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SYMPOSIUM: MINIMALLY INVASIVE SPINE SURGERY

Indirect Decompression of Lumbar Stenosis With Transpsoas Interbody Cages and Percutaneous Posterior Instrumentation

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Abstract

Background The minimally invasive lateral transpsoas retroperitoneal approach to address lumbar stenosis offers advantages to traditional approaches, including sparing of the AP annulus and longitudinal ligament and less risk to the peritoneal contents and retroperitoneal vascular structures. Few studies have presented longitudinal measures of radiographic indirect decompression and relief of pain and restoration of function using the lateral approach to spine fusion.

Question/purposes We determined (1) whether radiographic measures suggestive of decompression were achieved after surgery and maintained 1 year after surgery, (2) whether the intervention resulted in sustained improvements in patient-reported outcomes scores 1 year after surgery, and (3) the frequency of pseudarthrosis on CT scans at 1 year after surgery in patients with moderate or severe lumbar stenosis treated with the approach.

Methods Between 2008 and 2012, 158 patients were surgically treated to alleviate symptoms associated with degenerative lumbar stenosis, of whom 60 (38%) were treated with lateral lumbar interbody fusion. Of these 60 patients, 36 (60%) received CT scans preoperatively and at 1-year postoperatively and were available for radiographic analysis. Of the 60 treated patients, 16 (27%) were lost to followup before 12 months, leaving the records of 44 patients available for review of patient-reported improvements in pain and return to function. Radiographic increases in disc height, foraminal area, and canal area were measured by one observer on CT scans postoperatively and at 1 year and compared to preoperative values. Patient-reported scores, including VAS pain score and Oswestry Disability Index (ODI), were collected preoperatively and at 3 and 12 months postoperatively.

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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 Florida Orthopaedic Institute, Tampa, FL, USA.

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Results Increases in disc height (67%, $p < 0.001$), foraminal area (24%–31%, $p < 0.001$), and canal area (7%, $p = 0.011$) measured immediately postoperatively were sustained at 1-year followup. VAS pain score and ODI both improved ($p < 0.001$) at 3 months and were maintained at 1 year. No pseudarthroses were noted radiographically.

Conclusions The lateral transpsoas approach to interbody fusion is capable of sustaining indirect decompression of the neural structures and resolving preoperative claudication and radiculopathy. A larger series of patients with longer followup should be studied to substantiate these early clinical results.

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

Introduction

Stenosis is characterized by diminished space available for the neural and vascular elements in the spine [1]. In the central canal, stenosis can lead to neurogenic claudication or radicular symptoms when present within the foramen [9]. When nonoperative pain management fails to alleviate symptomatic low-back pain, surgical interventions such as laminectomy and facetectomy may be necessary. Nerve root injury (9%–16%), postoperative radiculitis (6.7%–16.4%), and incidental durotomies (5.4%–10%) are complications of these decompressive procedures [6, 8], which lead to tissue devitalization and increased postoperative pain.

Newer minimally disruptive indirect decompression techniques have been developed to avoid the morbidity of traditional open surgery. One technique utilizes the lateral transpsoas approach to the lumbar spine to remove the collapsed disc and replace it with an interbody cage [14, 17]. The interbody cage provides an indirect decompression by restoring disc height, which reduces spinal deformities through ligamentotaxis since the anterior and posterior ligamentous structures are left intact. Reduction of the spinal deformities has been shown to increase the foraminal and central canal area [16]. Once indirect decompression is accomplished, the cages can be used in stand-alone fashion [5, 16] or with supplemental instrumentation such as percutaneous pedicle screws, which confer maximum stability to the affected segment [3, 15]. Both the indirect decompression and percutaneous pedicle screws are accepted minimally invasive surgical (MIS) techniques that require little soft tissue dissection and minimal blood loss.

In a previously published cadaver study [13], we demonstrated that interbody cage placement through the lateral transpsoas approach increased disc height, foraminal areas, and central canal area when compared to the noninstrumented lumbar spine. In a separate biomechanical study, we demonstrated that pedicle screw and rod instrumentation provided the best limitation to motion of the spinal segments [15]. While important in ascribing acute efficacy to the lateral transpsoas approach to fusion, these basic science studies could not determine whether the noted radiographic changes would result in longitudinal relief of pain and restoration of function.

