Complications of the Lateral Transpsoas Approach for Lumbar Interbody Arthrodesis

A Case Series and Literature Review

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Published online: 23 September 2011
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Abstract

Background The lateral transpsoas approach to the lumbar spine was developed to eliminate the need for an anterior-approach surgeon and retraction of the great vessels and has the potential for shorter operative times. However, the reported complications associated with this approach vary.

Questions/purposes We identified the incidence of complications associated with the lateral transpsoas approach to the lumbar spine.

Patients and Methods We retrospectively reviewed 45 patients who underwent a lateral transpsoas approach to the spine for various diagnoses between January 1, 2006, and October 31, 2010. The patients' average age was 63.3 years. Sixteen (35.6%) patients had prior lumbar spinal surgery.

One of the authors (AAP) owns stock in Amedica (Salt Lake City, UT), Nocimed (Redwood City, CA), and Cytonics (Jupiter, FL); consults for Amedica, Biomet (Warsaw, IN), and Stryker Spine (Kalamazoo, MI); receives royalties from Amedica; and has received research funding from Stryker Spine through his institution. All ICMJE Conflict of Interest Forms for authors and *Clinical Orthopaedics and Related Research* editors and board members are on file with the publication and can be viewed on request. Each author certifies that his or her institution approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained. This work was performed at both the University of Utah and Stanford University.

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Twenty-one patients (46.7%) underwent supplemental posterior instrumentation. Minimum followup was 0 months (mean, 11 months; range, 0–34 months).

Results Eighteen of the 45 patients (40%) had complications: 10 (22.2%) developed postoperative iliopsoas weakness, three had quadriceps weakness, and one experienced foot drop. Eight patients (17.8%) developed anterior thigh hypoesthesia, which did not fully resolve in seven of the eight patients at an average of 9 months' followup. Three patients had postoperative radiculopathies, one a durotomy, and one died postoperatively from a pulmonary embolism.

Conclusions We found a 40% incidence of complications and a nontrivial frequency and severity of postoperative weakness, numbness, and radicular pain in patients who underwent a lateral transpsoas approach to the spine. Given the expanding use of the approach, a thorough understanding of the risks associated with it is essential for patient education, medical decision making, and identifying methods of reducing such complications.

Level of Evidence Level IV, therapeutic study. See Guidelines for Authors for a complete description of levels of evidence.

Introduction

Traditionally, interbody arthrodesis is achieved through open surgical approaches, including anterior lumbar interbody fusion (ALIF) [4, 10, 21, 27, 29, 31], posterior lumbar interbody fusion (PLIF) [9], and transforaminal interbody fusion (TLIF) [8, 18, 24, 27, 35]. Several studies have documented the complications of these surgical techniques [1, 5, 11, 23, 30]. The reported rates of complications in

isolated anterior and posterior surgery in the thoracic and lumbar spine vary widely in the literature. Anterior-approach complications include damage to the abdominal organs (< 1%), vascular injury (1.3%–15.6%), disruption of the sympathetic plexus (1.7%–13.3%), and postoperative ileus (0.6%–5.6%) [6, 29–31]. Posterior approaches avoid the aforementioned risks but can lead to soft tissue devitalization, nerve root injuries (9%–16%), postoperative radiculitis (6.7%–16.4%), and incidental durotomies (5.4%–10%) [5, 9, 26, 31]. Newer surgical techniques were developed in hopes of minimizing surgical risks, decreasing in-hospital stay, and potentially improving patient satisfaction [17]. In the United States, there has been substantial growth in the utilization of many of these newer techniques over the past 5 years [2]. However, despite this rapid growth, the literature remains sparse with regard to surgical complications.

One alternative technique is a lateral transpsoas approach to the anterior lumbar spine [17]. An initial description of lateral retroperitoneal interbody arthrodesis was presented by Pimenta in 2001 [19]. His retroperitoneal endoscopic technique led to further development of lateral transpsoas approaches. The lateral transpsoas approach eliminates the need for an anterior approach and retraction of the great vessels and has the potential for shorter operative times compared to traditional open approaches [16]. During this approach, the surgeon transverses through the psoas muscle. Similar to other anterior approaches, risk for vascular injury exists. The major unique risk is injury to the lumbar nerves as they exit the neural foramen and travel through the psoas muscle forming the lumbosacral plexus. This can lead to complications related to pain, neuropraxia, and weakness [3, 15, 32]. Recent studies have identified complication rates ranging from 6.2% to 52% [4, 7, 13–16, 20, 26, 27, 32–34, 36]. However, inconsistent definitions of complications confound interpretation of these reports. Furthermore, the financial conflicts of interest of the authors may have limited interpretation of the majority of published reports.

