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Original Article

Risk Factors of Unsatisfactory Outcomes Requiring Additional Intervention Following Oblique Lateral Interbody Fusion

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Objective: Oblique lateral interbody fusion (OLIF) is a minimally invasive procedure for stabilizing the spine and indirectly decompressing the neural elements. There is sparse data on unsatisfactory outcomes that require additional interventions (surgery or intervention) after OLIF. This study aimed to identify the causes, and risk factors of these reintervention.
Methods: This was a single-center retrospective study of the patients who underwent the OLIF procedure from June 2016 to March 2023. Several clinical and radiographic parameters were studied. We also analyzed associations between several potential risk factors and the reintervention following OLIF.
Results: A total of 231 patients were included. Over an average of 2.5 years of follow-up, 28 patients (12.1%) required a reintervention. Adjacent segment disease (ASD) was the most common cause of reintervention. The risk factors associated with reintervention were previous surgery (adjusted odds ratio [aOR], 4.44; 95% confidence interval [CI], 1.21–16.33; p = 0.02) and high preoperative Oswestry Disability Index (ODI) scores (aOR, 1.04; 95% CI, 1.00–1.08; p = 0.03). Although increasing the duration of follow-up was not statistically significant, the 95% CI was consistent with an increased risk of reintervention with longer follow-up (OR, 1.18; 95% CI, 0.94–1.50).
Conclusion: This study showed that patients with prior lumbar surgery and high preoperative ODI scores were more likely to require additional intervention after the OLIF procedure. In addition, an increasing duration of follow-up was associated with an increased risk of reintervention. The most common reason for reintervention was ASD after OLIF.

Keywords: Unsatisfactory, Oblique lateral interbody fusion, Reintervention, Risk factors, OLIF

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INTRODUCTION

Degenerative disease of the lumbar spine is one of the most common causes of morbidity in aging societies. Patients with degenerative lumbar spine diseases, who failed conservative treatment ultimately required surgery.[1,2] Oblique lateral interbody fusion (OLIF), a lateral lumbar interbody fusion (LLIF) technique, has gained popularity among spinal surgeons, a safe and effective surgical treatment for patients with degenerative lumbar spine diseases.[3-5] This minimally invasive surgery technique, which is an alternative to the standard posterior approach, accesses the spine between the great vessels and the psoas mus-

cle, thereby decreasing the risk of intraoperative lumbar plexus injury compared to extreme lateral interbody fusion (XLIF), the other LLIF techniques.[6,7]

With OLIF procedure, decompression of the neural elements is achieved indirectly by restoring disc and foraminal height, and unbuckling of the ligamentum flavum.[5] Numerous studies reported favorable clinical and radiographic outcomes following the OLIF procedure.[8,9] Also, OLIF showed several benefits compared to open posterior spinal surgeries, such as decreased blood loss, and length of hospital stays.[10]

Although OLIF provide promising results, various complications following the procedure were reported in the literature, including transient psoas muscle weakness, lumbar sympathetic chain injury, and anterior thigh pain.[11,12] In addition, there is sparse data on unsatisfactory outcomes that require additional intervention or surgery after the OLIF procedure. Few studies have reported specifically on the revision rates, and failure mechanisms following OLIF procedures. The purpose of this study was to identify the causes, and risk factors of these outcomes in patients who underwent OLIF without direct posterior decompression.

MATERIALS AND METHODS

1. Study Design and Study Population

We conducted a single-center retrospective analysis of patients who underwent OLIF between June 2016 and March 2023. This study involving human participants was in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. The Human Investigation Committee of the Faculty of Medicine, Chulalongkorn University Institutional Review Board (IRB) approved this study (IRB number 0904/66). The need for written informed consent was waived. The inclusion criteria were patients who underwent OLIF procedure for degenerative spine disease at 1 to 4 consecutive spinal levels, with a minimum follow-up of 6 months. The exclusion criteria were spinal trauma, tumor, or infection. Patients were classified into 2 groups based on the postoperative clinical outcomes: nonreintervention, and reintervention groups. The reintervention was defined as the need for any additional intervention, including major revision surgery or minor procedures, such as selective nerve root block, at the previously operated spinal level or adjacent level, following the OLIF procedure. The patients who needed reintervention had already failed medications and physical therapy and needed further management.

