The lateral transpsoas approach to the lumbar and thoracic spine: A review

Paul M. Arnold, Karen K. Anderson, Robert A. McGuire Jr.1

Department of Neurosurgery, University of Kansas Medical Center, 3901 Rainbow Blvd., Kansas City, KS 66160, USA. 1Traumatic and Reconstructive Spinal Surgery, University of Mississippi Medical Center, 2500 North State St., Jackson MS 39216, USA

E-mail: *Paul M. Arnold : parnold@kumc.edu; Karen K. Anderson : kanderson3@kumc.edu; Robert A. McGuire Jr. - rmcguire@umc.edu
*Corresponding author

Available FREE in open access from: http://www.surgicalneurologyint.com/text.asp?2012/3/4/198/98583

Copyright: © 2012 Arnold PM. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

Abstract

Background: In the last several years, the lateral transpsoas approach to the thoracic and lumbar spine, also known as extreme lateral interbody fusion (XLIF) or direct lateral interbody fusion (DLIF), has become an increasingly common method to achieve fusion. Several recent large series describe several advantages to this approach, including less tissue dissection, smaller incisions, decreased operative time, blood loss, shorter hospital stay, reduced postoperative pain, enhanced fusion rates, and the ability to place instrumentation through the same incision. Indications for this approach have expanded and now include degenerative disease, tumor, deformity, and infection.

Methods: A lateral X-ray confirms that the patient is in a truly lateral position. Next, a series of tubes and dilators are used, along with fluoroscopy, to identify the mid-position of the disk to be incised. After continued dilation, the optimal site to enter the disk space is the midpoint of the disk, or a position slightly anterior to the midpoint of the disk. XLIF typically allows for a larger implant to be inserted compared to TLIF or PLIF, and, if necessary, instrumentation can be inserted percutaneously, which would allow for an overall minimally invasive procedure.

Results: Fixation techniques appear to be equal between XLIF and more traditional approaches. Some caution should be exercised because common fusion levels of the lumbar spine, including L4-5 and L4-S1, are often inaccessible. In addition, XLIF has a unique set of complications, including neural injuries, psoas weakness, and thigh numbness.

Conclusion: Additional studies are required to further evaluate and monitor the short and long-term safety, efficacy, outcomes, and complications of XLIF procedures.

Key Words: Lateral transpsoas approach, extreme lateral interbody fusion, direct lateral interbody fusion, lumbar spine, lumbosacral plexus, surgical technique
INTRODUCTION

The minimally invasive lateral transpsoas approach to the lumbar and thoracic spine, also known as extreme lateral interbody fusion (XLIF) or direct lateral interbody fusion (DLIF), was first described in 2001. This technique has become an increasingly popular approach for achieving interbody fusion. The reported advantages include minimally invasive access to the spine, less blood loss compared to open procedures, decreased operative times, shorter hospital stays, and less postoperative pain. Studies have shown equivalency between XLIF and anterior lumbar interbody fusion. The reported advantages include shorter hospital stays, and less postoperative pain.

Table 1: Comparison of minimally invasive surgical approaches for lumbar interbody fusion

| Anterior lumbar interbody fusion | Posterior lumbar interbody fusion | Transforaminal lumbar interbody fusion | Extreme lateral interbody fusion |
|----------------------------------|-----------------------------------|---------------------------------------|---------------------------------|
| **Access**                      | **Approach**                      | **Visualization of surgical field**   | **Differences between the lateral transpsoas approach, anterior lumbar interbody fusion, posterior lumbar interbody fusion, and transforaminal interbody fusion** |
| Open, Minimally Invasive, or Laparoscopic | Transperitoneal or retroperitoneal; Avoids paraspinal musculature trauma, epidural scarring, traction on nerve roots, and dural tears; Retraction may injure the great vessels, peritoneal contents and superior hypogastric sympathetic plexus | Direct, endoscopic, or laparoscopic visualization, with fluoroscopic guidance; Direct visualization of the disk space may allow a more complete discectomy and better fusion than lateral or posterior approaches; Limited access to the posterior space for treating nerve compression | Differences between the lateral transpsoas approach, anterior lumbar interbody fusion, posterior lumbar interbody fusion, and transforaminal interbody fusion |
| • Open, with long midline incision or • Minimally Invasive (with bilat. paramedian incisions) | • Incision centered over spine with laminectomy/laminotomy and nerve retraction; Uses specialized tubular retractors to access the pedicles and foramen; Typically involves partial laminotomies and facetectomies; Decompression allows treatment of spinal canal pathology as well as spine stabilization by interbody fusion | • Direct, endoscopic, or microscopic visualization, with fluoroscopic guidance | The lateral transpsoas procedure differs from traditional anterior lumbar interbody fusion (ALIF), traditional posterior lumbar interbody fusion (PLIF), and transforaminal lumbar interbody fusion (TLIF) in several important ways. In the lateral transpsoas procedure, the patient is placed in the lateral decubitus position rather than being prone. Neural monitoring, including electromyography (EMG), is mandatory with the XLIF, because it employs a muscle-splitting technique that exposes the lumbar plexus to potential injury. In fact, injury to this plexus is one of the main risk factors of this procedure. | • Open or minimally Invasive |
| • Minimally Invasive or Laparoscopic | • Offset from spine through intervertebral foramen; Uses specialized tubular retractors in a unilat. facetectomy approach to the disk space; Partial laminectomy performed; Needs less dural retraction; Eliminates contralateral scar formation; Provides access to posterior elements and intervertebral disk space | • Direct visualization with neurologic monitoring and fluoroscopic guidance; Exposure to the spine may be more limited than ALIF; Dissection done primarily within the anterior psoas major to reduce risk of nerve root injury; May not allow complete discectomy thus decreased ability to address posterior element pathology | • Minimally Invasive |
| | • Uses specialized retractors in a lateral retroperitoneal approach to the anterior spine through the psoas; Dissection of the psoas major may injure nerves of the lumbar plexus | | |
METHODS OF THE LATERAL TRANSPSOAS APPROACH TO THE SPINE

Monitoring and x-ray confirmation of proper positioning
After the patient is properly positioned and the appropriate surgical area is localized, electrodes are placed that correspond to the myotomes L2-L5. Stimulation is then performed to achieve adequate twitch strength, allowing for accurate and reproducible EMG recordings. A lateral X-ray confirms that the patient is in a truly lateral position.

Performing the lateral transpsoas approach utilizing multiple tubes/dilators
Several techniques utilize the XLIF approach to the disk space. A series of tubes and dilators are used, along with fluoroscopy, to identify the mid-position of the disk to be incised. The first dilator is introduced through a small incision, and from a second small posterior incision, the surgeon’s index finger directs the dilator through the retroperitoneal space to the psoas muscle.

Positioning of the dilator and exposure for the lateral transpsoas approach
The surgeon’s index finger, now in the retroperitoneal space, guides the dilator from the first incision to the psoas muscle, taking care not to injure the intra-abdominal organs. The fibers of the psoas muscles are separated with the initial dilator, and the neural monitoring system can evaluate how close the dilator is to the lumbar nerve roots, which is a critical step in guarding against neural injury. The closer the tip of the electrode is to a nerve, the greater the current adjacent to the nerve. However, direct vision of the surgical field may reveal nerve tissue that does not respond to customary EMG stimulation. This stimulation usually localizes the lumbosacral plexus to the inferior posterior quadrant of the dilator tube over the lateral disk space. Thus, with continued dilation, the optimal site to enter the disk space is the midpoint of the disk, or a position slightly anterior to the midpoint of the disk.

Application of the retractor for the lateral transpsoas approach
After the second and then third dilators are introduced over the initial dilator, a retractor is inserted over the last dilator and fixed in place to the operating room table. The retractor is then opened to the surgical field over the disk space and neural monitoring is again checked to assure the neural elements are not being stretched across the operative field.