Given the lack of consistent reporting and broad complication profile range, we (1) identified our operative complications with this novel approach and (2) performed a comprehensive review of the literature on complications.

Patients and Methods

We retrospectively identified patients who had transpsoas lumbar interbody fusion at two tertiary institutions between January 1, 2006, and October 31, 2010. All patients presented with back pain and/or radicular pain that was refractory to nonoperative management. We did not exclude patients on the basis of diagnosis. We identified

45 patients: 29 women and 16 men with an average age of 63 years (range, 33–81 years). Diagnosis prompting fusion was spondylosis with stenosis in 24 patients, degenerative scoliosis in 10, degenerative disc disease in eight, adjacent segment degeneration in six, pseudoarthrosis in two, and kyphosis in one; some patients had more than one diagnosis. Sixteen (35.6%) patients had prior lumbar spinal surgery. Minimum followup was 0 months (mean, 11 months; range, 0–34 months). No patients were lost to followup. We did not recall patients specifically for this study; we obtained all data from medical records and radiographs.

The lateral interbody fusion was performed using the technique previously described by Ozgur et al. [16]. For the procedure, the patients were positioned in an accentuated lateral decubitus position and fluoroscopic localization of the affected level was preformed, followed by lateral retroperitoneal dissection to expose the lateral surface of the spine. The lumbosacral plexus was protected since the psoas muscle was traversed using automated electrophysiology via dynamic discrete evoked electromyography. An expandable retractor was placed and visualization of the disc space obtained. Discectomy and preparation of the interbody space were performed, followed by placement of the interbody device and bone graft. No patients underwent autologous iliac crest harvesting; all patients received a graft with either allograft bone or local autograft bone.

We had no standardized protocol for postoperative followup dates. From the medical records, we extracted demographics (age, sex), diagnosis, prior lumbar surgery, procedure (including level(s) operated on), supplemental instrumentation, intraoperative complications, postoperative complications, implant-related complications, and reoperation rates. We considered a complication to have occurred if a patient had any new complaint and/or examination finding, such as thigh numbness, pain, or weakness, during the postoperative period that was not present preoperatively. We reviewed all pre- and postoperative notes and specifically asked all patients about pain, numbness, or weakness. We distinguished thigh pain from groin pain. All patients had hip flexors, knee extensors, ankle dorsiflexor, ankle plantar flexors, and extensor hallucis longus tested and documented on examination. We also performed a lower-extremity sensory examination on most patients. In 18 patients, we also reviewed the 0- to 10-point visual analog pain scale (VAS) score for back pain obtained before surgery and at each postoperative office visit.

We treated a total of 71 interbody levels (1.53 levels/patient) in 45 patients. Twenty-eight patients had single-level fusion, nine had two-level fusion, and eight had fusions involving three or more levels. Three procedures were performed at L1–2 (4.2%), 15 at L2–3 (21.1%), 27 at

Table 1. Patient characteristics

Characteristic	Value
Number of patients	45
Number of disc levels treated	71
Number of approaches/level	
L1–2	3 (4.2%)
L2–3	15 (21.1%)
L3–4	27 (38%)
L4–5	26 (36.6%)
Number of patients with supplemental posterior instrumentation	21 (46.7%)
Number of patients with supplemental anterior instrumentation	10 (22.2%)
Number of patients with concomitant procedure at different level	7 (15.6%)
Average estimated blood loss (mL)	230.8
Average preoperative/postoperative VAS score for back pain	6.8/2.7

VAS = visual analog scale.

L3–4 (38%), and 26 at L4–5 (36.6%) (Table 1). Twenty-one patients (46.7%) underwent supplemental posterior pedicle screw instrumentation through either a standard or minimally invasive approach at the time of index operation or in a staged fashion, 10 (22.2%) had supplemental anterolateral fixation, and seven (15.6%) had a concomitant procedure performed at a different level (ie, ALIF, TLIF, etc) (Table 1). The mean total blood loss was 230.8 mL (146 mL/level) for the entire series, including any additional posterior procedures (Table 1). The mean ($\pm$ SD) preoperative VAS back pain score was 6.8 ($\pm$ 2.3; 95% confidence interval = 0.7; range, 6.1–7.5) compared to a mean postoperative score of 2.7 ($\pm$ 2.4; 95% confidence interval = 0.8; range, 1.9–3.5) (Table 1).

