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Predictors of the Best Outcomes Following Minimally Invasive Surgery for Grade 1 Degenerative Lumbar Spondylolisthesis

BACKGROUND: The factors driving the best outcomes following minimally invasive surgery (MIS) for grade 1 degenerative lumbar spondylolisthesis are not clearly elucidated.
OBJECTIVE: To investigate the factors that drive the best 24-mo patient-reported outcomes (PRO) following MIS surgery for grade 1 degenerative lumbar spondylolisthesis.
METHODS: A total of 259 patients from the Quality Outcomes Database lumbar spondylolisthesis module underwent single-level surgery for degenerative grade 1 lumbar spondylolisthesis with MIS techniques (188 fusions, 72.6%). Twenty-four-month follow-up PROs were collected and included the Oswestry disability index (ODI) change (ie, 24-mo minus baseline value), numeric rating scale (NRS) back pain change, NRS leg pain change, EuroQoL-5D (EQ-5D) questionnaire change, and North American Spine Society (NASS) satisfaction questionnaire. Multivariable models were constructed to identify predictors of PRO change.
RESULTS: The mean age was 64.2 ± 11.5 yr and consisted of 148 (57.1%) women and 111 (42.9%) men. In multivariable analyses, employment was associated with superior postoperative ODI change (β-7.8; 95% CI [−12.9 to −2.6]; $P = .003$), NRS back pain change (β −1.2; 95% CI [−2.1 to −0.4]; $P = .004$), EQ-5D change (β 0.1; 95% CI [0.01-0.1]; $P = .03$), and NASS satisfaction (OR = 3.7; 95% CI [1.7-8.3]; $P < .001$). Increasing age was associated with superior NRS leg pain change (β −0.1; 95% CI [−0.1 to −0.01]; $P = .03$) and NASS satisfaction (OR = 1.05; 95% CI [1.01-1.09]; $P = .02$). Fusion surgeries were associated with superior ODI change (β −6.7; 95% CI [−12.7 to −0.7]; $P = .03$), NRS back pain change (β −1.1; 95% CI [−2.1 to −0.2]; $P = .02$), and NASS satisfaction (OR = 3.6; 95% CI [1.6-8.3]; $P = .002$).
CONCLUSION: Preoperative employment and surgeries, including a fusion, were predictors of superior outcomes across the domains of disease-specific disability, back pain, leg pain, quality of life, and patient satisfaction. Increasing age was predictive of superior outcomes for leg pain improvement and satisfaction.

KEY WORDS: Lumbar, Spondylolisthesis, Minimally invasive, Quality outcomes database, Patient-reported outcomes

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Though surgical treatment is established as effective[1] for well-selected patients failing conservative treatment for symptomatic degenerative lumbar spondylolisthesis, the optimal surgical strategy—decompression alone vs decompression and fusion—remains unclear. Indeed, 2 recent randomized control trials (RCTs)[2,3] and a prospective registry study[4] have arrived at somewhat inconsistent conclusions about the utility of the addition of a fusion

ABBREVIATIONS: ALIF, anterior lumbar interbody fusion; **BMI,** body mass index; **EQ-5D,** EuroQoL-5D; **IRB,** Institutional Review Board; **MCID,** minimal clinically important difference; **MIS,** minimally invasive surgery; **NASS,** North American Spine Society; **NRS,** numeric rating scale; **ODI,** Oswestry disability index; **PRO,** patient-reported outcome; **QOD,** quality outcomes database; **RCT,** randomized control trial

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for grade 1 lumbar spondylolisthesis. These conflicting findings have established a need to identify subgroups of patients that may have unique factors driving surgical outcomes following spondylolisthesis surgery. One such group—the population receiving minimally invasive surgery (MIS)—is of particular interest given the relatively nascent investigation thus far in the degenerative lumbar spondylolisthesis literature and the lack of MIS-specific investigation in the aforementioned RCTs.[2,3]

MIS techniques have been increasingly applied to degenerative lumbar spondylolisthesis surgery and are associated with reduced cost, faster recovery, superior perioperative outcome metrics, and comparable clinical outcomes compared to open surgery.[5-7] Despite these potential benefits, multiple patient-based (eg, revision surgery) and surgeon-based considerations (eg, learning curve, lack of familiarity with MIS instrumentation or techniques) preclude the use of MIS techniques for some patients. Though there has been an increasing utilization of MIS surgical techniques,[8] the factors driving the best outcomes for MIS degenerative lumbar spondylolisthesis surgery are incompletely defined.

To this end, we utilized the prospective quality outcomes database (QOD) registry to identify factors associated with superior clinical outcomes following MIS for grade 1 degenerative lumbar spondylolisthesis.

