Shafa Ortho J. 2018 August; 5(3):e81419. doi: 10.5812/soj.81419.

Published online 2018 July 18.

Research Article

Radiographic and Surgical Outcomes After Stand-Alone Lateral Lumbar Interbody Fusion

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Received 2018 June 27; **Accepted** 2018 July 15.

Abstract

Objectives: Lateral lumbar interbody fusion (LLIF) is increasingly being utilized in isolation to achieve a large surface-area interbody fusion with an indirect decompression for spinal stenosis. This retrospective chart review was done to determine the viability of performing stand-alone (SA) LLIF.
Methods: Forty-nine patients at least 18 years of age with minimum one-year follow-up at a single institution underwent SA-LLIF using minimally invasive surgery (MIS) approach without further posterior surgery between 2011 and 2015. One to five-level fusions were included. Retrospective review of surgical outcomes and radiographic parameters were examined preoperatively, acutely post-operatively and at 1 year postoperatively.
Results: Forty-nine patients (102 spinal segments) underwent SA-LLIF. Fusion levels ranged from one to five with a mean of 2.1 ± 2.1. Mean blood loss was 68 ± 63.2cc and mean surgical time was 143.4 ± 66.5 minutes. Fifty-seven percent had undergone prior spine surgery unrelated to their index procedure. Complication rate was 38.9% and reoperation rate was 20.4%. No difference in complication rates was noted between constructs with three or more levels fused versus less than three levels fused. At one-year, significant improvement was noted with pelvic tilt, pelvic incidence, and lumbar lordosis.
Conclusions: SA-LLIF is an optional MIS treatment of stable degenerative disc disease and spinal stenosis, with good one-year correction and maintenance of radiographic parameters. With complication rate of 38.9% and reoperation rate of 20.4%, true benefit of forgoing posterior supplemental fixation may be questioned.

Keywords: Lateral Lumbar Interbody Fusion, Minimally Invasive Surgery, Tand-Alone Interbody Fusion, Degenerative Disc Disease, Spinal Stenosis

1. Background

Degenerative disc disease (DDD) is almost universal in the aging population (1). Long-term sequela of this condition can lead to loss of disc height, neuroforaminal and central canal stenosis, and eventual endplate sclerosis as advanced arthritic disease begins (2, 3). Treatment for DDD is often a spectrum ranging from conservative management to decompression and fusion.

Posterior decompression procedures can put spinal levels, already biomechanically abnormal due to underlying disease, at further risk of instability (4, 5). Spondylolisthesis as well as sagittal and coronal plane deformities can develop, subsequently worsening stenosis and neurologic compromise.

Lateral lumbar interbody fusion (LLIF) through a minimally-invasive surgery (MIS) approach is increasingly being utilized in isolation to achieve a large surface-area interbody fusion with an indirect decompression for spinal stenosis (6-10). This technique forgoes posterior fixation with a pedicle screw-rod construct in the appropriately selected patient with a stable spinal segment. The obvious benefits include decreased blood loss, shorter operative time, and absence of posterior soft-tissue disruption (11-13). Scant data exists regarding surgical and radiographic outcomes following this treatment algorithm that intuitively may have the benefits of decreasing adjacent-segment forces and the potential disadvantage of a less-stable fusion construct.

2. Methods

To identify the viability of stand-alone (SA)-LLIF, a retrospective case series review of patients undergoing the procedure for DDD, spinal stenosis, and low-grade spondylolisthesis between T12 and L5 was conducted at a single institution after approval from an institutional review board.

Forty-nine patients at least 18 years of age underwent SA-LLIF via a standard MIS retroperitoneal, trans-psoas approach as previously described in the literature. Interbody cages varied from 8 to 12 mm in height, 45 to 60 mm in width, 18 to 26 mm in depth, and 8 to 10 degrees of lordosis. No further posterior surgery was performed. Index procedures occurred between 2011 and 2015 with a minimum one-year follow-up. One to five-level SA-LLIF were included. A retrospective review of surgical outcomes and radiographic parameters were employed preoperatively, acutely postoperatively and at one year postoperatively.

Clinical data was assessed through chart review of physical examination and clinical history in both the inpatient and outpatient settings. Two independent surgeons that were not involved with direct care of the patients analyzed digital x-ray images. The following radiographic parameters were assessed utilizing Surgimap Spine software (Nemaris Inc, New York, NY, USA): pelvic tilt (PT), sacral slope (SS), pelvic incidence (PI), lumbar lordosis (LL), L4 to S1 LL (PI-LL), motion segment angle (MSA), and intradiscal angle (IDA). X-rays were reviewed preoperatively, postoperatively, and at one year. Computed tomography (CT) and x-rays images were reviewed to assess fusion.

