

## Women fare best following surgery for degenerative lumbar spondylolisthesis: a comparison of the most and least satisfied patients utilizing data from the Quality Outcomes Database

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**OBJECTIVE** The American Association of Neurological Surgeons launched the Quality Outcomes Database (QOD), a prospective longitudinal registry that includes demographic, clinical, and patient-reported outcome (PRO) data, to measure the safety and quality of neurosurgical procedures, including spinal surgery. Differing results from recent randomized controlled trials have established a need to clarify the groups that would most benefit from surgery for degenerative lumbar spondylolisthesis. In the present study, the authors compared patients who were the most and the least satisfied following surgery for degenerative lumbar spondylolisthesis.

**METHODS** This was a retrospective analysis of a prospective, national longitudinal registry including patients who had undergone surgery for grade 1 degenerative lumbar spondylolisthesis. The most and least satisfied patients were identified based on an answer of “1” and “4,” respectively, on the North American Spine Society (NASS) Satisfaction Questionnaire 12 months postoperatively. Baseline demographics, clinical variables, surgical parameters, and outcomes were collected. Patient-reported outcome measures, including the Numeric Rating Scale (NRS) for back pain, NRS for leg pain, Oswestry Disability Index (ODI), and EQ-5D (the EuroQol health survey), were administered at baseline and 3 and 12 months after treatment.

**RESULTS** Four hundred seventy-seven patients underwent surgery for grade 1 degenerative lumbar spondylolisthesis in the period from July 2014 through December 2015. Two hundred fifty-five patients (53.5%) were the most satisfied and 26 (5.5%) were the least satisfied. Compared with the most satisfied patients, the least satisfied ones more often

**ABBREVIATIONS** ASA = American Society of Anesthesiologists; BMI = body mass index; CAD = coronary artery disease; MI = minimally invasive; NASS = North American Spine Society; NRS-BP = Numeric Rating Scale for back pain; NRS-LP = NRS for leg pain; ODI = Oswestry Disability Index; PRO = patient-reported outcome; QOD = Quality Outcomes Database; VA = Veterans Affairs.

**SUBMITTED** August 30, 2017. **ACCEPTED** October 27, 2017.

**INCLUDE WHEN CITING** DOI: 10.3171/2017.10.FOCUS17553.

had coronary artery disease (CAD; 26.9% vs 12.2%,  $p = 0.04$ ) and had higher body mass indices ( $32.9 \pm 6.5$  vs  $30.0 \pm 6.0$  kg/m<sup>2</sup>,  $p = 0.02$ ). In the multivariate analysis, female sex (OR 2.9,  $p = 0.02$ ) was associated with the most satisfaction. Notably, the American Society of Anesthesiologists (ASA) class, smoking, psychiatric comorbidity, and employment status were not significantly associated with satisfaction. Although there were no significant differences at baseline, the most satisfied patients had significantly lower NRS back and leg pain and ODI scores and a greater EQ-5D score at 3 and 12 months postoperatively ( $p < 0.001$  for all).

**CONCLUSIONS** This study revealed that some patient factors differ between those who report the most and those who report the least satisfaction after surgery for degenerative lumbar spondylolisthesis. Patients reporting the least satisfaction tended to have CAD or were obese. Female sex was associated with the most satisfaction when adjusting for potential covariates. These findings highlight several key factors that could aid in setting expectations for outcomes following surgery for degenerative lumbar spondylolisthesis.

<https://thejns.org/doi/abs/10.3171/2017.10.FOCUS17553>

**KEY WORDS** lumbar; spondylolisthesis; satisfaction; Quality Outcomes Database; patient-reported outcomes

**D**EGENERATIVE lumbar spondylolisthesis is a significant cause of back pain. Surgical treatment has been shown to be effective<sup>29</sup> and is considered when conservative treatment has failed. In 2007, in a randomized controlled trial of patients with degenerative spondylolisthesis and at least 3 months of symptoms, Weinstein and colleagues demonstrated that surgery, as compared with nonsurgical treatment, significantly decreased pain and improved function.

More recently, 2 randomized controlled trials, which arrived at different conclusions, have renewed interest in the outcomes of surgery for degenerative lumbar spondylolisthesis. In the Spinal Laminectomy versus Instrumental Pedicle Screw (SLIP) trial by Ghogawala and colleagues, the addition of fusion, as compared with laminectomy alone, was associated with a significant improvement in quality of life as well as a lower rate of reoperation (14% vs 34%).<sup>12</sup> However, in a subgroup analysis of patients with degenerative spondylolisthesis, Försth and colleagues found no significant benefit to the addition of fusion in any patient-reported outcome (PRO) metric at the 2-year follow-up.<sup>10</sup> These somewhat conflicting results call for the identification of factors that portend the best outcomes following surgery for degenerative lumbar spondylolisthesis.

One outcome metric for quality of care is patient satisfaction. Several studies have shown that high patient satisfaction may be correlated with efficient and high-quality surgical care<sup>28</sup> and superior surgical outcomes.<sup>20</sup> Authors investigating lumbar spine surgery have specifically linked various patient characteristics to satisfaction, including smoking, depression, disability-derived unemployment,<sup>4</sup> sex,<sup>9</sup> obesity,<sup>13</sup> preoperative diagnosis,<sup>7</sup> payer status, worse baseline pain and disability scores,<sup>6</sup> and psychological comorbidity.<sup>2</sup> However, the patient characteristics affecting postoperative satisfaction in those undergoing surgery for degenerative lumbar spondylolisthesis, in particular, remain unclear. Identifying factors that predict which patients will be most satisfied after surgery for degenerative lumbar spondylolisthesis is valuable to multiple stakeholders, including hospitals, surgeons, patients, and payers.

To this end, we analyzed the data from 11 sites participating in the prospective, multicenter, multidisciplinary Quality Outcomes Database (QOD) to identify factors as-

sociated with the most and the least satisfaction following surgery for grade 1 degenerative lumbar spondylolisthesis.

## Methods

The QOD is a prospective longitudinal registry that includes demographic, clinical, and PRO data to measure the safety and quality of neurosurgical procedures, including spinal surgery. The QOD was established with the aim of evaluating risk-adjusted expected morbidity and surgical outcomes to improve care for patients undergoing spinal surgery.<sup>16</sup> In contrast to the narrow inclusion criteria of randomized clinical trials, the registry offers a glimpse into the actual practice patterns of high-volume neurosurgical and orthopedic spine centers in the United States. Outcomes reported in the QOD, including the PROs collected directly from patients through the spine surgeon's office, allow unique insights into the efficacy of surgery for lumbar spondylolisthesis.

