Assessing the differences in characteristics of patients lost to follow-up at 2 years: results from the Quality Outcomes Database study on outcomes of surgery for grade I spondylolisthesis

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OBJECTIVE Loss to follow-up has been shown to bias outcomes assessment among studies utilizing clinical registries. Here, the authors analyzed patients enrolled in a national surgical registry and compared the baseline characteristics of patients captured with those lost to follow-up at 2 years.

METHODS The authors queried the Quality Outcomes Database for patients with grade I lumbar degenerative spondylolisthesis undergoing a surgical intervention between July 2014 and June 2016. Only those patients enrolled in a multi-site study investigating the impact of fusion on clinical and patient-reported outcomes (PROs) among patients with grade I spondylolisthesis were evaluated.

RESULTS Of the 608 patients enrolled in the study undergoing 1- or 2-level decompression (23.0%, n = 140) or 1-level fusion (77.0%, n = 468), 14.5% (n = 88) were lost to follow-up at 2 years. Patients who were lost to follow-up were more likely to be younger (59.6 ± 13.5 vs 62.6 ± 11.7 years, $p = 0.031$), be employed (unemployment rate: 53.3% [n = 277] for successful follow-up vs 40.9% [n = 36] for those lost to follow-up, $p = 0.017$), have anxiety (26.1% [n = 23] vs 16.3% [n = 85], $p = 0.026$), have higher back pain scores (7.4 ± 2.9 vs 6.6 ± 2.8 , $p = 0.010$), have higher leg pain scores (7.4 ± 2.5 vs 6.4 ± 2.9 , $p = 0.003$), have higher Oswestry Disability Index scores (50.8 ± 18.7 vs 46 ± 16.8 , $p = 0.018$), and have lower EQ-5D scores (0.481 ± 0.2 vs 0.547 ± 0.2 , $p = 0.012$) at baseline.

CONCLUSIONS To execute future, high-quality studies, it is important to identify patients undergoing surgery for spondylolisthesis who might be lost to follow-up. In a large, prospective registry, the authors found that those lost to follow-up were more likely to be younger, be employed, have anxiety disorder, and have worse PRO scores.

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KEYWORDS follow-up; spondylolisthesis; Quality Outcomes Database; QOD; spine surgery; lumbar; registry; database

ABBREVIATIONS ASA = American Society of Anesthesiologists; NASS = North American Spine Society; NRS = numeric rating scale; ODI = Oswestry Disability Index; PRO = patient-reported outcome; QOD = Quality Outcomes Database.

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THE Affordable Care Act of 2010 introduced some important legislation in order to curb increasing healthcare costs.⁷ This legislation was primarily focused around promoting a more value-based care model of healthcare, which equates value to the quality of care delivered divided by the cost incurred.⁶ An important aspect of this effort was to encourage physicians, hospitals, and other stakeholders of healthcare to engage in critical research on quality and cost-effectiveness of treatment.²³ However, defining the quality in healthcare is challenging, and the resources and infrastructure for assessing it are not often available.³ To address this shortcoming, clinical registries have been heralded as a plausible platform to define, assess, and promote quality in healthcare.³

One of the key challenges in clinical registries is loss to follow-up or attrition, where a patient, after being enrolled in a study, has to be excluded from the final analysis due to missing outcomes assessments.¹² Loss to follow-up has been shown to bias the outcomes assessment of patients as well as reduce statistical power.^{16–20,29,30} Moreover, previous studies have shown that patients who are lost to follow-up in clinical trials may have worse outcomes than those who successfully complete follow-up.^{27,31} However, not much is known about the characteristics of patients enrolled in surgical registries who are lost to follow-up and how they differ from patients who successfully complete follow-up.

Herein, we analyzed patients with Meyerding grade I lumbar spondylolisthesis who underwent a surgical intervention and were enrolled in a clinical registry, and we compared the characteristics of patients lost to follow-up at 2 years with those who successfully underwent follow-up.

