Short-term outcomes of lateral lumbar interbody fusion without decompression for the treatment of symptomatic degenerative spondylolisthesis at L4–5

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OBJECTIVE Recently, authors have called into question the utility and complication index of the lateral lumbar interbody fusion procedure at the L4–5 level. Furthermore, the need for direct decompression has also been debated. Here, the authors report the clinical and radiographic outcomes of transposas lumbar interbody fusion, relying only on indirect decompression to treat patients with neurogenic claudication secondary to Grade 1 and 2 spondylolisthesis at the L4–5 level.

METHODS The authors conducted a retrospective evaluation of 18 consecutive patients with Grade 1 or 2 spondylolisthesis from a prospectively maintained database. All patients underwent a transposas approach, followed by posterior percutaneous instrumentation without decompression. The Oswestry Disability Index (ODI) and SF-12 were administered during the clinical evaluations. Radiographic evaluation was also performed. The mean follow-up was 6.2 months.

RESULTS Fifteen patients with Grade 1 and 3 patients with Grade 2 spondylolisthesis were identified and underwent fusion at a total of 20 levels. The mean operative time was 165 minutes for the combined anterior and posterior phases of the operation. The estimated blood loss was 113 ml. The most common cage width in the anteroposterior dimension was 22 mm (78%). Anterior thigh dysesthesia was identified on detailed sensory evaluation in 6 of 18 patients (33%); all patients experienced resolution within 6 months postoperatively. No patient had lasting sensory loss or motor deficit. The average ODI score improved 26 points by the 6-month follow-up. At the 6-month follow-up, the SF-12 mean Physical and Mental Component Summary scores improved by 11.9% and 9.6%, respectively. No patient required additional decompression postoperatively.

CONCLUSIONS This study offers clinical results to establish lateral lumbar interbody fusion as an effective technique for the treatment of Grade 1 or 2 degenerative spondylolisthesis at L4–5. The use of this surgical approach provides a minimally invasive solution that offers excellent arthrodesis rates as well as favorable clinical and radiological outcomes, with low rates of postoperative complications. However, adhering to the techniques of transposas lateral surgery, such as minimal table break, an initial look-and-see approach to the psoas, clear identification of the plexus, minimal cranial caudal expansion of the retractor, mobilization of any traversing sensory nerves, and total psoas dilation times less than 20 minutes, ensures the lowest possible complication profile for both visceral and neural injuries even in the narrow safe zones when accessing the L4–5 disc space in patients with degenerative spondylolisthesis.

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KEY WORDS XLIF; DLIF; LLIF; extreme lateral interbody fusion; lateral lumbar interbody fusion; direct lateral interbody fusion; lateral fusion; spondylolisthesis; transposas

DEGENERATIVE spondylolisthesis (DS) is often characterized by disc and facet degeneration that allows sagittal translation of the involved segment, commonly resulting in lateral recess and/or foraminal stenosis.¹⁷ It disproportionately affects older females at the L4–5 level and is often associated with more sagittally

oriented facet joints.⁷ Treatment options have ranged from limited decompression to decompression with anterior and/or posterior fusion with or without listhesis correction to multilevel fusion for deformity correction. Recent randomized controlled trials have shown clinically significant improvement in patients with spondylolisthesis who

ABBREVIATIONS DS = degenerative spondylolisthesis; LLIF = lateral lumbar interbody fusion; MCS = Mental Component Summary; ODI = Oswestry Disability Index; PCS = Physical Component Summary.

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undergo treatment not only with surgical procedures in general but, more specifically, with the addition of fusion to the procedure.^{8,33}

Recent comparative analyses have evaluated a variety of fusion procedures in treating DS at the L4–5 level, including anterior lumbar interbody fusion, posterior lumbar interbody fusion, transforaminal lumbar interbody fusion, and lateral lumbar interbody fusion (LLIF).¹⁶ Despite a great deal of investigation, no approach has clinically been proven more effective than the others, and no universal treatment guidelines have been proposed.²⁶

Often, anterior lumbar interbody fusion approaches are associated with a significant degree of difficulty with exposure. This is generally due to difficulty with venous mobilization or retroperitoneal scarring, whereas disruption of the lumbar paraspinal musculature and the nerve root injury secondary to cage insertion are problematic complications of the posterior lumbar interbody fusion and transforaminal lumbar interbody fusion procedures.¹⁹ Because of its ability to provide indirect decompression without disrupting the posterior elements, segmental stability, and lordosis restoration, the transposas LLIF technique has been proposed as a treatment option for DS at L4–5.^{1,11,15,25,27} However, concerns exist about the rate of neurological complications associated with the lateral approach.^{5,10,14,24} Furthermore, these complications are most conspicuous at the L4–5 level due to the anatomical arrangement of the lumbar plexus with narrower safe working zones more inferiorly in the lower lumbar spine.³⁰ Anterolisthesis at the L4–5 level serves to exacerbate this risk.²⁷ The purpose of this study is to evaluate the clinical and radiographic outcomes of utilizing LLIF for the indication of DS at the L4–5 level.