Eleven of the highest-enrolling sites participate in a lumbar spondylolisthesis module, as we reported in a prior study.<sup>19</sup> We queried the lumbar spondylolisthesis module for patients who had undergone surgery for grade 1 lumbar spondylolisthesis in the period from July 2014 through December 2015. Preoperative plain radiographs (standing or dynamic) were obtained and were evaluated by surgeons at the participating sites to confirm the diagnosis of grade 1 spondylolisthesis (Fig. 1) as defined by the Meyerding classification.<sup>18</sup> Patients with grade 2 or higher spondylolisthesis were excluded.

## Demographic, Clinical, and Surgical Variables

The QOD registry collects data on demographic variables (age, sex, body mass index [BMI], ethnicity, insurance, education level, employment), patient comorbidities (smoking, diabetes, anxiety, coronary artery disease [CAD], osteoporosis, depression, American Society of Anesthesiologists [ASA] classification), clinical characteristics (dominant presenting symptom, ambulation status, presence of motor deficit), baseline and follow-up PRO scores (Oswestry Disability Index [ODI], EQ-5D [the EuroQol health survey], Numeric Rating Scale for leg pain [NRS-LP] and back pain [NRS-BP], North American

Spine Society [NASS] Satisfaction Questionnaire), and surgical variables (type of approach, use of minimally invasive [MI] techniques, performance of laminectomy, whether fusion was performed, estimated blood loss, operative time, length of hospitalization, discharge disposition).

Ethnicity (Hispanic or Latino vs Not Hispanic or Latino), insurance status (private insurance vs Medicare, Medicaid, or Veterans Affairs [VA]/government), education level (4-year-degree post-high school education or greater vs less than a 4-year-degree post-high school education), employment status (employed or on leave vs unemployed), ambulation status (independently ambulatory vs nonindependently ambulatory [for example, with assistive device]), and discharge disposition (discharge to home or home health care vs discharge not to home or home health care) were 2-level variables. Dominant presenting symptom was a 3-level variable (pain predominant, motor predominant, or sensory predominant).

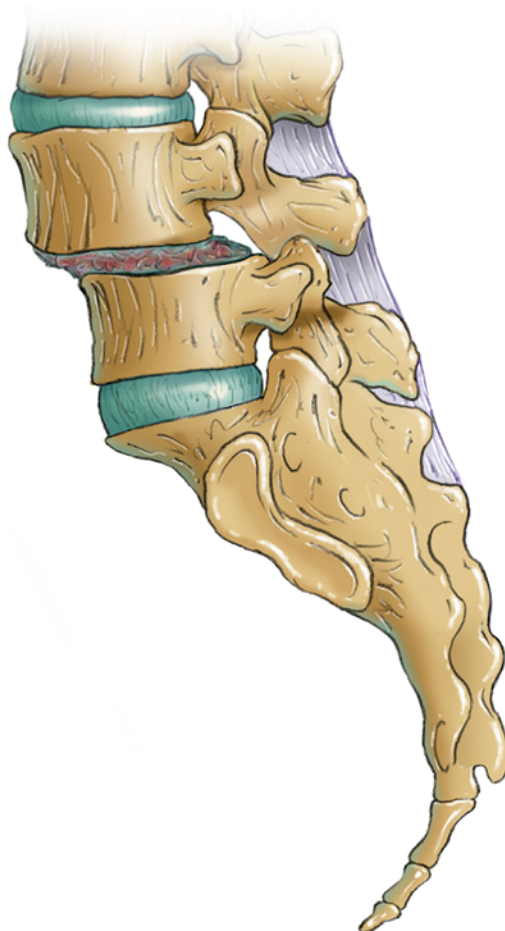
Surgical approaches included posterior only, anterior only, lateral only, and a staged approach. In accordance with our prior work,<sup>19</sup> surgeries were categorized as utilizing MI techniques if any of the following were involved: MI laminectomy, MI pedicle screws, MI interbody grafts, cortical screws, or percutaneous screws.

### Primary Outcome

The NASS Satisfaction Questionnaire assesses patient satisfaction following surgery via 4 questions whose answers are scored 1–4: 1) Surgery met my expectations; 2) I did not improve as much as I had hoped, but I would undergo the same operation for the same results; 3) Surgery helped, but I would not undergo the same operation for the same results; and 4) I am the same as or worse than before surgery. This questionnaire has been established as a valid and reliable measure of outcomes, including satisfaction, following surgery.<sup>8</sup> A study investigating the effectiveness of the questionnaire has demonstrated high test-retest and internal reliability,<sup>8</sup> and the satisfaction portion of the questionnaire has been published in multiple articles on lumbar spine surgery.<sup>5,7,26,27</sup> At the 12-month follow-up, we identified patients who scored a 1 as the most satisfied and those who scored a 4 as the least satisfied.

### Statistical Analysis

Descriptive statistics were reported as the means  $\pm$  standard deviations or frequencies and percentages, as appropriate. Continuous variables were compared using rank-sum tests, and categorical variables were compared using Pearson's chi-square test and Yates' correction for continuity, as appropriate, via custom and built-in scripts (MATLAB, MathWorks). Multivariate linear regression models were fitted for predictors of the most satisfaction, compared with predictors of the least satisfaction, after controlling for covariates of interest. Variables that reached a significance level of  $p < 0.20$  on univariate analyses were included in the multivariate analysis, which was conducted using R 2.15.2 (R Foundation for Statistical Computing). Missing values in the data were imputed using the "missForest" R package, a nonparametric imputa-



**FIG. 1.** Illustration depicting degenerative L4–5 grade 1 spondylolisthesis. Copyright Praveen Mummaneni. Published with permission.

tion method based on the random forest algorithm. The  $p$  values were 2-tailed, and an alpha of 0.05 was considered statistically significant.