2. Surgical Techniques

All surgeries were done by 1 of 3 senior spine surgeons, each with more than 5 years of experience in performing OLIF. The procedure was performed in the right lateral decubitus position. The skin incision was determined using O-arm navigation or fluoroscopy. Muscle dissections were performed layer by layer to identify the oblique prepsoas corridor. Then, sequential dilators and tubular retractors were applied to access the targeted intervertebral disc. Annulotomy, discectomy, and endplate preparation were performed in standard fashion. The trial cage for OLIF (Clydesdale Spinal System, Medtronic, Minneapolis, MN, USA) was inserted using the orthogonal maneuver. After the appropriate size was determined, a cage filled with demineralized bone matrix (ATTRAX, NuVasive Inc., San Diego, CA, USA) was implanted. The supplemental instrumentation, such as pedicle screws-rod fixation, anterolateral plate system, and lateral screws-rod system was performed in most cases. The stand-alone OLIF was also performed in some patients.

3. Data Collection and Outcome Measurements

The patients' postoperative clinical data were retrospectively collected from electronic medical records. Patients were scheduled for follow-up at 1, 3, 6, and 12 months after the surgery in the first postoperative year. The demographic and clinical characteristics that were collected included age, sex, bone mineral density (BMD), body mass index, diagnosis, number of operated levels, smoking status, history of previous lumbar surgery, comorbidities, length of follow-up period, preoperative Oswestry Disability Index (ODI), visual analogue score of leg pain, and back pain. Radiographic parameters collected included disc and foraminal height, reducible disc height (percentage of disc height discrepancy between supine and standing position), segmental lordotic angle, pelvic tilt, lumbar lordosis, pelvic incidence-lumbar lordosis mismatch, cage position, and cage subsidence, which were measured on plain radiographs. The disc height was calculated as the average sum of the anterior and posterior disc heights in the lateral radiograph. The segmental lordotic angle was measured as the angle between the upper endplate of the upper vertebrae and the lower endplate of the lower vertebrae of each fusion level. The foraminal height of each spinal level was measured as the maximum distance between the inferior margin of the pedicle of the superior vertebra and the superior margin of the pedicle of the inferior vertebra of each fusion level. The postoperative lateral image was utilized to evaluate the cage position, which was obtained from the distances between the anterior edge of the upper endplate of the lower vertebral

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body to both the anterior and posterior edges of the interbody cage (Fig. 1). The position of the cage center was calculated as the midpoint of both distances, which was then divided by the length of the upper endplate to normalize the calculation of cage position for each surgical level. Cages with a center position scale <0.5 were classified as anteriorly placed, whereas cages with a center position >0.5 were classified as posteriorly placed. Cage subsidence grading was also evaluated on postoperative lateral radiograph by measuring the percentage of endplate collapses as described by Marchi et al.[13] which was classified as low-grade (grade 0, 0%–24%; grade I, 25%–50%), and high-grade subsidence (grade II, 51%–74%; grade III, 75%–100%) (Fig. 2). The preoperative T2-weighted axial image of the magnetic resonance imaging (MRI) with the most severe stenosis of each spinal level was utilized to measure the midline dural sac diameter, midline spinal canal diameter, and dural sac cross-sectional area (Fig. 3).

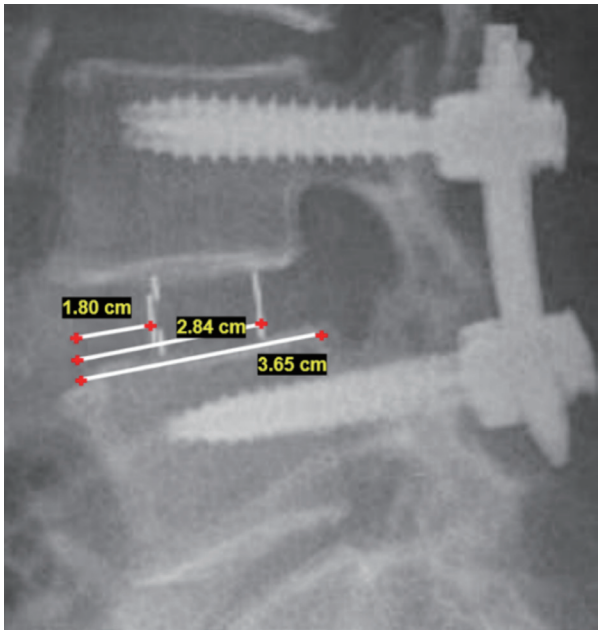

Fig. 1. Cage position assessment: The distances between the anterior edge of the upper endplate of the lower vertebra and both the anterior and posterior edges of the cage were measured. The length of the upper endplate is also measured. The position of the cage center is calculated as the midpoint of both distances, which is then divided by the length of the upper endplate of the lower vertebral body to normalize the calculation for each surgical level. For example, $(1.80\ \text{cm}+2.84\ \text{cm})/(2\times 3.65\ \text{cm})=0.64$, which means that the cage is located slightly posterior on the upper endplate.