Methods

A retrospective review of a prospectively maintained database was performed after institutional review board approval was received. All patients had undergone unsuccessful conservative treatment for at least 6 months or exhibited worsening neurological symptoms during the conservative management period. Outcomes data were collected at a single institution with multiple spine surgeons. Inclusion criteria for the study were consecutive patients with Grade 1 or Grade 2 degenerative spondylolisthesis at L4–5 treated with a 1- or 2-level LLIF procedure between July 1, 2016, and July 1, 2017. Patients meeting these criteria were included; there were no exclusions. Outcomes were collected preoperatively and at standard follow-up intervals: 2 and 6 weeks, and 3, 6, and 12 months postoperatively, as applicable. All other fusion indications were excluded (degenerative disc disease, mechanical collapse, adjacent-segment disease, and degenerative scoliosis). Eighteen consecutive patients were identified for inclusion in the study. All patients presented with back and leg symptomatology.

Surgical Technique

All patients underwent LLIF to the L4–5 disc space via a transposas approach for the treatment of spondylolisthesis. Based on surgeon preference, either titanium or polyetheretherketone intervertebral cages were used. Implant-

ed cages varied between 7° and 10° of lordosis, and graft material also varied by surgeon preference. Neurophysiological monitoring was performed in all cases. All cases relied on indirect decompression, and the use of supplemental posterior fixation with pedicle screws was standard practice. Unilateral fixation was only considered as an option in conjunction with the placement of a 26-mm cage.

Every patient underwent specific evaluation for anterior thigh dysesthesia at each clinical encounter, with a complete sensory evaluation of light touch and pinprick in both lower extremities. Motor function testing was also performed at each visit, which encompassed testing of 5 myotomes from L-2 to S-1. Reflex function in the knee and ankle was also evaluated both pre- and postoperatively.

Patient outcomes; complications, including plexopathy (even if transient); Oswestry Disability Index (ODI) scores; and scores for both components (mental and physical) of the SF-12 were evaluated. Substantial clinical benefit thresholds for the ODI were defined as a 15-point improvement in the ODI score. The SF-12 is a multipurpose short-form survey with 12 questions, all selected from the SF-36 Health Survey. Any improvement in the components of the SF-12, which would be represented by a higher score, was considered significant.

Radiographic assessments were made using standing lumbar lateral radiographs at preoperative evaluation and on the date of last clinical follow-up. Evaluation was performed to assess overall changes in lumbar lordosis at pre- and postoperative intervals. Lumbar lordosis was measured as the angulation from the superior endplate of L-1 to the superior endplate of S-1. Slip measurements associated with postoperative reductions were performed on calibrated lateral standing radiographs at the L4–5 level (Sectra IDS7, Sectra AB). Any endplate subsidence was also noted.

Results

Eighteen consecutive patients were included in this study cohort. The mean age at the time of surgery was 64 years, and 61% of patients were female. The L4–5 level was treated in isolation in 89%, and 11% of patients underwent an L3–4 and L4–5 LLIF. Twenty levels were treated in total. Slip was characterized as Grade 1 in 83% of patients and Grade 2 in 17%. The mean follow-up time was 6.2 months, with a range of 3–13 months.

Posterior instrumentation was placed with bilateral pedicle screws in 89% of patients and a unilateral pedicle screw construct in 11%. All procedures were performed in the traditional direct lateral position and then repositioned for the posterior approach. Biplane fluoroscopy was employed for placement of all pedicle screws. No patient underwent additional open or endoscopic central or foraminal decompression posteriorly. The mean operative time was 165 minutes for the combined anterior and posterior phases of the operation. The mean estimated blood loss was 113 ml. The most common cage width in the anteroposterior dimensions at the L4–5 level was 22 mm (78%), followed by 18 mm and 26 mm, each with an 11% utilization rate. Complete demographic and treatment data are detailed in Table 1.