### Results

From July 1, 2014, through December 31, 2015, there were 477 patients at the 11 participating sites who were entered into the lumbar spondylolisthesis QOD. These patients had undergone surgery for grade 1 lumbar spondylolisthesis. Two hundred fifty-five patients (53.5%) were the most satisfied and 26 (5.5%) were the least satisfied. Descriptive preoperative variables are presented in Table 1. At baseline, the most satisfied cohort had a significantly lower mean BMI ( $30.0 \pm 6.0$  vs  $32.9 \pm 6.5$  kg/m<sup>2</sup>,  $p = 0.02$ ) and lower rate of CAD (12.2% vs 26.9%,  $p = 0.04$ ). Though not statistically significant, there was a trend toward a greater proportion of female patients in the most satisfied cohort (58.4% vs 38.5%,  $p = 0.0503$ ). There were no other significant differences between the cohorts at baseline, including with regard to baseline NRS-BP, NRS-LP, ODI, and EQ-5D scores.

Table 2 demonstrates the surgical variables, including perioperative outcomes associated with the most and least satisfied cohorts. There were no significant differences in

**TABLE 1. Preoperative characteristics of patients who underwent surgery for grade 1 lumbar spondylolisthesis, stratified by the most versus least satisfaction**

Characteristic	Most Satisfied	Least Satisfied	p Value
No. of patients	255	26	
Mean age in yrs	63.4 ± 10.6	63.0 ± 10.3	0.80
Female	149 (58.4%)	10 (38.5%)	0.05
Mean BMI in kg/m <sup>2</sup>	30.0 ± 6.0	32.9 ± 6.5	0.02*
Smoker	23 (9.0%)	4 (15.4%)	0.29
Comorbidities			
Diabetes mellitus	52 (20.4%)	7 (26.9%)	0.44
CAD	31 (12.2%)	7 (26.9%)	0.04*
Anxiety	51 (20.0%)	3 (11.5%)	0.30
Depression	59 (23.1%)	3 (11.5%)	0.17
Osteoporosis	15 (5.9%)	1 (3.8%)	0.67
Dominant presenting symptom			0.75
Pain predominant	100 (39.2%)	12 (46.2%)	
Motor predominant	51 (20.0%)	4 (15.4%)	
Sensory predominant	104 (40.8%)	10 (38.5%)	
Motor deficit	56 (22.0%)	8 (30.8%)	0.31
Independently ambulatory at presentation	231 (90.6%)	22 (84.6%)	0.33
ASA class			0.29
I or II	145 (56.9%)	12 (46.2%)	
III or IV	110 (43.1%)	14 (53.8%)	
Type of insurance			0.17
Private	134 (52.5%)	10 (38.5%)	
Medicare, Medicaid, or VA/government	121 (47.5%)	16 (61.5%)	
Ethnicity			0.52
Hispanic or Latino	37 (14.5%)	5 (19.2%)	
Not Hispanic or Latino	218 (85.5%)	21 (80.8%)	
Level of education			0.36
4-yr degree or more	112 (43.9%)	9 (34.6%)	
<4-yr degree	136 (53.3%)	17 (65.4%)	
Employment status			0.39
Employed or on leave	113 (44.3%)	9 (34.6%)	
Not employed	138 (54.1%)	16 (61.5%)	
Mean baseline PROs			
NRS-BP	6.6 ± 2.7	7.4 ± 2.4	0.11
NRS-LP	6.5 ± 2.8	6.7 ± 3.0	0.88
ODI	43.4 ± 15.5	48.9 ± 20.0	0.14
EQ-5D	0.56 ± 0.20	0.52 ± 0.22	0.21

Values are expressed as the mean ± standard deviation or as frequency (%). Percentages do not add up to 100% where responses were not given by participants.

\* A statistically significant relationship, alpha level 0.05.

surgical approach (p = 0.89), the use of an MI technique (p = 0.51), or the performance of laminectomy or arthrodesis (p = 0.78 and 0.64, respectively). Neither were there any differences in perioperative outcomes in terms of blood

**TABLE 2. Surgical variables for the most and least satisfied patients who underwent surgery for grade 1 lumbar spondylolisthesis**

Variable	Most Satisfied	Least Satisfied	p Value
No. of patients	255	26	
Approach			0.89*
Posterior only	239 (93.7%)	24 (92.3%)	
Anterior only	6 (2.4%)	0 (0.0%)	
Lateral only	3 (1.2%)	0 (0.0%)	
2-stage approach	7 (2.7%)	2 (7.7%)	
MIS	85 (33.3%)	7 (26.9%)	0.51
Laminectomy	239 (93.7%)	24 (92.3%)	0.78
Fusion	217 (85.1%)	23 (88.5%)	0.64
Mean EBL in ml	246.5 ± 248.9	390.8 ± 629.6	0.11
Mean op time in mins	200.9 ± 86.1	203.3 ± 101.3	0.77
Mean hospital LOS in days	3.1 ± 1.8	2.8 ± 1.8	0.88
Discharge disposition			0.83
Home or home health care	229 (89.8%)	23 (88.5%)	
Not to home or home health care	26 (10.2%)	3 (11.5%)	

EBL = estimated blood loss; LOS = length of stay; MIS = minimally invasive surgery.

Values are expressed as the mean ± standard deviation or as frequency (%).

\* Chi-square comparison made using approach as a 2-level variable (posterior-only approach vs non-posterior-only approach).