METHODS

We utilized data obtained from the prospective multicenter QOD registry. Twelve of the highest enrolling QOD sites formed a study group (lumbar spondylolisthesis module/study group[6,9,10-18]) to investigate the effectiveness of fusion for degenerative lumbar spondylolisthesis. We queried this dataset, which enrolled patients undergoing surgery for Meyerding[19] grade 1 degenerative lumbar spondylolisthesis from July 2014 through June 2016. All diagnoses were confirmed on preoperative plain films (standing or dynamic), which were evaluated by surgeons at each participating site. For this study, we identified patients who underwent surgery via MIS techniques defined as MIS laminectomy, MIS pedicle screws, and/or interbody grafts (for posterior-based surgeries and 2-stage procedures) or techniques that are considered less invasive than traditional, open, and posterior-based approaches (ie, anterior and lateral procedures). We included surgeries involving a single-disc segment (eg, single-level fusions and single or 2-level laminectomies). In addition to QOD exclusion criteria,[20] we excluded patients who had grade II or higher spondylolisthesis. For all eligible patients, all variables were audited for data element accuracy. Informed consent and Institutional Review Board (IRB) approval was obtained (University of California, San Francisco, IRB 16-20085).

Demographic, Clinical, and Surgical Variables

The QOD registry collects data on demographic variables, patient comorbidities, clinical characteristics, and baseline and follow-up patient-reported outcome (PRO) scores [Oswestry disability index (ODI), EuroQol-5D (EQ-5D), numeric rating scale (NRS) leg pain, NRS back pain, North American Spine Society (NASS) satisfaction questionnaire], and surgical variables (type of approach, use of MIS techniques, and whether a fusion was performed).

Two-level variables included insurance status (private insurance vs Medicare, Medicaid, or VA/government), ethnicity (Hispanic or Latino vs not Hispanic or Latino), employment status (employed or employed and on leave vs unemployed), education level (4-yr degree post high school education or greater vs less than a 4-yr degree post high school education), ambulation status [independently ambulatory vs non-independently ambulatory (eg, with an assistive device)], and symptom duration (greater or equal to 3 mo vs less than 3 mo). Dominant presenting symptom was a 3-level variable (back pain predominant, leg pain predominant, or back and leg pain equally predominant). Surgical approaches included posterior only, anterior only, lateral only, and those who underwent a 2-staged approach.

Primary and Secondary Outcomes

The primary outcome of interest was 24-mo ODI change (ie, 24-mo value minus baseline value). Secondary outcomes included the 24-mo NASS satisfaction questionnaire (scored 1 through 4, respectively, for the following patient responses: surgery met my expectations; I did not improve as much as I had hoped, but I would undergo the same operation for the same results; surgery helped, but I would not undergo the same operation for the same results; and I am the same or worse as compared to before surgery) and 24-mo EQ-5D change, NRS back pain change, and NRS leg pain change.

Additionally, perioperative outcomes were collected, including estimated blood loss, operative time, length of hospitalization, discharge disposition, 90-d readmission rate, and cumulative reoperation rate. Readmissions and reoperations were recorded if deemed related to surgery.

Statistical Analysis

Descriptive statistics were reported as means and standard deviations and frequencies and percentages unless stated otherwise. Univariate analyses for continuous variables utilized unpaired and paired Student's *t*-tests where appropriate. For categorical variables, Pearson's chi-square analyses (with Yates' correction for continuity as appropriate) were utilized. For multivariable analyses, multivariable linear regression models were fitted for ODI, EQ-5D, NRS back pain, and NRS leg pain 24-mo change scores (ie, 24-mo value minus baseline value). An ordinal logistic regression model was fit for NASS satisfaction questionnaire score. Models included the following variables: age, sex, body mass index (BMI), American Society of Anesthesiologists grade, presence of comorbidities (diabetes mellitus, coronary artery disease, anxiety, depression, and osteoporosis), smoking status, clinical presentation (dominant presenting symptom, motor deficit upon presentation, independent ambulation at baseline, symptom duration greater or less than 3 mo),