Methods

Cohort

For this study, the Quality Outcomes Database (QOD), formerly known as the National Neurosurgical Quality and Outcomes Database (N²QOD), was queried for patients undergoing surgery for Meyerding grade I degenerative lumbar spondylolisthesis between July 1, 2014, and June 30, 2016. The QOD is a prospective multi-institutional registry, established in 2012 with the objective of assessing risk-adjusted expected morbidity and 30-day and 12-month patient-reported outcomes (PROs) and clinical outcomes in order to establish a data-driven mechanism of providing insight into improving quality of care for routinely performed spine surgeries in the United States.^{19,25} As of February 2019, more than 78,879 patients undergoing any lumbar surgery for degenerative disease across 105 participating sites throughout the nation have been enrolled in the lumbar spine surgery QOD module.²⁸ Among these sites, the 12 highest-enrolling sites that were enrolling patients into the lumbar spine module came together to initiate a focused project to assess the impact of fusion on PROs in patients undergoing surgery for grade I lumbar spondylolisthesis.^{1,8,9,10,26} In order to determine the diagnosis of grade I spondylolisthesis, surgeons at each of the participating sites evaluated preoperative standing or dynamic radiographs.^{1,8,9,10,26} The primary outcome of in-

terest for this study was Oswestry Disability Index (ODI). Informed consent and institutional review board approval from the University of Utah were obtained.

Outcome of Interest

For the current study, the outcome of interest was the status of follow-up at 2 years, based on the availability of ODI data, the primary outcome of interest, and patients were categorized as either lost to follow-up or successfully captured.

Variables Compared

The following variables were included in the analyses for the current study:^{1,8,9,10,26} 1) demographic characteristics, including age, sex, BMI, ethnicity, insurance, education level, employment, and workers' compensation; 2) comorbidities, including smoking, diabetes, anxiety, osteoporosis, depression, and American Society of Anesthesiologists (ASA) classification; 3) clinical characteristics, such as symptom duration, dominant symptom, ambulation, and presence of motor deficit; and 4) baseline PROs, including ODI,¹⁴ EQ-5D,¹³ and numeric rating scale (NRS) for back and leg pain.²¹ Other surgical variables, such as intraoperative blood loss, operative time, interbody graft, and use of minimally invasive techniques, were also documented. A case was regarded as a minimally invasive procedure if there was documentation of utilization of percutaneous or tubular screw fixation or tubular laminectomy with or without intervertebral body graft placement.

Statistical Analysis

Continuous variables are summarized using means with SD, and categorical variables are summarized using frequencies with proportions. We also performed a multivariable analysis to predict loss to follow-up at 2 years after adjusting for a multitude of demographic, clinical, and comorbid characteristics and baseline PROs. All analyses were performed using the rms and Arsenal packages (<https://cran.r-project.org/web/packages/arsenal>) in R (version 3.3.1, R Foundation for Statistical Computing, www.R-project.org); p values were two-tailed and were considered significant at < 0.05.

Results

Patient Population and Follow-Up

A total of 608 patients across the 12 sites underwent surgical intervention for grade I spondylolisthesis. Of these, 141 (23.0%) underwent 1- or 2-level decompression alone, whereas 467 (77.0%) underwent 1-level decompression and fusion. At the 2-year follow-up, a total of 88 patients (14.5%) were lost to follow-up, while the remaining 520 patients (85.5%) were successfully followed up.

Demographic Characteristics

Patients who were lost to follow-up were slightly younger than those who were successfully followed up (59.6 ± 13.5 vs 62.6 ± 11.7 years, $p = 0.031$). Compared with patients who were successfully followed up, patients who were lost to follow-up were more likely to be em-

TABLE 1. Analysis of demographic characteristics between patients who were lost to follow-up and those who were successfully followed up