Patients who required additional interventions after OLIF were analyzed in details, describing the cause of the unsatisfactory result, and the duration time from the index procedure elapsed to the reintervention.

4. Statistical Analyses

Formal comparisons between continuous parameters fixed within patients were made using the Wilcoxon rank-sum test for continuous data and the Fisher exact test for categorical data. Comparisons of variables that differed by level in patients with procedures at 2 levels or more were assessed using logistic regression models. Factors with $p<0.1$, in univariate models, were adjusted for in a multivariable model. The statistical significance level was set at $p<0.05$. Marginal predicted probabilities of intervention were calculated based on the multivariable model. Decisions regarding statistical and clinical significance were made based on p-values and a 95% confidence interval (CI).[14] Model fit and discrimination were assessed using a Hosmer

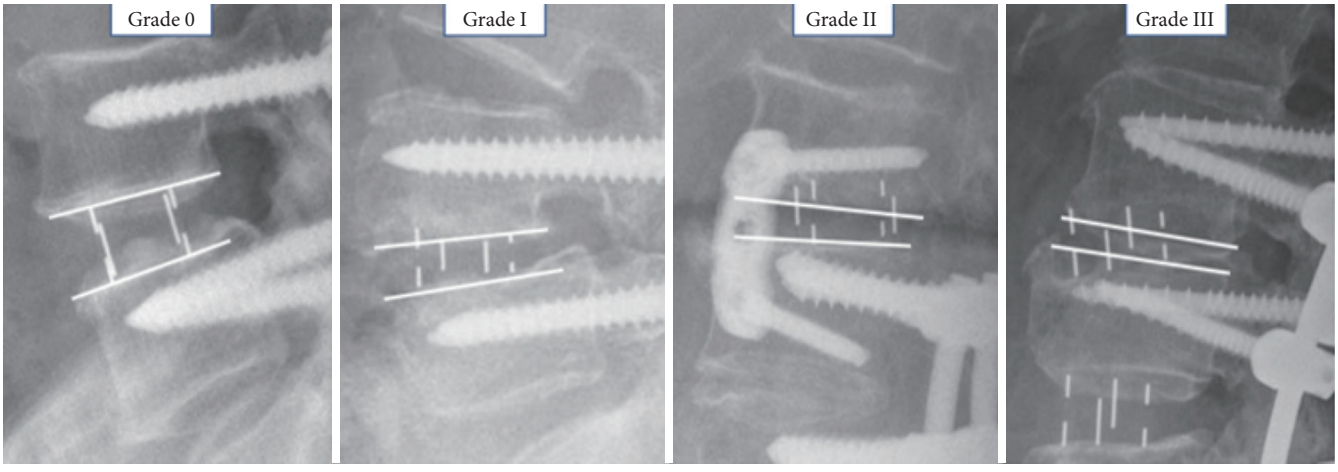

Fig. 2. Cage subsidence grading. Lateral plain radiographs showing examples of the different subsidence grades (0–III).

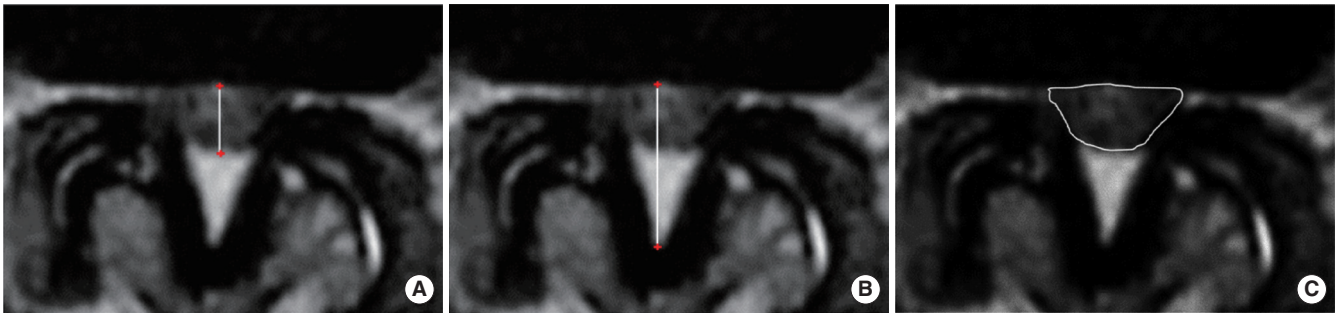

Fig. 3. The preoperative T2-weighted axial magnetic resonance imaging with the most severe stenosis of each spinal level was utilized to measure the midline dural sac diameter (A), midline spinal canal diameter (B), dural sac cross-sectional area (C).

and Lemeshow goodness of fit test, and area under the receiver operating characteristics curve (AROC), respectively. Statistical analysis was conducted using Stata 18.0 (StataCorp LLC, College Station, TX, USA).