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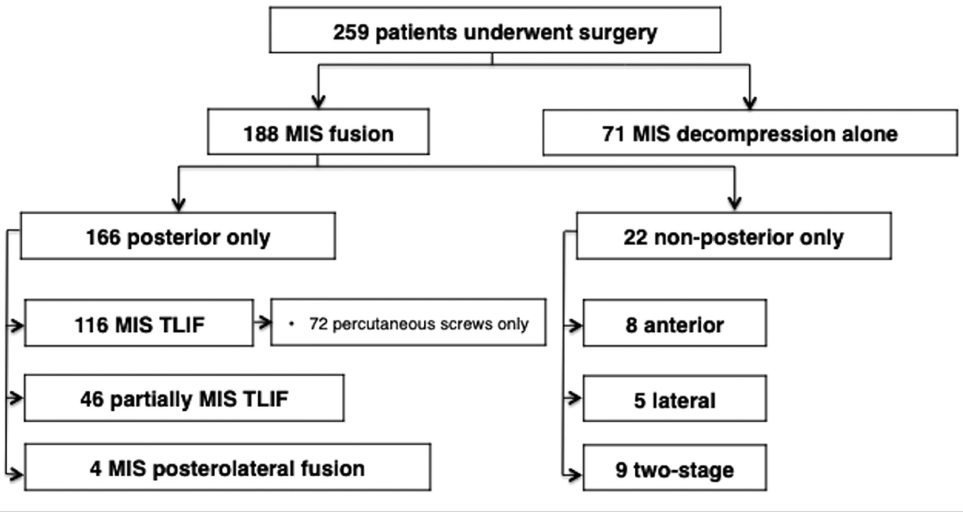

FIGURE 1. *Surgical procedures.*

ethnicity (Hispanic or non-Hispanic), education (4 yr of post high school education or more vs less than 4 yr of education), employment (employed or employed and on leave at baseline), use of private insurance, use of workman's compensation, surgical approach (posterior only, anterior only, lateral only, and 2-stage approach), whether a fusion was performed, and baseline ODI, NRS back pain, NRS leg pain, and EQ-5D. Statistical analyses were performed using R 2.15.2 (R: a language and environment for statistical computing; R Foundation for Statistical Computing, Vienna, Austria). The "missForest" R package was used to impute missing values. An alpha of .05 was considered statistically significant, and *P* values were 2 tailed.

RESULTS

From July 1, 2014, through June 30, 2016, there were 259 patients in the QOD lumbar spondylolisthesis module at the 12 participating sites that underwent surgery for grade 1 degenerative lumbar spondylolisthesis utilizing MIS techniques. 188 (72.6%) underwent a fusion procedure, whereas 71 (27.4%) underwent a decompression procedure alone (Figure 1). The mean age of our cohort was 64.2 ± 11.5 yr (range 22.2-95.0 yr), and 57.1% (n = 148) were women and 42.9% (n = 111) were men. Descriptive variables are presented in Table 1. Table 2 demonstrates the surgical variables, including perioperative and long-term outcomes associated with MIS. Table 3 demonstrates the PRO change scores and NASS satisfaction at 24 mo. Figure 2 demonstrates PRO scores at baseline and 24 mo following surgery.

ODI improved significantly at 24-mo follow-up (19.6 ± 19.3) compared to baseline (47.2 ± 17.7) ($P < .001$). NRS back pain improved significantly at 24-mo follow-up (3.1 ± 3.1) compared to baseline (6.6 ± 3.0) ($P < .001$). NRS leg pain improved significantly at 24-mo follow-up (2.4 ± 3.2) compared to baseline (6.6 ± 2.9) ($P < .001$). EQ-5D improved significantly at 24-mo follow-up (0.80 ± 0.18) compared to baseline (0.54 ± 0.23) ($P < .001$).

Multivariable Analysis

We conducted multivariable analyses to identify significant predictors of PROs when adjusting for potential confounders. Significant predictors of 24-mo change scores (ODI, NRS back pain, NRS leg pain, and EQ-5D) and 24-mo NASS satisfaction are reported in Table 4.

For each model, each respective baseline PRO was associated with 24-mo change scores where more severe baseline PRO values (ie, higher preoperative NRS back pain, NRS leg pain, ODI and lower EQ-5D) were associated with greater improvements (Table 4). Aside from baseline PRO values, only 2 patient-related factors and a single surgical factor were significantly associated with multiple 24-mo PRO change scores. The 2 patient-related factors included preoperative employment at presentation and age. Employment was associated with superior postoperative ODI change (β −7.8; 95% CI [−12.9 to −2.6]; $P = .003$), NRS back pain change (β −1.2; 95% CI [−2.1 to −0.4]; $P = .004$), EQ-5D change (β 0.1; 95% CI [0.01-0.1]; $P = .03$), and NASS satisfaction (OR = 3.7; 95% CI [1.7-8.3]; $P < .001$). Increasing age was associated with superior NRS leg pain change (β −0.1; 95% CI [−0.1 to −0.01]; $P = .03$) and NASS satisfaction (OR = 1.05; 95% CI [1.01-1.09]; $P = .02$). The one surgical factors was the addition of fusion to the index procedure. The addition of a fusion was associated with superior ODI change (β −6.7; 95% CI [−12.7 to −0.7]; $P = .03$), NRS back pain change (β −1.1; 95% CI [−2.1 to −0.2]; $P = .02$), and NASS satisfaction (OR = 3.6; 95% CI [1.6-8.3]; $P = .002$). Baseline ODI was also significantly associated with inferior 24-mo NRS back pain change (β 0.03; 95% CI [0.003-0.06]; $P = .03$).