Literature Search Strategy and Criteria

We performed a comprehensive literature review to assess the safety of the direct lateral transposas approach in patients undergoing interbody arthrodesis procedures. We searched the PubMed database for relevant studies from the last 10 years, limiting the results to English studies, as that is our primary language. The search strategy consisted of a combination of Medical Subject Headings (MeSH) keywords concerning the technical procedure (spinal fusion, spinal arthrodesis, discectomy, surgical procedures, minimally invasive) and keywords regarding the anatomic features and pathology (lumbosacral region, lumbar vertebrae, osteoarthritis, intervertebral disk degeneration, low back pain). We further combined this search with the keywords “intraoperative or postoperative complications”

Fig. 1 The flowchart demonstrates the method for the comprehensive review of the literature, noting the number of articles identified by the initial search guidelines (78) and the exclusion steps that led to the final included number (13).

or “lumbosacral plexus” to refine the search. Additionally, we searched using the specific common names of the approach/procedure as free text, including “xlif,” “extreme lateral interbody fusion,” “transposas approach,” and “direct lateral.” We then inspected the references of all primary studies for additional references not identified in the initial search. We initially identified and reviewed 78 articles (Fig. 1) and included studies pertaining only to lumbar fusions through a transposas approach. We included observational, cohort, case-control, retrospective review, randomized controlled trials, and case series with clear documentation of perioperative complications. After reviewing the titles and abstracts of these 78 articles, we excluded 41 articles that did not pertain to the lateral transposas approach to the spine. After searching the

reference sections of each article, we added four additional articles pertaining to the transposas approach. We screened the text of these 41 articles and excluded any biomechanical studies, cadaveric studies, purely radiographic studies, and case reports. Of these, 13 studies met all selection criteria (Table 2).

Relevant data from the included studies were study methodology, population (number of patients in study, age, diagnosis, obesity), vertebral level(s) operated, estimated blood loss, length of hospital stay, followup period, complications, and reoperations. We also identified reported pain intensity (VAS, Oswestry Disability Index [ODI], SF-12, and SF-36 health surveys). Lastly, we recorded any author conflict of interest, as stated in the paper's disclosures.

Results

Eighteen of 45 patients (40%) had complications (Table 3). Multiple complications occurred in seven patients (15.5%). The most common complications were iliopsoas weakness (10, 22.2%), anterior thigh numbness (eight, 17.8%), quadriceps weakness (three, 6.7%), and radiculopathy (three, 6.7%) (Table 4). These 24 complications occurred in 15 of the 45 patients (33.3%). Of these 24 complications, 13 occurred during a single-level surgery (eight of which at the L3–4 level), while 11 occurred during an operation in which multiple levels were fused through a transposas approach (Table 4). Of these 15 patients who had neurologic complications, eight had one-level, four had two-level, two had three-level, and one had four-level fusion (Table 3). The majority of the complications occurred at the L3–4 level, followed by the L4–5 level (Table 5).

Of the 10 patients who developed postoperative iliopsoas weakness (Grade 3 to 4 on a 5-point scale), five had resolution of their symptoms at an average of 5 months after surgery and the remaining five had persistent weakness at an average of 11 months' followup. Of the eight patients who developed anterior thigh hypoesthesia, it was in the ipsilateral leg in seven patients and the contralateral leg in one patient. This numbness did not fully resolve in seven of the eight patients at an average of 9 months' followup. Of three patients with quadriceps weakness (Grade 4 on a 5-point scale), it resolved in only one patient at an average of 21 months' followup. Of the three postoperative radiculopathies, one resolved after selective nerve root injection, one resolved with no intervention, and one persisted. One patient developed a foot drop (Grade 3 on a 5-point scale) that was persistent at 11 months' followup. The only intraoperative complication was a dural tear in one patient during a revision posterior decompression. We did not identify any vascular injuries. There were

no instrumentation complications and no wound infections. No patients required surgical revision.

We identified other, nonsurgical complications. One patient had a prolonged intensive care unit stay for altered mental status with urinary retention and one developed an incisional hernia. There was one postoperative ileus that resolved in 3 days. There was one death on Postoperative Day 15 from a pulmonary embolism.

Discussion

Given the lack of consistent reporting and broad range of complications, we reviewed our operative complications with the transposas approach and performed a comprehensive review of the literature on this topic. Through this combined approach, we were able to refine our understanding of the risks associated with the transposas approach to lumbar interbody arthrodesis.