RESULTS

The patients' demographic, clinical, and procedure-related characteristics are summarized in Table 1. A total of 231 patients were enrolled in our study: 142 underwent a single-level procedure, 54 underwent a 2-level procedure and 35 underwent a 3 to 4-level procedure. The median (interquartile range [IQR]) follow-up was 2.5 years (1–4 years). The median (IQR) patient's age was 65 years (59–73 years), with a female predominance (180 of 231 patients, 77.9%). The most common diagnoses were lumbar spondylolisthesis, followed by lumbar spinal stenosis and degenerative scoliosis in 42.0%, 23.8%, and 14.7%, respectively. Patients in the reintervention group were more likely to have the supplemental fixation with the anterolateral plate or stand-alone OLIF, and less likely to have fixation using a pedicle screw-rod system than those in the non-reintervention group ($p = 0.006$). The reintervention group had a longer follow-up period, and a higher incidence of prior lumbar surgery compared to the nonreintervention group ($p < 0.001$). All patients who had prior lumbar surgery had a history of open decompressive laminectomy and posterolateral fusion or decompression alone. The preoperative ODI scores were significantly higher in the reintervention group ($p = 0.008$). There was no significant difference in age, gender, underlying disease, smoking status, number of treated levels, and cage profile between the 2 groups. In 152 patients, who had preoperative BMD data available, the median (IQR) BMD was not significantly different between both groups ($p = 0.32$).

The radiographic data are shown in Table 2. All radiographic parameters showed no significant difference between patients who ultimately did or did not require additional intervention.

The total reintervention rates were 12.1% (28 of 231 patients), with a mean interval between the index surgery and the reintervention of 26 months (4.3–47.1 months). Patients who underwent the reintervention at the level of the index surgery (11 of 231 patients, 4.8%) had a mean interval of 14.8 months (2–27.6 months). Patients who underwent a reintervention at the adjacent level of the index surgery (17 of 231 patients, 7.4%) had a mean interval of 32.7 months (9.5–55.9 months). The most common reasons for additional intervention were the occurrence of adjacent segment disease (ASD), which is defined as symptomatic worsening of spinal level adjacent to the previous spinal surgery (57.1%), followed by indirect decompression failure (IDF) (14.3%). Of the patients who required reintervention, 6.5% (15 of 231 patients) underwent reoperation, and the other 5.6% (13 of 231 patients) required one of the minor procedures including transforaminal epidural steroid injection (TFESI), caudal epidural steroid injection (CESI), or percutaneous radiofrequency ablation (PRFA).

Patients, who required additional intervention at the same level of the index surgery ($n = 11$), were categorized based on the reasons for reintervention. The reasons were failed indirect decompression ($n = 4$), hardware complications ($n = 3$), including pedicle screw pull-out, implant irritation, and rod breakage, recurrent radiculopathy ($n = 3$), and facet joint syndrome ($n = 1$). The patients diagnosed with failed indirect decompression were treated with additional direct posterior decompression. The hardware complications were managed by revision of the instrumentations. Patients diagnosed with recurrent radiculopathy and facet joint syndrome demonstrated no residual or new neural elements compression on the postoperative MRI and were treated with minor procedures. Of the 17 patients who underwent a reintervention at the adjacent level of the index surgery, the most

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Table 1. Patient's preoperative demographic, clinical, and procedure-related characteristics