We therefore determined (1) whether radiographic measures suggestive of decompression were achieved after surgery and maintained for at least 1 year postoperatively, (2) whether the intervention resulted in sustained improvements in patient-reported outcome scores 1 year after surgery, and (3) the frequency of pseudarthrosis on CT scans at 1 year after surgery in patients with moderate or severe lumbar stenosis who underwent indirect decompression and lateral lumbar interbody fusion with percutaneous pedicle screw and rod instrumentation.

Patients and Methods

Study Patients

This study was a nonrandomized, single-center institutional review board-approved clinical and radiographic evaluation of patients suffering from low-back pain and claudication symptoms resulting from lumbar spine degeneration with central and/or lateral stenosis. Included patients were surgically managed with indirect spinal decompression at the affected level(s) using the lateral transpsoas approach. Inclusion criteria were symptomatic low-back pain resulting from single- or multilevel degenerative lumbar stenosis and failed nonoperative management, which included physical therapy, NSAIDs, analgesics, or epidural steroid injections. Exclusion criteria

Table 1. Demographic data

Variable	Total patient population	Available for CT analysis	Available for clinical outcomes analysis
Number of patients	60	36	44
Number of levels	161	94	117
Numbers of levels/case*	2.7 (2.4–3.0)	2.8 (2.4–2.9)	2.7 (2.4–2.9)
Age (years)*	66 (64–68)	66 (64–68)	66 (63–68)
Sex (number of females/males)	33/27	20/16	21/23
BMI*	29.2 (27.9–30.4)	29.8 (28.0–30.6)	29.4 (28.0–30.5)

* Values are expressed as mean, with 95% CI in parentheses.

were prior lumbar surgery and presence of a fused facet and/or a large extruded and migrated disc fragment.

Between 2008 and 2012, 158 patients were surgically treated to alleviate symptoms associated with degenerative lumbar stenosis, of whom 60 (38%) were treated with lateral lumbar interbody fusion by a single senior spine surgeon (AEC). Of the 60 patients included for study, 36 (60%) received CT scans preoperatively and at 1-year postoperatively and were available for radiographic analysis. Of the 60 treated patients, 16 (27%) were lost to followup before 12 months, leaving the records of 44 patients (Table 1) available for review of patient-reported improvements in pain and return to function.

Surgery Indications and Procedure

The indication for surgical treatment was single- or multilevel degenerative lumbar stenosis with at least 6 months of failed nonoperative treatment. All patients underwent insertion of large-footprint, 18-mm (AP dimension) interbody polyetheretherketone (PEEK) cage (CoRoent® XL; NuVasive, Inc, San Diego, CA, USA) with freeze-dried cortical-cancellous allograft supplemented with BMP-2 (INFUSE™; Medtronic, Inc, Memphis, TN, USA) through the lateral transpsoas approach first described by Ozgur et al. [17] (Fig. 1). After radiographic analysis of cage placement postoperatively, a second procedure was performed on average 2.5 days later during which percutaneous pedicle screw and rod fixation were placed to confer additional rigidity to the repaired lumbar level(s). Interbody cages sizes were determined intraoperatively for each patient and each level. A total of 161 symptomatic lumbar levels were treated in the 60 patients. In the first and second stages of surgery, mean operative time was 195 minutes (range, 63–443 minutes) and 215 minutes (range, 111–438 minutes), respectively, and mean estimated blood loss was 217 mL (range, 5–350 mL) and 242 mL (range, 5–500 mL), respectively.

Radiographic Analysis

Of the 60 patients available for study, 36 (94 lumbar levels) obtained preoperative and immediate postoperative CT scans, as well as a third scanning procedure at the 1-year postoperative time point. CT scans with 1.25-mm slice thickness (GE LightSpeed QX/i; GE Healthcare, Waukesha, WI, USA) were taken as part of the standard preoperative protocol of the senior author. Followup CT scans were taken in the immediate postoperative period to assess the extent of the indirect decompression and the need for further posterior decompression before the pedicle screw instrumentation. The CT scans taken at 1 year were evaluated for maintenance of the decompression and interbody arthrodesis as evidenced by bridging bone.