	Total	Lost to Follow-Up	Successfully Followed Up	p Value
No. of patients (%)	608	88 (14.5)	520 (85.5)	
Age in yrs, mean (SD)	62.2 (12.1)	59.6 (13.5)	62.6 (11.7)	0.031
Sex, n (%)				0.277
Female	350 (57.6)	46 (52.3)	304 (58.5)	
Male	258 (42.4)	42 (47.7)	216 (41.5)	
Insurance, n (%)				0.722
Medicaid	36 (5.9)	6 (6.8)	30 (5.8)	
Medicare	235 (38.7)	30 (34.1)	205 (39.4)	
Private	319 (52.5)	48 (54.5)	271 (52.1)	
Uninsured	1 (0.2)	0 (0.0)	1 (0.2)	
VA/government	17 (2.8)	4 (4.5)	13 (2.5)	
Workers' compensation, n (%)	27 (4.4)	5 (5.7)	22 (4.2)	0.533
BMI, mean (SD)	30.4 (6.4)	31.6 (5.9)	30.2 (6.4)	0.068
Ethnicity, n (%)				0.427
Hispanic	29 (4.8)	6 (6.8)	23 (4.4)	
Non-Hispanic	560 (92.1)	78 (88.6)	482 (92.7)	
Prefer not to answer	19 (3.1)	4 (4.5)	15 (2.9)	
Education, n (%)				0.564
4-yr college degree	121 (19.9)	17 (19.3)	104 (20.0)	
High school	238 (39.1)	39 (44.3)	199 (38.3)	
Less than high school	17 (2.8)	1 (1.1)	16 (3.1)	
Post-college	108 (17.8)	10 (11.4)	98 (18.8)	
Prefer not to answer	10 (1.6)	2 (2.3)	8 (1.5)	
2-yr college degree	109 (17.9)	18 (20.5)	91 (17.5)	
Employment, n (%)				0.017
Employed & working	244 (40.1)	41 (46.6)	203 (39.0)	
Employed but not working*	31 (5.1)	4 (4.5)	27 (5.2)	
Unemployed	313 (51.5)	36 (40.9)	277 (53.3)	

VA = Veterans Affairs.

Boldface type indicates statistical significance.

* For example, on disability leave.

ployed (unemployment rate: 53.3% [n = 277] for those with successful follow-up vs 40.9% [n = 36] for those lost to follow-up, $p = 0.017$ overall). The 2 groups did not differ in distribution of sex ($p = 0.277$), insurance status ($p = 0.722$), BMI ($p = 0.068$), ethnicity ($p = 0.427$), and education status ($p = 0.564$). These characteristics are presented in Table 1.

Comorbidity Status and Clinical Characteristics

Compared with patients who were successfully followed up, those lost to follow-up were more likely to have an anxiety disorder (26.1% [n = 23] vs 16.3% [n = 85], $p = 0.026$). We did not find any difference between the two groups in distribution of those on workers' compensation ($p = 0.533$), those with a history of major surgery in the past ($p = 0.5$), smoking status ($p = 0.179$), diabetes (0.848), coronary artery disease ($p = 0.954$), depression ($p = 0.136$), osteoporosis ($p = 0.812$), dominant symptom ($p =$

0.116), motor deficit at the time of presentation ($p = 0.808$), ambulation status ($p = 0.090$), and symptom duration ($p = 0.376$). These results are summarized in Table 2.

Operative Characteristics

The proportion of patients undergoing laminectomy alone and laminectomy and fusion was found to be similar between the two groups (laminectomy and fusion: 75% [n = 66] in those lost to follow-up vs 77.3% [n = 402], $p = 0.634$). Moreover, we did not find any difference between the two groups in terms of ASA class ($p = 0.626$), surgical approach ($p = 0.053$), proportion of patients undergoing minimally invasive decompression ($p = 0.758$), proportion of patients undergoing minimally invasive fusion ($p = 0.260$), estimated blood loss ($p = 0.212$), length of surgery ($p = 0.280$), length of stay ($p = 0.333$), or discharge disposition ($p = 0.501$). These results are summarized in Table 3.

