Original Article

AO SPINE

Global Spine Journal
2020, Vol. 10(5) 619-626

DOI: 10.1177/2192568219867289
journals.sagepub.com/home/gsj

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Complication Risk in Primary and Revision Minimally Invasive Lumbar Interbody Fusion: A Comparable Alternative to Conventional Open Techniques?

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Abstract

Study Design: Retrospective cohort study of prospective patients undergoing minimally invasive lumbar fusion at a single academic institution.

Objective: To assess differences in perioperative outcomes between primary and revision MIS (minimally invasive surgical) lumbar interbody fusion patients and compare with those undergoing corresponding open procedures.

Methods: Patients ≥18 years old undergoing lumbar interbody fusion were grouped by surgical technique: MIS or open. Patients within each group were propensity score matched for comorbidities and levels fused. Patient demographics, surgical factors, and perioperative complication incidences were compared between primary and revision cases using means comparison tests, as appropriate.

Results: Of the 214 lumbar interbody fusion patients included after propensity score matching, 44 (21%) cases were MIS, and 170 (79%) were open. For MIS patients, there were no significant differences between primary and revision cases in estimated blood loss (EBL; 344 vs 299 cm^3, $P = .682$); however, primary cases had longer operative times (301 vs 246 minutes, $P = .029$). There were no differences in length of stay (LOS), intensive care unit LOS, readmission, and intraoperative or postoperative complications (all $P > .05$). For open patients, there were no differences between primary and revision cases in EBL ($P > .05$), although revisions had longer operative times (331 vs 278 minutes, $P = .018$) and more postoperative complications (61.7% vs 23.8%, $P < .001$). MIS revision procedures were shorter than open revisions (182 vs 213 minutes, $P = .197$) with significantly less EBL (294 vs 965 cm^3, $P < .001$), shorter inpatient and intensive care unit LOS, and fewer postoperative complications (all $P < .05$).

Conclusions: Clinical outcomes of revision MIS lumbar interbody fusion were similar to those of primary surgery. Additionally, MIS techniques were associated with less EBL, shorter LOS, and fewer perioperative complications than corresponding open revisions.

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Keywords
minimally invasive surgical procedures, postoperative complications, lumbosacral region, retrospective studies, length of stay, operative time, patient readmission, comorbidity

Introduction

The advent of novel surgical techniques has recently increased the utility of fusion procedures in the treatment of degenerative lumbar disease.[1] Lumbar interbody fusion is an effective treatment option for numerous lumbar pathologies, including degenerative disc disease, spondylolisthesis, stenosis, and degenerative facet joint disease.[2-7] Recently, minimally invasive surgical (MIS) techniques have gained popularity[8] due to patient and health care provider expectations of shorter inpatient hospital stays, reduced blood loss, and faster recovery times.[9-12]Although the literature investigating indications and outcomes of MIS spine surgery has grown over the past decade, relatively few studies have compared MIS and open surgical techniques in the context of primary and revision lumbar interbody fusion.[10,13]

Lumbar interbody fusion is useful both as a stand-alone procedure and an adjunct to decompressive procedures. Decompression has historically been the gold standard for degenerative lumbar disease; however, studies have shown many patients require revision surgery due to recurrent symptoms.[1,14] Interbody fusion has been shown to increase construct stability and segmental flexibility compared with standard decompressive procedures, thus reducing overall cost and morbidity associated with revision surgery.[15,16] When paired with MIS techniques, interbody fusions can be attractive surgical treatment options for patients requiring revision.

MIS interbody fusion has been reported as a safe and effective alternative to conventional open fusion, both as a primary and revision procedure.[17-20] However, limited data exists which directly compares outcomes of MIS and open lumbar interbody fusions in terms of primary and revision index. This study aims to compare perioperative complications of patients undergoing primary and revision interbody fusions across both open and MIS techniques.