2.1. Statistical Analysis

All statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS Version 24, Chicago, Ill, USA). Pre- to postoperative comparisons were assessed by non-parametric Wilcoxon signed-rank test. Between group comparisons were assessed by non-parametric Mann-Whitney U test. Categorical variables were compared using chi-squared test. Statistical significance was set at alpha level of 0.05.

3. Results

Forty-nine patients (102 spinal segments) underwent SA-LLIF. The mean age, fusion levels, estimated blood loss and surgical time are provided in Table 1.

Prior spine surgery unrelated to their index procedure had been undergone by 57.1%. Overall complication rate was 38.9% (Table 2).

Table 1. Patient Demographics

Descriptor (N = 49)	Mean	Range	Standard Deviation
Age, y	63.2	(32, 84)	9.8
BMI	27.4	(18.4, 46.3)	5.3
Number of LLIFs	2.1	(1, 5)	1.3
Total estimated blood loss, ml	68	(0, 300)	63.2
Total surgical time, minutes	143.4	(72, 328)	66.5

Abbreviations: BMI, body mass index; LLIF, lateral lumbar interbody fusion.

Table 2. Complications Experienced

Complications	No. (%)
Overall complication	19 (38.9)
Reoperation	10 (20.4)
Major	2 (4.1)
Minor	17 (34.7)
Surgical	18 (36.7)
Infection	0 (0.0)
Implant	2 (4.1)
Radiographic	10 (20.4)
Neurologic	8 (16.3)
Cardiopulmonary	0 (0.0%)
Vascular	0 (0.0)
Gastrointestinal	0 (0.0)
Renal	0 (0.0)
Operative	1 (2.0)
Wound problems	0 (0.0)
Adjacent segment disease	5 (10.2)
Pseudoarthrosis	3 (6.1)

Eight cases were adjacent segment disease (ASD), seven being symptomatic, five undergoing reoperation at >1 year, 2 at < 1 year. Four cases were pseudoarthrosis, one undergoing reoperation at >1 year, two at < 1 year, and one non-operatively managed. One case was an endplate fracture at 6 weeks postoperative requiring the addition of posterior fixation. Others included three cases of ongoing radiculopathy (2 L5, 1 S1) and two cases of residual motor deficit (one foot dorsiflexion and one hip abductor) at 1 year. Overall reoperation rate was 20.4%. No difference in complication rates were noted between constructs with three or more levels fused versus less than three levels fused or constructs with prior fusions (Table 3).

At 1-year, significant improvement was seen with PT, PI,

Table 3. Complication Rates Were Noted Between Constructs With and Without Prior Fusions

Descriptor	No. Prior Lumbar Fusion (N = 36), No. (%)	Prior Lumbar Fusion (N = 13), No. (%)	P
Complication	12 (33.3)	7 (53.8)	0.193
Reoperation	6 (16.7)	4 (30.8)	0.280
Major	1 (2.8)	1 (7.7)	0.443
Minor	11 (30.6)	6 (46.2)	0.311
Surgical	11 (30.6)	7 (53.8)	0.135
Implant	1 (2.8)	1 (7.7)	0.443
Radiographic	7 (19.4)	3 (23.1)	0.781
Neurologic	5 (13.9)	3 (23.1)	0.442
Operative	1 (2.8)	0 (0.0)	0.544

and LL. PI-LL were both significantly improved acutely postoperative and at 1 year (Table 4). At both acutely postoperative and 1-year follow-up, mean IDA and MSA were significantly improved when compared with preoperative values (Table 5).

Sub-analysis showed no difference in postoperative radiographic parameters for patients that underwent reoperation (Table 6).

Further sub-analysis was performed to evaluate the effect of deformity, defined as preoperative sagittal PI-LL > 10 and PT > 20, on SA-LLIF. There were 22 (44.9%) deformity patients (DEF) and 27 (55.1%) non-deformity patients (NDEF) (Table 7).