Characteristic	Total (n = 231)	Nonreintervention (n = 203)	Reintervention (n = 28)	p-value
Age (yr)	65 (59–73)	67 (61–74)	65 (59–73)	0.590
Sex				0.810
Male	51 (22.1)	46 (22.7)	5 (17.9)	
Female	180 (77.9)	157 (77.3)	23 (82.1)	
BMI (kg/m^2)	25 (22–28)	25 (22–28)	27 (23–30)	0.180
BMD (T-score) (n = 152)	-1.7 (-2.3 to 1.1) (n = 152)	-1.7 (-2.3 to -1.1) (n = 135)	-1.3 (-2.1 to 0.7) (n = 17)	0.320
Diabetes				0.280
No	192 (83.12)	171 (84.24)	21 (75.00)	
Yes	39 (16.88)	32 (15.76)	7 (25.00)	
Hypertension				0.840
No	112 (48.5)	99 (48.8)	13 (46.4)	
Yes	119 (51.5)	104 (51.2)	15 (53.6)	
Smoking				0.620
No	219 (94.8)	193 (95.1)	26 (92.9)	
Yes	12 (5.2)	10 (4.9)	2 (7.1)	
Diagnosis				< 0.001*
Lumbar spondylolisthesis	97 (42.0)	89 (43.8)	8 (28.6)	
Lumbar spinal stenosis	55 (23.8)	47 (23.2)	8 (28.6)	
Degenerative scoliosis	34 (14.7)	34 (16.7)	0 (0)	
Adjacent segment disease	21 (9.1)	15 (7.4)	6 (21.4)	
DDD/HNP	16 (6.9)	14 (6.9)	2 (7.1)	
FBSS	8 (3.5)	4 (2.0)	4 (14.3)	
Previous lumbar surgery				< 0.001*
No	201 (87.0)	183 (90.1)	18 (64.3)	
Yes	30 (13.0)	20 (9.9)	10 (35.7)	
Cage size (n = 462)				0.061
8 mm	30 (13.0)	27 (13.3)	3 (10.7)	
10 mm	103 (44.6)	89 (43.8)	14 (50.0)	
12 mm	87 (37.7)	77 (37.9)	10 (35.7)	
14 mm	10 (4.3)	10 (4.9)	0 (0)	
16 mm	1 (0.4)	0 (0)	1 (3.6)	
Cage lordosis (n = 462)				0.758
6°	173 (74.9)	153 (75.4)	20 (71.4)	
8°	4 (1.7)	4 (2.0)	0 (0)	
12°	53 (22.9)	45 (22.2)	8 (28.6)	
16°	1 (0.4)	1 (0.5)	0 (0)	
Supplemental fixation				0.006*
None (stand-alone OLIF)	4 (1.7)	2 (1.0)	2 (7.7)	
Pedicle screws-rod system	214 (92.6)	192 (94.6)	22 (78.6)	
Anterolateral plate system	7 (3.0)	4 (2.0)	3 (11.5)	
Lateral screws-rod system	6 (2.6)	5 (2.4)	1 (3.9)	

(*Continued*)

Table 1. Patient's preoperative demographic, clinical, and procedure-related characteristics (Continued)

Characteristic	Total (n = 231)	Nonreintervention (n = 203)	Reintervention (n = 28)	p-value
VASB	7 (5–8)	7 (5–8)	8 (5–10)	0.070
VASL	7 (5–8)	7 (5–8)	6 (4–9)	0.820
ODI	49 (40–58)	47 (38–56)	54 (46–65)	0.008*
No. of treated levels				0.080
One	142 (61.5)	125 (61.6)	17 (60.7)	
Two	54 (23.4)	44 (21.7)	10 (35.7)	
Three to four	35 (15.2)	34 (16.7)	1 (3.6)	
Follow-up period (yr)	2.5 (1–4)	2 (1–4)	4 (2–5)	0.006*

Values are presented as median (interquartile range) or number (%).
BMI, body mass index; BMD, bone mineral density; DDD, degenerative disc disease; HNP, herniated nucleus pulposus; FBSS, failed back surgery syndrome; OLIF, oblique lateral interbody fusion; VASB, visual analogue scale of back pain; VASL, visual analogue scale of leg pain; ODI, Oswestry Disability Index.
*$p < 0.05$, statistically significant differences.

Table 2. Preoperative and postoperative radiographic parameters, by reintervention group

Characteristic	Total (n = 231)	Nonreintervention (n = 203)	Reintervention (n = 28)	p-value
Preoperative				
Disc height (mm)	7.10 ± 2.10	7.02 ± 2.11	7.73 ± 1.91	0.090
Foraminal height (mm)	15.28 ± 2.85	15.26 ± 2.89	15.45 ± 2.59	0.744
Segmental lordotic angle (°)	14.48 ± 9.10	14.52 ± 9.34	14.14 ± 7.30	0.837
Reducible disc height (%)	23.89 ± 32.44	22.93 ± 29.61	30.78 ± 48.48	0.231
Spinal canal diameter (mm)	10.73 ± 3.52	10.69 ± 3.47	11.01 ± 3.97	0.658
Dural sac area (mm^2)	77.65 ± 45.89	78.25 ± 47.23	73.14 ± 34.56	0.588
Dural sac diameter (mm)	7.98 ± 2.54	8.03 ± 2.55	7.66 ± 2.52	0.478
Postoperative				
Disc height (mm)	12.37 ± 7.44	12.42 ± 7.88	12.02 ± 2.44	0.789
Foraminal height (mm)	19.71 ± 2.86	19.64 ± 2.80	20.19 ± 3.26	0.341
Segmental lordotic angle (°)	14.93 ± 7.16	15.10 ± 7.23	13.68 ± 6.64	0.325
Pelvic tilt (°)	18.55 ± 9.15	18.55 ± 9.15	17.46 ± 9.59	0.558
Lumbar lordosis (°)	43.96 ± 12.69	44.29 ± 12.75	41.61 ± 12.28	0.295
PI–LL mismatch (°)	7.48 ± 12.65	7.37 ± 12.48	8.25 ± 14.03	0.732
Cage subsidence				0.318
Grade 0	199 (86.2)	176 (86.7)	23 (82.1)	
Grade 1	19 (8.2)	17 (8.4)	2 (7.1)	
Grade 2	3 (1.3)	3 (1.5)	0 (0)	
Grade 3	10 (4.3)	7 (3.5)	3 (10.7)	
Cage position				0.148
Anterior	174 (75.3)	156 (76.9)	18 (64.3)	
Posterior	57 (24.7)	47 (23.2)	10 (35.7)	