Methods

Data Collection

The present study is a retrospective clinical review of a prospectively maintained database for patients undergoing lumbar interbody fusion at a single institution from 2012 to 2017. Inclusion criteria were patients $\geq$18 years of age undergoing 1- to 4-level lumbar interbody fusion with available preoperative, operative, anesthetic, and early postoperative (30 days) records. Those with primary malignancy, trauma, or infection were excluded, as were patients undergoing hybrid or "mini-open" procedures. Baseline demographics, including age, sex, body mass index (BMI), and Charlson Comorbidity Index (CCI) were collected for all included patients. Operative factors such as fusion length, surgical approach, operative time, estimated blood loss (EBL), and intraoperative complications were also collected, in addition to postoperative complication rates, inpatient length of stay (LOS), and intensive care unit length of stay (ICU LOS).

Patient Cohorts

Patients were grouped by surgical technique (MIS or open) then further stratified according to surgical history (primary or revision). Primary patients were defined as those undergoing lumbar interbody fusion with or without lumbar decompression (LD) as a primary procedure. Revision patients were defined as those undergoing lumbar interbody fusion as a revision to primary lumbar decompression or fusion. To control for potential confounders, this study used propensity score matching analyses to match primary and revision patients for differences in fusion length and comorbidity burden. Within matched primary and revision groups, MIS and open patients were again matched for fusion length and comorbidity burden. For both primary and revision cases, the decision to undergo either MIS or open surgery was left up to the preference of the surgeon, as randomization of treatment may have inferred with the normal "standard of care" treatment and the individual surgeons' comfort levels.

Statistical Analysis

Statistical analysis was performed using SPSS software (v23.0, IBM Corp, Armonk, NY, USA). Differences in demographic and perioperative variables were reported using descriptive means and standard deviations for continuous variables, and percentages for categorical variables. Demographics, operative factors, and early postoperative complication rates were compared within and across MIS/open groups using independent-samples t tests for normally distributed continuous variables and Pearson's chi-square tests for categorical variables. Compilations assessed included intraoperative (captured per operative note; eg, durotomy, venotomy, difficult Foley placement, oliguria, and self-limited bradycardia), mechanical (screw loosening, screw fracture, rod fracture, and disconnection of instrumentation), and perioperative cardiac, neurologic, pulmonary, urinary, infection, and anemia events. Statistical significance was set to $P < .05$.

Results

Patient Overview

A total of 578 lumbar interbody fusion patients (age 57 $\pm$ 13 years, 52.8% female, BMI 29.2 $\pm$ 6.1 kg/m^2) were included at

Table 1. Baseline Demographics With Operative and Clinical Outcomes for MIS Versus Open Procedures.

	MIS			Open		
	Primary (n = 22)	Revision (n = 22)	P^a	Primary (n = 85)	Revision (n = 85)	P^a
Demographics						
Age, y, mean ± SD	57 ± 15	58 ± 10	.773	65 ± 11	62 ± 10	.068
BMI, kg/m^2, mean ± SD	30 ± 5	29 ± 8	.808	29 ± 6	29 ± 6	.748
Sex, % female	41	59	.228	59	58	.876
Charlson Comorbidity Index, mean ± SD	1.7 ± 2.2	1.5 ± 1.4	.625	2.5 ± 1.5	2.3 ± 1.7	.301
Operative factors						
Levels fused, mean ± SD	1.5 ± 0.6	1.7 ± 1.0	.273	1.7 ± 0.9	1.8 ± 1.1	.490
Decompression, mean ± SD	1.2 ± 0.6	1.0 ± 0.7	.262	1.8 ± 0.9	1.6 ± 0.7	.174
Number of interbodies, mean ± SD	1.5 ± 0.6	1.3 ± 0.5	.407	1.5 ± 0.7	1.3 ± 0.5	.056
Operative time, min, mean ± SD	301 ± 96	246 ± 63	**.029**	278 ± 106	331 ± 174	**.018**
EBL, cm^3, mean ± SD	344 ± 437	299 ± 262	.682	608 ± 581	663 ± 689	.574
Surgical approach, % TLIF	82	59	.185	87	64	**<.001**
Clinical outcomes						
Inpatient LOS, d, mean ± SD	3.7 ± 2.1	2.8 ± 1.4	.092	3.7 ± 1.6	4.4 ± 2.3	**.028**
ICU LOS, d, mean ± SD	0.00	0.00	1.000	0.14 ± 0.6	0.2 ± 0.8	.495
Readmission, 30-day, %	0.0	0.0	1.000	1.4	0.0	1.000
Readmission, 90-day, %	2.0	0.0	1.000	5.7	0.0	1.000
Complications, %						
Overall intraoperative	4.5	0.0	1.000	1.2	5.2	.304
Overall postoperative	22.7	14.3	.698	23.8	61.7	**<.001**
Cardiac	9.1	0.0	.499	3.6	11.5	.143
Neuro	9.1	0.0	.499	8.2	14.3	.461
Pulmonary	4.5	6.3	1.000	3.5	17.2	.025
Urinary	0.0	0.0	1.000	4.2	10.3	.352
Infection	0.0	0.0	1.000	2.4	0.0	1.000
Anemia	4.5	5.9	1.000	4.7	40.0	**<.001**
Mechanical	0.0	0.0	1.000	4.7	0.0	1.000