Despite our relatively high rate of complications, all but one patient reported an improvement in their VAS pain score. The 10-point VAS is the only form we routinely have patients complete both pre- and postoperatively. We were limited by the retrospective nature of the study and ideally would have included other quality-of-life measures such as the ODI and the SF-36. Both single-item and multiple-item quality measures have their strengths and weaknesses. The VAS is an imperfect measure of outcomes after surgery; however, we believe the simplicity and ease of use result in a higher rate of completed responses and operational efficiency such as data entry and data analysis.

The literature and our review were also subject to various limitations. First, the literature on transposas complications was clouded by inconsistencies in the definition of complications. In a review of 100 patients, Rodgers et al. [25] noted "post-operative thigh discomfort was routine and slight lateral thigh numbness rare. These symptoms resolved completely within four to six weeks in all cases." Some authors considered the side effect profile of transient thigh discomfort to be a complication [7, 12–15, 20, 32–34, 36], while others described it as an accepted, approach-related symptom [16, 26, 37]. Other authors attempted to categorically identify their complications, listing "major adverse events" versus "approach-related complaints" [15] or as "major and minor" [12]. Studies from our systematic review that have characterized the complications of lateral transposas approaches (Table 2) included adverse medical outcomes (ileus, pneumonia, renal, pulmonary embolus, cardiac [26, 27], anemia, volvulus [27], rhabdomyolysis [7], pleural effusion, sepsis [12]) and surgery-specific complications (vertebral fracture [14, 26, 27, 32], end plate fracture [27], iatrogenic herniated nucleus pulposus [27], graft subsidence [7], sensory disturbance [14–16, 20, 26, 32, 33],

Table 2. Literature regarding the complication profile of the lateral transposas approach to the spine

Study	Design	Number of patients	Additional procedures	Average age (years)	Diagnoses	Levels	Average followup (months)
Dakwar et al. [7]	Retrospective cohort study	25	23/25 (92%) with pedicle screw and/or lateral plate instrumentation	62.5 (35–77)	Thoracolumbar degenerative deformity	Any number between T10 and S1	11 (3–20)
Isaacs et al. [12]	Prospective multicenter nonrandomized observational study	107	Supplemental pedicle screw fixation (75.7%), lateral fixation (5.6%), XLIF alone (18.7%)	68.4 (45–87)	Thoracolumbar scoliosis	Any number between T8 and S1 (451 total; 4.4 average/patient)	6
Karikari et al. [13]	Retrospective review	22	1 posterior pedicle screw instrumentation	64.6 (50–81)	Degenerative scoliosis (11), pathologic fx from tumors (2), adjacent-level disease from prior fusions (5), thoracic disc herniations (3), discitis/osteomyelitis (1)	47 total, spanning from T6–7 to L1–2	16.4 (3–50)
Kepler et al. [14]	Retrospective cohort study	13	Unilateral pedicle screw instrumentation and anterior instrumentation	60.1 (43.7–76.8)	Spondylolisthesis with stenosis (8), disc collapse with foraminal stenosis (2), adjacent-level degeneration (2), postdiscectomy degeneration (1)	1-level interbody fusion at L3–4 (n = 2) or L4–5 (n = 11)	12
Knight et al. [15]	Prospective nonrandomized chart review	58	Not reported	61 (32–80)	Lumbar degenerative conditions	79 total levels, 38 1-level, 19 2-level, 1 3-level	15 (3–34)
Ozgur et al. [16]	Retrospective chart review	62	45 (73%) posterior pedicle fixation, 4 (6%) lateral fixation, 13 (21%) stand-alone	63.8 (31–88)	35.5% degenerative scoliosis, 32.2% DDD, 22.6% spondylolisthesis, 9.7% stenosis	113 levels total, 26 (42%) 1-level, 13 (21%) 2-level, 23 (37%) 3 or more levels	24
Pimenta et al. [20]	Prospective single-center nonrandomized observational study	36	18 hybrid procedures: ALIF at L5–S1 and TDR at L4–5 (17) or L3–4 (1)	42.6 (22–60)	1- or 2-level degenerative disc disease	15 1-level TDR at L3–4 or L4–5, three 2-level TDR spanning L3–4 and L4–5	24
Rodgers et al. [26]	Retrospective review of prospective data	313 (156 obese)	Not reported	58.9 (obese), 62.9 (nonobese)	36 DDD, 42 HNP, 28 postlaminectomy instability, 20 scoliosis, 52 spondylolisthesis, 134 stenosis	Not reported	Minimum 3
Rodgers et al. [27]	Retrospective review of prospective data	600	511 (85%) posterior instrumentation; 84 (14%) lateral fixation; 5 (1%) XLIF alone	61.4 (22–89)	50.8% stenosis, 14.5 spondylolisthesis, 11.8% DDD, 9.7% HNP, 6.8% scoliosis, 6.2% postlaminectomy, 0.2% osteomyelitis	741 levels total, 80.8% 1-level, 15% 2-level, 4% 3-level, 0.2% 4-level; 59.3% included L4–5	308 (51%) 12 months; rest < 12 months but at least 6 weeks