Disk excision utilizing the lateral transpsoas approach
The disk can now be incised and removed. Fluoroscopy is useful to ascertain the depth to which the disk is resected; XLIF typically allows for a larger implant to be inserted compared to either TLIF or PLIF. If instrumentation is necessary, it can be inserted percutaneously, which will allow for an overall minimally invasive procedure. Ozgur et al. provides a comprehensive discussion of the details of XLIF.[44]

ANATOMY

Definition of “safe” working zones for the lateral transpsoas approach
Because nerve injury during the transpsoas approach is the most common and potentially the most devastating complication of the XLIF procedure,[28,37] several studies have looked at defining “safe” working zones. These studies have included cadaver,[5,41,47,65] electrical,[66] and radiographic[24,25,51] evaluations.

Cadaver studies for the lateral transpsoas approach
Several cadaver studies defined the anatomy of the lumbar plexus and proposed an appropriate working space where dilators could be placed at each level of the lumbar spine.[5,41,47,65] The position of the lumbar plexus and the location of where the genitofemoral nerve emerged into the abdominal space were identified [Figures 1 and 2]. Generally, these studies showed that when approaching the lumbar spine from L3, L2, or L1, the psoas muscle should be split into the ventral three-quarters of the vertebral body (VB) to avoid nerve injury.[24] There is risk to the genitofemoral nerve if the psoas major muscle is split at L3 or L4. The lumbosacral plexus is most dorsally positioned at the posterior endplate of L1-2, with a general trend of progressive ventral migration of the plexus on the disk space from L2-3 to L4-5. Placing the dilator or retractor in a posterior position may result in nerve injury, especially at L4-5.[9,32,47] Uribe et al. discussed the potential of injury to the ilioinguinal, iliohypogastric, and lateral femoral cutaneous nerves in the retroperitoneal space.[65] Hu et al. showed similar findings in a magnetic resonance imaging (MRI) study.[29] EMG monitoring during surgery is essential to preventing neural injury during the XLIF.[63]

RESULTS OF XLIF SURGERY

Levels and limitations of XLIF surgery
The most common XLIF procedure involves treatment of one disk level, although four- and five-level disease has been treated with this approach. The L5-S1 disk space is usually inaccessible due to the presence of the sacrum, and nearly half the time the L4-5 interspace is similarly obscured.[10,61] Smith et al. also found that approaching a lumbarized sacrum via this approach was a relative contraindication.[64]
Multiple indications for XLIF surgery
The majority of XLIF procedures are performed for degenerative conditions, including spondylolisthesis, herniated disk, degenerative disk disease, postlaminectomy kyphosis, adjacent segment disease, and degenerative scoliosis. Rarely has the procedure been used to treat osteomyelitis or tumor [Table 2].

Most common indication for XLIF (degenerative lumbar disease) and outcomes
One of the most common indications for XLIF is degenerative disease of the lumbar and thoracolumbar spine. Ozgur et al., in advancing the technology from endoscopy to the XLIF, published the first feasibility study in 2006.44 They reported no complications in their first 13 patients, although surgical indications were not discussed.

Fusion rates and outcomes after XLIF surgery
The bulk of the large series detailing outcomes and complications for XLIF were published in the past few years. Most of these studies were retrospective, and surgical procedures were typically performed at one or two levels accompanied by supplemental fixation (plates or pedicle screws) [Table 3A]. Knight et al. published an early complication profile in 2009 in which 58 patients underwent mostly one- and two-level fusions for degenerative lumbar disease.37 There was a 22.4% overall complication rate, and most complications were approach related. Significantly, two patients continued to have L4 motor deficits one year after surgery. Clinical outcomes were not discussed in more detail.

Complications after XLIF surgery
Rodgers et al. further assessed fusion rates and patient outcomes in 66 patients one year after surgery; 96.6% of levels were judged as fused on CT scan, with nearly 90% of patients “satisfied or very satisfied.”153 Complications other than those described in their previous reports were not discussed in this series.152,53

Ozgur et al. reported a series of 62 patients who had two-year follow-up following XLIF.145 They reported a 91% fusion rate and 75% frequency of “clinical success” (ODI-change definition). There was a 19% minor complication rate. The most frequent complication was hip flexion weakness that typically resolved within six weeks after surgery. Additionally, one patient with pseudarthrosis required revision surgery.

Complication rate for XLIF in obese patients not increased
Rodgers et al. reported on a series of 156 obese patients who underwent XLIF and found that they were no more likely to experience complications than the nonobese patients.53 However, the obese patients had
Table 3A: Extreme lateral interbody fusion for degenerative conditions: recent large series reporting outcomes and complications (adjacent segment disease, degenerative disk disease, HNP, postlaminectomy kyphosis, spondylolisthesis, stenosis)

| Author(s)          | Study population                                                                 | Levels treated | Internal fixation | LOS               | Mean F/U       | Complications                                                                                                                                 |
|--------------------|----------------------------------------------------------------------------------|----------------|------------------|-------------------|----------------|------------------------------------------------------------------------------------------------------------------------------------------------|
| Knight et al.      | 58 patients<br>Degenerative lumbar conditions<br>L2-5<br>43 f, 15 m<br>Avg. age 61 years, range 32-80 | 1 level (38); 2 (19); 3 (1) | None noted       | 5 days (range 1–12 days) | 15 months (range 3–34 months) | Overall complication rate 22.4% (13/58 pts.)<br>- Approach-related complications (9):<br>- Ipsilateral L4 nerve root injury (2) (both showed continued motor deficits at 1 year postop);<br>- Meralgia paresthetica due to irritation of the LFCN (1) (significant paresthesias at 1 year but no adverse effects);<br>- Significant psoas muscle spasm requiring extended LOS (1);<br>- Implant bone interface failure with implant subsidence requiring reoperation (1);<br>- Also: MI, urinary retention, acute dementia |
| Rodgers et al.     | 100 patients<br>ASD after prior lumbar fusion<br>59 f, 41 m<br>Avg. age 62.2 years (range not noted) | Not reported | 99/100 had supplemental fixation: unilat. PS/rods, bilat. PS/rods, facet screws, and supplemental lateral instrumentation | 1.13 days | 6 months | Complications (9):<br>- VB fracture (revised with posterior instrumentation);<br>- Nonunion (revised to ALIF at 6 months);<br>- Weakness of anterior tibialis (resolved by 2 weeks);<br>- Also: ileus; MI; atrial fibrillation; urinary retention (had catheter drainage) |
| Rodgers et al.     | 66 patients<br>Mini-ALIF using XLIF<br>41 f, 25 m<br>Avg. age 62.2 years (range not noted) | 1 level (50); 2 (10); 3 (6) | 61/66 had supplemental posterior instrumentation (56 PS, 5 facet); 4/66 had lateral instrumentation; 1/66 had a 3-level stand-alone | N/A    | 12 months; 85/88 levels (96.6%) fused on CT, 64/66 patients (97.0%) fused on CT | Radiographic and CT study (complications not discussed); 89.4% of patients “satisfied or very satisfied” |
| Rodgers et al.     | 313 patients<br>Degenerative disease<br>156 obese patients (BMI >30 kg/m²)<br>157 nonobese (BMI <30 kg/m²) | Not noted | None noted | 1.33 days (obese); 1.27 days (nonobese) | 3 months; Pts. with primary diagnosis of DDD and recurrent HNP had higher complication rate than those with stenosis and spondylolisthesis. | Overall complication rate 8.6%.<br>- Approach-related complications in the obese: VB fractures (2) (1 pt. required posterior stabilization for VB fracture with subsidence of interbody graft); nerve injury (1); hardware failure (2);<br>- Approach-related complications in the nonobese: VB fracture (1); nerve injury (3); incisional hernia (1); hardware failure (1); recurrent stenosis after cage subsidence (1) (repaired with posterior decompression);<br>XLIF has no greater risk of complication in obese patients. |

