Multilevel standalone lateral interbody fusion: Radiographic and clinical outcomes

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ABSTRACT:

Introduction

Stand-alone lateral lumbar interbody fusion (SA-LLIF) without posterior instrumentation is increasingly being performed for various spine pathologies. There have been no studies to date regarding clinical and radiographic outcomes of patients who underwent multilevel SA-LLIF.

Methods

A retrospective review assessed patients undergoing multilevel SA-LLIF without posterior instrumentation between August 2017 to October 2021. Demographic information, comorbidities, and complications were collected. Clinical outcomes were characterized utilizing Oswestry Disability Index (ODI) and Visual Analogue Scale (VAS). Spinopelvic parameters, subsidence rates, and re-operation rates were collected.

Results

Forty-three patients met inclusion criteria. Mean (SD) age was 70 years (8.1), and 31 (72.1%) of patients were male. Mean (SD) body mass index (BMI) was 28.2 (5.0). There were often multiple indications for surgery, with 37 (86%), 28 (65.1%), and 9 (20.9%) patients undergoing surgery for deformity correction, degenerative disc disease, and adjacent segment disease, respectively. Mean number of levels treated was 2.42 (range 2-4 levels, total 104 levels treated). Mean time to follow-up imaging was 2.01 years (range 30 days to 4.95 years). Mean difference in pre- and post-operative LL, PI-LL mismatch, PT, and SVA were 4.9 degrees increase ($p<0.001$), 2.3 degrees decrease ($p=0.08$), 1.4 degrees decrease ($p=0.08$), and 0.94cm improvement ($p=0.10$). Fifteen patients (34.9%) had coronal deformity with largest cobb angle >20 degrees pre-op, and 11 (73.3%) had improvement in cobb angle postoperatively. Mean change in coronal cobb was 5.4 degrees improvement (28.6 degrees to 23.2 degrees postoperatively; $p=0.01$). Five of seven (71.4%) patients with spondylolisthesis had improved Meyer-Ding grade post-operatively. Fifteen patients (34.9%) experienced Grade 1 or more subsidence, with 23 of 104 levels (22.1%) affected. Three (7.0%) patients experienced symptomatic subsidence requiring re-operation. Five (11.6%) patients total required re-operation for progressive pain/radiculopathy and/or progressive deformity. There were significant improvements in ODI, VAS back, and VAS leg after surgery. Median (IQR) pre-operative ODI was 38 (28 to 48.5), compared to 25 (17.5 to 38.5) post-operatively ($p<0.001$). Average pre-operative VAS were 7.0 and 6.0 for back and leg, respectively, compared to 3.5 and 0.0 post-operatively ($p=0.002$; $p=0.001$).

Conclusions

Multilevel standalone LLIF can be a safe and effective surgical option with good clinical and radiographic outcomes.

Introduction

Lateral lumbar interbody fusion (LLIF) is one of various interbody surgical techniques utilized to achieve fusion in the thoracolumbar spine. As compared to transforaminal lumbar interbody fusion (TLIF) and posterior lumbar interbody fusion (PLIF), LLIF allows for larger interbody footprints with subsequent increased indirect decompression, more substantial alignment correction (e.g., segmental lordosis), and decreased subsidence risk due to increased endplate coverage.[1,2] The placement of multiple interbodies can serve to correct deformity without having to perform large osteotomies and can decrease operative time, blood loss, and morbidity.[3-7] In select patients who would be considered higher risk for open extensive fixation (such as elderly patients), MIS correction may also be considered for adult spinal deformity (ASD).[5,8] However, studies highlighting MIS deformity correction have few to zero patients who underwent standalone procedures. This this the first study to explore radiographic and clinical outcomes of multilevel standalone lateral lumbar interbody fusion (SA-LLIF) for patients with primarily ASD and degenerative disk disease (DDD).

Methods

A retrospective chart review assessed patients undergoing multilevel SA-LLIF without posterior instrumentation between August 2017 to October 2021, with follow-up until July 2023. Surgeries were performed by two spine neurosurgeons at a single academic institution, J.T. and J.U. Patients were included if they underwent multilevel LLIF without posterior instrumentation. Demographic information was collected including age, gender, body mass index (BMI), and medical comorbidities.

Indications for surgery included ASD, DDD, and adjacent segment disease with associated clinically debilitating mechanical back pain and/or radicular symptoms. Patients were offered standalone typically if they were older or if comorbidities limited a longer surgery. The risk/benefit of the possibility of a less robust construct but shorter operation was discussed with patients prior to surgery.