Table 2. continued

Study	Design	Number of patients	Additional procedures	Average age (years)	Diagnoses	Levels	Average followup (months)
Sharma et al. [32]	Retrospective review	43	10 stand-alone anterior cages; 9 lateral plate and unilateral screw; 24 pedicle screws	63.9 (40–82)	25 degenerative scoliosis, 7 degenerative spondylolisthesis; 11 DDD ± stenosis	87 total: 20 L1-level, 6 L2-level, 13 L3-level, 4 L4-level; 9 L1–2 (10%), 27 L2–3 (31%), 26 L3–4 (30%), 25 L4–5 (29%)	Minimum 12
Tohmeh et al. [33]	Prospective multicenter nonrandomized clinical study	102	Not reported	63 (21–88)	67 stenosis with instability, 52 spondylolisthesis, 51 DDD, 40 disc height loss, 25 spondylolisthesis, 16 scoliosis, 9 recurrent disc herniation, 9 adjacent segment degeneration, 6 postlaminectomy instability, 5 loss of lordosis	132 total: 24 L3–4, 48 L4–5, 30 both	2 days
Tormenti et al. [34]	Retrospective review	8	All (100%) had supplemental open posterior pedicle screw instrumentation	60 (48–69)	Adult degenerative deformity	Variable L1–5	10.5 (3–16)
Wang et al. [36]	Prospective multicenter nonrandomized observational study	23	All (100%) percutaneous posterior pedicle screw fixation	64.4 (42–84)	Thoracolumbar degenerative deformity	86 total, 3.7/patient (2–7)	13.4 (6–34)
Study	Number of patients with complications	Neurovascular complications	Instrument complication	Other complications	Average estimated blood loss (mL)	Reoperations	Conflict of interest (yes/no)
Dakwar et al. [7]	6 (24%)	3 (12%) transient anterior thigh numbness	1 asymptomatic instrumentation failure, 1 asymptomatic subsidence	1 rhabdomyolysis requiring hemodialysis	53/level	Not reported	Yes
Isaacs et al. [12]	13 (12.1%)	7 motor deficit, 36 (33.6%) some weakness of which 86.2% resolved	None	1 MI, 1 sepsis, 3 wound infection, 1 kidney laceration, 1 DVT	< 100 (62.5%) > 300 (8.4%)	3 (2.8%)	Yes
Karikari et al. [13]	3 (13.6%)	None	1 graft subsidence	1 adjacent-level disease, 1 wound infection	227.5	3 (13.6%)	Yes

Table 2. continued

Study	Number of patients with complications	Neurovascular complications	Instrument complication	Other complications	Average estimated blood loss (mL)	Reoperations	Conflict of interest (yes/no)
Kepler et al. [14]	6 (46.2%)	3 (23%) transient hip flexion weakness, 1 (4.5%) transient thigh numbness	2 (15.4%) fx through anterior screw tracts	None	225	Not reported	Not reported
Knight et al. [15]	13 (22.4%)	2 (3.4%) L4 nerve root injury, 6 (10.3%) meralgia paresthetica, 6 (10.3%) psoas muscle spasm	1 loss of fixation requiring reoperation	None	136 (25–600)	1 (1.7%)	Yes
Ozgun et al. [16]	No major and 12 (19%) minor complications	“Common” to have transient hip flexion weakness and bilateral upper thigh numbness	None	3 wound-related events, 3 respiratory events, 2 ileus, 2 cardiovascular events, 1 renal event, 1 pseudarthrosis	183 (91/level)	None	Not reported
Pimenta et al. [20]	Not reported	5 (13.8%) psoas weakness, 3 (8.3%) anterior thigh numbness (all resolved in 2 weeks)	None	None	60 (30–150)	2 (5.6%) removal of TDR and revision to fusion for device-related complications	Yes
Rodgers et al. [26]	27 (8.6%) total complications (10 in obese, 17 in nonobese)	4 nerve injuries	3 vertebral body fx, 3 hardware failure	7 ileus, 2 renal, 3 pneumonia, 1 PE, 1 incisional hernia, 3 cardiac	Not reported	4 (1.3%)	Yes
Rodgers et al. [27]	37 (6.2%)	3 transient quadriceps weakness, 1 tibialis anterior weakness	1 EF fx, 1 VB fx, 1 OP fx, 2 adjacent-level compression fx, 1 iatrogenic HNP, 1 implant fx, 1 screw breakage	1 wound hernia, 1 hematoma, 6 ileus, 1 volvulus, 5 pneumonia, 2 PE, 5 A fib, 1 MI, 2 renal, 1 anemia	Not reported	11 (1.8%)	Yes
Sharma et al. [32]	Not reported	15 transient anterior thigh pain, 11 hip flexor weakness (1 persisted at 1 year), 4 quadriceps weakness (1 persisted at 1 year)	“end plate breach common,” 2 vertebral body fx, 1 malpositioned cage	1 infection, 1 retroperitoneal hemorrhage	200 (50–350)	3 (7%)	Not reported