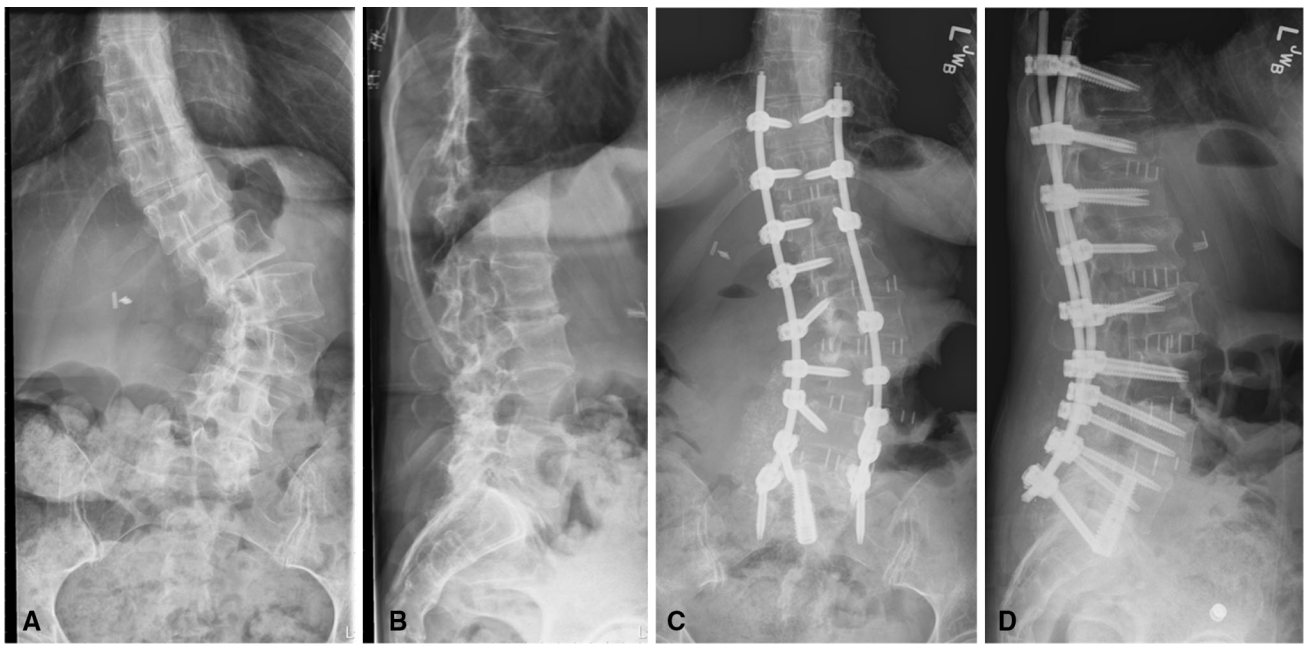

Fig. 1A–D Preoperative (**A**) AP and (**B**) lateral radiographs show the spine of a patient with severe lumbar deformity and coronal imbalance. The minimally invasive lateral transpsoas approach with rigid posterior instrumentation was used to promote indirect decompression and reconstruct the spinal column. (**C**) AP and (**D**) lateral radiographs show the spine 12 months postoperatively.