TABLE 2. Analysis of comorbid status and clinical characteristics between patients who were lost to follow-up and those who were successfully followed up

	Total	Lost to Follow-Up	Successfully Followed Up	p Value
	608	88	520	
Any major surgery in the past	70 (11.5)	12 (13.6)	58 (11.2)	0.500
Smoking status	71 (11.8)	14 (16.1)	57 (11.1)	0.179
Diabetes	101 (16.6)	14 (15.9)	87 (16.7)	0.848
CAD	68 (11.2)	10 (11.4)	58 (11.2)	0.954
Anxiety	108 (17.8)	23 (26.1)	85 (16.3)	0.026
Depression	123 (20.2)	23 (26.1)	100 (19.2)	0.136
Osteoporosis	38 (6.2)	6 (6.8)	32 (6.2)	0.812
Dominant symptom				0.116
Back dominant	230 (37.8)	35 (39.8)	195 (37.5)	
Leg dominant	131 (21.5)	25 (28.4)	106 (20.4)	
Leg equals back	247 (40.6)	28 (31.8)	219 (42.1)	
Motor deficit	139 (22.9)	22 (25.0)	117 (22.5)	0.808
Ambulation				0.090
Independent	537 (88.3)	73 (83.0)	464 (89.2)	
Not independent	71 (11.7)	15 (17.0)	56 (10.8)	
Symptom duration				0.376
>3 mos	571 (93.9)	82 (93.2)	489 (94.0)	
<3 mos	15 (2.5)	1 (1.1)	14 (2.7)	

CAD = coronary artery disease.

Values are presented as number of patients (%). Boldface type indicates statistical significance.

TABLE 3. Analysis of operative characteristics between patients who were lost to follow-up and those who were successfully followed up

	Total (n = 608)	Lost to Follow-Up (n = 88)	Successfully Followed Up (n = 520)	p Value
ASA class, n (%)				0.626
I or II	346 (56.9)	47 (53.4)	299 (57.5)	
III or IV	237 (39.0)	36 (40.9)	201 (38.7)	
Surgical approach, n (%)				0.053
Anterior only	17 (2.8)	3 (3.4)	14 (2.7)	
Lateral only	7 (1.2)	0 (0.0)	7 (1.3)	
Posterior only	559 (91.9)	83 (94.3)	476 (91.5)	
2-stage	24 (3.9)	1 (1.1)	23 (4.4)	
Group, n (%)				0.634
Laminectomy alone	140 (23.0)	22 (25.0)	118 (22.7)	
Laminectomy & fusion	468 (77.0)	66 (75.0)	402 (77.3)	
MIS decompression, n (%)	226 (37.2)	34 (38.6)	192 (36.9)	0.758
MIS fusion, n (%)	157 (25.8)	27 (30.7)	130 (25.0)	0.260
Estimated blood loss, mean (SD)	185.9 (200.6)	161.2 (168.5)	190.3 (205.4)	0.212
Length of surgery, mean (SD)	176.2 (85.6)	167.1 (86.1)	177.8 (85.5)	0.280
Length of stay, mean (SD)	2.7 (1.8)	2.6 (1.8)	2.7 (1.8)	0.333
Discharge disposition, n (%)				0.501
Home	516 (84.9)	72 (81.8)	444 (85.4)	
Not home	89 (14.6)	15 (17.0)	74 (14.2)	

MIS = minimally invasive surgery.

Patient-Reported Outcomes

Compared with patients who were successfully followed up, those lost to follow-up were more likely to have higher back pain NRS scores (7.4 ± 2.9 vs 6.6 ± 2.8 , $p = 0.010$), higher leg pain NRS scores (7.4 ± 2.5 vs 6.4 ± 2.9 , $p = 0.003$), higher ODI scores (50.8 ± 18.7 vs 46 ± 16.8 , $p = 0.018$), and lower EQ-5D scores (0.481 ± 0.2 vs 0.547 ± 0.2 , $p = 0.012$) at baseline.

We also evaluated the 3-month and 12-month outcomes of these patients. Of those who were lost to follow-up at 2 years, 80.7% ($n = 71$) had 3-month outcomes, while among those who were captured successfully at 2 years, 88.7% ($n = 461$) had available 3-month outcomes. Patients who were lost to follow-up had a significantly greater change in 3-month EQ-5D scores (0.329 ± 0.317 vs 0.220 ± 0.293 , $p = 0.005$). We observed no difference in 3-month ODI scores, change in 3-month ODI scores, 3-month NRS back pain scores, change in 3-month NRS back pain scores, 3-month NRS leg pain scores, change in 3-month NRS leg pain scores, 3-month EQ-5D scores, North American Spine Society (NASS) patient satisfaction at 3 months, and return to work at 3 months. We also observed no difference between the two groups for back pain, leg pain, ODI score, EQ-5D, and patient satisfaction at 12 months. These results are summarized in Table 4.