Table 2. continued

Study	Number of patients with complications	Neurovascular complications	Instrument complication	Other complications	Average estimated blood loss (mL)	Reoperations	Conflict of interest (yes/no)
Tohmeh et al. [33]	Not reported	28 (27.5%) hip flexion weakness, 18 (17.6%) upper thigh numbness, 3 (2.9%) new motor weakness (2 quadriceps, 1 tibialis anterior)	None	2 (1.96%) minor peritoneum perforations	Not reported	Not reported	Yes
Tormenti et al. [34]	Not reported	6 postoperative sensory radiculopathy, 2 postoperative motor radiculopathy	None	2 pleural effusions requiring chest tube, 1 bowel perforation, 1 infection, 1 intraoperative hemodynamic instability, 1 PE, 1 ileus, 1 durotomy	Not reported	Not reported	No financial support received; however, industry relations not stated
Wang et al. [36]	12 (52.2%)	7 (30.4%) thigh numbness/weakness/dysesthesias (persistent in 1 patient)	1 screw pullout	2 pneumothorax, 1 A fib, 1 CSF leak	477 (200–3500)	2 (8.7%)	Yes

XLIF = extreme lumbar interbody fusion; ALIF = anterior lumbar interbody fusion; TDR = total disc replacement; fx = fracture; DDD = degenerative disc disease; HNP = herniated nucleus pulposus; EP = endplate; VB = vertebral body; OP = osteophyte; MI = myocardial infarction; DVT = deep venous thrombosis; PE = pulmonary embolism; A fib = atrial fibrillation; CSF = cerebrospinal fluid.

Table 3. Characteristics of the patients experiencing a complication

Patient	Age (years)	Sex	Diagnosis	Procedure and level	Followup (months)	Complications	Estimated blood loss (mL)	Preoperative/postoperative VAS score for back pain
1	81	Male	L4–5 spondylosis with stenosis	L4–5 XLIF with posterior decompression	11	Foot drop, psoas weakness, L4 radiculopathy (persistent)	500	
2	71	Female	L3–4 spondylosis with stenosis	L3–4 XLIF with revision posterior decompression	18	Durotomy, L5 radiculopathy (relieved with nerve root injections)	400	
3	66	Female	L3–5 spondylosis with stenosis	L3–5 XLIF with posterior decompression	2	L4–5 radiculopathy, resolved in 1 day	100	
4	60	Female	L1–5 degenerative scoliosis	L1–5 XLIF, L5–S1 TLIF	12	Quadriceps weakness (persistent)	1500	
5	52	Female	L4–5 spondylosis with stenosis	L4–5 XLIF with posterior instrumentation	6	Thigh and groin numbness (persistent)	50	
6	53	Female	Scoliosis, severe DDD s/p previous L4–5 TLIF	L2–4 XLIF with posterior instrumentation, removal of L4–L5 instrumentation	2	Thigh numbness (persistent)	500	
7	52	Male	DDD and spondylosis L3–4 and L4–5	L3–4, L4–5 XLIF with anterolateral instrumentation	11	Transient (5 month) psoas and quadriceps weakness, thigh numbness (persistent)	100	7/3
8	76	Female	Stenosis L1–S1, degenerative scoliosis, s/p laminectomy L4–5	L2–3, L3–4, L4–5 XLIF, laminectomy L1–S1, PLIF L5–S1, posterior instrumentation T10 to ilium	16	Prolonged ICU stay for altered mental status, urinary retention		8/6
9	68	Female	Failed L4–5 fusion with pseudoarthrosis	L4–5 XLIF with posterior instrumentation	21	Transient (3-month) psoas weakness, transient (3-month) anterior thigh pain	250	5/0
10	54	Male	L3–4 DDD	L3–4 XLIF with anterolateral instrumentation	1	Psoas weakness and thigh numbness (persistent)		
11	75	Female	Degenerative scoliosis L2 to sacrum, spondylosis, spinal stenosis	L2–3 XLIF, L5–S1 TLIF, decompression L3–S1, posterior instrumentation L2–S1		Death on POD 15 from PE	1000	
12	52	Male	Pseudoarthrosis L3–4 s/p multiple prior lumbar surgeries	L3–4 XLIF with revision posterior instrumentation L2–S1	12	Thigh numbness and psoas weakness (persistent)	800	3/1
13	33	Female	L3–4 DDD	L3–4 XLIF with anterolateral instrumentation	12	Transient (3-month) psoas weakness	50	7/1
14	60	Female	Kyphosis L1–2 with hardware failure s/p L2–S1 PSF	L1–3 XLIF, L2 corpectomy	30	Thigh numbness, psoas and quadriceps weakness (persistent)		9/2