Lower BMI, as a continuous variable, was predictive of superior EQ-5D change (β 0.01 per unit BMI change; 95% CI [0.001-0.01]; $P = .009$). In order to provide a clinically useful BMI cutoff, we conducted a subsequent classification tree analysis (using R package *rpart*) to identify a BMI cutoff associated

TABLE 1. Characteristics of Patients Undergoing MIS for Grade 1 Lumbar Spondylolisthesis

Age (yr), mean ± SD	64.2 ± 11.5
Female, n (%)	148 (57.1)
BMI, mean ± SD	29.7 ± 5.8
Smoker, n (%)	27 (10.4)
Comorbidities, n (%)	
Diabetes mellitus	43 (16.6)
Coronary artery disease	32 (12.4)
Anxiety	39 (15.1)
Depression	48 (18.5)
Osteoporosis	20 (7.7)
Dominant presenting symptom, n (%)	
Back pain dominant	98 (37.8)
Leg pain dominant	62 (23.9)
Back pain = leg pain	99 (38.2)
Motor deficit present at presentation, n (%)	56 (21.6)
Independently ambulatory, n (%)	226 (87.3)
Symptom duration, n (%)	
<3 mo	5 (1.9)
>3 mo	241 (93.1)
ASA grade, n (%)	
1 or 2	159 (61.4)
3 or 4	88 (34.0)
Ethnicity, n (%)	
Hispanic or latino	14 (5.4)
Education level, n (%)	
4 yr of college education or more	111 (42.9)
Employment status, n (%)	
Employed or employed and on leave	106 (40.9)
Private insurance, n (%)	134 (51.7)
Worker's compensation, n (%)	19 (7.3)
ODI, baseline, mean ± SD	47.2 ± 17.7
NRS back pain, baseline, mean ± SD	6.6 ± 3.0
NRS leg pain, baseline, mean ± SD	6.6 ± 2.9
EQ-5D, baseline, mean ± SD	0.54 ± 0.23
Surgical variables	
Approach, n (%)	
Posterior only	237 (91.5)
MIS decompression alone	71 (27.4)
MIS TLIF[a]	116 (44.8)
With percutaneous screws only	72 (27.8)
Partially MIS TLIF[b]	46 (17.8)
MIS posterolateral fusion	4 (1.5)
Anterior only	8 (3.1)
Lateral only	5 (1.9)
Two-stage	9 (3.5)
Fusion surgery, n (%)	188 (72.6)
Decompression alone, n (%)	71> (27.4)
>2-yr Follow-up rate, n (%)	216 (83.4)

[a]MIS TLIF defined as interbody placed via a Wiltse plane approach through a tubular retractor and screw placement via (1) a tubular retractor or (2) percutaneous methods.
[b]Partially MIS TLIF defined as a procedure involving at least one component of TLIF procedure conducted via MIS methods ie, decompression via a tubular retractor, interbody placed via a Wiltse plane approach through a tubular retractor, and/or screw placement via (1) a tubular retractor or (2) percutaneous methods.
BMI – body mass index; ASA – American Society of Anesthesiologists; MIS – minimally invasive surgery; ODI – Oswestry disability index; NRS – numeric rating scale; EQ-5D - EuroQol-5D. Values do not add up to 100% where there is missing data.

TABLE 2. Hospital Data for Patients Undergoing MIS For Grade 1 Lumbar Spondylolisthesis

Estimated blood loss (ml), mean ± SD	103.2 ± 100.8
Operative time (min), mean ± SD	173.5 ± 93.7
Length of hospitalization (d), mean ± SD	2.3 ± 1.9
Discharge disposition	
Home or home health care, n (%)	236 (91.1)
Other than home or home health care, n (%)	23 (8.9)
Readmissions, 3 mo, n (%)	8 (3.1)
Reoperations, 36 mo, n (%)	17 (6.6)
Deaths, n (%)	0 (0.0)

Ml, milliliters.

TABLE 3. Patient Reported Outcomes for Patients Undergoing MIS for Grade 1 Lumbar Spondylolisthesis

ODI, change, mean ± SD	−26.2 ± 21.1
NRS back pain, change, Mean ± SD	−3.3 ± 3.7
NRS leg pain, change, Mean ± SD	−4.1 ± 3.7
EQ-5D, change, mean ± SD	+0.24 ± 0.24
NASS satisfaction, n (%)	
1	129 (62.3)
2	40 (19.3)
3	17 (8.2)
4	21 (10.1)

ODI – Oswestry disability index; NRS – numeric rating scale; EQ-5D – EuroQol-5D.

with reaching EQ-5D minimal clinically important difference (MCID) (defined as 0.20 or greater improvement[9]). A BMI value of 33.89 was identified as the optimal BMI cutoff in the classification tree analysis of reaching EQ-5D MCID.