Multivariable Analysis to Predict Loss to Follow-Up at 2 Years

A multivariable logistic regression analysis was fit to identify factors associated with loss to follow-up at 2 years. We found that active employment, compared with unemployment, was associated with lower odds of being successfully captured at 2 years (OR 0.48, 95% CI 0.23–0.99; $p = 0.038$) (Fig. 1).

Discussion

In the current study of patients with Meyerding grade I spondylolisthesis undergoing surgical management, we found that 88 (14.5%) were lost to follow-up at 2 years. Moreover, we found that patients lost to follow-up at 2 years were more likely to be younger, be employed, have an anxiety disorder, and have worse scores on PRO measures at baseline.

Loss to follow-up poses a threat to the validity of the results in prospective studies.¹² Experts in evidence-based medicine have stated that a loss to follow-up rate of greater than 20% may significantly bias the results.²⁴ In our cohort, 14.5% patients were lost to follow-up, thus increasing the confidence in our overall results and preventing significant bias to be introduced in the study. Moreover, even without a significantly higher proportion of patients who were lost to follow-up, a differential loss to follow-up may still bias outcomes. In most cases, differential loss to follow-up is said to occur if patients in one of the groups stratified by the primary predictor of interest may be at a higher “differential” risk of loss to follow-up. In our cohort, we found that those who were lost to follow-up did not differ significantly in terms of our primary predictor of interest, i.e., the proportion of patients undergoing laminectomy alone versus laminectomy and fusion.

We found that demographic characteristics may be associated with a higher likelihood of patients being lost to follow-up. In our cohort, those lost to follow-up were more likely to be younger and employed at the time of surgery. These results agree with those presented by Solberg et al. in their experience with the Norwegian Registry for Spine Surgery (NORspine), who found that patients who did not return for follow-up or return a postal questionnaire were more likely to be younger and also more likely to be working full time at the time of surgery.³² It is important to highlight that even patients on Medicaid were successfully followed up to 2 years (30/36 or 83.3%). This subset of patients has been shown to be at a higher risk of being lost to follow-up in previous studies.¹¹ Successful follow-up of such patients speaks to the value of having a strong infrastructure in the form of a national registry, which may guide future prospective multiinstitutional research studies.

We also found that patients with anxiety disorder were more likely to be lost to follow-up. Bair et al. followed 3623 patients for 2.8 years who presented with pain due to a temporomandibular disorder in the Orofacial Pain: Prospective Evaluation and Risk Assessment (OPPERA) study and found that patients who were lost to follow-up (16%) were more likely to perform poorly on the baseline psychological questionnaire.⁵ On the other hand, Solberg et al. in the NORspine study found no difference between the two groups in terms of anxiety and/or depression.³²

In terms of PROs, we found that patients lost to follow-up were more likely to have higher back pain scores, higher leg pain scores, and worse ODI and EQ-5D scores than those who were successfully followed up. While these results may indicate a relatively more severe state of disease and poorer quality of life at baseline, previous studies have shown that PRO scores at baseline may not be significantly associated with long-term outcomes.⁴ We also found that patients who were lost to follow-up had significantly greater improvement in their quality of life at 3 months, as evident by the greater change in EQ-5D scores at 3 months, compared with those who were successfully followed up. This finding, along with younger age and active employment among those who were lost to follow-up in our cohort, may be indicative of the fact that younger patients with more physiological reserve and capacity to improve may be at risk of being lost to follow-up and should thus be counseled appropriately preoperatively regarding the importance of following up with the provider team. This should involve a discussion regarding how this follow-up information may help the community at large by guiding physicians and other stakeholders to identify effective care treatments and rethink less effective ones.