Contd...
| Author(s) | Study population | Levels treated | Internal fixation | LOS | Mean F/U | Complications |
|-----------|------------------|----------------|-------------------|-----|----------|---------------|
| Ozgur et al. (2010)[45] | 62 patients | 1 level (26); 2 (13); 3 + (23) | 73% had supplemental pedicle fixation; 6% lateral fixation; 21% stand-alone | 3.9 days (not including staged procedures) | 2 years; 91% fusion rate, 71% clinical success rate by ODI-change definition | 19% complication rate (minor only, no major): • Postop Hip flexion weakness and bilat. upper thigh numbness (common, resolved by 6 weeks); • Wound-related (3), pseudarthrosis (1) (required revision); also: respiratory (3), GI (2), cardiovascular (2), renal (1) |
| Oliveira et al. (2010)[43] | 15 patients | 1 level (L4-L5) (all) | None; all procedures were stand-alone | 24 hours (range 12-48 hours) | 2 years; All patients showed evidence of fusion and all patients showed significant improvement in VAS and ODI. | Heterotopic ossification leading to foramen stenosis (1) (had foraminotomy for decompression); • Adjacent level degeneration (1) (had additional XLIF surgery); • Cage subsidence (1) (no surgery required; patient fused at 12 months); • Congenital small pedicles (1) (treatment changed to direct decompression) |
| Oliveira et al. (2010)[42] | 21 patients | 1 level (4); 2 (13); 3 (3); 4 (1); L1-L2 (3); L2-L3 (6); L3-L4 (17); L4-L5 (17) | None; all procedures were stand-alone | 29.5 hours | 2 weeks (range 1-6 weeks) | Psoas weakness (14.3%) (resolved within days); Psoas hematoma (4.8%) (resolved without treatment); Reoperation required (2): • Early postop evidence of implant subsidence (1) (had revision and supplemental PS fixation); • Inadequate disk and foraminal height restoration (1) (had hemilaminectomy and supplemental bilat. PS) |
| Youssel et al. (2010)[71] | 84 patients | 1 level (45); 2 (25); 3 (14) | XLIF-only stand-alone (15); XLIF-only with lateral plate (31); XLIF with supplemental PSF (38) | 2.6 days (range 1-10 days) | 15.7 months (range 9.5-37.8 months); 68/84 patients showed solid arthrodesis, 14/84 showed developing arthrodesis | Periop complication rate 2.4%; pulmonary artery embolism (1); incidental durotomy during posterior procedure (1) (repaired and monitored); Postop complication rate 6.1%: • Nondisplaced bilat. pedicle fracture (1) (braced); • Ipsilateral psoas weakness and numbness (1) (resolved by 7 weeks); • Endplate fracture (1) (braced); • VB fracture (1) (revision corpectomy); • Subsidence of adjacent plates (1) (no treatment required); • ASD (2) (1 had adjacent level decompressive laminectomy, other treated nonoperatively); • Pyelonephritis (1) (had antibiotics and catheter) |
| Author(s) | Study population | Levels treated | Internal fixation | LOS | Mean F/U | Complications |
|-----------|------------------|----------------|-------------------|-----|----------|---------------|
| Sharma et al. (2011)[58] | • 43 patients | 1 level (20); 2 (6); 3 (13); 4 (4); L1-2 (9); L2-3 (27); L3-4 (26); L4-5 (25) | Stand-alone (10 patients); with posterior lateral plate and unilat. screw fixation (9); with posterior PS fixation (24) | Stand-alone: 3.4 days (range 3–5 days); with supplemental posterior instrumentation: 8.2 days (range 3–28 days) | 12 months; authors reported “significant improvement” in VAS, ODI, and SF-12 1 year postop | • Anterior thigh pain and hip flexor weakness (most common); endplate breach (common); • Anterior thigh pain (15) (resolved by 3 days to 6 weeks); • Hip flexor weakness (11) (9 resolved by 6 weeks, 1 had persistent weakness at 1 year); • Quadriceps weakness (4) (3 resolved before D/C, 1 had persistent weakness at 1 year); • Endplate fractures, grade 0 (69), grade I (14), grade II (1), grade III (3); nonunion (2 patients, 5 levels) (1 had XLIF cage revision, other had brace); • VB fracture (2) (1 had kyphoplasty, other conservative treatment); • Infection at posterior instrumentation site (1); • Malpositioned anterior cage (1) (fusion at 1 year with no further displacement); • Retroperitoneal hemorrhage (1) (had embolization) |
| Rodgers et al. (2011)[58] | • 600 patients | 1 level (485); 2 (90); 3 + (25) | Lateral fixation alone (84); supplemental posterior instrumentation (511) of which 93.2% were PS fixation; no supplemental fixation | 1.21 days | Overall intra- and early postop complication rate 6.2%. | No individual comorbidity was predictive of complication development. |
| Pimenta et al. (2011)[48] | • 36 patients | 1 level at L4-L5 (14); 1 level at L3-L4 (1); 2 levels at L3-4, L4-5 (3) | N/A | 1.36 days (range 1–3 days) | 24 months; clinical success rate of 82.8% by ODI-change definition | also: GI (7), respiratory (7), cardiac (6), renal (2), hematologic (1) |

Contd...
## Table 3A: Contd...

| Author(s)         | Study population | Levels treated | Internal fixation | LOS            | Mean F/U         | Complications                                                                 |
|-------------------|------------------|----------------|-------------------|----------------|------------------|-------------------------------------------------------------------------------|
| Karikari et al.   | 22 patients      | T6-T7 (1); T7-T8 (1); T8-T9 (2); T9-T10 (4); T10-T11 (2); T11-T12 (9); T12-L1 (12); L1-L2 (16) | 1/22 cases required posterior supplemental fixation with PS | 4.8 days (range 2–8 days) | 16.4 months (range 3–50 months); a 95.5% substantial clinical benefit observed | reoperation required (3); Subsidence of interbody graft into adjacent VB (1) (had vertebroplasty at 3 months); ASD (1) (had fusion extension); Wound infection (1) (had washout and antibiotics) |
| Karikari et al.   | 66 patients      | XLIF (41), TLIF (27); stand-alone XLIF (11), XLIF (3+ levels) (13); L1-L2 (1); L2-L3 (2); L3-L4 (4); L4-L5 (9); L5-L6 (4); L2-L4 (2); L1-L3 (1); L2-L5 (8); L1-L5 (7); T11-L3 (1); T11-L5 (1); T12-L4 (1) | XLIF with supplemental PS fixations (17) | 3.5 days (stand-alone XLIF), 3.9 days (XLIF with PS fixation) | 14.7 months (range 1.5–50 months) | major complications (5, 7.4%, overall low rate): XLIF interbody graft subsidences (4); 3 were symptomatic: (1 had vertebroplasty, 2 had posterior PS supplementation, 1 had posterior microendoscopic decompression); ASD at 1 year postop (1) (had fusion extension); minor complications (17, 25.0%): Intraoperative dural tear (2) (surgical repair); Remote compression fracture (1) (had kyphoplasty); pedicle fracture (1) (supplemented with PMMA); also: ileus (3); urinary retention (2); UTI (1); hypotension (1); anemia requiring transfusions (6) |
| Le et al. (2012)  | 101 patients     | 1 level (56); 2 (27); 3 (15); 4 (3) | XLIF with supplemental lateral plates | Not noted | 14.3 months | Ipsilateral thigh numbness (18); Ipsilateral iliopsoas weakness (2); Paresthesias/radiculopathy (2); Surgical complications (6, 5.9%): Dislodged lock nut and lateral plate (3) (2 pts. chose no surgery, 3rd had hardware removal, laminectomy and foraminotomies, PS and posterolateral fusion); VB fractures (3) (1 right-sidet, 1 coronal plane with kyphosis, 1 coronal with lateral listhesis; 1 pt. chose no surgery, 1 had laminectomy, decompression, PS and posterolateral fusion, 1 had hardware removal with instrumentation and fusion) |
Table 3A: Contd...