Mean age was 65.2 and 61.6 in DEF and NDEF, respectively. No statistical differences between groups was seen in demographics. An average of 1.9 levels were fused in NDEF vs. 2.5 (P = 0.135) in DEF. Complication (DEF 40.7% and NDEF 36.4%, P = 0.754) and reoperation rates (22.7% DEF and 22.1% NDEF, P = 0.966) were similar between groups. Reoperation at < 1 year for DEF included one pseudoarthrosis and for NDEF one endplate fracture, one symptomatic ASD, and two pseudoarthrosis (PSA). At > 1-year reoperations included for DEF one PSA and three ASD; for NDEF two ASD. Other complications included for DEF was one residual hip abductor weakness, one persistent S1 radiculopathy, one asymptomatic ASD, and one symptomatic PSA treated non-operatively. NDEF had one residual foot dorsiflexion weakness and two persistent L5 radiculopathies. Overall neurologic risk was 13.6% for DEF and 18.5% for NDEF, which did not reach significance (p = 0.646).

4. Discussion

Much discussion exists about how to manage the degenerative milieu of DDD, spinal stenosis, low-grade spondylolisthesis and mild degenerative deformities. When the decision to proceed with fusion is made, debate again exists about the method to use. MIS techniques attempt to provide a stable fusion construct while minimizing collateral damage that may further progress the underlying disease process (14, 15). SA-LLIF is a relatively new technique that attempts to minimize the deleterious effects of posterior instrumentation while still providing a reliable segmental fusion.

Several biomechanical studies have shown SA-interbody fusion provide sufficient stability while reducing stress at adjacent levels (16, 17). By restoring tensile strain on intact ligamentous structures, insertion of an interbody device can provide adequate stability while restoring disc height and correcting anterior and middle column alignment (18).

Marchi et al. (12), reported a revision rate of 13.5% after SA-LLIF with the majority related to implant subsidence. Previous studies show that subsidence plays no role in reported outcome measures but is a source of at least one revision in this case series. The majority of revisions reported were due to pseudoarthrosis and adjacent segment failure in this case series. Adjacent segment failure remains controversial as possibly the natural course of the degenerative process. In the case series by Ahmadian et al. (14), only two patients out of 59 underwent reoperation for continued symptomatic stenosis and cage migration. Watkins et al. (19) found a 19% pseudoarthrosis rate in a case series of 23 consecutive patients and 37 levels treated. Another study identified a surgical revision rate of 10.3% in 117 patients undergoing SA-LLIF (20). Tempel et al. (21), had two vertebral body fractures in a series of 335 patients after SA-LLIF.

Several previously published studies indicate that SA-LLIF consistently adds approximately 2° - 3° of segmental lordosis per level. This is consistent with the current data. Malham et al. (22), reported a significant overall lumbar lordosis improvement from 48.8° to 55.2° at 1 year. Several other studies have shown mixed correction of global lordosis similar to the current study (23, 24).

No previous studies have examined the use of SA-LLIF in adult deformity surgery despite the increasing trend for MIS lateral spine surgery in this population. Though SA-LLIF remains controversial, advocates can see based on

Table 4. Results Preoperative, Acutely Postoperative and One-Year Postoperative

Descriptor	Preoperative	Postoperative	1-Year Postoperative
Pelvic tilt, degrees	20.7 ± 9.4	20.8 ± 9.0	18.4 ± 7.8[a]
Sacral slope, degrees	34.6 ± 8.4	33.4 ± 8.5	35.4 ± 8.5
Pelvic incidence, degrees	55.3 ± 11.4	54.1 ± 11.1	53.7 ± 11.6[a]
PI-LL, degrees	13.3 ± 21.4	8.0 ± 12.7[a]	6.9 ± 11.8[a]
Lumbar lordosis, degrees	42.0 ± 20.3	46.1 ± 11.4	46.8 ± 12.5[a]
L4-S1 LL, degrees	33.1 ± 14.3	33.3 ± 8.9	35.0 ± 9.8

Abbreviations: PI-LL, pelvic incidence-lumbar lordosis; LL, lumbar lordosis.
[a] Significantly different from preoperative.