Finally, a discussion regarding preventing and mitigating loss to follow-up in such clinical registries is also warranted. Some of the most crucial aspects of starting and maintaining a clinical registry are to have a clear definition of the target population and the availability of resources at each participating institution.¹⁵ Moreover, Klaiman et al. identified 6 key characteristics for maintaining a successful clinical registry; one of these is “accuracy/completeness of data,” for which other authors have stated,

TABLE 4. Analysis of PROs at baseline and at 3 and 12 months between patients who were lost to follow-up and those who were successfully followed up

	Total (n = 608)	Lost to Follow-Up (n = 88)	Successfully Followed Up (n = 520)	p Value
Baseline Measures				
ODI, mean (SD)	46.7 (17.2)	50.8 (18.7)	46 (16.8)	0.018
NRS back pain, mean (SD)	6.7 (2.8)	7.4 (2.9)	6.6 (2.8)	0.010
NRS leg pain, mean (SD)	6.6 (2.8)	7.4 (2.5)	6.4 (2.9)	0.003
EQ-5D, mean (SD)	0.537 (0.2)	0.481 (0.2)	0.547 (0.2)	0.012
3-Mo Outcomes				
ODI, mean (SD)	26.357 (19.324)	26.746 (19.253)	26.297 (19.355)	0.855
Change in ODI, mean (SD)	26.357 (19.324)	24.942 (29.892)	19.563 (26.367)	0.121
NRS back pain, mean (SD)	20.268 (26.886)	24.942 (29.892)	19.563 (26.367)	0.588
Change in NRS back pain, mean (SD)	3.071 (2.644)	3.232 (2.635)	3.047 (2.648)	0.356
NRS leg pain, mean (SD)	3.528 (3.722)	3.935 (3.991)	3.468 (3.682)	0.691
Change in NRS leg pain, mean (SD)	2.278 (2.866)	2.406 (2.820)	2.259 (2.876)	0.095
EQ-5D, mean (SD)	0.760 (0.192)	0.770 (0.179)	0.759 (0.194)	0.645
Change in EQ-5D score, mean (SD)	0.235 (0.298)	0.329 (0.317)	0.220 (0.293)	0.005
NASS satisfaction, n (%)				0.067
1	383 (72.1)	44 (63.8)	339 (73.4)	
2	90 (16.9)	18 (26.1)	72 (15.6)	
3	25 (4.7)	5 (7.2)	20 (4.3)	
4	33 (6.2)	2 (2.9)	31 (6.7)	
Return to work (among preoperatively employed), n (%)	81/275 (29.5)	12/45 (26.7)	69 (30.0)	
12-Mo Outcomes				
ODI, mean (SD)	22.072 (19.868)	25.442 (22.831)	21.726 (19.537)	0.238
Change in ODI, mean (SD)	24.338 (19.601)	25.445 (22.209)	24.225 (19.339)	0.695
NRS back pain, mean (SD)	2.880 (2.723)	3.375 (2.924)	2.833 (2.703)	0.229
Change in NRS back pain, mean (SD)	3.800 (3.181)	4.086 (3.320)	3.773 (3.171)	0.578
NRS leg pain, mean (SD)	2.332 (2.978)	2.625 (3.184)	2.304 (2.960)	0.515
Change in NRS leg pain, mean (SD)	2.332 (2.978)	2.625 (3.184)	2.304 (2.960)	0.515
EQ-5D score, mean (SD)	0.775 (0.205)	0.760 (0.219)	0.776 (0.203)	0.631
Change in EQ-5D score, mean (SD)	-0.230 (0.242)	0.266 (0.262)	0.227 (0.240)	0.302
NASS satisfaction, n (%)				0.340
1	306 (66.2)	24 (58.5)	282 (67.0)	
2	87 (18.8)	11 (26.8)	76 (18.1)	
3	39 (8.4)	2 (4.9)	37 (8.8)	
4	30 (6.5)	4 (9.8)	26 (6.2)	

Boldface type indicates statistical significance.