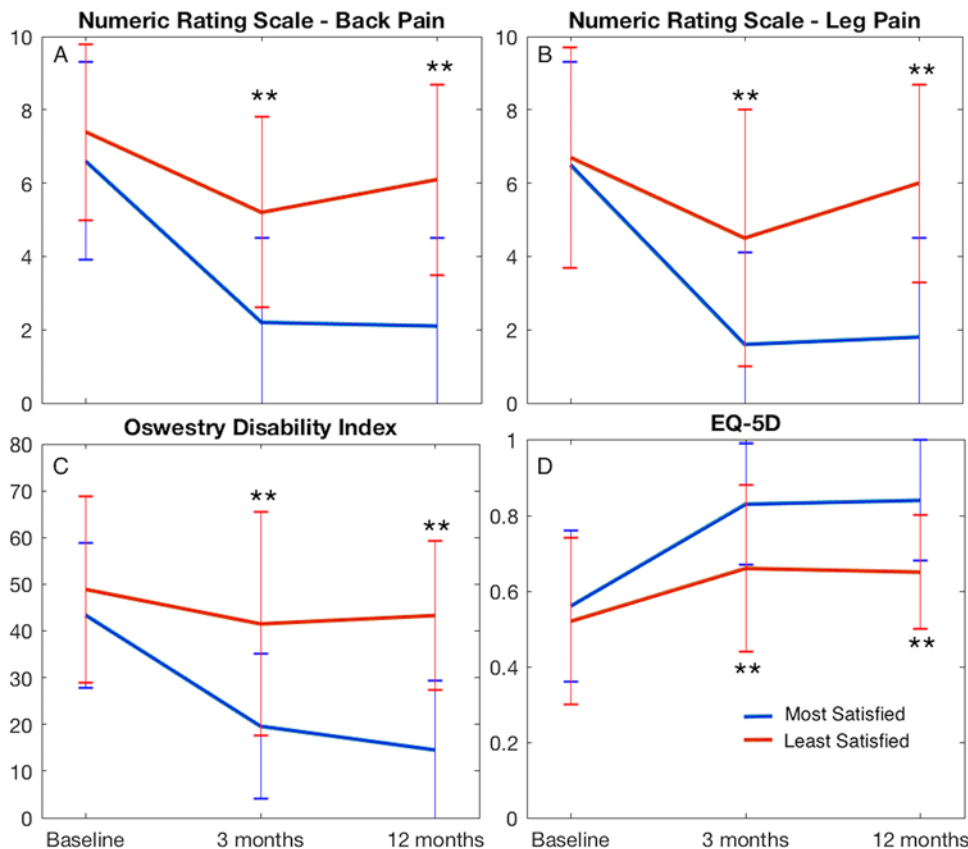
loss (p = 0.11), operative time (p = 0.77), length of hospitalization (p = 0.88), or discharge disposition (p = 0.83).

**Readmission, Reoperation, and PROs**

Nine (3.5%) most satisfied patients and 3 (11.5%) least satisfied patients required a readmission within 3 months of surgery. Thirteen (5.1%) most satisfied patients and 3 (11.5%) least satisfied patients required reoperation within the 12-month follow-up period. There were no significant differences between the 3-month readmission rates and 12-month reoperation rates (p = 0.16 and p = 0.37, respectively).

There were no significant differences in baseline NRS-BP scores between the 2 cohorts; however, the least satisfied patients had worse scores than the most satisfied patients at 3 months (5.2 ± 2.6 vs 2.2 ± 2.3, p < 0.001) and 12 months (6.1 ± 2.6 vs 2.1 ± 2.4, p < 0.001). Both cohorts significantly improved from baseline at the 3- and 12-month follow-ups (p < 0.05 for all comparisons). Figure 2A demonstrates the trend in NRS-BP scores according to patient satisfaction over the study period.

There were no significant differences in baseline NRS-LP scores between the 2 cohorts. The least satisfied patients had greater leg pain than the most satisfied patients at both 3 months (4.5 ± 3.5 vs 1.6 ± 2.5, p < 0.001) and 12 months (6.0 ± 2.7 vs 1.8 ± 2.7, p < 0.001). The most satisfied cohort improved from baseline at both the 3- and 12-month follow-ups (p < 0.001). Though the least satisfied cohort demonstrated significant improvement in leg pain at 3 months (p = 0.02), as compared with baseline,



**FIG. 2.** Baseline, 3-month, and 12-month PROs following surgery for grade 1 lumbar spondylolisthesis. **A:** Average NRS-BP scores at baseline and 3 and 12 months after surgery by patient cohort. **B:** Average NRS-LP scores at baseline and 3 and 12 months after surgery by patient cohort. **C:** Average ODI at baseline and 3 and 12 months following surgery by patient cohort. **D:** Average EQ-5D at baseline and 3 and 12 months following surgery by patient cohort. Error bars represent 1 SD. Though there were no significant differences between the 2 cohorts at baseline, they did differ in terms of improvement over time. For the most satisfied cohort, there were statistically significant improvements in NRS-BP, NRS-LP, ODI, and EQ-5D scores at the 3- and 12-month follow-ups, relative to baseline ( $p < 0.001$ , all comparisons). The least satisfied cohort demonstrated significant improvements in NRS-BP, NRS-LP, and EQ-5D at the 3-month follow-up ( $p < 0.05$ ) but only demonstrated significant improvement in NRS-BP at the 12-month follow-up ( $p = 0.048$ ). In the least satisfied cohort, there were no differences in NRS-LP, ODI, and EQ-5D at 12 months, compared with baseline. \*\*A statistically significant difference at  $p < 0.001$  between the most and least satisfied cohorts.

there was no significant improvement at 12 months ( $p = 0.38$ ). Figure 2B demonstrates the trend in NRS-LP scores according to patient satisfaction over the study period.

There was no significant difference in baseline ODI scores between the 2 cohorts. However, the least satisfied patients had worse ODI scores than the most satisfied patients at 3 months ( $41.5 \pm 23.9$  vs  $19.6 \pm 15.5$ ,  $p < 0.001$ ) and 12 months ( $43.3 \pm 16.0$  vs  $14.5 \pm 14.8$ ,  $p < 0.001$ ). The most satisfied cohort improved from baseline at both the 3- and 12-month follow-ups ( $p < 0.001$ ); however, the least satisfied cohort demonstrated no significant change in ODI at either the 3- or 12-month follow-up ( $p = 0.26$  and  $0.28$ , respectively). Figure 2C demonstrates the trend in ODI scores according to patient satisfaction over the study period.

There was no significant difference in baseline EQ-5D scores between the 2 cohorts; however, the least satisfied patients had worse scores at 3 months ( $0.66 \pm 0.22$  vs  $0.83 \pm 0.16$ ,  $p < 0.001$ ) and 12 months ( $0.64 \pm 0.15$  vs  $0.84 \pm 0.16$ ,  $p < 0.001$ ). The most satisfied cohort improved from

**TABLE 3. Multivariate analysis of most versus least satisfaction following surgery for grade 1 lumbar spondylolisthesis**

Variable	Adjusted OR* (95% CI)	p Value
Female	2.87 (1.18–7.41)	0.02†
Private insurance	1.70 (0.71–4.22)	0.24
CAD	0.42 (0.15–1.22)	0.09
Depression	3.31 (0.95–16.38)	0.09
BMI	0.94 (0.88–1.01)	0.07
Readmission w/in 3 mos	0.26 (0.06–1.44)	0.09
Baseline NRS-BP	0.87 (0.70–1.07)	0.22
Baseline ODI	0.98 (0.95–1.01)	0.24

\* Represents odds predicting the most satisfaction relative to the least satisfaction. Covariates were adjusted for variables that reached a significance value of  $p < 0.20$  on univariate analysis: sex, insurance, CAD, depression, BMI, readmission within 3 months, and baseline NRS-BP and ODI.  
 † A statistically significant relationship, alpha level 0.05.

baseline at the 3- and 12-month follow-ups ( $p < 0.001$ ). And though the least satisfied cohort demonstrated significant improvement in EQ-5D scores at 3 months ( $p = 0.03$ ), there was no significant improvement at 12 months ( $p = 0.057$ ). Figure 2D demonstrates the trend in EQ-5D scores according to satisfaction over the study period.