Table 5. Comparison of Preoperative and Postoperative Angles

Descriptor	N	Preoperative	Acute Postoperative	P
Intradiscal angles, Degrees	102	3.0 ± 3.4	7.2 ± 3.9	< 0.001
Motion-segment angles, Degrees	104	9.7 ± 9.6	12.6 ± 9.1	< 0.001
		Preoperative	**Latest**	
Intradiscal angles, Degrees	104	3.0 ± 3.4	6.6 ± 3.5	< 0.001
Motion-segment angles, Degrees	101	9.9 ± 9.5	12.6 ± 9.4	< 0.001
		Acute Postoperative	**Latest**	
Intradiscal angles, Degrees	102	7.2 ± 3.9	6.6 ± 3.6	0.117
Motion-segment angles, Degrees	101	12.7 ± 9.1	12.6 ± 9.4	0.789

Table 6. Sub-Analysis Showed No Difference in Postoperative Radiographic Parameters for Patients Who Underwent Reoperation

Descriptor	No. Reoperation (N = 39)	Reoperation (N = 10)	P
Postoperative pelvic tilt, Degrees	21.5	19.3	0.705
Postoperative sacral slope, Degrees	33.9	31.4	0.549
Postoperative pelvic incidence, Degrees	55	50.7	0.285
Postoperative pelvic incidence-lumbar lordosis, Degrees	8.5	6.1	0.517
Postoperative lumbar lordosis, Degrees	46.5	44.6	0.817
Postoperative L4-S1 lumbar lordosis, Degrees	33.5	32.6	0.913

the current study that SA-LLIF is a reasonable alternative to more traditional reconstruction approaches used in an appropriately selected patient population.

Limitations of this study include the lack of patient reported outcome measures. This study focused on surgical complications and radiographic outcomes. The retrospective case series cohort is a limitation. More long-term follow-up beyond 1-year radiographic data would be helpful in further delineating the nature of adjacent segment disease and complication rates. We further acknowledge that full-length scoliosis radiographs would have been ideal for measuring global sagittal parameters in the deformity population.

SA-LLIF is a viable option for minimally invasive treatment of stable DDD and spinal stenosis, with good one-year correction and maintenance of radiographic sagittal parameters. With an overall complication rate approaching 40%, the true benefit of forgoing posterior supplemental fixation may be questioned and the appropriate candidate may need to be defined for this less invasive procedure to minimize complications.

Acknowledgments

We thank the scripps clinic medical group for the internal grant to support this research and the Shiley center for orthopaedic research and education at scripps clinic for their expertise and support.

Table 7. Sub-Analysis Performed to Evaluate the Effect of Deformity, Defined as Preoperative Sagittal PI-LL > 10 and Pelvic Tilt > 20, on Stand-Alone Lateral Interbody Fusion

Descriptor	Non-Deformity Patients	Deformity Patients	P
N	27	22	0.329
Age, y	61.6	65.2	0.944
Female	12 (44.4%)	10 (45.5%)	0.406
Body mass index	27.9	26.8	0.136
Prior spine surgery, N	18 (66.7%)	10 (45.5%)	0.135
Total LLIFs, N	50	54	0.967
Preoperative hemoglobin	14.1	14.2	0.7
Total estimated blood loss, mL	68	68.1	0.132
Total operating room time, minutes	132.4	156.9	0.004[a]
Total length of surgery, hours	1.9	2.9	0.329
Complication, N (%)	11 (40.7%)	8 (36.4%)	0.754
Reoperation, N (%)	5 (18.5%)	5 (22.7%)	0.716
Major complications, N (%)	2 (7.4%)	0 (0.0%)	0.192
Minor complications, N (%)	9 (33.3%)	8 (36.4%)	0.825
Surgical complications, N (%)	11 (40.7%)	7 (31.8%)	0.519
Implant complications, N (%)	2 (7.4%)	0 (0.0%)	0.192
Radiographic, N (%)	4 (14.8%)	6 (27.3%)	0.282
Neurologic, N (%)	5 (18.5%)	3 (13.6%)	0.646
Operative, N (%)	1 (3.7%)	0 (0.0%)	0.362
Pre to 1-y PT, degrees	0.6[a]	-6[a]	0.003[a]
Pre to 1-y SS, degrees	-1.6	3.7[a]	0.03[a]
Pre to 1-y PI, degrees	-1	-2.3	0.351
Pre to 1-y PI-LL, degrees	-6[a]	-6.9[a]	0.01[a]
Pre to 1-y LL, degrees	4.9	4.6	0.116
Pre to 1-y L4-S1 LL, degrees	2	1.9	0.475
Pre to 1-y IDA, degrees	4.1	4	0.608
Pre to 1-y MSA, degrees	4.1	1.8	0.183

Abbreviations: IDA = intradiscal angles; LL = lumbar lordosis; MSA = motion-segment angles; PI = pelvic incidence; PI-LL = pelvic incidence-lumbar lordosis; PT = pelvic tilt; SS = sacral slope.
[a] Indicates statistical significance.

Footnote

Funding/Support: An internal grant from scripps clinic medical group supported this research.

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