| Author(s)         | Study population | Levels treated | Internal fixation | LOS Mean F/U | Complications |
|-------------------|------------------|----------------|-------------------|--------------|---------------|
| Berjano et al.    | 93 patients      | 1 level (48); 2 (40); 3 (8); 4 (1); stand-alone cage (14) | Bilat. PS, unilat. PS; translaminar screws; interspinous plate; interspinous elastic device; lateral plate | 12.1 months (range 6–28 months); clinical success rate 92%; only 8/93 failed to improve | Thigh discomfort (9) (resolved in 1–4 weeks); L4 weakness (4) (resolved by 1 month); L4 hypoesthesia (3) (resolved by 3 months); Dural tear during posterior open decompression (1) (had primary repair); Psoas hematoma (1) (resolved spontaneously); DVT (1); infection of posterior wound (1) (had debridement and IV antibiotics) |

an approximate 7% complication rate, and four patients required secondary surgery. Nevertheless, there were fewer neural injuries in the obese vs. the nonobese population. When Rodgers et al. reported on another series of 100 patients in whom XLIF was used to treat adjacent segment disease, patients achieved excellent results with short hospital stays and minimal complications.[52]

**XLIF surgery with bone morphogenetic protein rhBMP-2 [INFUSE® Bone Graft, (Medtronic Sofamor Danek Inc., Memphis TN, USA)]**

Oliveira et al. reported on a series of 15 patients who underwent one-level stand-alone XLIFs supplemented with bone morphogenetic protein (rhBMP-2: INFUSE®).[43] Although all patients achieved solid fusion, two (13.3%) required repeat surgery. One secondary procedure addressed excessive (ectopic) bone formation that led to nerve root compression, which is a commonly described complication directly attributable to rhBMP-2/INFUSE® Bone Graft. The other secondary procedure addressed the failure of “indirect decompression” attributed to congenital small pedicles. Otherwise, all patients experienced significant improvement utilizing standard outcome measures. Furthermore, the average hospital length of stay was a remarkable 30 hours.

**Dramatic increase in use of rhBMP-2 (INFUSE®) in the last decade**

The use of rhBMP-2 in spinal fusion surgeries increased dramatically in the last decade. The results of preliminary human trials of rhBMP-2 in lumbar fusion were published in 2000 and 2002, and neither study reported any adverse events directly related to rhBMP-2.[8,9] From 2003 to 2009, several industry-sponsored or industry-associated studies again reported no adverse events directly related to rhBMP-2.[11-14,19,21,23,26]

**Safety concerns regarding rhBMP-2 (INFUSE®) since 2002**

As early as 2002, however, safety concerns regarding the use of rhBMP-2 in spine fusions were reported.[16,56] These safety issues included bony overgrowth or uncontrolled bone formation (heterotopic ossification), graft subsidence, loss of fixation, inflammation, infection, cancer risk, toxicity (local, systemic, and reproductive), neurological events/deterioration, retrograde ejaculation, radiculitis, and functional loss.[16,50] Despite those concerns, the nationwide usage of rhBMP-2 (INFUSE®) in spine fusions increased from 0.7% in 2002 to 24.3% in 2006.[15]

**Intense scrutiny of rhBMP-2 (INFUSE®) since 2006 by United States Food and Drug Administration**

In 2006, the first of a series of studies describing serious complications associated with the use of rhBMP-2 was published.[62,67] Soon rhBMP-2 and its manufacturer, Medtronic Inc. (Memphis TN, USA), came under intense...
Complications of XLIF: transient neurological deficits and requirement for reoperations

Rodgers et al. reported on the largest series of XLIF procedures, and found a 6.2% complication rate in the early (six weeks) postoperative period in 600 procedures.\(^{[14]}\) The authors noted shorter hospitalizations and fewer vascular, neurologic, or infectious complications compared with traditional open procedures; specifically, they observed four transient but no permanent neurologic injuries. The revision rate (reoperation rate) in their series of 1.5% was also comparable to that found in other series, and included five revisions for fractures, two for hardware, and two abdominal procedures. Similar results were reported in the other recent series [Table 3A].

Advantages of the XLIF approach with total disk replacement

Pimenta et al. concluded that the XLIF was safer and less invasive than the anterior approach (ALIF), demonstrated minimal morbidity (maintaining pain relief and functional improvement), avoided mobilization of the great vessels, preserved the anterior longitudinal ligament (ALL), resulted in biomechanical stability, and offered broader revision options.\(^{[48]}\) When Pimenta et al. evaluated the clinical (pain and function) and radiographic ROM outcomes of a true lateral transpsoas (XLIF) approach for lumbar total disk replacement (TDR), they found that XLIF offered several advantages over the traditional anterior approach.\(^{[48]}\) The authors prospectively evaluated 36 patients (mean age 42.6 years) with 1- or 2-level DDD who underwent TDR procedures and were followed for a minimum of 24 months, and observed that all patients were walking within 12 hours of surgery. Furthermore, at two years’ follow-up, the average VAS and ODI scores had improved 69.6% and 61.4%, respectively; ROM averaged 8.6°, which was well within normal limits.

Neurological complications of the XLIF approach with total disk replacement

Nevertheless, in the Pimenta et al. study, significant neurological complications were observed following XLIF for TDR. For instance, five patients had new psoas weakness and three had new anterior thigh numbness; fortunately, both conditions resolved within 2 postoperative weeks. However, one patient had leg weakness ipsilateral to the approach side which required 6 months to resolve, while another patient had quadriiceps hypertrophy contralateral to the approach side which required 12 months to resolve. In two cases, removal of the TDR device and revision to fusion were required for pain that failed to resolve within 2 postoperative years.

Outcomes and complications of XLIF utilized to address scoliosis, tumors, prior fusions, thoracic disks, and discitis/osteomyelitis

Kankari et al. evaluated clinical, radiographic, operative,
postoperative, and functional outcomes of 22 patients (mean age 64.6 years) treated with XLIF for various conditions including degenerative scoliosis, pathological fractures from tumors, adjacent level disease from prior fusions, thoracic disk herniations, and discitis/osteomyelitis.[14] In patients treated for degenerative scoliosis, the mean preoperative and postoperative coronal Cobb angles were 22° and 14°, respectively. The mean preoperative and postoperative sagittal angles were 39° and 44°, respectively, and the average estimated blood loss and length of stay were 227.5 mL and 4.8 days, respectively. There were three complications that required reoperations: wound infection, subsidence, and adjacent level disease. There were no neural, vascular, or visceral injuries, or deaths. At a mean follow-up of 16.4 months (range 3-50 months), they observed a 95.5% substantial clinical benefit. All patients at 6-month follow-up (95.5%) demonstrated radiographic evidence of fusion. The authors concluded that the XLIF technique was a feasible and safe treatment option for thoracic spine diseases with minimal complications and favorable initial outcomes. Although traditional open approaches achieve a higher degree of deformity correction, the reduced invasiveness of XLIF may be more tolerable for the elderly and for patients with significant medical comorbidities.

Results of minimally invasive interbody fusion (XLIF, TLIF) in the elderly
In a companion study published the same year involving minimally invasive interbody fusions (41 cases of XLIF and 27 cases of TLIF), Karikari et al. evaluated the rate of perioperative and postoperative complications in the elderly.[15] Sixty-six consecutive patients, aged 70 years or older (mean age 74.9 years, range 70-86 years), underwent minimally invasive interbody lumbar fusion; the mean follow-up interval was 14.7 months (range 1.5-50 months). The authors found a low rate of major complications, including four cases of interbody graft subsidence and one case of adjacent level disease. There were no intraoperative medical complications nor any myocardial infarctions, pulmonary embolisms, hardware complications requiring removal, or wound infections, nor were there any major visceral, vascular, or neural injuries, or deaths. The authors concluded that although the effects of even minor complications can be more pronounced in elderly patients (age 70 and older), complex minimally invasive interbody fusion in patients 70 years or older is safe and well tolerated, without significant morbidity or mortality.

Complications of minimally invasive thoracolumbar XLIF instrumented fusions
Le et al. investigated hardware-associated complications in 101 patients who underwent minimally invasive lateral interbody thoracolumbar fusions using lateral plates for multilevel fusions or deformity correction.[16] The authors found a 5.9% complication rate which included three hardware failures, two coronal plane VB fractures, and one lateral VB fracture related to the lateral plate. All complications occurred in multilevel cases, and all cases presented with recurrent back pain except one which was identified incidentally. The authors concluded that minimally invasive lateral interbody fusion is a safe, practical, and direct technique that avoids the complications associated with other types of instrumentation.