Abbreviations: BMI, body mass index; TLIF, transforaminal lumbar interbody fusion; MIS, minimally invasive surgery; EBL, estimated blood loss; TLIF, transforaminal lumbar interbody fusion; LOS, length of stay; ICU LOS, intensive care unit length of stay.
[a]Values in boldface represent statistical significance at $P < .05$.

baseline. Overall, 58.0% (n = 335) patients underwent open surgery and 42.0% (n = 243) underwent MIS; 22.3% (n = 129) of cases were revision, and 77.7% (n = 449) were primary surgeries. Primary and revision patients showed significant differences in baseline comorbidity burden (CCI primary 1.2 ± 1.5 vs revision 2.2 ± 1.7) and fusion length (1.4 ± 0.7 vs 2.0 ± 1.2, both $P < .001$). To minimize these potentially confounding differences, primary and revision groups were propensity score matched for baseline comorbidity status (CCI) and fusion length.

Following propensity score matching analysis, 214 patients were included. Within this matched cohort, 44 patients (20.6%) were MIS and 170 patients (79.4%) were open. Proportion of revision cases was 50% (107 patients, 22 MIS and 85 open) and proportion of primary cases was 50% (107 patients, 22 MIS and 85 open). Preoperative diagnoses for MIS primary patients included degenerative lumbar spondylolisthesis (41.1%), lumbar spinal stenosis (26.6%), degenerative disc disease (19.8%), and herniated nucleus pulposus (12.5%). Among preoperative diagnoses for MIS revision patients, lumbar degenerative spinal stenosis was most common (38.1%), followed by spondylolisthesis (23.8%), pseudarthrosis (12.5%), adjacent segment disease (4.8%), and herniated nucleus pulposus (4.8%). The majority of MIS revision patients had open decompression with fusion as a primary procedure (62%), followed by decompression alone (24%) and MIS fusion (14%). Approximately 67% of MIS revisions patients underwent re-operation at primary index level while 33% underwent surgery at adjacent levels.

Within both MIS and open groups, there were no differences between primary and revision procedures with regards to baseline age, sex, BMI, levels fused, or CCI (all $P > .05$) (Table 1).

Operative Factors

Within the MIS group, primary and revision patients did not differ in estimated blood loss (EBL) (344 vs 299 cm^3, respectively, $P = .682$), but primary fusions had longer operative times (301 vs 246 minutes, respectively, $P = .029$). Primary and revision cases did not differ in fusion length (1.5 ± 0.6 vs 1.7 ± 1.0 levels, respectively, $P = .273$), number of decompressions (1.2 ± 0.6 vs 1.0 ± 0.7, respectively, $P = .262$), or number of interbodies (1.5 ± 0.6 vs 1.3 ± 0.5, respectively, $P = .407$). Primary and revision cases did not differ in surgical approach (82% vs 59% transforaminal, respectively, $P = .185$).

Within the open group, primary and revision patients did not differ in EBL (608 vs 663 cm^3, respectively, $P = .574$), fusion length (1.7 ± 0.9 vs 1.8 ± 1.1 levels, respectively, $P = .490$), number of decompressions (1.8 ± 0.9 vs 1.6 ± 0.7, respectively, $P = .174$), or number of interbodies (1.5 ± 0.7 vs 1.3 ± 0.5, respectively, $P = .056$). Revision procedures had longer operative times than primary procedures (331 vs 278 minutes, respectively, $P = .018$), while primary procedures utilized a transforaminal approach more often (87% vs 64%, respectively, $P < .001$) (Table 1).