Subgroup Analysis for Posterior-Only Surgeries

Similar analyses to identify significant predictors of PROs in the 237 patients undergoing posterior-only MIS approaches (excluding anterior, lateral, and 2-stage procedures) is provided in **Table**, **Supplemental Digital Content**. Factors predictive of superior outcomes remained similar and included the addition of fusion, 4 or more years of post high school level education, active employment or employed and on leave, and lower BMI. Baseline PROs remained associated with 24-mo outcomes. For NASS satisfaction, a clinical presentation with equal severity of back and leg pain (as opposed to back pain alone) portended worse satisfaction (OR = 0.45; 95% CI [0.21-0.95]; $P = .04$).

DISCUSSION

In an analysis of 259 patients undergoing MIS for grade 1 degenerative lumbar spondylolisthesis, we found multiple patient- and surgery-related predictors of outcomes at 24 mo.

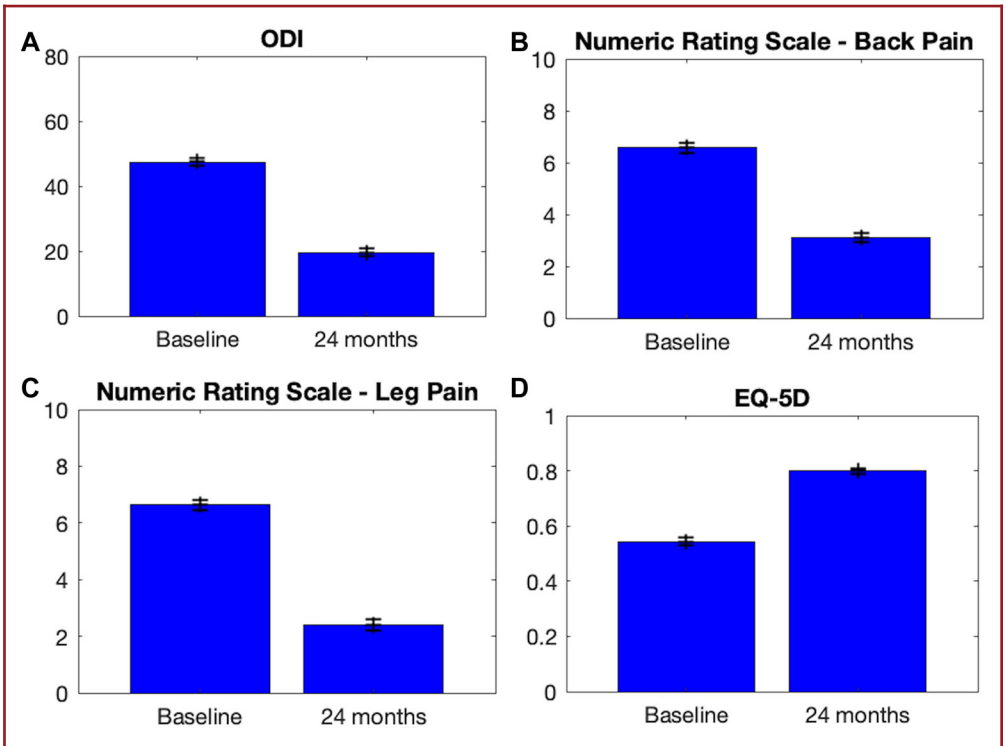

FIGURE 2. *PROs. Mean* **A**, *ODI scores,* **B**, *NRS back pain,* **C**, *NRS leg pain, and* **D**, *EQ-5D at baseline and 24 mo following surgery. Error bars represent standard error. The cohort demonstrated significant improvements at 24-mo follow-up, relative to baseline, for ODI, NRS back pain, NRS leg pain, and EQ-5D (P < .001, all comparisons).*

Active employment at baseline was associated with superior improvement in disability, back pain, quality of life, and satisfaction. Older patients had larger magnitudes of leg pain improvement and higher satisfaction. Patients who received a fusion surgery—as opposed to decompression alone—had greater improvements in disability, back pain, and were the most satisfied at 24 mo. Higher levels of education (at least 4 yr of post high school education and greater) and anterior (as opposed to posterior approach) were associated with the greatest improvement in disability. However, higher BMI and Hispanic ethnicity portended worse quality of life outcomes. Each baseline PRO was linked to 24-mo improvement for each respective PRO, though greater baseline disability was also associated with inferior back pain improvement at 24 mo.