### Multivariate Analysis

We conducted a multivariate analysis to determine whether there were independent predictors of satisfaction at 12 months when adjusting for potential confounders. We adjusted for factors that reached a significance level  $< 0.20$  on univariate analysis. In the adjusted multivariate analysis (Table 3), female sex was independently associated with the most satisfaction (adjusted OR 2.9, 95% CI 1.2–7.4,  $p = 0.02$ ).

We conducted separate subgroup multivariate analyses with the cohort that underwent fusion (240 patients) and the cohort that underwent laminectomy alone (41 patients). Baseline characteristics, surgical variables, and perioperative outcomes for this subgroup analysis are presented in Table 4. In the multivariate analysis of the fusion cohort, female sex remained the sole predictor of the most satisfaction following surgery for degenerative lumbar spondylolisthesis (adjusted OR 3.3, 95% CI 1.3–9.3,  $p = 0.02$ ; Table 5). In the laminectomy-alone cohort, there were only 3 patients identifying as the least satisfied, precluding multivariate analysis of this subgroup. Of note, there was no difference in the proportion of most and least satisfied patients within the fusion cohort—217 (90.4%) and 23 (9.6%), respectively—and the laminectomy cohort—38 (92.7%) and 3 (7.3%), respectively (Yates'  $\chi^2 = 0.03$ ,  $p = 0.86$ ).

### Additional Data

Descriptive and surgical variables, including perioperative outcomes for patients who were intermediately satisfied (NASS Satisfaction Questionnaire score of 2 or 3), are presented in Table 6.

## Discussion

In an analysis of 477 patients undergoing surgery for grade 1 degenerative lumbar spondylolisthesis, we found that 255 patients identified as most satisfied and 26 identified as least satisfied 12 months after the index surgery. The most satisfied patients had a significantly lower mean BMI and a lower rate of CAD. Though there were no significant differences between the 2 cohorts with regard to baseline PROs (NRS-BP, NRS-LP, ODI, and EQ-5D), the most satisfied patients significantly improved at the 12-month follow-up, whereas the least satisfied patients demonstrated no significant change in NRS-LP, ODI, or EQ-5D at the 12-month follow-up relative to baseline.

In a multivariate analysis, female sex was independently associated with the most satisfaction at 12 months after surgery. This finding—in adjusted analysis—is a novel one. In prior investigations of lumbar spinal surgery, female sex was associated with inferior<sup>9,11,22</sup> or equivocal<sup>23,25</sup> satisfaction. In 2 studies, one on patients over 65 years of age<sup>22</sup> and another single-center prospective analysis of 384 patients,<sup>9</sup> with both groups undergoing lumbar spine surgery, female

sex was associated with dissatisfaction. In another study of spinal fusion in a mixed cohort including 112 patients with isthmic spondylolisthesis and degenerative disc disease, male sex increased the likelihood of a positive result, which was defined as patient satisfaction as well as return to work and reduced medication.<sup>11</sup> A number of studies have also shown that patient sex is not predictive of outcome. For example, in a study of patients who underwent surgery for lumbar disc herniation, the authors found no significant differences in satisfaction between male and female patients.<sup>25</sup> In another large-registry study of patients with lumbar spinal stenosis without spondylolisthesis, patient sex was not predictive of satisfaction in an adjusted analysis.<sup>23</sup> In contrast, our finding that female patient sex was associated with the most satisfaction following surgery for degenerative lumbar spondylolisthesis warrants further investigation. Specifically, factors that may differ in an etiology-specific manner should be identified.

In the present study, based on the adjusted OR of 2.87 for women and the most satisfaction, as well as the 86.9% chance of most satisfaction for men (the reference group), the calculated adjusted risk ratio<sup>21</sup> is 1.09, indicating a 9% increased chance of most satisfaction for women—an effect size that is not exceedingly large. Nonetheless, the literature is skewed toward men having superior outcomes in lumbar spinal surgery,<sup>9,11,22</sup> and our study provides contrasting evidence that women may fare better in some circumstances, such as following surgery for lumbar spondylolisthesis. Surgeons should continue to offer surgery for lumbar spondylolisthesis to well-selected patients—regardless of their sex, given the high rates of satisfaction for both women and men.

In our univariate comparisons, we found that the least satisfied patients had a higher mean BMI and a greater rate of CAD. The association between obesity and satisfaction following lumbar spinal surgery has been inconsistent. In a large-registry study of 2633 lumbar stenosis patients, obese patients, in general, had less satisfaction following surgery.<sup>13</sup> However, in a study by McGuire and colleagues, there was no difference between obese and nonobese patients in symptom satisfaction at 12 months following surgery specifically for degenerative lumbar spondylolisthesis.<sup>17</sup> It is important to note that in our multivariate analysis, when adjusting for potential confounders, BMI was not a significant independent predictor of satisfaction. This suggests that other factors—for example, patient sex—may be more important for preoperative counseling and the determination of which patients will be most satisfied after surgery for degenerative lumbar spondylolisthesis. The association between CAD and inferior outcomes following lumbar spinal surgery, in general, is clearer. In a systematic review of 21 studies on preoperative predictors of outcomes of surgery for lumbar spinal stenosis, cardiovascular comorbidity was associated with poor patient satisfaction at the 2-year follow-up.<sup>1</sup> Increased attention to cardiac comorbidities may be considered to optimize satisfaction following surgery for degenerative lumbar spondylolisthesis.