Clinical Outcomes

Within MIS, there were no differences in LOS (3.7 ± 2.1 vs 2.8 ± 1.4 days, respectively, $P = .092$), ICU LOS (0 vs 0 days, respectively, $P = 1.000$), or readmission rates (30 and 90-day, respectively, $P = 1.000$).

Open revisions were associated with longer LOS than open primaries (4.4 ± 2.3 vs 3.7 ± 1.6 days, respectively, $P = .028$), but similar ICU LOS (0.14 ± 0.6 vs 0.2 ± 0.8 days, respectively, $P = .495$). There were no significant differences in 30- or 90-day readmission rates between both groups ($P = 1.000$).

Complications

Within both MIS and open groups, there were no differences in intraoperative complication rates for primary vs revision patients (MIS $P = 1.000$, open = .304). For open fusions, revision surgery was associated with more overall postoperative complications than primary surgery (61.7% vs 23.8%, $P < .001$), specifically postoperative acute blood loss anemia (40% vs 4.7%, $P < .001$). MIS primary and revision fusions did not differ in overall postoperative complications ($P = .698$), including cardiac, neurological, pulmonary, urinary, infection, anemia, and mechanical (Figure 1)

Comparison of MIS and Open Techniques

Primary Procedures. Conventional open techniques resulted in greater EBL than MIS (635 vs 337 cm^3, Figure 2a) and longer LOS (3.7 vs 3 days, Figure 2b). No significant differences in operative time or ICU LOS were noted (Figure 2c). MIS techniques had more overall intraoperative complications than open techniques (9.5% vs 3.4%, Figure 2d), but less overall postoperative complications (14.9% vs 23.9%, Figure 2e).

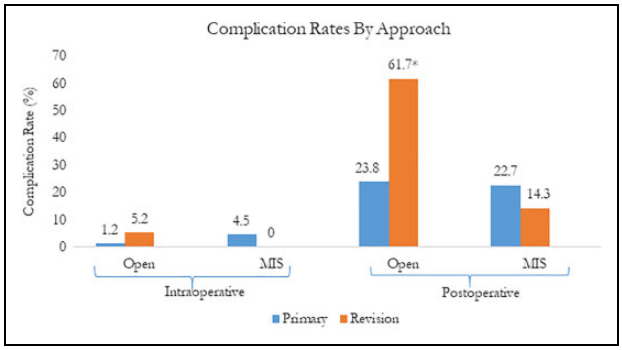

Figure 1. Intraoperative and postoperative complication rates for primary and revision surgeries within MIS and open groups. Asterisks indicate value reached significance to $P < .05$. MIS, minimally invasive surgery.