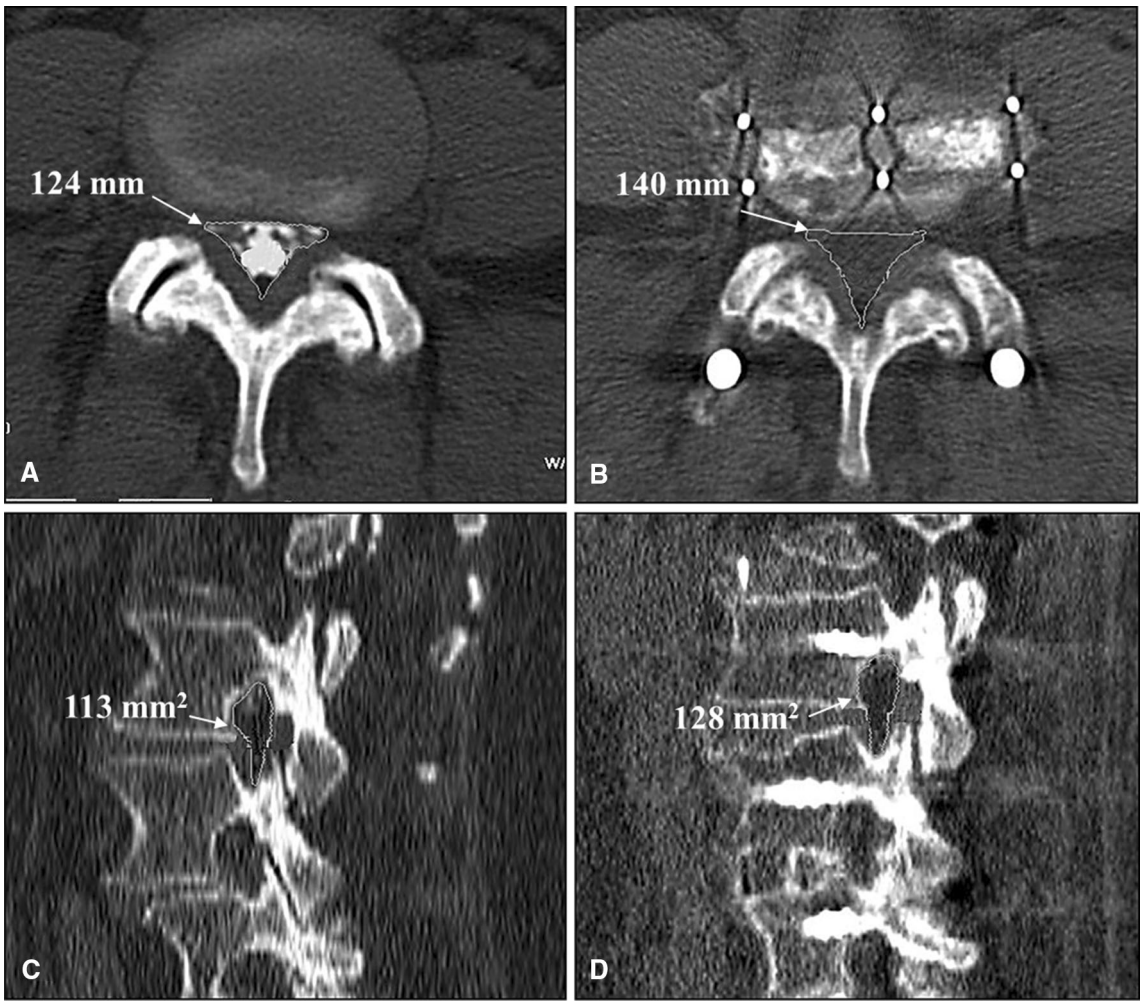

Fig. 2A–D Axial CT images demonstrate an increase in canal area after placement of the large-footprint interbody cage from (**A**) preoperative baseline to (**B**) 12 months. Sagittal CT images demonstrate an increase in foraminal area from (**C**) preoperative baseline to (**D**) 12 months.

The CT scans were analyzed using three-dimensional radiographic reconstruction software (Vitrea® 2, Version 3.5; Vital Images, Inc, Minnetonka, MN, USA). We measured disc height, right and left foraminal areas, and canal area dimensions before and after interbody cage implantation on a standardized radiology workstation (Fig. 2). Specifically, images were reconstructed using multiplanar techniques into sagittal and coronal planes. First, we chose an axial image at the disc space level. Using the Vitrea® software, we manipulated the image in oblique planes to confirm that the axial image was truly parallel to the disc space, corrected for scoliotic curvature. Once it was confirmed that it was a true axial image, the sagittal images were manipulated in similar fashion to be perpendicular to the foramen. An oblique sagittal image in the middle $^1/_3$ of the foramen was chosen for measurements. Using the Vitrea® area tool, we calculated the area of the foramen, exclusive of normal bone, osteophytes, and any disc material in the foramen. A similar approach was used on the contralateral foramen at the same level. We then returned to the axial images and chose an image centered in the disc space. We measured the canal area at this level using the same Vitrea® area tool. The disc was chosen as the ventral border of the area measured. The dorsal/lateral border was chosen as the ligamenta flava. In the midline dorsally, the border was either ligamentum flavum or lamina. Laterally, the area measured included the lateral recesses. Similar measurements for the foraminal and canal area were obtained at the other index levels using a similar technique. A fellowship-trained musculoskeletal radiologist (RM) measured radiographic parameters independently to assess the effect of cage implantation on radiographic indexes of indirect decompression at the instrumented levels. Presence of absence of interbody fusion, evidenced by bony bridging across the instrumented level, was also assessed at 1 year. Prior CT analyses by our group on lumbar spines instrumented with laterally placed interbody cages and measured independently by multiple observers

indicated excellent interobserver reliability (intraclass correlation coefficient = 0.986; 95% CI: 0.850–0.994) [21]. The mean from all the instrumented levels was compared between the preoperative CT scan and the images obtained at 1-year followup.