Radiographic spinopelvic parameters were collected on standing XR when available. Deformity cases were defined as pelvic incidence-lumbar lordosis mismatch of 10 degrees or more, coronal cobb angle >20, pelvic tilt of 25 degrees or more, global coronal imbalance of 5cm or more, and/or sagittal vertical axis (SVA) of 5cm or more. Surgical variables were collected including hardware construct (standalone interbody fusion versus additional posterior instrumentation), level of surgery (L1-2, L2-3, L3-4, L4-5), side of approach (left or right), duration of surgery, and estimated blood loss (EBL). Intraoperative, in-hospital, and long-term complications were recorded. Oswestry Disability Index (ODI) and Visual Analogue Scale (VAS) for back and leg were documented functional outcome measures. Subsidence grading was categorized according to Marchi et al[1] based upon most recent post-operative CT (preferred) or XR if CT was unavailable.

Statistical Methods

Statistics were completed utilizing SciPy v1.11.3 and Microsoft Excel. Mean and standard deviation were utilized for parametric descriptive statistics. Independent samples t-tests, One-way ANOVA, and Chi-square tests were performed to compare continuous and categorical variables respectively. Pre- and post-operative spinopelvic parameters, subsidence rates, and re-operation rates were collected. Preoperative and postoperative ODI, VAS back, and VAS leg scores were compared using the Wilcoxon signed rank test in each group. Logistic regression was utilized to determine relationships between two continuous variables. A p-value of <0.05 was considered significant.

Results

Baseline and Demographic Characteristics

473 total LLIF procedures were performed by spine surgeons JT and JU in the study period, and 43 patients underwent multilevel SA-LLIF. Thirty-one (72.1%) of patients were male. Mean age of patients at time of surgery was 70.1 years (SD 8.1; range 51.1-81.1 years). Mean body mass index (BMI) was 28.2 (SD 5.0; range 20-41), and all but one patient had at least one comorbidity (mean 4.3 comorbidities per patient). Twenty-five (58%) had prior lumbar surgery. The average Hounsfield units (HU) unit at L1 was 127.9, and 21 patients (48.8%) had osteoporosis or osteopenia (T score <-1) on pre-operative bone density imaging. **Table 1** summarizes demographic data. On linear regression, Age and HU had no relationship (p=0.079).

Surgical Characteristics

There were often multiple indications for surgery, with 37 (86%), 28 (65.1%), and 9 (20.9%) patients undergoing surgery for deformity correction, degenerative disc disease, and adjacent segment disease, respectively. Seven (16.3%) patients had spondylolisthesis, all of which were Grade 1 on the Meyer-Ding scale. Twenty-six (60.5%) of patients had a prior lumbar surgery.

The average number of levels fused was 2.4 (range 2-4). Twenty-seven patients had two levels, 14 had three levels, and 2 had four levels (total 104 levels). Average length of stay (LOS) was 2.0 days (SD=1.47 days, range 1-9 days). Mean duration of surgery was 2 hours and 14 minutes (range 1 hour 7 minutes to 7 hours and 25 minutes), and mean estimated blood loss (EBL) was 54cc (SD=65.6 cc, range minimal to 300cc). PEEK and titanium grafts were utilized in 23 (53.5%) and 20 (46.5%) patients, respectively.

Clinical Outcomes

There were significant improvements in ODI, VAS back, and VAS leg after surgery. Mean time to follow up for ODI and VAS were 1.75 years (range 40 days to 4.75 years) and 1.40 years (range 40 days to 5 years). There were significant improvements in ODI, VAS back, and VAS leg after surgery. Median (IQR) pre-operative ODI was 38 (28 to 48.5), compared to 25 (17.5 to 38.5) post-operatively ($p<0.001$). Average pre-operative VAS were 7.0 and 6.0 for back and leg, respectively, compared to 3.5 and 0.0 post-operatively (p=0.002; p=0.001) (**Table 2**). Five patients (11.6%) required additional lumbar surgery. Three patients had further

laminectomy or foraminotomy without posterior fixation for persistent back pain or radicular symptoms. Two patients had progressive symptoms and deformity requiring posterior pedicle screw fixation. Three of the five patients who underwent revision surgery had subsidence noted on imaging. Ten patients (23%) developed immediate or delayed post-operative complications including postoperative delirium, urinary retention, and ileus.

Subsidence

Fifteen patients (34.9%) experienced Grade 1 or more subsidence, with 23 of 104 levels (22.1%) affected with imaging follow-up mean 2.01 years (range 30 days to 4.95 years). Nineteen (43.1%) had Grade 1 subsidence, and 4 (9.1%) had Grade 2 subsidence. There were no statistically significant differences in age, smoking, and DEXA score with subsidence rates. There was no difference in functional clinical outcomes as measured by ODI, VAS leg, or VAS back with patients who experienced or did not experience subsidence (p=0.345, 0.729, 0.176, respectively). Of the 15 patients with subsidence, 3 (20%) required reoperations. Overall, reoperation rates due to symptomatic subsidence was 7% (3 patients of 43).