Values are presented as mean ± standard deviation or number (%).
PI–LL, pelvic incidence-lumbar lordosis.

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common reasons were ASD (n = 16), followed by proximal junction failure (PJF) (n = 1). Fifty percent (8 of 16 patients) of patients who developed ASD were treated with revision surgery, and the remaining patients were treated with minor procedures. The patient, who developed PJF, was treated with extended instrumented fusion (Table 3).

In a univariable analysis, factors associated with reintervention were higher preoperative ODI scores, history of previous lumbar spinal surgery, longer duration of follow-up, and supplemental fixation type. In the multivariable model, prior lumbar spinal surgery and higher preoperative ODI scores showed an association with reintervention. For each unit increase in ODI scores, the adjusted odds of reintervention increased by 4% (odds ratio [OR], 1.04; 95% CI, 1.00–1.08; p = 0.03). The patients who had a history of lumbar spinal surgery had an adjusted odds ratio of 4.44 (95% CI, 1.21–16.33; p = 0.02) when compared to patients who did not have the previous surgery. Although increasing the duration of the follow-up was not statistically significant, the 95% CI was consistent with an increased risk of reintervention with longer follow-up (OR, 1.18; 95% CI, 0.94–1.50) (Table 4). The multivariable model showed no evidence of poor fit (Hosmer and Lemeshow goodness of fit p = 0.85), and the AROC was 0.77 (95% CI, 0.69–0.88). The causes of reintervention following OLIF procedure were demonstrated in Table 5.

Table 3. Reasons for reintervention after the oblique lateral interbody fusion procedure

Reason	No. of patients (%)	Duration time since the index surgery (mo)
Same-level reintervention		
Failed indirect decompression	4 (14.3)	13.0
Hardware complications	3 (10.7)	18.0
Pedicle screw pull-out	1 (3.6)	3.0
Implant irritation	1 (3.6)	21.0
Rod breakage	1 (3.6)	30.0
Recurrent radiculopathy	3 (10.7)	16.7
Facet joint syndrome	1 (3.6)	7.0
Adjacent-level reintervention		
Adjacent segment disease	16 (57.1)	33.8
Proximal junction failure	1 (3.6)	15.0

DISCUSSION

Our findings showed a total of 12.1% (28 of 231 patients) required reintervention in this cohort of patients undergoing OLIF without direct posterior decompression, at an average follow-up

Table 4. Univariate and multivariate analyses of factors associated with the reintervention

Characteristic	OR (95% CI)	p-value	aOR (95% CI)	p-value
VAS back score (per 1 unit increase)	1.14 (0.95–1.37)	0.146	0.97 (0.79–1.18)	0.740
ODI scores (per 1 unit increase)	1.04 (1.01–1.07)	0.019	1.04 (1.00–1.08)	0.035*
Follow-up duration (per 1 year increase)	1.02 (1.01–1.04)	0.008	1.18 (0.94–1.50)	0.160
Previous lumbar spinal surgery		< 0.001		0.025*
No	1.00 (reference)		1.00 (reference)	
Yes	5.08 (2.07–12.51)		4.44 (1.21–16.33)	
No. of operated levels		0.212		0.230
1	1.00 (reference)		1.00 (reference)	
2	1.72 (0.73–4.05)		1.51 (0.54–4.21)	
≥ 3	0.22 (0.03–1.70)		0.24 (0.03–1.98)	
Supplemental fixation type				0.690
None (stand-alone)	1.00 (reference)		1.00 (reference)	
Pedicle screws-rod system	0.11 (0.02–0.85)	0.035	0.29 (0.03–3.09)	
Anterolateral plate system	0.75 (0.06–8.83)	0.819	0.37 (0.03–5.25)	
Lateral screws-rod system	0.20 (0.01–3.66)	0.278	0.15 (0.01–3.94)	

The above multivariable model is based on characteristics which do not vary at the patient level and were identified in the univariable screen with p < 0.1 (in Table 1).
OR, odds ratio; aOR, adjusted OR; CI, confidence interval; VAS, visual analogue scale; ODI, Oswestry Disability Index.
*p < 0.05, statistically significant differences.