Table 3. continued

Patient	Age (years)	Sex	Diagnosis	Procedure and level	Followup (months)	Complications	Estimated blood loss (mL)	Preoperative/postoperative VAS score for back pain
15	66	Female	Spondylosis, degenerative scoliosis, spinal stenosis	L2–3, L3–4, L4–5 XLIF with anterolateral instrumentation (stage I of II)	12	Transient (12-month) psoas weakness	150	8/8
16	69	Female	Degenerative lumbar scoliosis	L2–3, L3–4, L4–5 XLIF with posterior instrumentation L1–5	34	Postoperative ileus, transient (2-month) psoas weakness	350	4/0
17	68	Female	Lumbar spondylosis, L3–4 adjacent to prior L4–S1 PSF	L3–4 XLIF with anterolateral instrumentation	1	Psoas weakness and contralateral anterior thigh numbness (persistent)	75	4/2
18	61	Male	Degenerative scoliosis, spinal stenosis, spondylosis	L2–3, L3–4, L4–5 XLIF with L5–S1 TLIF and posterior instrumentation L2 to pelvis	19	Incisional hernia	150	

VAS = visual analog scale; DDD = degenerative disc disease; s/p = status post; TLIF = transforaminal interbody fusion; PSF = posterior spinal fusion; XLIF = extreme lumbar interbody fusion; PLIF = posterior lumbar interbody fusion; ICU = intensive care unit; POD = postoperative day; PE = pulmonary embolism.

Table 4. Surgical complications

Complication	Number of patients affected	Number of patients with single-level surgery	Number of patients with multilevel surgery
Iliopsoas weakness	10 (22.2%)	6	4
Anterior thigh numbness	8 (17.8%)	5	3
Quadriceps weakness	3 (6.7%)	0	3
Radiculopathy	3 (6.7%)	2	1
Foot drop	1 (2.2%)	1	0
Durotomy	1 (2.2%)	1	0

motor deficits [12, 14–16, 20, 26, 27, 32, 33], incisional hernias [4, 26], hardware failures [12, 27], loss of fixation [15], malpositioned cage, retroperitoneal hemorrhage [32], hematoma [27], wound infection [12, 20], durotomy, pneumothorax, and peritoneum perforation [33]). Second, none of the literature reviewed was of high quality. There were no Level I studies, and there were obvious pitfalls to making clinical decisions based on Level III or IV evidence. Third, in nine of the 13 studies included in our review, there was a clear conflict of interest through industry relations, as disclosed by the authors. In the remaining four articles, there was no statement as to what the authors' industry relationships were and whether they had any conflicts of interest. While collaboration between industry and surgeons is important, this financial relationship adds the potential for bias, especially in the reporting of surgical complications [37]. We have no conflicts of interest to report as related to any of the devices used in this study. One of the authors

(AAP) has potential conflicts of interest with medical device manufacturers involved with interbody devices performed through the transpsoas and other surgical approaches (ALIF, TLIF, PLIF).