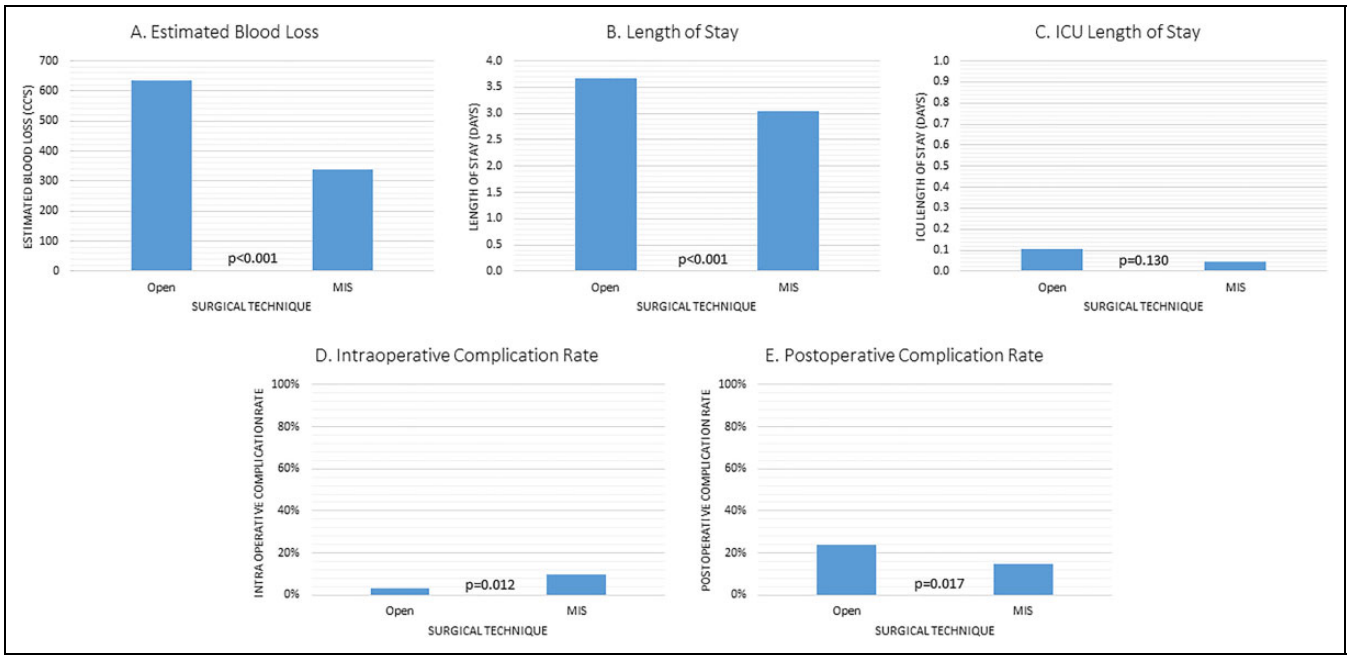

Figure 2. Operative and clinical outcomes across revision surgeries for MIS and open patients. All values indicate significance at $P < .05$. MIS, minimally invasive surgery; EBL, estimated blood loss; Op Time, operative time; LOS, length of stay; ICU LOS, intensive care unit length of stay.

Figure 3. Preoperative (left) and postoperative (right) scoliosis radiographs of a 49-year-old woman who underwent open posterior spinal fusion from L1-S1 and pelvis. Surgical course was complicated by acute blood loss anemia, which resolved.

Revision Procedures. Conventional open revisions resulted in greater EBL than MIS revisions (965 vs 294 mL, Figure 3a), slightly longer operative times (213 vs 182 minutes, $P = .197$), greater LOS (5.1 $\pm$ 3 vs 2.8 $\pm$ 1.4, Figure 3b), and greater ICU LOS (0.5 $\pm$ 1.3 vs 0 days, Figure 3c). Open revisions had significantly more postoperative complications (56% vs 14.3%, Figure 3e) and more overall intraoperative complications, but this did not reach statistical significance (8.4% vs 0% Figure 3d).

Case Examples

A 49-year-old woman with a history of adult lumbar scoliosis and degenerative spinal stenosis with radiculopathy presented with intractable lower back pain. Radiographs were obtained and the patient was counseled on the benefits and risks of surgery. She agreed to undergo open posterior spinal fusion from L1-S1 and pelvis with decompression, in addition to an L5-S1 transforaminal lumbar interbody fusion (TLIF). EBL was 2000 mL and postoperative complications included acute blood loss anemia, which resolved. Inpatient length of stay was 6 days and ICU LOS was zero days (Figure 3).

A 74-year-old man with a similar history of lumbar scoliosis and stenosis presented with sciatica and lower back pain. He underwent a combined extreme lateral interbody fusion from L1-L5 with L5-S1 TLIF utilizing a minimally invasive approach, in addition to a posterior spinal instrumented fusion from L1-Pelvis. Estimated intraoperative blood loss was 700 mL, and total inpatient LOS was 4 days. No postoperative complications were noted, and the patient was discharged unremarkably (Figure 4).