Clinical outcomes and complications of XLIF
Berjano et al. reported on the clinical outcomes and complications in 97 consecutive XLIF cases with a minimum 6-month follow-up (mean 12 months).[7] Transient thigh discomfort/numbness was observed in 9%, and transient neurological symptoms presented in 7% of cases; all conditions resolved within one postoperative month. No instances of permanent neurological impairment, vascular or visceral injuries, or wound infections were observed. The authors acknowledged a 92% clinical success rate six months postoperatively. The authors concluded that XLIF is a safe and effective minimally invasive technique for treating lumbar and thoracolumbar spinal pathologies requiring anterior spinal fusion.

Degenerative scoliosis: another indication for XLIF
In the last few years, surgeons have expanded the indications for XLIF to include degenerative scoliosis. Due to the nature of this disease, deformity procedures tend to involve several levels of fixation. Anand et al. published a feasibility study in 2008, reporting on their first 12 scoliotic patients; surgical procedures involved an average of 3.64 segments and an average 13° correction per patient.[12] All patients underwent percutaneous pedicle fixation, and all patients requiring sacral fusion underwent AxiaLIF® (axial lumbar interbody fusion, TranS1, Inc., Wilmington, NC, USA); all procedures utilized rhBMP-2 to supplement the fusions. There were no permanent postoperative complications. Two years later, these same authors reported on their mid-term and long-term results for degenerative scoliosis; all 28 patients fused and maintained their immediate postoperative correction.[13] Complications were minimal and clinical outcomes were good, despite a mean length of stay/hospitalization (LOS) of ten days.

Similarly, Dakwar et al. reported on a series of 25 patients who underwent XLIF for thoracolumbar degenerative deformity.[16] Although sagittal balance was not corrected in one-third of the patients, clinical outcomes were acceptable and were accompanied by minimal long-term complications over an average 11-month follow-up interval. Wang and Mummaneni published a comparable series[19] and achieved an average 20° correction, which
was a greater deformity correction than that reported by Dakwar et al.\cite{[18]} Their fusion rates were excellent, despite a higher complication rate of 30%. Although symptoms resolved in all but one patient, two patients required revision surgery - one for cerebrospinal fluid (CSF) leak and one for hardware failure.

**Comparison of outcomes/morbidity of XLIF and TLIF for scoliosis**

In a small study, Tormenti et al. compared the surgical treatment of adult scoliosis utilizing the XLIF approach (eight patients) vs. standard posterior-only TLIF (four patients).

Patients in the XLIF group achieved greater deformity correction but had more extensive complications, including bowel injury requiring laparotomy (one patient), permanent motor radiculopathy (one patient), and persistent sensory symptoms (five of six patients).

**Morbidity of XLIF for deformity/scoliosis**

Neural decompression and fusion in patients with adult degenerative scoliosis presents a surgical challenge. Recent studies on surgical treatment of adult scoliotic deformity have found that the lateral transpsoas approach, when compared to traditional open approaches, results in less blood loss, shorter lengths of stay, and earlier mobilization, along with lower rates of infection and fewer transfusions.\cite{[2,3,18,31,52,64,69]} Nevertheless, these studies also observed more early reoperations and more major complications.\cite{[2,3,18,31,52,64,69]}

**XLIF resulted in excellent deformity correction for scoliosis**

Accosta et al. analyzed changes in coronal and sagittal plane alignment following XLIF for degenerative scoliosis and noted excellent results for deformity correction in both planes.\cite{[1]} Clinical outcomes were also excellent, and included sufficient long-term follow-up results. The authors concluded that the direct lateral transpsoas approach, when combined with posterior fixation, resulted in statistically significant improvement in segmental, regional, and global coronal plane alignment in patients with degenerative lumbar conditions, including degenerative scoliosis. However, the authors also found that there were no statistically significant improvements in regional lumbar lordosis or global sagittal alignment.\cite{[1]}

**Perioperative complications for XLIF with degenerative scoliosis**

Isaacs et al. reported on perioperative complications in a prospective series of 107 patients treated for an average 4.4 level degenerative scoliosis.\cite{[51]} The mean hospital length of stay was three days, and there was a 12.1% major complication rate. A lower major complication rate of 9% was seen for patients undergoing stand-alone XLIF or XLIF with percutaneous instrumentation, while a higher major complication rate of 20.7% was seen in patients undergoing XLIF with posterior instrumentation. Although the presence of at least one comorbidity increased the incidence of major complications, the strongest independent predictor of complications was the total number of levels treated per patient. The authors concluded that their rates of adverse events compared favorably to those cited in other degenerative deformity series [Table 3B].

**XLIF with total disk arthroplasty**

Pimenta et al. extended the XLIF indications when they published a series of 36 patients who underwent this procedure for total disk replacement rather than fusion.\cite{[48]} The patients underwent either a one- or two-level lumbar arthroplasty, and the authors reported excellent results at two-year follow-up. There were no long-term complications, although two patients required revision to fusion due to persistent pain.

**XLIF for osteomyelitis or tumor**

In three earlier mentioned series,\cite{[34,54,71]} patients underwent successful XLIF surgery for the treatment of osteomyelitis or tumor.

**XLIF and asymptomatic pseudarthrosis**

When Youssef et al. evaluated outcomes of 84 patients who underwent XLIF for various degenerative and deformity conditions, including one patient treated for tumor, the overall complication rate was 61.0%.\cite{[71]} At an average of 15.7 months postoperatively, 68 patients demonstrated solid arthrodesis on both CT and dynamic radiographs, while the remaining 14 patients developed pseudarthrosis but without complications. Average pain and function scores (VAS and ODI) at one year were significantly improved over preoperative scores. Their results corroborated prior reports that XLIF is a safe and effective approach for lumbar fusion, and that it carries a low morbidity rate. Furthermore, patients maintain long-term improvement in pain and function as well as long-term improvement on radiographic measures.

**Results of XLIF with supplemental posterior instrumentation**

Rodgers et al. were the first to delineate complications in the early postoperative period (within the first six weeks) in 600 XLIF cases, 511 of whom underwent supplemental posterior instrumentation.\cite{[54]} The XLIF procedure was utilized primarily for deformity and degenerative conditions, though one case of osteomyelitis was included as well. The authors noted an immediate 65% improvement in VAS pain scores. The overall early complication rate was 6.2%. When compared to traditional open posterior or anterior approaches, there were fewer total and fewer serious complications using the XLIF approach. The authors suggested that rare and transient postoperative neural deficits might be prevented in patients undergoing surgery at L4-L5 by the preoperative administration of dexamethasone before skin incision.
Table 3B: Extreme lateral interbody fusion for degenerative scoliosis: recent large series reporting outcomes and complications