Patient-Related Factors: Baseline PROs, Age, and BMI

We demonstrate that greater baseline PRO severity was associated with the greatest improvements for each respective PRO. This is consistent with prior studies investigating predictors of PRO improvement following spine surgery[21-23] and is attributable to ceiling effects involving the use of change scores as an outcome metric as opposed to absolute PRO values. In fact—underscoring the importance of baseline PROs—in a study of 110 patients undergoing lumbar surgery for degenerative disease, preoperative ODI was the single significant independent predictor of change in ODI.[23] Interestingly, baseline ODI was also significantly associated with 24-mo back pain change whereby increasing baseline disability was associated with less back pain improvement at 24 mo. This may not be surprising, as patients with greater disease-specific disability may be unable to participate in adjunctive recovery regimens, which may in turn portend less back pain and quality of life improvement than that achievable by less-disabled patients. As such, baseline disease-specific disability is an important predictive factor for multiple PRO outcomes, and its severity may help inform the shared surgical decision-making process.

In this cohort, advanced age was predictive of greater benefits for leg pain and satisfaction following MIS spondylolisthesis surgery. Of note, this relationship was not driven by an underlying correlation between baseline NRS leg pain and age (*Pearson* $r = -0.08$; $P = .21$). The finding extends a previous report that advanced age may lead to the best outcomes following lumbar fusion for degenerative disease in general.[24] On the other hand, the effect of obesity on surgical outcomes has been somewhat mixed. Here, we found that lower BMI, as a continuous variable, was associated with superior EQ-5D improvement and that a BMI cutoff of 33.89 was associated with a higher chance of reaching EQ-5D MCID. In a subgroup analysis of

TABLE 4. Significant Predictors of 24-mo Outcomes Following MIS for Grade 1 Lumbar Spondylolisthesis

	Adjusted[a] β coefficient (95% CI)	*P* value
ODI,[b] change		
Addition of fusion to procedure	−6.7 (−12.7 to −0.7)	.03
4 of more years of college level education	−7.4 (−12.0 to −2.8)	.002
Employed or employed and on leave	−7.8 (−12.9 to −2.6)	.003
Surgical approach		
Anterior only (posterior only as reference)	−14.4 (−26.2 to −2.6)	.02
ODI, baseline	−0.6 (−0.8 to −0.4)	<.001
NRS back pain,[c] change		
Addition of fusion to procedure	−1.1 (−2.1 to −0.2)	.02
Employed or employed and on leave	−1.2 (−2.1 to −0.4)	.004
NRS back pain, baseline	−0.9 (−1.0 to −0.7)	<.001
ODI, baseline	0.03 (0.003-0.06)	.03
NRS leg pain,[d] change		
Age	−0.1 (−0.1 to −0.01)	.03
NRS leg pain, baseline	−0.8 (−0.9 to −0.6)	<.001
EQ-5D,[e] change		
BMI (per 1 unit BMI lower)	0.01 (0.001-0.01)	.009
Hispanic ethnicity	−0.1 (−0.2 to −0.005)	.04
Employed or employed and on leave	0.1 (0.01-0.1)	.03
EQ-5D, baseline	−0.8 (−0.9 to −0.7)	<.001
	Adjusted[a] odds ratio (95% CI)	***P* value**
NASS satisfaction[f]		
Addition of fusion to procedure	3.6 (1.6-8.3)	.002
Age	1.05 (1.01-1.09)	.02
Employed or employed and on leave	3.7 (1.7-8.3)	<.001

ODI – Oswestry disability index; NRS – Numerical Rating Scale; EQ-5D – EuroQol-5D; BMI – body mass index; NASS – North American Spine Society.

β coefficients are reported such that $\beta < 0$ for ODI, NRS back pain, NRS leg pain and $\beta > 0$ for EQ-5D represents an association with superior outcomes at 24 mo. Odds ratios (OR) are reported such that OR > 1.0 for NASS satisfaction represents superior satisfaction at 24 mo.

[a]Multivariate models adjusted for age, sex, BMI, American Society of Anesthesiologists grade, presence of comorbidities (diabetes mellitus, coronary artery disease, anxiety, depression, osteoporosis), smoking status, clinical presentation (dominant presenting symptom, motor deficit upon presentation, independent ambulation at baseline, symptom duration greater or less than 3 mo), ethnicity (Hispanic or non-hispanic), education (4 yr of post high school education or more vs less than 4 yr of education), employment (employed or employed and on leave at baseline), use of private insurance, use of workman's compensation, surgical approach (posterior only, anterior only, lateral only, 2-stage approach), whether a fusion was performed, and baseline ODI, NRS back pain, NRS leg pain, and EQ-5D.