TABLE 1. Baseline demographic and treatment data from patients undergoing LLIF for the treatment of spondylolisthesis

Variable	Value
No. of patients	18
Age in yrs, mean $\pm$ SD	64 $\pm$ 10.5
BMI in kg/m ² , mean $\pm$ SD	34 $\pm$ 7
Female, n (%)	11 (61)
Grade of spondylolisthesis, n (%)	
1	15 (83)
2	3 (17)
Levels treated, n (%)	
L3–4 & L4–5	2 (11)
L4–5	16 (89)
Posterior instrumentation	100%
Additional decompression	0%
EBL in ml, mean $\pm$ SD	113 $\pm$ 79
Op in mins, mean $\pm$ SD	165 $\pm$ 58
Cage width at L4–5 in mm, n (%)	
18	2 (11)
22	14 (78)
26	2 (11)
Follow-up in mos, mean $\pm$ SD	6.2 $\pm$ 2.7

BMI = body mass index; EBL = estimated blood loss.

Radiographic evaluation identified a mean preoperative global lordosis as 60.3° and a mean postoperative global lordosis of 62.4°. Complete reduction of spondylolisthesis

(< 1 mm) occurred in 13 of 18 patients (72%) (Fig. 1). Of those patients who had a complete reduction of listhesis postoperatively, 11 patients initially had Grade 1 and 2 patients had Grade 2 spondylolisthesis. Of the remaining 5 patients without postoperative resolution of the slip, a 43% reduction in slip size was noted. Four of 5 of these patients had Grade 1 spondylolisthesis preoperatively. One patient was noted radiographically to have 20% subsidence of the lateral cage into the superior endplate of L-5. This finding was not clinically significant.

There were no intraoperative complications. No patient required hospital readmission during the 90-day perioperative period. One patient (6%) experienced atrial fibrillation postoperatively and underwent treatment in an outpatient setting. Anterior thigh dysesthesia was identified on detailed sensory evaluation in 6 of 18 patients (33%). All cases resolved between 2 weeks and 6 months postoperatively. Thigh dysesthesia contralateral to the exposure was present in 1 case, with the remaining 5 patients reporting sensory loss ipsilateral to the side of exposure and psoas manipulation. One patient also had mild transient hip flexor weakness that resolved by 4 weeks postoperatively. There were no cases of hardware failure or pseudarthrosis that required additional surgical intervention.

From preoperatively to the 3-month follow-up, the mean ODI score improved from 49.1 to 34.5 (29.7%). At the 6-month follow-up time point, the ODI score continued to improve to 23.1 (53.0%; Fig. 2). A marked reduction in ODI score was seen at the 12-month follow-up, but this was graphically excluded, as this metric was only available for 2 patients in the study population. The mean follow-up time was 6.2 months, with a range of 3–13 months.

FIG. 1. Preoperative (A) and postoperative (B) lateral radiographs showing the reduction of a Grade 2 spondylolisthesis after LLIF and placement of supplemental posterior instrumentation.

FIG. 2. Bar graph showing the mean ODI scores with standard deviations preoperatively, and at 2-week (Immediate), 6-week, 3-month, and 6-month postoperative intervals.

The mean SF-12 Mental Component Summary (MCS) and Physical Component Summary (PCS) scores improved after 6 weeks. At the time of the 3-month follow-up, PCS scores improved by 3.1 points and MCS scores improved by 4.8 points. At the 6-month follow-up, the mean PCS and MCS scores improved by 5.4 points and 4.7 points, respectively (Figs. 3 and 4). As with the ODI outcome, 12-month data were excluded because of a paucity of data, as they were only available for 2 patients.

Discussion

Lateral lumbar interbody fusion is a minimally invasive alternative to conventional fusion techniques that allows access to the intervertebral disc space without disrupting the anterior longitudinal ligament or posterior facets. The main aim of LLIF surgery is to restore disc space height with subsequent reduction of pain and improvement in disability.¹³ In traditional LLIF procedures, the psoas major muscle is split while the patient is in the direct lateral position, and an interbody graft is inserted between the vertebral apophyseal rings at one or more lumbar levels. This procedure has been successfully used for obtaining effective reduction and favorable alignment through a minimally disruptive approach and indirect decompression of the spinal canal and intervertebral foramen.^{2,21,25} A minimally invasive LLIF approach has been reported to reduce postoperative pain, tissue trauma, and operative and recovery times, thereby resulting in shorter hospital stays and brisker overall symptom improvement compared with traditional approaches.^{22,25}

Neurological complications associated with lateral approaches are frequently discussed in the literature.^{5,18} Previous anatomical and radiographic evaluations have identified that the lumbar plexus migrates dorsally to ventrally from L2–3 as the lumbosacral plexus descends caudally to the L4–5 and L5–S1 levels.^{3,10,30} The underlying anatomi-

cal arrangement can endanger the lumbosacral plexus in a transpoas approach to the L4–5 level.²⁷ Anterolisthesis of the L-4 vertebral body further dislocates the plexus even more ventrally, narrowing the safe zones of exposure to the L4–5 disc.³⁰ In addition, sex-related anatomical variability can also make surgical exposure more difficult at L4–5, particularly in men with a large psoas muscle and a high iliac crest.²⁹