Spinopelvic parameters and deformity correction

Mean difference in pre- and post-operative LL, PI-LL mismatch, PT, and SVA were 4.9 degrees increase (p<0.001), 2.3 degrees decrease (p=0.08), 1.4 degrees decrease (p=0.08), and 0.94cm improvement (p=0.10). 15 patients (34.9%) had coronal deformity with largest cobb angle >20 degrees pre-op, and 11 (73.3%) had improvement in cobb angle postoperatively. Mean change in coronal cobb was 5.4 degrees improvement. Five of seven (71.4%) patients with spondylolisthesis had improved Meyer-Ding grade post-operatively. 20 patients experienced subsidence, with 32 of 104 levels (30.8%) affected.

Discussion

Lateral lumbar interbody fusion is a powerful tool in the surgeon's armamentarium. It allows for fusion across the load bearing disc space, indirect decompression via disc and foraminal height restoration, and potential coronal and/or sagittal alignment correction.[9,10] It is relatively safe, with low risks of subsidence and dural tear compared to smaller interbodies that are placed via a posterior approach. LLIF, when placed without posterior instrumentation, can be performed relatively quickly, with minimal tissue trauma and blood loss. Patients undergoing standalone LLIF have decreased length of stay, postoperative pain, and infection rates compared to cases with posterior instrumentation.[3-7,11] In our cohort of 43 patients who underwent multilevel SA-LLIF, patients had good clinical outcomes and radiographic outcomes. Multilevel SA-LLIF is a safe and effective option for patients who may be higher risk for more invasive surgeries.

Spinopelvic Parameters and Deformity

The ISSG previously published guidelines regarding which deformity patients may tolerate MIS correction of deformity. They created 3 classes of patients, with Class I as the group who may be good candidates for standalone single-level MIS surgery and Class II as the group who may require multilevel surgery. Class I patients have an SVA <6cm, PT <25, LL-PI mismatch <10, coronal Cobb <20, and thoracic kyphosis <60. Class II patients have SVA <6cm, PI-LL mismatch 10-30 degrees, major curve with coronal Cobb >20, and Grade 1 or 2 spondylolisthesis. Class III indicates patients with more severe deformity than the above 2 classes, and it is not recommended these patients have MIS surgery. However, this study did not distinguish standalone versus supplemental posterior instrumentation, and there is little guidance in the literature regarding the selection of patients for standalone multilevel LLIF. [8,12]

As introduced above, the utility of LLIF for spinal deformity has been explored primarily in combination with percutaneous posterior fixation (circumferential minimally invasive surgery [cMIS]) or a hybrid approach with open posterior correction. Anand et al[13] found mean correction of coronal cobb from 24 degrees to 9.5 and coronal imbalance correction from 26mm to 11mm in ASD patients who underwent cMIS. However, other studies note that cMIS surgery may not be enough to correct imbalance in ASD patients. Haque et al[14] performed a retrospective review on 184 patients who underwent cMIS, hybrid, or open surgery. Mean PI-LL mismatch was 16 in the cMIS group compared to 2.1 and 2.0 in the hybrid and open groups, respectively. Correction in SVA followed a similar trend with negligible effect on SVA in cMIS group and on average, 3.3cm in the open group. Choi et al[15] attempted to explore the effect of SA-LLIF on spinopelvic parameters by treating 40 patients with 2-stage surgeries: first stage with SA-LLIF and second stage with posterior laminectomies and pedicle screws. Between the two stages and after the second stage, standing scoliosis XR was obtained. Lumbar lordosis was corrected in total from 19.2 to 15.7, and 55.9% of the difference was accounted for by the SA-LLIF. SVA change was from 61.7mm to 42.0mm, and 18% was attributable to SA-LLIF.

Interestingly, in our cohort, 37 (86%) patients met criteria for deformity as previously outlined in our methods. Of these patients, there was significant correction of LL (increase 4.9 degrees) and mean improvement of coronal cobb of 5.4 degrees. Only two patients had re-operation due to progression of deformity. However, correction of deformity in our cohort was not as robust as listed in the previous literature above for cMIS. Despite this, quality of life improvements were significant after surgery.

Subsidence

As noted above, a primary concern for multilevel SA-LLIF is subsidence. Standalone constructs have increased stress on the endplates that can increase risk of cage subsidence. Overall rates of subsidence in SA-LLIF are reported to range from 11.4% to 19.1%[16-19] and reoperation rates for subsidence at 2.7%.[20] Multilevel LLIF or SA-LLIF has also previously been reported as a risk for subsidence.[16,21] In our cohort, fifteen patients (34.9%) experienced Grade 1 or more subsidence, which is higher than rates cited previously in the literature for multilevel

LLIF or SA single level LLIF. However, this had no bearing on clinical outcomes, with no significant difference in ODI or VAS between the group with and without subsidence.