Table 5. Patients with a history of prior lumbar surgery, underwent OLIF, and need reintervention in this study

Age (yr)	Sex	Prior lumbar surgery	Index diagnosis	Index procedure	Causes for reintervention	Reintervention procedures
83	F	PLF L2–5	ASD L5–S1	OLIF L5–S1	L2 radicular pain, new L1–2 foraminal impingement (ASD L1–2)	OLIF L1–2 (22 mo)
85	F	PLF L4–5	ASD L3–4	OLIF L3–4	L3 radicular pain, cage subsidence (IDF)	Endoscopic decompression L3–4 (4 mo)
54	F	PLF L4–5	ASD L5–S1	OLIF L5–S1	Left side radicular pain, cage subsidence (IDF)	Endoscopic decompression L3–4 (37 mo)
80	M	PLF L3–S1	ASD L2–L3	OLIF L2–3	Left side radicular pain, left side L2–3 foraminal stenosis (IDF)	Microscopic decompression (8 mo)
71	F	PLF L3–5	ASD L2–3	OLIF L2–3	Bilateral radicular pain, cage subsidence (IDF)	Microscopic decompression (3 mo)
85	F	PLF L3–5	ASD L2–3	OLIF L2–3	Right side radicular pain, central disc herniation (ASD L1–2)	Open decompression (18 mo)
53	F	DCL L2–4	Postlaminectomy kyphosis	OLIF L2–4	Back pain due to hardware irritation	Remove posterior instrumentation (21 mo)
62	F	PLF T10–S1	Pseudarthrosis L3–4	OLIF L3–4	Rod breakage	Revised rod (30 mo)
75	F	PLF T10–L5	ASD L5–S1	OLIF L5–S1	Back pain due to T9 compression fracture (proximal junction failure)	Extended fusion T6-S2AI with T9 vertebroplasty (15 mo)
65	F	PLF L3–5	Pseudarthrosis L3–5	OLIF L3–5	Recurrent bilateral L4, L5 radicular pain	TFESI (24 mo)

OLIF, oblique lateral interbody fusion; PLF, posterolateral fusion; ASD, adjacent segment disease; IDF, indirect decompression failure; DCL, decompressive laminectomy; S2AI, S2 alar-liac; TFESI, transforaminal epidural steroid injection.

of 2.5 years. The reintervention was performed at the same level as the previous index surgery, and the adjacent level in 4.8%, and 7.4%, respectively. Patients, who needed the reintervention, underwent revision surgery and minor procedures in 6.5% (15 of 231 patients), and 5.6% (13 of 231 patients), respectively. Nguyen et al.[15] reported similar reoperation rates (5.7%) after indirect decompression procedures by using the stand-alone anterior lumbar interbody fusion and LLIF with a 2.37-year follow-up.

The incidence of symptomatic ASD requiring reoperation after lumbar spinal fusion ranges from 1.7 to 9%, increasing substantially during years after surgery.[16] Okuda et al.[17] reported reoperation rates of 5%, 9%, and 15% at 2, 5, and 10 years after the surgery, respectively, for ASD following posterior lumbar interbody fusion. Nayar et al.[18] reported reoperation rates of 3.3% over 4 years of follow-up for ASD following the stand-alone LLIF technique. The most common cause for the reintervention in this study was the development of ASD after the OLIF (16 of 231 patients, 6.9%). Eight patients (3.5%) who developed ASD in this study were successfully treated with minor procedures, such as TFESI, and CESI. However, the remaining 8 patients (3.5%) required revision surgery at the adjacent segment of the previous index surgery. Three of the 8 underwent additional OLIF procedure, and the other 5 patients were successfully treated with extended fusion with the standard posterior approach.