The rate of perioperative medical complications in this survey was low (5.6%). However, the rate of anterior thigh numbness or dysesthesia was noted to be 33%. A review of the literature suggested that this complication occurs with a frequency of between 0% and 75% of LLIF cases.⁶ It is the practice at our institution to perform a complete lower-extremity sensory evaluation to light touch and pinprick at each postoperative encounter in all patients who undergo lateral surgery. Five patients reported ipsilateral sensory loss to the anterior thigh. One patient experienced 4 weeks of quadriceps weakness, which resolved completely. All sensory and motor symptoms resolved, most by the 6-week postoperative time point. One patient experienced thigh dysesthesia contralateral to the exposure, which resolved 6 months postoperatively. Imaging performed in this patient did not reveal any compressive pathology due to a migrated disc fragment or osteophyte. Papanastassiou et al. reported 2 cases of contralateral femoral nerve compression symptoms after LLIF, but both were secondary to anatomical compression from either extruded disc or osteophytes displaced into the contralateral psoas.²³ With regard to neuropathic symptoms after LLIF, we posit a theory that has often been reported in studies evaluating complication reporting. Complication incidence varies widely throughout the literature due to variance in both the actual definition of the event as well as the perioperative examiner's extent of clinical vigilance, standardized exploration, and focus on a specific event or set of events.^{4,20,34}

Given the risk of neurological complications, several

FIG. 3. Mean SF-12 PCS scores preoperatively, and at 2-week, 6-week, 3-month, and 6-month postoperative intervals.

FIG. 4. Mean SF-12 MCS scores preoperatively, and at 2-week, 6-week, 3-month, and 6-month postoperative intervals.

strategies for reducing postoperative neural injury during LLIF have been presented in the literature. These range from novel finger electrode usage for intraoperative monitoring,¹⁹ triggered intermittent electromyography monitoring during psoas retraction,³¹ saphenous nerve somatosensory evoked potential monitoring²⁸ to complete avoidance of the transpsoas technique utilizing a prepsaos oblique lateral corridor for access to the disc space.¹² When employing LLIF for the indication of DS at L4–5, we feel that by strictly adhering to lateral access surgical principles, such as minimal table break, an initial look-and-see approach to the psoas, clear identification of the plexus, minimal expansion of the retractor, mobilization of any traversing sensory nerves, and psoas dilation times less than 20 minutes, ensure the lowest possible complication profile for both visceral and neural injuries even in the narrow safe zones experienced in accessing the L4–5 disc space in patients with DS.

In the current study, the mean ODI score improved more than 15 points at the 6-month time point. SF-12 MCS and PCS scores improved roughly 10% at the 3- and 6-month time points. The FDA standards identify good to excellent operative outcomes when there is a 15-point improvement in ODI, plus maintenance or improvement in SF-36 score.⁹ To replicate the validity of the SF-36 with brevity and facilitate outcomes reporting at multiple time points, the SF-12 was developed and has been validated to report less than a 10% difference of the longer outcome measurement instrument across population studies.³² In the current study, we confirm the attainment of good to excellent clinical outcomes at the 3- and 6-month postoperative time points when treating Grade 1 and 2 DS with a transpsoas approach to the L4–5 disc space utilizing the FDA metrics.

Limitations of the current study include its relatively small sample size and the lack of 2- to 5-year follow-up data. These longer-term data are necessary for determining pseudarthrosis rates and for any meaningful comparison regarding adjacent-segment disease. As previously reported, given that this is a retrospective evaluation, complications are generally underreported compared with those of a true prospective study with a wide definition of a complication.^{4,20} In addition, the demographics in this patient survey were skewed to older and more obese patients, with a mean age of 64 years and average body mass index of 34.1 kg/m². Given this higher risk in our population, the

data and outcomes may not be entirely comparable to a study with younger, leaner patients.

Conclusions

LLIF is a safe and effective treatment for patients with Grades 1 and 2 spondylolisthesis at L4–5. The use of this surgical approach provides a minimally invasive solution that offers favorable clinical and radiological outcomes with low rates of postoperative complications. However, the difficulty of exposure and the narrow neural safe zones mandate careful adherence to the lateral surgical technique and a detailed understanding of regional anatomy.

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Conception and design: Campbell. Acquisition of data: Campbell, Nunley, Frank. Analysis and interpretation of data: Campbell. Drafting the article: Campbell. Critically revising the article: Frank, Stone. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Campbell.

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