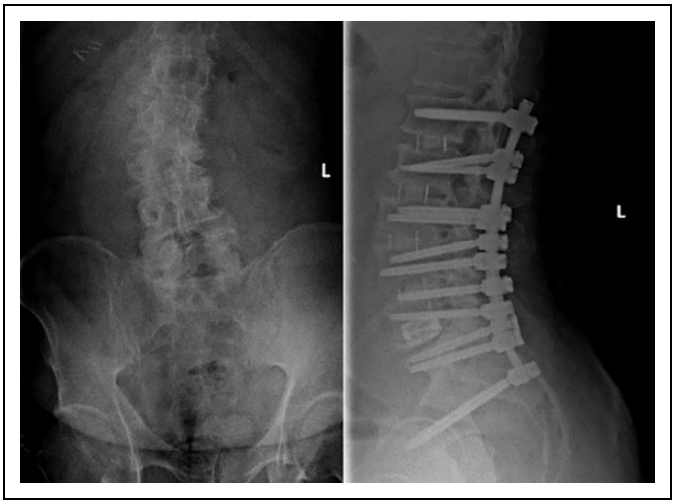

Figure 4. Pre-operative (left) and post-operative (right) scoliosis radiographs of a 74-year-old man who underwent L1-L5 MIS XLIF with L1-Pelvis posterior spinal instrumented fusion. There were no peri-operative complications and patient was discharged home unremarkably.

Discussion

Minimally invasive approaches have gained popularity over recent years as a treatment option for various lumbar spinal pathologies, including but not limited to symptomatic disc disease, spondylolisthesis, stenosis, and degenerative lumbar scoliosis.[2,3,5] Although the literature is rich in studies assessing risk factors and complication rates of primary lumbar fusion procedures, studies assessing clinical outcomes of revision procedures have been somewhat inconclusive.[15,19,21] This study compares primary and revision lumbar interbody fusions across 2 techniques: conventional open and MIS.

The present study compared demographics, operative factors, and complication rates of primary versus revision procedures in an open or MIS technique. Results showed that open revisions had similar intraoperative complication rates as open primary fusions but more overall postoperative complications. Within the MIS group, revision lumbar interbody fusions were comparable to corresponding primary procedures across all outcomes, including intraoperative and postoperative complication rates. Furthermore, across techniques, MIS revisions were associated with less EBL, shorter LOS and ICU LOS, and fewer postoperative complications overall. Interestingly, MIS revision procedures were associated with shorter operative times than corresponding primary MIS procedures. While revision surgery may potentially take a longer time due to extensive

scar tissue exploration and anatomical distortion, revision of a primary surgical construct does not necessarily entail revision of the entire construct. It is possible that only a portion of the initial surgery is being revised, resulting in a shorter operative time than the index procedure, although this is speculative and warrants future study.

Previous studies have investigated outcomes between primary and revision fusions. A study by Potter et al[22] reviewed outcomes of 100 patients undergoing conventional open TLIF and found that revision patients had a higher incidence of dural tears (DT) per level than primary patients, though this trend did not reach statistical significance (6.5%/level vs 3.7%/level, $P = .07$). Tormenti et al[23] conducted a large single-center study on 531 open TLIF patients and found that those who had undergone revision were 1.75 times more likely to experience perioperative complications. On the other hand, Khan et al[24] retrospectively analyzed 187 open TLIF patients and found no differences in perioperative complications between open primary and revision groups, including DTs, neural injuries, and wound-related complications. It is important to note, however, that patients who underwent >1 previous lumbar decompressive surgery prior had a higher risk of perioperative complications/DTs during revision. Our results showed that open revisions had more overall postoperative complications within a 30-day period than open primary procedures, including cardiac, pulmonary, urinary, and blood loss anemia. However, due to the nature of the database, further follow-up (1- or 2-year data) is required to assess for any differences in long-term surgical outcomes.

Our study did not find differences in intraoperative complications between open primary and revision surgeries. Nonetheless, complications associated with revision surgery (including interbody fusions) have been well-documented in the literature.[8,17,21] Previous open spine surgery predisposes patients to a greater risk of perioperative complications and poorer clinical outcomes due to extensive scar tissue exploration and distortion of anatomical landmarks.[21] Fewer studies, however, have explored the utility of minimally invasive techniques for revisions. As such, our study sought to describe outcomes for MIS interbody fusions with regard to primary and revision procedures.