We identified surgical complications in 18 of 45 (40%) of our patients, with seven (15.5%) experiencing multiple complications. In the literature, the total complication rates varied from 6.2% to 52% [7, 12–16, 20, 26, 27, 32–34, 36]. The most common reported complications included anterior thigh numbness, radiculopathy, iliopsoas weakness, and quadriceps weakness [7, 12–16, 20, 26, 27, 32–34, 36]. Less commonly seen were hardware complications, including end plate fracture and graft subsidence. Reported blood loss ranged from 53 to 477 mL [7, 12–16, 20, 32, 36]. The average reported length of hospital stay ranged from 1.2 to 8.2 days, with longer stays associated with staged procedures or those with additional posterior stabilization [7, 12–16, 20, 26, 27, 32, 36]. The average reported followup ranged from 2 days to 24 months [7, 12–16, 20, 26, 27, 32–34, 36]. VAS pain score, reported in eight of 13 studies, improved on average from 8.3 to 3.6, and ODI, reported in five of 13 studies, improved on average from 48.1 to 27.3 [7, 13, 14, 16, 20, 27, 32, 34, 36].

After reviewing the available literature, we have no clear answer as to why our complication rate was higher than most studies. There are a number of potential explanations. First, our inclusive definition of complications may be one explanation. Several authors did not include postoperative hip flexor weakness and thigh numbness as complications but instead described them as transient,

Table 5. Complication profile per level involved

Level	Total approaches performed at this level	Iliopsoas weakness	Anterior thigh numbness	Quadriceps weakness	Radiculopathy	Total complications	Number performed as single-level procedure/multilevel procedure
L1–2	3	1	1	2	0	4	0/4
L2–3	15	3	2	2	0	7	0/7
L3–4	27	7	5	2	2	16	8/8
L4–5	26	5	3	2	2	12	5/7
Total	71	16	11	8	4	39	13/26

approach-related symptoms. However, our experience was to the contrary: 50% of patients with hip flexor weakness and 87.5% of patients with numbness had persistent symptoms. These problems could have led to substantial disability, prevented ambulation, and were a hindrance to postoperative rehabilitation. While longer followup may have demonstrated these to be self-limited, the duration of symptoms among our patients was extensive (up to 11 months) and we could not discount it.

Second, our complication rate may have been higher due to a surgical learning curve. However, compared to our earliest (2006) and latest period (2010), we found no difference in complication rate. Although we noted no difference in complication rates based on our early versus most recent experience, it should not be concluded the complication rate is constant for the inexperienced surgeon compared to one who has performed many transpsoas approaches to the spine. Our numbers are not large enough to comment on surgeon experience as it relates to the complication profile of the transpsoas approach. We realize making such a statement could be a Type II error given the small sample size, ie, noting no difference when, in fact, one exists. Most surgeons included in this study performed this operation fewer than five times per year; only one surgeon performed it at least 10 times per year. While we saw no differences in complication rate between surgeons or between institutions, this remains a potential explanation for the difference in complication rate between studies.

Despite the difference in complication rates, the complications reported in this study and the literature most commonly involved neurologic and vascular injuries. Knowledge of the anatomy of the retroperitoneal vasculature and exiting nerve roots as seen from the lateral approach can be unfamiliar to those who do not routinely perform the transpsoas approach. Regev et al. [22] investigated 100 lumbar MRIs to identify the “safe corridor” for the lateral approach. They found the degree of overlap between the retroperitoneal vasculature and the vertebrae increased progressively from L1 to S1 as the vessels move posteriorly and laterally relative to the vertebral bodies. The exiting nerve moved slightly anteriorly relative to the

vertebral bodies as one progress caudally, making the safe corridor considerably narrower with an abrupt change seen at L4–5. While the risk of vascular injury with this approach was relatively small, and none were seen in our series, there was a case report demonstrating intraoperative injury necessitating vascular repair [28].

The incidence and clinical impact of postoperative weakness, numbness, and radicular pain after surgery with the transpsoas approach are not trivial. As this technique becomes more widely used, a thorough understanding of the risks and benefits associated with the approach is essential not only for the spine surgeon but for patient education as well. The adverse outcomes, presented by both our own multicenter, multisurgeon data and through the literature review, serve as reminders of the necessity of a thorough understanding of the unbiased complication profile of relatively new techniques. It is our hope this will lead to a more realistic and thorough discussion of the risks, benefits, and alternatives to transpsoas anterior spinal column stabilization between surgeons and patients. Ideally, the patient and surgeon should carefully discuss the advantages and drawbacks of the different surgical options to make an informed decision and develop an optimal treatment plan.

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