Of note, our study did not reveal associations between patient satisfaction with surgery for degenerative lumbar spondylolisthesis and ASA class, psychiatric comorbidity, smoking, and employment status. In contrast, in a recent

**TABLE 4. Characteristics and surgical variables for the most and least satisfied patients stratified by fusion versus laminectomy alone for grade 1 lumbar spondylolisthesis**

Variable	Fusion (n = 240)			Laminectomy Alone (n = 41)		
	Most Satisfied	Least Satisfied	p Value	Most Satisfied	Least Satisfied	p Value
No. of patients	217	23		38	3	0.86
Mean age in yrs	61.8 ± 10.2	61.8 ± 10.0	0.92	72.4 ± 8.6	71.9 ± 8.8	0.94
Female	130 (59.9%)	9 (39.1%)	0.05	19 (50.0%)	1 (33.3%)	0.96
Mean BMI in kg/m <sup>2</sup>	30.4 ± 6.2	33.2 ± 6.3	0.02*	27.9 ± 4.2	30.1 ± 8.2	0.71
Smoker	21 (9.7%)	4 (17.4%)	0.43	2 (5.3%)	0 (0%)	NA
Comorbidities						
Diabetes mellitus	43 (19.8%)	7 (30.4%)	0.23	9 (23.7%)	0 (0%)	NA
CAD	26 (12.0%)	7 (30.4%)	0.01	5 (13.2%)	0 (0%)	NA
Anxiety	43 (19.8%)	3 (13.0%)	0.61	8 (21.1%)	0 (0%)	NA
Depression	53 (24.4%)	3 (13.0%)	0.22	6 (15.8%)	0 (0%)	NA
Osteoporosis	11 (5.1%)	1 (4.3%)	0.72	4 (10.5%)	0 (0%)	NA
Dominant presenting symptom			0.82			0.83
Pain predominant	89 (41.0%)	11 (47.8%)		11 (28.9%)	1 (33.3%)	
Motor predominant	32 (14.7%)	3 (13.0%)		19 (50.0%)	1 (33.3%)	
Sensory predominant	96 (44.2%)	9 (39.1%)		8 (21.1%)	1 (33.3%)	
Motor deficit	45 (20.7%)	5 (21.7%)	0.91	11 (28.9%)	3 (100%)	NA
Independently ambulatory at presentation	199 (91.7%)	20 (87.0%)	0.71	32 (84.2%)	2 (66.7%)	>0.99
ASA class			0.16			NA
I or II	118 (54.4%)	9 (39.1%)		27 (71.1%)	3 (100%)	
III or IV	99 (45.6%)	14 (60.9%)		11 (28.9%)	0 (0%)	
Type of insurance			0.10			0.68
Private	124 (57.1%)	9 (39.1%)		10 (26.3%)	1 (33.3%)	
Medicare, Medicaid, or VA/government	93 (42.9%)	14 (60.9%)		28 (73.7%)	2 (66.7%)	
Ethnicity			0.53			NA
Hispanic or Latino	36 (16.6%)	5 (21.7%)		1 (2.6%)	0 (0%)	
Not Hispanic or Latino	181 (83.4%)	18 (78.3%)		37 (97.4%)	3 (100%)	
Level of education			0.25			0.96
4-yr degree or more	93 (42.9%)	7 (30.4%)		19 (50.0%)	2 (66.7%)	
<4-yr degree	124 (57.1%)	16 (69.6%)		19 (50.0%)	1 (33.3%)	
Employment status			0.26			0.82
Employed or on leave	105 (48.4%)	8 (34.8%)		8 (21.1%)	1 (33.3%)	
Not employed	109 (50.2%)	14 (60.9%)		30 (78.9%)	2 (66.7%)	
Baseline PROs						
NRS-BP	6.7 ± 2.6	7.7 ± 2.3	0.06	5.8 ± 3.1	5.0 ± 2.6	0.60
NRS-LP	6.5 ± 2.8	7.0 ± 2.8	0.54	6.5 ± 2.9	4.0 ± 4.0	0.24
ODI	44.6 ± 15.0	51.0 ± 19.1	0.10	36.3 ± 16.3	33.3 ± 23.2	0.69
EQ-5D	0.55 ± 0.21	0.48 ± 0.20	0.05	0.57 ± 0.21	0.80 ± 0.20	0.10
Approach			0.85†			NA
Posterior only	201 (92.6%)	21 (91.3%)		38 (100%)	3 (100%)	
Anterior only	6 (2.8%)	0 (0.0%)		0 (0%)	0 (0%)	
Lateral only	3 (1.4%)	0 (0.0%)		0 (0%)	0 (0%)	
2-stage approach	7 (3.2%)	2 (8.7%)		0 (0%)	0 (0%)	
MIS	68 (31.3%)	4 (17.4%)	0.17	17 (44.7%)	3 (100%)	NA
Mean EBL in ml	279.3 ± 254.0	438.9 ± 655.4	0.047*	62.0 ± 87.6	21.7 ± 5.8	0.22
Mean op time in mins	213.2 ± 83.5	215.5 ± 101.3	0.84	128.2 ± 62.6	109.3 ± 22.5	0.78
Mean hospital LOS in days	3.4 ± 1.7	3.1 ± 1.7	0.76	1.3 ± 1.3	1.0 ± 1.7	0.59

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**TABLE 4. Characteristics and surgical variables for the most and least satisfied patients stratified by fusion versus laminectomy alone for grade 1 lumbar spondylolisthesis**

Variable	Fusion (n = 240)			Laminectomy Alone (n = 41)		
	Most Satisfied	Least Satisfied	p Value	Most Satisfied	Least Satisfied	p Value
Discharge disposition			0.94			NA
Home or home health care	195 (89.9%)	20 (87.0%)		34 (89.5%)	3 (100%)	
Not to home or home health care	22 (10.1%)	3 (13.0%)		4 (10.5%)	0 (0%)	
Readmission w/in 3 mos	8 (3.7%)	3 (13.0%)	0.13	1 (2.6%)	0 (0%)	NA
Reop w/in 12 mos	12 (5.5%)	3 (13.0%)	0.34	1 (2.6%)	0 (0%)	NA

NA = not applicable.

Percentages do not add up to 100% where responses were not given by participants.

\* A statistically significant relationship, alpha level 0.05.