MIS revision has been studied as a potential alternative to open revision across various surgical procedures. Chen et al[2] analyzed self-reported clinical outcome scores of 43 patients who underwent MIS TLIF as a revision to primary discectomy with an average follow-up of 45 months. Using the Japanese Orthopaedic Association score assessment, patients reported an average improvement of 15.7 points postoperatively. In addition, fusion rates utilizing MIS techniques were 100% at final follow-up. Similarly, Khechen et al[18]found, among 52 patients undergoing MIS TLIF (26 primary and 26 revision to a primary decompression), that there were no significant differences in absolute patient-reported outcomes (PROs) including Oswestry Disability Index (ODI), visual analogue scale (VAS) back scores, and VAS leg scores.[18] Furthermore, MIS TLIF revision patients demonstrated a 96% fusion rate. Though our study did not assess PROs, we found no difference in most perioperative outcomes (intraoperative and postoperative complications, LOS, ICU LOS, readmission rates, EBL) between MIS revision and primary fusion patients.

Similarly, Selznick et al[8] compared 17 patients undergoing MIS TLIF as revision to primary decompression at the same operative level with 26 patients undergoing primary MIS TLIF. No differences were found between primary and revision groups with regard to intraoperative blood loss (280 vs 300 mL, $P = .24$). However, higher rates of incidental durotomy were reported in revision cases compared with primary cases for both TLIF and PLIF approaches. Kang et al[17] also investigated perioperative outcomes in MIS TLIF patients undergoing primary surgery or revision. No differences were reported in EBL (94.4 vs 87.5 mL, $P > .05$), operative time (88.8 vs 88.4 minutes, $P > .05$), or intraoperative complication rates ($P = .16$). Such findings suggest MIS interbody fusion can be utilized as a noninferior alternative to open fusion according to the discretion of the surgeon performing the revision.

Across techniques, MIS revisions had less EBL, shorter operative times, shorter LOS and ICU LOS, and less overall postoperative complications than corresponding open revisions. Overall, MIS techniques led to better surgical outcomes than open techniques in revision procedures, but effects were more modest in primary cohorts. Our study did not find differences in operative time or ICU LOS between the 2 techniques (MIS vs open) in primary fusion patients, although open techniques did result in greater EBL.

Limitations to this study include the retrospective nature of our data collection, which predisposes to selection bias. Additionally, the small sample size of MIS patients limits the statistical power of our findings, as some results may reflect spurious statistical noise. This single-institution database was also limited to a 30-day postoperative course for all reported outcomes, which did not allow for long-term follow-up. In addition, revision patients may or may not have had their revision procedure done by their original surgeon, which predisposes such patients' outcomes to further variation. Furthermore, the number of previous decompressions per patient and the time elapsed between primary and revision procedures were not included. By nature, not all revision cases are amenable to treatment with MIS techniques, so this study's findings apply only to cases in which both open and MIS approaches were viable options. This study includes patients from a single surgical center where some surgeons use exclusively MIS approaches, some use exclusively open approaches, and others use either MIS or open depending on the circumstances. For the few surgeons that use both MIS and open approaches, there may be selection bias in favor of utilizing an MIS approach for less technically challenging cases, which may have influenced our results. Future studies should include 1- or 2-year postoperative outcomes and health-related quality of life metrics for patients undergoing MIS revisions.

Conclusions

The results of this study demonstrated that for patients undergoing lumbar interbody fusion as a revision to primary decompression or previous fusion, an MIS technique was associated with superior outcomes, including less EBL, shorter LOS and ICU LOS, shorter operative times, and fewer postoperative complications than open techniques. MIS revisions were comparable to MIS primary procedures across all outcomes, including intra- and postoperative complication rates. Such findings suggest that a history of previous lumbar decompression or fusion, whether done conventionally or minimally invasive, should not preclude patients from MIS consideration which may have favorable outcomes. Future, long-term prospective studies are necessary to further analyze the relationship between MIS techniques and surgical outcomes in patients requiring revision surgery.

Declaration of Conflicting Interests

The author(s) declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: Peter G. Passias, MD, reports personal consulting fees for Spinewave, Zimmer Biomet, and Medicrea outside the submitted work. Virginie Lafage, PhD, reports paid lectures from Depuy Synthes, Nuvasive, K2M, and Medtronic, and is a Nemaris board member and shareholder. Themistocles S. Protopsaltis, MD, reports personal fees from Medicrea International and grants from Zimmer Spine, outside the submitted work.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

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Ethical Approval

Each institution obtained approval from their local institutional review board to enroll patients in the prospective database and informed consent was obtained from each patient.

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