels. Note the restored sagittal balance of the lumbar spine with normal lordosis.

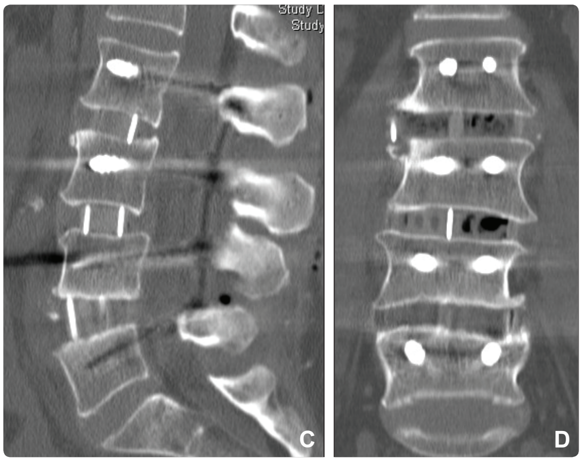

Figure 3C,D: Postoperative CT-scan reconstructions in sagittal and coronal planes showing the enlargement of the spinal canal in the operated segments and restoration of lumbar lordosis with normalization of sagittal balance. Note the size of the intervertebral PEEK cages in the coronal plane, reaching from one lateral apophyseal ring of the respective vertebral body to the other.

Discussion

We describe here the minimally invasive XLIF approach to the anterior lumbar spine, which allows for a safe and conveniently large exposure of the anterior and lateral lumbar disc space. This in turn forms the basis for complete discectomy, vertebral body distraction, large graft placement, and disc height restoration. The psoas muscle is traversed with a tubular retractor introduced over dilators of increasing diameter, which causes a minimum of trauma to the muscle. The lumbar plexus inside the psoas is protected by the use of automated intraoperative EMG-monitoring.

We have demonstrated here the clinical feasibility and advantages of the XLIF approach for lumbar spine degenerative disease. A group of 31 elderly patients with degenerative lumbar disease have undergone anterior lumbar spinal fusion by XLIF in combination with posterior percutaneous transpedicular screw fixation. All patients have experienced improvement of low back pain to a different degree. No procedure-related severe side effects or complications have been encountered.

Open or laparoscopic ALIF has been reported to be a safe surgical technique and is commonly performed [11-14]. The primary advantages of the endoscopic over the open surgical approach are less tissue trauma, reduced postoperative pain, shorter hospital stays, and earlier return to work. Nonetheless, the advantages of laparoscopy over open techniques have not been proven yet [15].

ALIF techniques may however have significant complications and side effects. Abdominal injury and injury to great vessels [16,17], retrograde ejaculation [18,19], and arterial thromboembolism [20] have been reported. Access to the anterior lumbar spine at L4-L5 is particularly challenging with ALIF techniques since it often requires ligation of the iliolumbar vein and mobilization of the great vessels [21]. Recently, Kaiser, et al. [22] reported on 98 patients who underwent ALIF procedures, 47 via laparoscopic approach and 51 via mini-open technique. A significantly longer preparation time was observed when using a laparoscopic approach versus an open approach.

The XLIF technique is a modification of the endoscopic retroperitoneal approach to the lumbar spine [4,5,12,23]. The technique was first presented in 2001 by Pimenta [4]. The MaXcess retractor system (NuVasive Inc.) has been specifically designed to aid XLIF approaches, and offers excellent handling and visibility because of the inbuilt illumination in the retractor blades [7].When compared with open or laparoscopic ALIF approaches to the lumbar spine, the XLIF approach has several advantages:

- It eliminates the need to violate or retract the peritoneum and avoids damage to the great vessels.
- Tissue dissection occurs under direct vision and without impairment of depth perception.
- It takes shorter time to carry out than any other approach.
- All steps of the procedure are in the hand of the spinal surgeon (no general surgeon involved).

Some anatomical limitations do however exist with the XLIF approach to the lumbar spine. Th12-L1 must be accessed transthoracally/transpleuraly, and L5/S1 from an anterior (ALIF) or posterior (PLIF) direction only [3,5,7]. Dissecting the psoas muscle with the aid of the EMG real-time neuromonitoring is safe and avoids injury to the lumbosacral plexus, however some transient, mostly pain-related weakness of the ipsilateral psoas is noted in some cases. It becomes fully reversible within a few weeks after surgery.

As with most minimally invasive and disruptive spinal approaches, intraoperative fluoroscopy use is critical and is significantly affected by the experience of the technician as well as the surgeon. In our hands fluoroscopy time was somewhat decreased compared with ALIF or PLIF techniques, however, quantitative analysis has not been performed.

The surgical results of XLIF in our hands have shown that it is a safe and reproducible technique. It has all the benefits of a minimally invasive procedure. With XLIF, the underlying objectives of spinal surgery need not be compromised for the sake of decreased morbidity. Disc heights is restored and spinal stability maintained by preserving ligamentous structures and inserting large interbody implants. This indirectly increases the neuroforaminal volume and results in reduction of radiculopathy. Although we have not been able to fully assess fusion rates because of the relatively short follow-up time of 6 months, all of the longer follow-up patients (not included in this study) have shown solid bony fusion in the operated levels.

Conclusion

Our study demonstrates in a selected group of elderly patients that the XLIF approach for anterior lumbar fusion is a safe and minimally invasive surgical technique, which avoids significant intraoperative blood loss, has no major intraoperative or postoperative complications or side effects, and results in improvement of clinical signs and symptoms. Given the well-known complications and challenges of ventral retroperitoneal approaches to the lumbar spine, XLIF may be a valuable alternative to open or laparoscopic anterior approaches for a ventral or 360° lumbar fusion.

The use of this technique is rapidly expanding and indications for it are increasing, to include degenerative lumbar scoliosis, and vertebral corpectomy and replacement. Longer follow-up for bony fusion and clinical condition is certainly required, but our early results are very encouraging.

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