† Chi-square comparison made using approach as a 2-level variable (posterior-only approach vs non-posterior-only approach).

prospective-registry study of 166 patients who had undergone lumbar spine surgery at a single center, it was found that depression, smoking, and employment status were significant predictors of patient satisfaction.<sup>4</sup> Other studies have shown worse satisfaction following lumbar spinal surgery in patients with depression<sup>14,24</sup> and smoking.<sup>3</sup> The literature has also shown the ASA class to predict patient satisfaction following lumbar spine surgery.<sup>15</sup> In a study by Mannion and colleagues, the percentage of patients satisfied with surgery was 87%, 85%, and 79% for preoperative ASA classes I, II, and III, respectively, indicating that higher ASA classes were associated with lower percentages of patient satisfaction. In contrast to these studies, our study focused only on patients with lumbar spondylolisthesis; thus, the differing pathology-specific factors may have contributed to the differences reported herein.

This study has several limitations, including those inherent to a large, multicenter registry. First, the data from a prospectively designed registry were analyzed retrospec-

tively; therefore, the findings are vulnerable to multiple confounding biases. As compared with the most satisfied cohort, the least satisfied cohort comprised a smaller number of patients. This reflects the real-world experience of surgeons providing surgery for degenerative lumbar spondylolisthesis but may limit the statistical power to detect significant differences between these 2 cohorts. Nonetheless, significant differences were found even with this limitation. We report initial 12-month outcomes here. Indeed, satisfaction is an outcome that can fluctuate with time. Longer-term study of this QOD cohort is important to identify any changes in satisfaction that may occur on extended follow-up. As a registry, there is no standardization of surgical decision making, surgical technique, or baseline patient characteristics. The observational nature of the study prevents identification of causal relationships between patient factors and satisfaction, though results can be suggestive. We defined surgeries as MI if the surgery used any of the following MI techniques: MI laminectomy, MI pedicle screws, MI interbody grafts, cortical screws, or percutaneous screws. Therefore, some surgeries classified as MI may have been partially MI and partially open. Our definition may have limited our ability to detect the impact of completely MI surgery on surgical outcomes for lumbar spondylolisthesis. For this study, baseline radiographic parameters and postoperative images were unavailable. Indeed, important preoperative (for example, dynamic instability, sagittal alignment) and postoperative (for example, fusion rates, progression or reduction of spondylolisthesis) radiographic parameters also likely affect outcomes of surgery for degenerative lumbar spondylolisthesis. Future studies should correlate these radiographic parameters to patient satisfaction. Lastly, the NASS Satisfaction Questionnaire does not have a clear option for patients to indicate that they were worse after surgery. Indeed, the NASS score 4 cohort (least satisfied) consists of patients who feel the same or worse after surgery, which could reflect a wide range of satisfaction. Future studies may consider a measure of satisfaction that includes a narrower definition of dissatisfaction, which could aid the identification of additional factors that predict satisfaction after surgery.

The findings in this study should be interpreted in the context of the above limitations. Still, it is important to

**TABLE 5. Multivariate analysis of most versus least satisfaction following fusion surgery for grade 1 lumbar spondylolisthesis**

Variable	Adjusted OR* (95% CI)	p Value
Female	3.33 (1.28–9.26)	0.02†
Private insurance	1.83 (0.70–4.96)	0.22
CAD	0.43 (0.14–1.38)	0.14
BMI	0.94 (0.86–1.01)	0.10
ASA class III or IV	0.99 (0.33–3.01)	0.98
MIS	2.43 (0.77–9.89)	0.16
Readmission w/in 3 mos	0.24 (0.05–1.38)	0.08
Baseline NRS-BP	0.85 (0.64–1.09)	0.22
Baseline ODI	0.98 (0.94–1.02)	0.34
Baseline EQ-5D	1.11 (0.07–17.00)	0.94

\* Represents odds predicting the most satisfaction relative to the least satisfaction. Covariates were adjusted for those variables that reached a significance value of  $p < 0.20$  on univariate analysis: sex, insurance, CAD, BMI, ASA class, MIS, readmission within 3 months, and baseline NRS-BP, ODI, and EQ-5D.

† Denotes a statistically significant relationship, alpha level 0.05.

**TABLE 6. Characteristics of patients undergoing surgery for grade 1 lumbar spondylolisthesis, stratified by satisfaction**

Variable	Most Satisfied	Intermediately Satisfied	Least Satisfied	p Value
No. of patients	255	97	26	
Mean age in yrs	63.4 ± 10.6	60.0 ± 12.1	63.0 ± 10.3	0.03*
Female	149 (58.4%)	58 (59.8%)	10 (38.5%)	0.13
Mean BMI in kg/m <sup>2</sup>	30.0 ± 6.0	31.2 ± 8.0	32.9 ± 6.5	0.06
Smoker	23 (9.0%)	8 (8.2%)	4 (15.4%)	0.52
Comorbidities				
Diabetes mellitus	52 (20.4%)	12 (12.4%)	7 (26.9%)	0.12
CAD	31 (12.2%)	8 (8.2%)	7 (26.9%)	0.04*
Anxiety	51 (20.0%)	17 (17.5%)	3 (11.5%)	0.54
Depression	59 (23.1%)	22 (22.7%)	3 (11.5%)	0.40
Osteoporosis	15 (5.9%)	5 (5.2%)	1 (3.8%)	0.89
Dominant presenting symptom				0.80
Pain predominant	100 (39.2%)	34 (35.1%)	12 (46.2%)	
Motor predominant	51 (20.0%)	18 (18.6%)	4 (15.4%)	
Sensory predominant	104 (40.8%)	45 (46.4%)	10 (38.5%)	
Motor deficit	56 (22.0%)	24 (24.7%)	8 (30.8%)	0.55
Independently ambulatory at presentation	231 (90.6%)	81 (83.5%)	22 (84.6%)	0.15
ASA class				0.57
I or II	145 (56.9%)	53 (54.6%)	12 (46.2%)	
III or IV	110 (43.1%)	44 (45.4%)	14 (53.8%)	
Type of insurance				0.31
Private	134 (52.5%)	53 (54.6%)	10 (38.5%)	
Medicare, Medicaid, or VA/government	121 (47.5%)	43 (44.3%)	16 (61.5%)	
Ethnicity				0.50
Hispanic or Latino	37 (14.5%)	18 (18.6%)	5 (19.2%)	
Not Hispanic or Latino	218 (85.5%)	75 (77.3%)	21 (80.8%)	
Level of education				0.01*
4-yr degree or more	112 (43.9%)	25 (25.8%)	9 (34.6%)	
<4-yr degree	136 (53.3%)	66 (68.0%)	17 (65.4%)	
Employment status				0.47
Employed or on leave	113 (44.3%)	38 (39.2%)	9 (34.6%)	
Not employed	138 (54.1%)	59 (60.8%)	16 (61.5%)	
Mean baseline PROs				
NRS-BP	6.6 ± 2.7	7.0 ± 2.4	7.4 ± 2.4	0.14
NRS-LP	6.5 ± 2.8	6.5 ± 2.8	6.7 ± 3.0	0.97
ODI	43.4 ± 15.5	46.5 ± 16.9	48.9 ± 20.0	0.10
EQ-5D	0.56 ± 0.20	0.50 ± 0.23	0.52 ± 0.22	0.12
Approach				0.80†
Posterior only	239 (93.7%)	89 (91.8%)	24 (92.3%)	
Anterior only	6 (2.4%)	4 (4.1%)	0 (0.0%)	
Lateral only	3 (1.2%)	1 (1.0%)	0 (0.0%)	
2-stage approach	7 (2.7%)	3 (3.1%)	2 (7.7%)	
MIS	85 (33.3%)	33 (34.0%)	7 (26.9%)	0.78
Laminectomy	239 (93.7%)	93 (95.9%)	24 (92.3%)	0.68
Fusion	217 (85.1%)	84 (86.6%)	23 (88.5%)	0.86
Mean EBL in ml	246.5 ± 248.9	271.5 ± 261.1	390.8 ± 629.6	0.06
Mean op time in mins	200.9 ± 86.1	186.0 ± 85.3	203.3 ± 101.3	0.34
Mean hospital LOS in days	3.1 ± 1.8	3.3 ± 1.9	2.8 ± 1.8	0.56