“robust methods need to be in place in order to minimize the amount of missing data and support meticulous follow-up efforts, particularly for patients who travel out of state for further evaluation or treatment.”²⁰ In that regard, the QOD has a well-defined plan for each of its participating members. For enrolling and following patients, all data extractors and site coordinators are required to undergo extensive training on data entry and standard operating procedures that have been outlined in the QOD infrastructure.^{2,19} The first 6 patients who are found to satisfy the pre-specified eligibility criteria are identified from the weekly posted surgical schedule. After that, these patients are then

contacted either in person at a clinic or by phone and the health status is assessed using an established framework. Each of the participating sites is informed weekly of missing data. In addition, periodic surgeon-led self-audits of data as well as random audits are performed to ensure data completeness and accuracy.³ These checks and balances are necessary to maintain the integrity of the data as well as minimizing loss to follow-up of patients who are included. Ultimately, the most critical role of such registries is to curb healthcare costs, by identifying effective care protocols and eliminating cost-intensive practices. For instance, Larsson et al. studied 13 registries from 5 countries, in-

FIG. 1. Multivariable model to identify factors associated with loss to follow-up at 2 years. Hx = history; MIS = minimally invasive surgery. Figure is available in color online only.

cluding the US, and suggested that by making outcomes data available and transparent to the public and providers, well-maintained registries may provide an opportunity to healthcare providers to engage in active learning and adapt evidence-based best clinical practices.²²

Limitations

Our study may have some limitations. Due to its multi-institutional design, there may be some unknown region-specific or site-specific factors that play a role in patients being lost to follow-up. Also, patients from 12 sites participating in the QOD were included in the current study. We acknowledge that there are numerous other sites in the QOD, and the generalizability of our findings reported here remains to be assessed. Moreover, it is crucial not only to investigate reasons why patients are lost to follow-up, but also to make an effort to investigate the longer-term outcomes of those who are lost to follow-up. Finally, we acknowledge that study coordinators have an important

role in ensuring follow-up for a registry, and factors pertaining to time commitment for coordinators and contact protocols may also have an impact on follow-up. Nevertheless, our study is one of the largest to date that has investigated the characteristics at baseline among patients who are lost to follow-up. Further investigation is required to validate our findings for other diagnoses and other spinal procedures.

Conclusions

In order to execute better-designed studies in the future, it is important to investigate the characteristics of patients who may be lost to follow-up in the long term. In this study of patients with Meyerding grade I spondylolisthesis undergoing surgical intervention and enrolled in a national clinical registry, we found that patients who were lost to follow-up at 2 years were more likely to be younger, be employed, have an anxiety disorder, and have worse scores on PRO measures.

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Disclosures

Dr. Bisson: consultant for nView, MiRus, and Stryker. Dr. Mummaneni: consultant for Globus, DePuy Synthes, and Stryker; direct stock ownership in Spinicity/ISD; clinical or research support for this study from NREF; support of non-study-related clinical or research effort from ISSG; honoraria from Spineart; and royalties from DePuy Synthes, Thieme Publishers, and Springer Publishers. Dr. Knightly: NPA board member. Dr. Chan: support of non-study-related clinical or research effort from Orthofix. Dr. Glassman: employee of Norton Healthcare; consultant for K2M and Medtronic; patent holder with Medtronic; clinical or research support for this study from NuVasive; royalties from Medtronic; chair of the American Spine Registry; and past president of the Scoliosis Research Society. Dr. Foley: consultant for Medtronic; direct stock ownership in Digital Surgery Systems, Discgenics, DuraStat, LaunchPad Medical, Medtronic, NuVasive, nView Medical, Practical Navigation/Fusion Robotics, SpineWave, TDi, and Triad Life Sciences; patent holder with Medtronic and NuVa-

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Author Contributions

Conception and design: Bydon, Bisson, Alvi. Acquisition of data: Alvi, Chan. Analysis and interpretation of data: Alvi, Chan. Drafting the article: Alvi, Chan, Biase. Critically revising the article: Bisson, Alvi, Goyal, Chan, Guan, Biase, Strauss, Glassman, Foley, Slotkin, Potts, M Shaffrey, CI Shaffrey, Haid, Wang, Park, Asher. Reviewed submitted version of manuscript: all authors.

Approved the final version of the manuscript on behalf of all authors: Bydon. Statistical analysis: Alvi, Fu. Administrative/technical/material support: Bydon, Bisson, Mummaneni, Knightly. Study supervision: Bydon, Bisson, Mummaneni, Knightly.

Supplemental Information

Previous Presentations

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