Clinical Evaluation

Patients completed a set of standardized and validated questionnaires that included a VAS score for back pain intensity [7] and the Oswestry Disability Index (ODI) [18]. We used a 100-point VAS, where 1 = least pain and 100 = worst pain. Clinical outcome data points were obtained preoperatively, at 3 months, and 1 year postoperatively. Complete data were available for 44 patients at 1-year followup.

Statistical Analysis

Changes in disc height, foraminal area, and canal area measurements after lateral interbody cage placement and pedicle screw instrumentation between the preoperative and immediate postoperative and 1-year CT scans were compared with a repeated-measures ANOVA and Tukey's post hoc multiple-comparison procedure. We used a similar analysis to compare changes in VAS score and ODI preoperatively and 3 and 12 months postoperatively. Significance was set at an alpha level of 0.05 and all comparisons were performed with IBM® SPSS® v20 statistical software (IBM Corp, Armonk, NY, USA).

Results

Was Decompression Obtained and Maintained at 1 Year?

Measurements for right and left foraminal area, disc height, and canal area improved as assessed on the immediate postoperative CT scan and were maintained at the 1-year cutoff (Table 2). The mean preoperative right foraminal area was 91 mm^2 (95% CI, 81–101 mm^2), which increased to 113 mm^2 (95% CI, 101–124 mm^2) at the immediate postoperative period ($p < 0.001$); this increase was maintained at 1 year, measuring on average 117 mm^2 (95% CI, 108–126 mm^2; $p < 0.001$ compared to the preoperative value). The mean preoperative left foraminal area was 87 mm^2 (95% CI, 78–96 mm^2), which increased to 114 mm^2 (95% CI, 103–126 mm^2) at the immediate postoperative period ($p < 0.001$); this increase was maintained at 1-year followup, measuring on average 118 mm^2 (95% CI, 109–126 mm^2; $p < 0.001$ compared to the preoperative value).

The mean preoperative disc height was 3 mm (95% CI, 2–3 mm) and increased to 5 mm (95% CI, 4–5 mm) at the immediate postoperative ($p < 0.001$); this increase was maintained at 1-year followup, measuring on average 5 mm (95% CI, 4–5 mm). The mean preoperative spinal canal area was 136 mm^2 (95% CI, 124–148 mm^2), increasing ($p < 0.011$) immediately postoperatively to 146 mm^2 (95% CI, 131–160 mm^2); this increase was maintained at 1-year followup, measuring on average 159 mm^2 (95% CI, 147–170 mm^2).

Were Patient-reported Outcomes Sustainably Improved?

There was an improvement in the preoperative VAS score at 3 and 12 months of followup (Table 3). The mean preoperative VAS score was 68 (95% CI, 63–79), which improved to 38 (95% CI, 33–47) ($p < 0.001$) at 3 months; this improvement was maintained at 12 months at 38 (95% CI, 22–44), with no difference between 3 and 12 months of followup ($p = 0.843$).

There was an improvement in the preoperative ODI at 3 and 12 months of followup. The mean preoperative ODI was 42 (95% CI, 34–48), which was improved at 3 months to 31 (95% CI, 26–36) ($p < 0.001$); this improvement was maintained at 12 months at 28 (95% CI, 18–32), with no difference between 3 and 12 months of followup ($p = 0.110$).

Pseudarthrosis and Complications

There were no pseudarthroses observed at the 1-year followup CT scan, which was obtained in 36 patients. There were no dural tears or infections. No pedicle screws required revision during surgery. We identified no postoperative changes in sensory or lower-extremity function.