| Author(s)            | Study population                                                                 | Levels treated                                                                 | Internal fixation                              | LOS           | Mean F/U              | Complications                                                                 | Postop sensory deficit rate 12%: |
|----------------------|-----------------------------------------------------------------|---------------------------------------------------------------------------------|-----------------------------------------------|---------------|-----------------------|------------------------------------------------------------------------------|--------------------------------|
| Anand et al. (2008)  | • 12 patients <br> • Symptomatic degenerative scoliosis and/or DDD; DDD with stenosis | Mean 3.5 levels per patient (range 2–8); L1-2 (4); L2-3 (12); L3-4 (12); L4-5 (4); L5-S1 (2); T12-L1 (1) | Posterior multilevel percutaneous PS fixation | 8.6 days      | Avg. 75.5 days <br> (range 15–140 days); <br> degree of deformity correction achieved was excellent; 32.4% experienced good early pain reduction | • Hip flexor weakness and pain on side of approach (common, usually resolved by 2 weeks); <br> • thigh dysesthesias (3) (resolved by 6 weeks); <br> • Quadriceps weakness (1) (resolved by 6 weeks) |
| Anand et al. (2010)  | • 28 patients <br> • Scoliosis (idiopathic and degenerative) with severe back pain and severe radiculopathy with central and lateral stenosis (10) or intermittent radiculopathy and foraminal stenosis (8) | L1-5 (6); L1-S1 (23); L2-5 (12); L2-S1 (10); L3-S1 (2); T10-S1 (8); T12-L5 (5); T12-S1 (33) | All patients had multilevel percutaneous PS instrumentation | 10 days <br> (range 3–20 days) | 22 months <br> (range 13–37 months); <br> all patients had radiographically confirmed solid arthrodesis at 1 year | • Hip flexor weakness and pain (several pts.) (resolved by 6 weeks); <br> • Thigh dysesthesia (17) (resolved by 6 weeks); <br> • Quadriceps palsy with vastus medialis weakness (2) (resolved by 6 months); <br> • Proximal screw prominence requiring removal (1); <br> • Asymptomatic proximal screw fracture (1) (no treatment required; went on to solid fusion); <br> retrocapsular renal hematoma (1) (tamponaded off) |
| Dakwar et al. (2010) | • 25 patients <br> • Adult degenerative scoliosis | 76 lateral grafts placed | Supplemenatal instrumentation (23 patients): PS (7), lateral plates (15), both PS and lateral plates (1) | 6.2 days | 11 months <br> (range 3–20 months); <br> 20/25 patients with at least 7 months f/u showed evidence of fusion | • Anterior thigh numbness ipsilateral to approach side (3); <br> • Rhabdomyolysis (1) (required temporary hemodialysis); <br> • Asymptomatic subsidence (1); <br> • Asymptomatic hardware failure (1) |
| Wang and Mummaneni (2010) | • 23 patients <br> • Adult spinal deformities (degenerative scoliosis, postlaminectomy and postvertebroplasty kyphosis, delayed PTK from burst fractures) | Avg. 3.7 intersegmental levels fused per patient (range 2–7) | Posterior supplemental fixation with PS and rods | 6.17 days <br> (range 3–20 days) | 13.4 months <br> (range 6–34 months); 84/86 treated levels showed evidence of fusion | • Thigh numbness, pain, weakness, and dysesthesias on side of approach (7, 30.4%) (resolved in postop period in all but 1 who required assistive ambul. device); <br> • Reoperation required (2): CSF leak (1) (no obvious dural tear seen on re-exploration); screw pullout (1) (had fusion extension); <br> • D/C to rehab (7, 30.4%), the rest D/C to home; <br> • Minimal or no improvement in symptoms (3); also: atrial fibrillation (1) (medical mgmt); pneumothorax requiring chest tube and longer LOS (1) |

Contd...
### Table 3B: Contd...

| Author(s) | Study population | Levels treated | Internal fixation | LOS | Mean F/U | Complications |
|-----------|------------------|----------------|-------------------|-----|----------|---------------|
| Tormenti et al. (2010)[64] | • 8 patients  
  • Adult degenerative scoliosis  
  • gender ratio not noted  
  • Avg. age 60 years, range 48–69 | compared XLIF (8 patients) to PLIF (4); XLIF levels: L1-4 (3); L1-3 (1); L1-5 (1); L2-4 (1); L2-5 (2) | All XLIF patients had supplemental posterior segmental PS instrumentation | Not noted | XLIF: 10.5 months (range 3–16 months) | • Thigh paresthesias or dysesthesias (sensory radiculopathy) (6, 75%) (1 resolved by 2 months, but all others’ persisted);  
  • Motor radiculopathy (2, 25%) (resolved in 1 after 2 months, persisted in other at 3 months);  
  • Durotomy during posterior decompression (1);  
  • bowel perforation (1);  
  • Wound infection that progressed to meningitis and sepsis (1) (had debridement and vacuum dressing);  
  also: pleural effusion requiring chest tube (2); intraop hemodynamic instability (1); pulmonary embolism (1); ileus (1) |
| Acosta et al. (2011)[31] | • 36 patients  
  • Spondylosis, degenerative scoliosis, ASD, spondylolisthesis, pseudarthrosis  
  • 27 f, 9 m  
  • Avg. age 62 years, range 43–84 | L1-2 (3); L2-3 (15); L3-4 (28); L4-5 (20) | 35/36 patients had supplemental percutaneous posterior fixation | Not noted | 21 months in 21/36 patients | A radiographic study; complications not discussed. |
| Isaacs et al. (2010)[33] | • 107 patients  
  • Symptomatic adult T-L scoliosis between T8–S1  
  • 72.9% f  
  • Avg. age 68.4 years, range 45–87 | 451 levels, 322 with XLIF: 1 level (8 patients); 2 (21); 3 (34); 4 (33); 5 (6); 6 (5); most frequent XLIF level: L3-L4 (92.5% of all patients) | Stand-alone (18.7%); supplemental fixation with posterior PS (75.7%), lateral fixation (5.6%) | 3.8 days overall (2.9 days, unstaged, 8.1 days, staged) | Periop only (up to 6 weeks); Strongest independent predictor of complications = total # of levels operated per patient; each additional level = approx. 59% increase in complication rate. | • Overall major complication rate 12.1%;  
  • Isolated proximal hip weakness (29/36) (transient in 86.2%);  
  • Protracted or severe hip weakness (7/107);  
  • 16 patients had major surgical complications; 11 patients had major medical complications;  
  • Complication rate with XLIF stand-alone or XLIF with percutaneous posterior instrumentation: 9.0%;  
  • Complication rate with XLIF and open posterior instrumentation: 20.7% |
Perioperative morbidities for thoracic and thoracolumbar disease
Karikari et al. reported on perioperative morbidities and initial clinical, radiographic, operative, and functional outcomes in 22 patients who underwent XLIF for isolated thoracic and thoracolumbar diseases.[34] This series also included one patient treated for osteomyelitis and another two patients treated for pathologic fracture secondary to tumor invasion.[34] Only one patient in the series required supplemental posterior instrumentation. All patients who reached at least the 6-month follow-up evaluation demonstrated radiographic evidence of fusion; furthermore, 21 of 22 patients had developed a complication. Although XLIF was originally developed for treating lumbar spine diseases, the authors concluded that XLIF is a feasible and safe option for treating thoracic spine disease. Nevertheless, to date, patients with osteomyelitis or tumor represent a small percentage of those undergoing XLIF.

COMPLICATIONS OF XLIF

Although the most common complications following XLIF include thigh numbness, lower extremity radiculopathy with weakness, and pseudarthrosis, other unusual complications have been reported in smaller series or case reports.[17,28,40,44,60,65,71] Table 4. Daffner and Wang reported a patient whose L3-L4 cage migrated one month after surgery.[17] Following cage revision utilizing a mini-open operation with lateral plate fixation, the patient fused and her leg pain resolved.

Contralateral femoral nerve compression following XLIF
Out of 14 patients who underwent XLIF, Papanastassiou et al. reported on two patients who developed the unusual complication of contralateral femoral nerve compression.[46] The first patient sustained a femoral nerve injury due to a displaced endplate fragment compressing the contralateral nerve, while the second patient developed a far lateral disk herniation. Although symptoms resolved in both patients following revision surgery, the authors cautioned against “overzealous” endplate removal in the opposite corner during surgery.

Ipsilateral nerve root injury during transpsoas approach for XLIF
Houten et al. described two patients who developed ipsilateral nerve root injuries during the transpsoas approach.[28] Neither deficit was detected on intraoperative EMG monitoring, leaving both patients with significant motor deficits that only partially recovered more than a year after surgery.