[b]For ODI, the addition of fusion, 4 or more years of post high school education, active employment (both employed or employed and on leave), anterior approach, and worse baseline ODI was associated with superior ODI change scores.

[c]For NRS back pain, the addition of fusion, active employment, worse (higher) baseline back pain, and lower baseline ODI were associated with superior NRS back pain change scores.

[d]For NRS leg pain, increasing age (as a continuous variable, in our dataset range was age 22-95 yr), and worse baseline leg pain were associated with superior NRS leg pain change scores.

[e]For EQ-5D, Hispanic ethnicity and higher baseline quality of life portended worse EQ-5D change scores. Lower BMI and active employment were associated with superior EQ-5D change scores.

[f]For NASS satisfaction, the addition of fusion, increasing age, and active employment were all associated with superior satisfaction.

the Spine Patient Outcomes Research Trial (SPORT), though obese patients experienced less improvement in Short Form 36 physical function scores, there were no other differences in 4-yr outcomes following spondylolisthesis surgery.[25] On the other hand, in a prior study by our group investigating degenerative lumbar spondylolisthesis in a mixed-open and MIS cohort, obesity was associated with inferior leg pain and quality of life 12 mo following surgery—the latter of which is consistent with the present MIS-only investigation.[4] Of note, however, obese patients were still able to achieve significant improvements in all PRO metrics at 12 mo. Taken together, though outcomes may be inferior for quality life following MIS spondylolisthesis surgery, well-selected obese patients may still stand to obtain a significant benefit from surgery. The association between a BMI cutoff of 33.89 and EQ-5D MCID may provide a BMI target for patients considering MIS spondylolisthesis surgery.

Socioeconomic Factors: Employment and Education

Patients able to retain active employment preoperatively may represent a subset of patients with adaptive psychological states, higher social support, greater job security, and income.[26-29] These factors may select patients that are better adapted to postoperative recovery (eg, time for participation in physical therapy regimens). Similarly, a higher education level may reflect a

subset of patients that have higher medical literacy and may reflect the type of occupation of the patient (eg, less physically labor intensive).[27] The former may result in a surgical candidate with more accurate expectations preoperatively—leading to improved adherence with postoperative pain and therapy regimens and expedited recovery with limited disability—which have been linked to improved outcomes.[30,31] Likewise, patients with more labor-intensive occupations may not be able to abide by appropriate postoperative restrictions and may exacerbate their pain and disability following surgery. These protective factors may aid appropriate expectation setting by patients and surgeons preoperatively.

Surgical Factors: Addition of Fusion and Surgical Approach

Because of avoidance of disruption of paraspinal musculature and the posterior tension band, some surgeons have suggested that MIS decompressions may limit the potential destabilization associated with decompression surgery alone for degenerative lumbar spondylolisthesis. In other words, the potential advantage of the addition of fusion—observed in the RCT by Ghogawala et al[3] and the interim analysis of a prospective registry study by our group[4]—may be diminished in a MIS-only analysis of spondylolisthesis surgery. However, the present analysis suggests that the addition of fusion remains beneficial in an MIS-only cohort for disability, back pain, and satisfaction—a finding consistent with a prior study by our group demonstrating superiority of MIS transforaminal lumbar interbody fusions compared to MIS decompressions alone[32] and a recent meta-analysis by Liang et al.[33] In the latter study, pooled satisfaction rates were superior following spinal fusion for degenerative lumbar spondylolisthesis.

Interestingly, we found that the patients receiving an anterior-only approach [ie, anterior lumbar interbody fusion (ALIF)] reported less disability than posterior-based approaches following MIS spondylolisthesis surgery. This is in contrast to a prior study comparing ALIF with posterior-based interbody placement for single-level spondylolisthesis reported by Lee et al.[34] In their study of ALIF (n = 27) vs posterior-interbody (n = 31) surgery for L4-5 spondylolisthesis, no significant differences were found between the 2 procedures for PROs including ODI—though the study was underpowered to detect such differences. On the other hand, ALIF demonstrated superiority for a variety of other clinical outcomes. ALIF was associated with greater improvements in segmental lordosis, disc height, foraminal height, and spondylolisthesis reduction. Additionally, ALIF was associated with a significantly lower rate of adjacent-segment disease (37.0% vs 64.5%, respectively). A comparison of a larger cohort of ALIF procedures with posterior-based MIS surgeries for spondylolisthesis should be undertaken in the future and radiographic analyses should be conducted.