Discussion

The lateral interbody approach and large-footprint interbody cage insertion for the treatment of symptomatic lumbar degeneration with central and/or lateral stenosis is an MIS technique to promote fusion compared to the posterior or anterior approach to the anterior column. The approach permits removal of the disc, preparation of the endplates, and placement of a large interbody PEEK cage that spans the apophyseal ring, promoting purchase on the strong cortical bone of the vertebral endplate and avoiding the weaker centrum of the vertebra. The relative novelty

Table 2. Radiographic measurement results

CT measurement	Preoperative	3 months	% change from preoperative	p value	1 year	% change from preoperative	p value
Right foraminal area (mm^2)	91 (81–101)	113 (101–124)	24	< 0.001	117 (108–126)	29	< 0.001
Left foraminal area (mm^2)	87 (78–96)	114 (103–126)	31	< 0.001	118 (109–126)	36	< 0.001
Disc height (mm)	3 (2–3)	5 (4–5)	67	< 0.001	5 (4–5)	67	< 0.001
Canal area (mm^2)	136 (124–148)	146 (131–160)	7	0.011	159 (147–170)	17	< 0.001

Values are expressed as mean, with 95% CI in parentheses.

Table 3. Patient-reported outcomes: VAS pain score and ODI

Variable	Preoperative	3 months	12 months	p value		
				Preoperative vs 3 months	Preoperative vs 12 months	3 months vs 12 months
VAS pain score	68 (63–79)	38 (33–47)	38 (22–44)	< 0.001	< 0.001	0.843
ODI	42 (34–48)	31 (26–36)	28 (18–32)	0.002	< 0.001	0.110

Values are expressed as mean, with 95% CI in parentheses; ODI = Oswestry Disability index.

of the MIS approach for spine fusion precludes significant work ascribing radiographic and clinical efficacy to the surgical technique. Therefore, we asked whether surgical management of spinal stenosis with the minimally invasive lateral approach and fusion would result in maintenance of decompression of the affected level(s) at 1-year followup and whether patient-reported clinical outcomes substantially improved at 1 year as a result of the procedure.

This study had a number of limitations. First, we acknowledge the potential for selection bias in our patient population in light of our report of no pseudoarthroses at 1 year and significant improvements and maintenance of radiographic indirect decompression and clinical outcomes. However, our only exclusion criteria were prior lumbar spine surgery and the presence of a fused facet joint and/or a large extruded and migrated disc fragment. For such patients, decompression via open laminectomy was performed. Thus, we believe the selection bias to be mitigated by the use of consistent selection criteria during the study period. We implemented no other criteria (ie, demographics, metabolic bone state, comorbidities) for patient selection and treatment with the lateral transpsoas approach. Future studies will need to determine whether this approach is suitable for patients who have had prior laminectomies and epidural fibrosis. Secondly, this was a retrospective study and we acknowledge a high loss to followup rate, with 16 patients lacking clinical outcomes at 1 year and 24 patients lacking preoperative and/or postoperative CT scans at 1 year. However, our radiographic data from 36 patients and 94 lumbar levels indicating immediate increases in interbody distraction at 3 weeks support prior work in a smaller number of patients (n = 21, 43 lumbar levels) reported by Oliveira et al. [16]. Nevertheless, we acknowledge that our results might have changed if we had lost fewer patients to followup at the 1-year time point. Thirdly, our radiographic and clinical data regarding the efficacy of the lateral approach to lumbar fusion are limited to a relatively short followup of 1 year. Maintenance of these radiographic and patient-reported outcomes at 2 years is critical in ascribing efficacy to the procedure and we intend to follow our patient cohort through this critical time frame. A final limitation of our study was that the radiographic measurements were performed by a single investigator. However, our group [21] has demonstrated excellent intra- and interobserver reliability using an identical measurement technique to that used in the current study in cadaveric lumbar spines. Based on this prior work and the demonstrated reliability in measuring disc height, canal area, and foraminal area, we opted not to use multiple observers.

We found in vivo improvement in radiographic metrics of disc height, foraminal areas, and canal area acutely and at 1 year postoperatively. Specifically, in the acute term, we noted 24%, 31%, 67%, and 7% increases in right and left foraminal area, disc height, and canal area, respectively. These acute findings are in agreement with our prior radiographic findings in cadaveric lumbar spines instrumented with laterally placed cages and supplemental internal fixation [13]. Our in vitro study results indicated increases in disc height (> 30%), foraminal area (> 35%), and canal area (> 30%). Further, an in vivo radiographic

study of 43 lumbar levels in 21 patients has been reported by Oliveira et al. [16] on the minimally invasive lateral transpsoas approach. In their consecutive series, lateral radiographic and sagittal and axial MRI measures of disc height, foraminal height, foraminal area, and central canal diameter increased by 42%, 14%, 25%, and 33%, respectively, 2 weeks postsurgery from the preoperative baseline. In general, these findings are in agreement with those reported in our current work. Our 1-year radiographic data further support the feasibility of the MIS approach for treatment of spinal stenosis as they confirm maintenance of decompression.