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**TABLE 6. Characteristics of patients undergoing surgery for grade 1 lumbar spondylolisthesis, stratified by satisfaction**

Variable	Most Satisfied	Intermediately Satisfied	Least Satisfied	p Value
Discharge disposition				0.10
Home or home health care	229 (89.8%)	79 (81.4%)	23 (88.5%)	
Not to home or home health care	26 (10.2%)	18 (18.6%)	3 (11.5%)	
Readmission w/in 3 mos	9 (3.5%)	8 (8.2%)	3 (11.5%)	0.08
Reop w/in 12 mos	13 (5.1%)	8 (8.2%)	3 (11.5%)	0.31

Values are expressed as the mean  $\pm$  standard deviation or as frequency (%). Percentages do not add up to 100% where responses were not given by participants or where 1 patient was uninsured in the intermediately satisfied group. Continuous variables were compared using a 1-way ANOVA, and categorical variables were compared using Pearson's chi-square test via custom and built-in scripts.

\* A statistically significant relationship, alpha level 0.05.

† Chi-square comparison made using approach as a 2-level variable (posterior-only approach vs non-posterior-only approach).

note that the study represents one of the largest, multi-institutional analyses to date to report on patients with grade 1 degenerative lumbar spondylolisthesis and thus provides important information about satisfaction as gleaned from real-world experience. Additionally, it is important to note that a greater proportion of patients in general undergoing surgery for spondylolisthesis reported high satisfaction postoperatively, as compared with those undergoing surgery for other lumbar pathologies, such as recurrent disc herniation, stenosis, adjacent segment degeneration, or mechanical disc collapse.<sup>7</sup> Thus, surgery for degenerative lumbar spondylolisthesis remains an important treatment option in well-selected patients.

## Conclusions

In adjusted analyses of 477 patients who underwent surgery for grade 1 degenerative lumbar spondylolisthesis, female sex was independently associated with the most satisfaction, 12 months following surgery. In univariate comparisons of the cohort with the most satisfaction and the cohort reporting the least satisfaction, the latter group had a higher mean BMI and a higher rate of CAD, a proxy for medical comorbidity. These findings highlight several key factors that may aid in expectation setting for patients considering surgery for degenerative lumbar spondylolisthesis.

## Acknowledgments

We thank all of the site research coordinators for their help with data extraction and validation. We also thank the Neurosurgery Research and Education Foundation for its financial support of this work (P.V.M.).

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## Disclosures

Dr. Bisson owns stock in NView. Dr. Glassman is an employee of Norton Healthcare and holds a patent with, has been a consultant for, and receives royalties from Medtronic. Dr. Foley has been a consultant for, receives royalties from, holds a patent with, and owns stock in Medtronic; owns stock in and holds a patent with NuVasive; owns stock in and is a member of the board of directors for Discgenics and TrueVision; and owns stock in Spine Wave. Dr. Potts has been a consultant for Medtronic. Dr. C. Shaffrey has been a consultant for Medtronic, NuVasive, and Zimmer-Biomet; owns stock in NuVasive; and holds patents with Medtronic, NuVasive, and Zimmer-Biomet. Dr. Coric has been a consultant for Spine Wave, Stryker, Medtronic, Globus Medical, and Premia Spine and owns stock in Spine Wave and Premia Spine. Dr. Knightly has a personal relationship with National Physicians Alliance board of directors. Dr. Park has been a consultant for Globus, Medtronic, NuVasive, and Zimmer-Biomet and receives royalties from Globus. Dr. Fu has been a consultant for SI-BONE. Dr. Slotkin has been a consultant for Stryker and Medtronic. Dr. Haid has been a consultant for, receives royalties from, and holds a patent with NuVasive; owns stock in SpineUniverse; receives royalties from and holds a patent with Medtronic Sofamor Danek; holds a patent with Globus Medical; and receives royalties from Elsevier Inc. Dr. Mummaneni has been a consultant for DePuy Spine, Globus, and Stryker; owns stock in Spinicity/ISD; receives royalties from DePuy Spine, Thieme, and Springer; and has received honoraria from AOSpine.

## Author Contributions

Conception and design: AK Chan, Bisson, Bydon, Glassman, Mummaneni. Acquisition of data: Virk, Kerezoudis, DiGiorgio. Analysis and interpretation of data: AK Chan, Bisson, Bydon, Kerezoudis, DiGiorgio, Mummaneni. Drafting the article: all authors. Critically revising the article: all authors. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: AK Chan. Statistical analysis: AK Chan, Virk, DiGiorgio. Administrative/technical/material support: Bisson, Bydon, Mummaneni. Study supervision: Bisson, Bydon, Mummaneni.

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