Failures and reoperations following XLIF with lateral fixation
XLIF has some significant technical shortcomings as indicated by the necessity for early reoperation to address chronic CSF leakage due to dural tears, infection, or...
Table 4: Contd...

| Complications reported | Studies reporting those complications |
|------------------------|---------------------------------------|
| Adjacent Segment Disease | Karikari et al. (2011)[33] |
| ASD                    | Karikari et al. (2011)[34] |
| ASD at 1 year postop   | Oliveira et al. (2010)[45] |
|                        | Youssef et al. (2010)[71] |
| Infection              | Berjano et al. (2012)[7] |
| Infection of posterior wound | Karikari et al. (2011)[30] |
| Wound infection that progressed to meningitis and sepsis | Sharma et al. (2011)[36] |
| UTI                    | Tormenti et al. (2010)[46] |
| Pyelonephritis         | Youssef et al. (2010)[71] |
| Vertebral Issues       | Karikari et al. (2011)[33] |
| Remote compression fracture | Le et al. (2012)[29] |
| Adjacent-level compression fracture | Oliveira et al. (2010)[45] |
| Pedicle fracture       | Rodgers et al. (2011)[54] |
| Nondisplaced bilateral pedicle fracture | Rodgers et al. (2010)[53] |
| VB fracture            | Sharma et al. (2011)[36] |
| VB fracture with subsidence | Youssef et al. (2010)[71] |
| Endplate fracture      | Rodgers et al. (2011)[54] |
| Osteophyte fracture    | Rodgers et al. (2010)[53] |
| Congenital small pedicles | Sharma et al. (2011)[36] |
| Heterotopic ossification leading to Foramen stenosis | Youssef et al. (2010)[71] |
| Lateral HNP            | Rodgers et al. (2011)[54] |
| Hardware               | Anand et al. (2010)[33] |
| Proximal screw prominence requiring removal | Berjano et al. (2012)[7] |
| Proximal screw fracture (asymptomatic) | Dakwar et al. (2010)[33] |
| Screw broke through endplate with Subsidence | Karikari et al. (2011)[33] |
| Screw pullout          | Karikari et al. (2011)[33] |
| Implant fracture with subsidence | Knight et al. (2009)[23] |
| Dislodged lock nut and lateral plate Subsidence (asymptomatic) | Le et al. (2012)[29] |
| Subsidence (asymptomatic) | Oliveira et al. (2010)[45] |
| Implant subsidence     | Oliveira et al. (2010)[45] |
| Cage subsidence        | Pimenta et al. (2011)[48] |
| Cage subsidence causing recurrent stenosis | Rodgers et al. (2011)[54] |
| Malpositioned anterior cage | Rodgers et al. (2010)[53] |
| Hardware failure       | Sharma et al. (2011)[36] |
| Hardware failure (asymptomatic) | Wang and Mummaneni (2010)[46] |
| Subsidence of adjacent plates | Youssef et al. (2010)[71] |
| Interbody graft subsidence | Rodgers et al. (2011)[54] |
| Interbody graft subsidence into adjacent VB | Rodgers et al. (2010)[53] |
| TDR device removal and revision | Youssef et al. (2010)[71] |

A tertiary care center 48 hours following an L2-3 XLIF[57] following blood transfusions and fluid for resuscitation, CT demonstrated a large retroperitoneal hematoma. An angiogram revealed a traumatic pseudoaneurysm of the left L2 radicular artery adjacent to the superior left lateral L2 screw, and the pseudoaneurysm was embozulated. Ultimately, the patient’s condition stabilized and he was discharged two days later.

CONCLUSIONS

Popularity and high fusion rates of XLIF

The XLIF procedure has gained significant popularity in the last decade and is likely to become even more popular in the next several years. Indications for its use have increased, and some traumatic lesions may soon be treated with this approach as well. XLIF has a similar fusion rate and outcome profile when compared with more invasive procedures, and, as technology advances, the XLIF may even surpass them. In addition, XLIF appears to be as equally cost-effective as standard interbody fusion procedures.

Unique complications of XLIF

XLIF has its own set of unique complications, and surgeons who continue to utilize this technique must remain vigilant to observe, record, and avoid potential pitfalls. As is true of any new surgical procedure, successful XLIF is based on thorough knowledge of the anatomy, proper patient selection, attention to detail regarding surgical technique, and appropriate preoperative planning.

REFERENCES

1. Acosta FL, Liu J, Slimack N, Moller D, Fessler R, Koski T. Changes in coronal and sagittal plane alignment following minimally invasive direct lateral interbody fusion for the treatment of degenerative lumbar disease in adults: A radiographic study. J Neurosurg Spine 2011;15:92-6.
2. Anand N, Baron EM, Thayananthan G, Khalsa K, Goldstein TB. Minimally invasive multilevel percutaneous connection and fusion for adult lumbar degenerative scoliosis: A technique and feasibility study. J Spinal Disord Tech 2008;21:459-67.
3. Anand N, Rosemann R, Khalsa B, Baron EM. Mid-term to long-term clinical and functional outcomes of minimally invasive correction and fusion for adults with scoliosis. Neurosurg Focus 2010;28:E6.
4. Bagan B, Patel N, Deutsch H, Harrop J, Sharan A, Yacarro AR, et al. Perioperative complications of minimally invasive surgery (MIS): Comparison of MIS and open interbody fusion techniques. Surg Technol Int 2008;17:381-6.
5. Benglis DM, Yanni S, Levi AD. An anatomical study of the lumbosacral plexus as related to the minimally invasive transspaso approach to the lumbar spine. J Neurosurg Spine 2009;10:139-44.
6. Bergey DL, Villavicencio AT, Goldstein T, Regan JJ. Endoscopic lateral transspaso approach to the lumbar spine. Spine 2004;29:1681-8.
7. Berjano P, Balsano M, Buric J, Petruazzi M, Lamartina C. Direct lateral access lumbar and thoracolumbar fusion: preliminary results. Eur Spine J 2012;21:37-42.
8. Boden SD, Kang J, Sandhu H, Heller JG. Use of recombinant human bone morphogenetic protein-2 to achieve posterolateral lumbar spine fusion in humans: A prospective, randomized clinical pilot trial. 2002 Volvo Award in clinical studies. Spine 2002;27:2662-73.
Boden SD, Zhedelkic TA, Sandhu HS, Heim SE. The use of rhBMP-2 in interbody fusion cages. Definitive evidence of osteoinduction in humans: A preliminary report. Spine 2000;25:376-81.

Brau SA. Mini-open approach to the spine for anterior lumbar interbody fusion: description of the procedure, results and complications. Spine J 2002;2:216-23.

Burkus JK, Gornet MF, Dickinson CA, Zedelkic TA. Anterior lumbar interbody fusion using rhBMP-2 with tapered interbody cages. J Spinal Disord Tech 2002;15:373-49.

Burkus JK, Transfeldt EE, Kitchel SH, Watkins RG, Balderston RA. Clinical and radiographic outcomes of anterior lumbar interbody fusion using recombinant human bone morphogenetic protein-2. Spine 2002;27:2396-408.

Daffner SD, Wang JC. Migrated XLIF cage: Case report and discussion of surgical technique. Orthopedics 2010;33:315.

Deluzio KJ, Lucio JC, Rodgers WB. Value and cost in less invasive spinal fusion procedures. JAMA 2009;302:58-66.

Dakwar E, Cardona RF, Smith DA, Uribe JS. Early outcomes and safety of the minimally invasive, lateral retroperitoneal transpsoas approach for adult degenerative scoliosis. Neurosurg Focus 2010;28:E8.

Dawson E, Bae HW, Burkus JK, Stambough JL, Glassman SD. Recombinant human bone morphogenetic protein-2 on an absorbable collagen sponge with an osteoconductive bulk agent in posterolateral arthrodesis with instrumentation: A prospective randomized trial. J Bone Joint Surg Am 2009;91:1604-13.

Dawson E, Bae HW, Burkus JK, Glassman SD. Recombinant human bone morphogenetic protein-2 on an absorbable collagen sponge with an osteoconductive bulk agent in posterolateral arthrodesis with instrumentation: A prospective randomized trial. J Bone Joint Surg Am 2009;91:1604-13.

Kahlil KS, Chi JH, Day A, Claus EB. Prevalence, complications, and hospital charges associated with use of bone-morphogenetic proteins in spinal fusion procedures. JAMA 2009;302:58-66.

Carragee EJ, Hurwitz EL, Weiner BK. A critical review of recombinant human bone morphogenetic protein-2 trials in spinal surgery: Is safety relative to concern and lessons learned. Spine J 2011;11:1471-91.

Caffier SD, Wang JC. Migrated XLIF cage: Case report and discussion of surgical technique. Orthop 2010;33:315.