Our second study goal was to determine whether indirect decompression of the neural structures offered good functional and patient-reported improvements without the need for open laminectomy. The VAS score for pain was improved at 3 months and maintained at 1 year. Similarly, ODI decreased at 3 months and was maintained at 1 year. None of the patients followed for 1 year required a revision with open laminectomy. Thus, patient-reported outcomes improved with the minimally invasive lateral approach to lumbar spine fusion. The improvements in clinical outcomes reported here with the lateral approach are similar to traditional open approaches to the lumbar spine for the treatment of symptomatic lumbar stenosis, including posterior, anterior, and transforaminal interbody fusion. Thaler et al. [25] reported significant improvements in ODI and VAS scores for leg and back pain at a minimum of 1-year followup after posterior lumbar interbody fusion using beta-tricalcium phosphate and bone marrow aspirate bone graft substitute. Additionally, Slosar et al. [24] have reported significant improvements in ODI after transforaminal lumbar interbody fusion procedures with allograft bone and BMP-2 (INFUSE™). Complications associated with these traditional open spine fusion procedures have been described and include visceral injury and neurologic deficits. By virtue of the newer lateral transpsoas approach to the lumbar spine, an access surgeon is not necessary and the need to mobilize the great vessels is obviated, which minimizes the potential for visceral and vascular complications [4, 10, 22, 26]. This advantage has been realized, with a recent clinical report of a zero incidence of intraoperative visceral injury [20]. Certainly, a larger series of patients with longer followup should be studied to substantiate these early clinical results.

Based on evaluation of 1-year CT scans and evidence of bony bridging across the disc space, we noted no incidence of pseudoarthrosis when the large-footprint cages were supplemented with rigid posterior instrumentation. Further, no major postoperative complications were noted in this small patient series. Our findings of a high rate of fusion are consistent with prior reports using the minimally invasive lateral approach. In 46 patients with degenerative lumbar scoliosis treated with stand-alone lateral interbody fusion, Castro et al. [5] reported an 84% fusion rate in 107 levels at 2 years postsurgery. In patients undergoing fusion with the lateral approach stabilized with unilateral pedicle screw fixation and anterior instrumentation, Kepler et al. [11] reported a 100% fusion rate in nine patients with 1-year radiographic followup. We believe that the increased rigidity of the posteriorly instrumented spine addressed the dynamic component of spinal stenosis. Our instrumentation approach promoted fusion in all patients in our clinical series at 1 year, which may be an important factor to long-term maintenance of the decompression. In vitro laboratory studies have demonstrated that stand-alone cages confer less rigidity to the treated spinal segment than when augmented with additional rigid posterior instrumentation [3]. This may lead to an increased incidence of pseudoarthrosis and the "sawing" effect of the cage, which may erode the endplate leading to cage subsidence and degradation of the radiographic and clinical findings over time. In fact, a leading radiographic finding associated with the lateral approach to fusion is interbody cage subsidence [2, 5, 12, 19, 23], which has been reported to occur at a rate up to 29% [5] when used as stand-alone fixation and may be associated with a decline in functional outcome. We have yet to quantify the rate of cage subsidence in our patient cohort and determine the relationship, if any, between subsidence and the recurrence of low-back pain. This analysis will be the subject of a future study, but no patient in this series through 1 year of followup believed that their postoperative symptoms warranted further surgical intervention.

In summary, we found the lateral interbody approach using a large-footprint interbody cage to achieve indirect decompression achieved satisfactory decompression that was maintained at least 1 year after surgery, excellent patient-reported outcomes scores, and (in this small series) no pseudarthroses. We believe that the lateral approach to fusion is able to treat single- and multilevel degenerative lumbar stenosis effectively in a less invasive manner, avoiding the risks and morbidity historically associated with traditional open procedures. A larger series of patients with longer followup should be studied to substantiate these early clinical results. As no patients in our small series had prior lumbar spine surgeries, the success of the minimally invasive lateral transpsoas approach in patients with prior laminectomies and epidural fibrosis may be of clinical interest.

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