In our study, 4 patients (1.7%) needed posterior direct decompression as the reintervention after the OLIF procedure due to the IDF. The causes of failure were identified to be a mild degree of cage subsidence and recompression of the neural elements from the buckling ligamentum flavum or foraminal stenosis. All patients experienced recurrent radiculopathy without significant back pain. Kirnaz et al.[19] reported that in patients who were treated with LLIF the incidence of IDF was 9% after an average of 21-month follow-up. Wang et al.[20] reported that the bony lateral recess stenosis was the only independent factor associated with insufficient indirect decompression after XLIF. Yingsakmongkol et al.[21] proposed criteria for the selection of patients in whom performing indirect decompression with LLIF was appropriate. Patients who achieved dynamic clinical symptoms, presence of reducible disc height, no profound motor weakness, and no static stenosis, such as facet cyst, and bony lateral recess stenosis, had satisfactory outcomes after the LLIF without direct posterior decompression. The incidence of IDF in their study was 6.8% after an average of 24 months of follow-up. We also used these criteria in this study, which resulted in satisfac-

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tory success rates.

Cage subsidence is a well-known phenomenon after LLIF. Many studies showed that it is a major cause of the IDF as it directly lessens the indirect decompression effect after the procedure, resulting in revision surgery.[22] Tempel et al.[23] showed that high-grade cage subsidence was a significant predictive factor for revision surgery in patients who underwent stand-alone LLIF. In our study, cage subsidence was not associated with reintervention. This might be explained by the fact most patients received posterior stabilization with pedicle screws-rod construct, which could help prevent further significant cage subsidence which leads to restenosis and IDF.

In addition, most patients in this study received supplemental posterior instrumentation, which could help reduce the risks of cage subsidence and restenosis. Alimi et al.[24] reported clinical results following the LLIF supplemented with posterior instrumentations in most cases. The authors stated that the increment of foraminal height after surgery remained similar 1 year after the operation. The other patient in our study, who had unsatisfactory results due to the facet joint syndrome, was successfully treated with PRFA.

In this study, we found that prior lumbar spinal surgery was a risk factor leading to reintervention after the OLIF procedure. This finding is in accordance with a study reported by Lambrechts et al.,[25] which found that revision spinal fusion had a higher rate of all-cause reoperation, and subsequent revision when compared to primary lumbar spinal fusion. Deyo et al.[26] also reported that a history of prior lumbar surgery was the strongest predictor for reoperation after lumbar stenosis surgery. The exact causes of failure in the patients who had a history of prior lumbar spinal surgery were unclear.[25,26] This might be explained by scar tissue from previous surgery that might obstruct the indirect decompression effect and cause higher failure rates. However, Jung et al.[27] showed contrasting results in their study, which included patients who underwent single-level OLIF. They found that the need for reintervention, specifically additional posterior decompression between the primary and revision surgery was not different. However, the patients who underwent OLIF for revision surgery had relatively worse clinical results.

Higher preoperative ODI scores were also a risk factor associated with unsatisfactory outcomes requiring additional intervention after OLIF in this study. Patients with higher ODI scores may suffer from more severe clinical symptoms or spinal pathologies. For example, patients with higher ODI scores and had lumbar spinal stenosis may have a more severe degree of canal stenosis that causes less effective indirect decompression than patients with lower ODI scores, resulting in suboptimal outcomes and the need for additional intervention after the OLIF. Previous studies, examining the influence of preoperative disability on postoperative clinical outcomes, showed mixed findings. Jacob et al.[28] reported that patients with worse preoperative disability demonstrated inferior postoperative satisfaction and several patient-reported outcomes (PROs) after minimally invasive transforaminal lumbar interbody fusion. Nie et al.[29] also found that patients with lower preoperative disability scores continued to report superior PROs in mental function, back pain, and disability, postoperatively. In contrast, Carreon et al.[30] showed that patients with worse preoperative ODI scores were more likely to improve their scores after lumbar fusion.

Several studies found that the revision rates increased with a longer follow-up period.[31-33] We found a similar result. patients with longer follow-up periods tended to increase the risk of additional intervention after the OLIF in this study. However, it was not statistically significant.

The strengths of our study were a large number of patients and more than 2.5 years of follow-up time on average. In addition, we included not only the patients who underwent revision surgery like in most of the previous studies but also minor procedures following the OLIF, which is more accurately related to the exact number of patients who required reintervention. Nevertheless, our study has several limitations. First, it was a retrospective observation study, and although the data were prospectively collected during routine hospital visits, the possibility of observed confounding cannot be discounted. Second, the clinical threshold, at which patients were offered an additional intervention, was not standardized among surgeons. Third, several radiographic parameters such as lumbar lordosis, pelvic incidence, and sagittal vertical axis were not analyzed in this study.

CONCLUSIONS

This study showed that patients with prior lumbar surgery and high preoperative ODI scores were more likely to require additional intervention after the OLIF procedure. In addition, an increased duration of follow-up was correlated with the reintervention. The most common reason for the reintervention was the ASD after OLIF.

NOTES

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