Dakwar E, Cardona RF, Smith DA, Uribe JS. Early outcomes and safety of the minimally invasive, lateral retroperitoneal transpsoas approach for adult degenerative scoliosis. Neurosurg Focus 2010;28:E8.

Dawson E, Bae HW, Burkus JK, Stambough JL, Glassman SD. Recombinant human bone morphogenetic protein-2 on an absorbable collagen sponge with an osteoconductive bulk agent in posterolateral arthrodesis with instrumentation: A prospective randomized trial. J Bone Joint Surg Am 2009;91:1604-13.

Deluzio KJ, Lucio JC, Rodgers WB. Value and cost in less invasive spinal fusion procedures. JAMA 2009;302:58-66.

Dakwar E, Cardona RF, Smith DA, Uribe JS. Early outcomes and safety of the minimally invasive, lateral retroperitoneal transpsoas approach for adult degenerative scoliosis. Neurosurg Focus 2010;28:E8.

Kahlil KS, Chi JH, Day A, Claus EB. Prevalence, complications, and hospital charges associated with use of bone-morphogenetic proteins in spinal fusion procedures. JAMA 2009;302:58-66.

Carragee EJ, Hurwitz EL, Weiner BK. A critical review of recombinant human bone morphogenetic protein-2 trials in spinal surgery: Is safety relative to concern and lessons learned. Spine J 2011;11:1471-91.

Caffier SD, Wang JC. Migrated XLIF cage: Case report and discussion of surgical technique. Orthop 2010;33:315.

Dakwar E, Cardona RF, Smith DA, Uribe JS. Early outcomes and safety of the minimally invasive, lateral retroperitoneal transpsoas approach for adult degenerative scoliosis. Neurosurg Focus 2010;28:E8.

Dawson E, Bae HW, Burkus JK, Stambough JL, Glassman SD. Recombinant human bone morphogenetic protein-2 on an absorbable collagen sponge with an osteoconductive bulk agent in posterolateral arthrodesis with instrumentation: A prospective randomized trial. J Bone Joint Surg Am 2009;91:1604-13.

Deluzio KJ, Lucio JC, Rodgers WB. Value and cost in less invasive spinal fusion procedures. JAMA 2009;302:58-66.

Dakwar E, Cardona RF, Smith DA, Uribe JS. Early outcomes and safety of the minimally invasive, lateral retroperitoneal transpsoas approach for adult degenerative scoliosis. Neurosurg Focus 2010;28:E8.

Kahlil KS, Chi JH, Day A, Claus EB. Prevalence, complications, and hospital charges associated with use of bone-morphogenetic proteins in spinal fusion procedures. JAMA 2009;302:58-66.

Carragee EJ, Hurwitz EL, Weiner BK. A critical review of recombinant human bone morphogenetic protein-2 trials in spinal surgery: Is safety relative to concern and lessons learned. Spine J 2011;11:1471-91.

Caffier SD, Wang JC. Migrated XLIF cage: Case report and discussion of surgical technique. Orthop 2010;33:315.
complications in extreme lateral interbody fusion: An analysis of 600 cases. Spine 2011;36:26-32.
55. Rodgers WB, Gerber EJ, Patterson JR. Fusion after minimally disruptive anterior lumbar interbody fusion: Analysis of extreme lateral interbody fusion by computed tomography. SAS J 2010;4:63-6.
56. Rouben D, Casnellie M, Ferguson M. Long-term durability of minimal invasive posterior transforaminal lumbar interbody fusion: A clinical and radiographic follow-up. J Spinal Disord Tech 2010.
57. Santillan A, Patalades A, Gobin YP. Endovascular embolization of iatrogenic lumbar artery pseudoaneurysm following extreme lateral interbody fusion (XLIF). Vasc Endovascular Surg 2010;44:601-3.
58. Sharma AK, Kepler CK, Girardi FP, Cammisa FP, Huang RC, Sama AA. Lateral lumbar interbody fusion: Clinical and radiographic outcomes at 1 year: a preliminary report. J Spinal Disord Tech 2011;24:242-50.
59. Shunwu F, Xing Z, Fengdong Z, Xianggian F. Minimally invasive transforaminal lumbar interbody fusion for the treatment of degenerative lumbar diseases. Spine (Phila Pa 1976) 2010;35:1615-20.
60. Simpson AK, Harrod C, White AP. Lateral Lumbar Trans-Psoas Interbody Fusion. Techn in Orthop 2011;26:156-65.
61. Smith WD, Yousef JA, Christian G, Serrano S, Hyde JA. Lumbarized sacrum as a relative contraindication for lateral transpsoas interbody fusion at L5-S6. J Spinal Disord Tech 2011;26:156-65.
62. Smoljanovic T, Pecina M, Re: Burkus J K, Sandhu HS, Gornet MF. Influence of rhBMP-2 on the healing patterns associated with allograft interbody constructs in comparison with autograft. Spine 2006;31:775-81 Spine (Phila Pa 1976) 2008;33:226.
63. Tohmeh AG, Rodgers WB, Peterson MD. Dynamically evoked, discrete-threshold electromyography in the extreme lateral interbody fusion approach. J Neurosurg Spine 2011;14:31-7.
64. Tormenti MJ, Mazzerati MB, Bonfield CM, Okonkwo DO, Kanter AS. Complications and radiographic correction in adult scoliosis following combined transpsoas extreme lateral interbody fusion and posterior pedicle screw instrumentation. Neurosurg Focus 2010;28:E7.
65. Uribe JS, Arredondo N, Dakwar E, Vale FL. Defining the safe working zones using the minimally invasive lateral retroperitoneal transpsoas approach: an anatomical study. J Neurosurg Spine 2010;13:260-6.
66. Uribe JS, Vale FL, Dakwar E. Electromyographic monitoring and its anatomical implications in minimally invasive spine surgery. Spine 2010;35(26 Suppl):368-74.
67. Yaida R, Wein R, Sethi A, Meisterling S, Hakeos W, Wybo CD. Interbody fusion with allograft and rhBMP-2 leads to consistent fusion but early subsidence. J Bone Joint Surg Br 2007;89:342-5.
68. Villavicencio AT, Burrellone S, Roca CM, Nelson EL, Mason A. Minimally invasive versus open transforaminal lumbar interbody fusion. Surg Neurol Int 2010;1:12.
69. Wang MY, Mummaneni PV. Minimally invasive surgery for thoracolumbar spinal deformity: Initial clinical experience with clinical and radiographic outcomes. Neurosurg Focus 2010;28:E9.
70. Wu RH, Fraser JF, Hartl R. Minimal access versus open transforaminal lumbar interbody fusion: Meta-analysis of fusion rates. Spine (Phila Pa 1976) 2010;35:2273-81.
71. Yousef JA, McAfee PC, Paty CA, Raley E, DeBauche S, Shucosky E, Chotikul L. Minimally invasive surgery: Lateral approach interbody fusion: results and review. Spine 2010;35(26 Suppl):S302-11.

Disclaimer: The authors of this paper have received no outside funding and have nothing to disclose.

Author Help: Reference checking facility

The manuscript system (www.journalonweb.com) allows the authors to check and verify the accuracy and style of references. The tool checks the references with PubMed as per a predefined style. Authors are encouraged to use this facility, before submitting articles to the journal.

- The style as well as bibliographic elements should be 100% accurate, to help get the references verified from the system. Even a single spelling error or addition of issue number/month of publication will lead to an error when verifying the reference.
- Example of a correct style
  Sheahan P, O’leary G, Lee G, Fitzgibbon J. Cystic cervical metastases: Incidence and diagnosis using fine needle aspiration biopsy. Otolaryngol Head Neck Surg 2002;127:294-8.
- Only the references from journals indexed in PubMed will be checked.
- Enter each reference in new line, without a serial number.
- Add up to a maximum of 15 references at a time.
- If the reference is correct for its bibliographic elements and punctuations, it will be shown as CORRECT and a link to the correct article in PubMed will be given.
- If any of the bibliographic elements are missing, incorrect or extra (such as issue number), it will be shown as INCORRECT and link to possible articles in PubMed will be given.