Study Limitations

This study holds the associated limitations with retrospective analyses of information from a multicenter, prospective registry. Multiple sources of bias stem from the lack of standardization of patient selection and operative technique across centers. For the former, future study may compare outcomes specifically for those presenting with back pain or leg pain predominant symptoms. For the latter, our study had a greater number of fusion procedures performed than decompression-only procedures, which may affect the generalizability of our results. Still, we used multivariable modeling to correct for potential confounding sources, including whether a fusion was performed. Additionally, the study is without important radiographic outcomes, which may also affect 24-mo outcomes. Radiographic outcomes should be further investigated in subsequent investigations. Lastly, we used a definition of MIS consisting of techniques that are less invasive than traditional, open methods. It is important to note that MIS remains an inconsistently defined—and thus heterogeneous—entity. A future, larger-cohort study may permit subgroup analyses of predictors of outcomes for specific MIS techniques.

Despite these limitations, predictors reported herein reflect the "real-world" practice patterns of high-volume, multi-disciplinary spine centers in the United States and may be shared with patients to aid in patient selection and expectation setting when considering MIS for grade 1 degenerative lumbar spondylolisthesis surgery.

CONCLUSION

In adjusted analyses of 259 patients undergoing minimally invasive spine surgery for grade 1 degenerative lumbar spondylolisthesis, several factors were associated with superior outcomes. Patients undergoing fusion had superior results to those undergoing decompression alone. Additionally, active employment at the time of surgery was associated with superior outcomes. Older age was associated with larger magnitudes of leg pain improvement and greater satisfaction. These findings highlight several key factors that may aid in expectation setting for patients and surgeons considering MIS for degenerative lumbar spondylolisthesis.

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Supplemental Digital Content. Table. Significant predictors of 24-mo outcomes following posterior-only MIS for grade 1 lumbar spondylolisthesis. ODI – Oswestry disability index; NRS – Numerical Rating Scale; EQ-5D – EuroQol-5D; BMI – body mass index; NASS – North American Spine Society.β Coefficients are reported such that an $\beta < 0$ for ODI, NRS back pain, and NRS leg pain, and a $\beta > 0$ for EQ-5D represents an association with superior outcomes at 24 mo. Odds ratios are reported such that an OR > 1.0 for NASS satisfaction represents an association with superior satisfaction at 24 mo. [1]Multivariate models adjusted for age, sex, BMI, American Society of Anesthesiologists grade, presence of comorbidities (diabetes mellitus, coronary artery disease, anxiety, depression, and osteoporosis), smoking status, clinical presentation (dominant presenting symptom, motor deficit upon presentation, independent ambulation at baseline, and symptom duration greater or less than 3 mo), ethnicity (Hispanic or non-Hispanic), education (4 yr of post high school education or more), employment (employed or employed and on leave at baseline), use of private insurance, use of workman's compensation, whether a fusion was performed, and baseline ODI, NRS back pain, NRS leg pain, and EQ-5D. [2]For ODI, the addition of fusion, 4 or more years of post high school education, active employment (both employed or employed and on leave), and worse baseline ODI was associated with superior ODI change scores. [3]For NRS back pain, the addition of fusion, active employment, lower BMI, and worse (higher) baseline back pain were associated with superior NRS back pain change scores. [4]For NRS leg pain, 4 or more years of post high school education, lower BMI, higher baseline back pain, and higher baseline leg pain were associated with superior NRS leg pain change scores. [5]For EQ-5D, active employment, lower BMI, and lower baseline quality of life portended superior EQ-5D change scores. [6]For NASS satisfaction, the addition of fusion and active employment were associated with superior satisfaction. Presenting with both back and leg pain of equal severity (as opposed to back pain alone) portended worse satisfaction following surgery.

COMMENT

In this article, the authors retrospectively review the factors that result in the best patient-reported outcome (PRO) survey data at 24 months following minimally surgery for grade one lumbar spondylolisthesis. The authors found 259 patients in the Quality Outcomes Database with completed Oswestry disability index (ODI), numeric rating scale (NRS) back pain, NRS leg pain, EuroQoL-5D (EQ-5D) questionnaire, and North American Spine Society (NASS) satisfaction questionnaire. Of these 259 patients, 188 underwent fusion surgery. Patient employment status was related to an improvement in ODI, NRS back pain, EQ-5D, and NASS satisfaction questionnaire. Increasing age was related to an improvement in NRS leg pain and NASS satisfaction questionnaire. Fusion surgery was related to an improvement in ODI, NRS back pain, and NASS satisfaction questionnaire.

From a clinical standpoint, while the improvement in PROs is appreciated, radiographic data would be interesting to know—specifically, arthrodesis rates following MIS surgery for grade 1 lumbar spondylolisthesis. Additionally, it would be enlightening to compare the degree of spondylolisthesis correction in MIS surgery versus open at 24 months, given that there is minimal to no disruption of the posterior ligamentous complex in MIS surgery.

The authors are commended for this interesting work that will help guide surgeons in setting patients' expectations after their surgeries.

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