As with all lateral interbodies, proper sizing is important. The interbody must span the entire disc space to cover the lateral borders of the apophyseal ring and cortical endplate. Oversizing the cage height (>11mm) or under-sizing the cage width (<22mm) has been associated with subsidence.[3] Liu et al.[22] performed a finite element study comparing the biomechanics of multilevel interbody fusion with and without supplementary instrumentation. Standalone constructs had significantly increased endplate stress, so it is important to have an adequate length of interbody to decrease risk of subsidence.

Limitations

This study is limited by its retrospective nature and small sample size. Additionally, it is only a descriptive study, with no comparison group. Therefore, it is difficult to extrapolate our results to the entire population, particularly when considering how a patient will fare with multilevel SA-LLIF versus multilevel LLIF with posterior instrumentation. This limitation is particularly important to consider in the context of patient selection. Patients in our study underwent standalone after extensive risk-benefit discussion if they had comorbidities that made longer surgery risky or if they were elderly.

Mean imaging follow-up was 2 years, so longer-term complications such as symptomatic subsidence or adjacent segment disease may not be completely captured in this timeframe. However, there is a paucity of literature regarding outcomes and indications for multilevel SA-LLIF, and our study is one of the first to report outcomes regarding multilevel LLIF as a standalone surgery.

Conclusions

Multilevel standalone LLIF can be a safe and effective surgical option with good clinical and radiographic outcomes.

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Tables

Table 1. Demographics and surgical characteristics

Demographics	**Total: N= 43 (%)**
Sex	**N (%)**
Male	31 (72.1)
Female	12 (27.9)
Age (years), (Mean, SD)	**70.1 (8.1)**
BMI (kg/m^2), (Mean, SD) Normal (18.5-24.9) Overweight (25-29.9) Obese (30-34.9) Morbidly Obese (>35)	**28.2 (5.0)** 11 (25.6) 21 (48.8) 5 (11.6) 6 (14.0)
Smoking Status Current Previous Never	**N (%)** 1 (2.3) 19 (44.2) 23 (53.4)

Diabetes Yes No	**N (%)** 11 (25.6) 32 (74.4)
Bone Quality (Mean, SD) Osteoporosis (t-score -2.5 or less) Osteopenia (t-score -1 to -2.5) Normal (-1 or greater) DEXA not obtained	**-1.38 (0.77)** 2 (4.7) 16 (37.2) 10 (23.3) 15 (34.9)
Hounsfield units of L1 on pre-op CT (Mean, SD)	**127.9 (43.0)**
Surgical Characteristics	
Surgical Indication Deformity correction Degenerative disc disease Adjacent segment disease Spondylolisthesis	**N (%)** 37 (86) 28 (65.1) 9 (20.9) 7 (16.3)
Number of Levels, Mean (SD) 2 3 4	2.4 (0.59) 27 (62.7) 14 (32.6) 2 (4.7)
Type of Cage PEEK Titanium	N (%) 23 (53.5) 20 (46.5)
Duration of surgery (Mean, SD)	134 mins (73 min)
Estimated blood loss (Mean, SD)	54.6 cc (65.6 cc)
Complications Intraoperative Minor Postoperative Major Postoperative	 0 (0) 10 (23.3) 0 (0)

Table 2. Clinical outcomes

Outcome measure	Pre-operative median (IQR)	Post-operative median (IQR)	p-value
ODI	38 (28 to 48.5)	25 (17.5 to 38.5)	0.001
VAS back	7.0 (5.0 to 8.0)	3.5 (1.0 to 6.75)	0.002

VAS leg	6.0 (1.0 to 8.0)	0.0 (0.0 to 5.0)	0.001

Table 3. Pre- and post-operative spinopelvic parameters

	Pre-operative mean (SD)	Post-operative mean (SD)	Change mean (SD)	p-value
Lumbar lordosis	38.26 (12.62)	43.16 (12.61)	4.90 (7.61)	p<0.001*
Pelvic incidence-lumbar lordosis mismatch	20.92 (11.10)	18.68 (10.24)	2.23 (9.94)	p=0.076
Pelvic tilt	25.37 (7.46)	23.94 (7.29)	1.42 (6.60)	p=0.084
Sacral slope	33.39 (7.11)	36.40 (8.46)	-3.01 (7.32)	p=0.0055*
Sagittal vertical axis	5.44 (4.02)	4.50 (4.77)	0.94 (3.61)	p=0.103
Global coronal imbalance	1.79 (1.57)	2.43 (2.41)	-0.64 (2.34)	p=0.090
Coronal cobb angle	28.64 (9.28)	23.22 (12.51)	5.41 (8.36)	p=0.013*