An analysis from the Quality Outcomes Database, Part 2. Predictive model for return to work after elective surgery for lumbar degenerative disease

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OBJECTIVE Current costs associated with spine care are unsustainable. Productivity loss and time away from work for patients who were once gainfully employed contributes greatly to the financial burden experienced by individuals and, more broadly, society. Therefore, it is vital to identify the factors associated with return to work (RTW) after lumbar spine surgery. In this analysis, the authors used data from a national prospective outcomes registry to create a predictive model of patients' ability to RTW after undergoing lumbar spine surgery for degenerative spine disease.

METHODS Data from 4694 patients who underwent elective spine surgery for degenerative lumbar disease, who had been employed preoperatively, and who had completed a 3-month follow-up evaluation, were entered into a prospective, multicenter registry. Patient-reported outcomes—Oswestry Disability Index (ODI), numeric rating scale (NRS) for back pain (BP) and leg pain (LP), and EQ-5D scores—were recorded at baseline and at 3 months postoperatively. The time to RTW was defined as the period between operation and date of returning to work. A multivariable Cox proportional hazards regression model, including an array of preoperative factors, was fitted for RTW. The model performance was measured using the concordance index (c-index).

RESULTS Eighty-two percent of patients (n = 3855) returned to work within 3 months postoperatively. The risk-adjusted predictors of a lower likelihood of RTW were being preoperatively employed but not working at the time of presentation, manual labor as an occupation, worker's compensation, liability insurance for disability, higher preoperative ODI score, higher preoperative NRS-BP score, and demographic factors such as female sex, African American race, history of diabetes, and higher American Society of Anesthesiologists score. The likelihood of a RTW within 3 months was higher in patients with higher education level than in those with less than high school–level education. The c-index of the model's performance was 0.71.

ABBREVIATIONS ASA = American Society of Anesthesiologists; BMI = body mass index; BP = back pain; CAD = coronary artery disease; CI = confidence interval; HR = hazard ratio; IQR = interquartile range; LP = leg pain; NRS = numeric rating scale; ODI = Oswestry Disability Index; PRO = patient-reported outcome; QOD = Quality and Outcomes Database; QOL = quality of life; RTW = return to work.

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CONCLUSIONS This study presents a novel predictive model for the probability of returning to work after lumbar spine surgery. Spine care providers can use this model to educate patients and encourage them in shared decision-making regarding the RTW outcome. This evidence-based decision support will result in better communication between patients and clinicians and improve postoperative recovery expectations, which will ultimately increase the likelihood of a positive RTW trajectory.

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KEY WORDS QOD; Quality Outcomes Database; patient-reported outcomes; return to work; RTW; lumbar; surgery; degenerative

Low-back pain associated with degenerative spine disease is the leading and most costly cause of work-related disability in the US.^{42,45,60,66,67} Among those gainfully employed, approximately 26 million individuals report frequent low-back pain, and of that number 8% become disabled in any given year; this annual disability is responsible for 40% of all lost workdays.^{20,26,30} This disability results in an estimated \$30 billion in direct medical costs due to back-related health care resource utilization^{42,63} and up to \$20 billion annually in indirect costs due to lost productivity.²

A considerable number of patients require surgery for lumbar degenerative conditions to restore functional and work-related capacity.^{1,17,62,67} Several prospective and randomized controlled trials have shown the efficacy of surgical treatment,^{1,17,65,67} but other studies have demonstrated that up to 25% of patients experience minimal improvement in quality of life (QOL),^{46,58,52} and up to 10% experience a major complication or require hospital readmission after surgery.^{10,14,25,38} Return to work (RTW) is an important functional outcome measure.²⁸ The time away from work and the individual's diminished work capacity after spine surgery create a significant individual and societal financial burden.^{11,15,55,60,63} Studies have demonstrated wide variability in disability and RTW rates following lumbar spine surgery, with permanent or temporary disability ranging from 18% to 68% and a RTW rate ranging from 41% to 81%.^{24,29,43,51,54} Therefore, identifying the preoperative factors associated with RTW will help employers, payers, and providers understand the variability in RTW outcomes.

In the current era of patient-centered care, engaging patients in shared decision-making in their treatment planning is of utmost importance. Shared decision-making is defined as a process "involving the patient and provider, both parties participating in the treatment decision-making process, requiring information sharing, and both parties agreeing to the treatment decision made."^{13,19} The concept of informed, shared decision-making was first popularized in a report issued by the President's Commission for the Study of Ethical Problems in Medicine and Biomedical and Behavioral Research in 1982.¹⁹ True informed decision-making is only achievable if patients are provided with the factual probability of outcomes based on their individual risk factors. The ability to predict RTW, based on preoperative patient-specific and surgery-specific factors, will allow surgeons to have substantive personalized discussion with patients. This will promote realistic expectations among patients, family members, payers, and employers regarding RTW after surgery.³⁵

However, to date, a validated prediction model capable of providing individualized estimations of RTW following elective lumbar spine surgery has yet to be introduced. Utilizing the Quality Outcomes Database (QOD), we aimed to create a clinically relevant predictive model for RTW following elective lumbar spine surgery for degenerative spine pathologies.

Methods

The QOD Registry

Data from patients undergoing elective spine surgery for degenerative lumbar disease were entered into the prospective multicenter QOD registry over a 2-year period. QOD is designed to establish risk-adjusted expected morbidity rates for the most common lumbar surgical procedures performed by spine surgeons.^{5,7} The QOD registry enrolls spine surgery patients from 74 participating centers across 26 US states via representative sampling and collects measures of surgical safety and patient-reported outcomes (PROs). A detailed account of QOD enrollment methodologies has been outlined in previous publications.^{6,7}

Inclusion and Exclusion Criteria

Patients undergoing lumbar surgery performed for primary stenosis, spondylolisthesis, disc herniation, symptomatic mechanical disc collapse, and revision surgery, including recurrent same-level disc herniation and adjacent-segment disease, were eligible for inclusion. Reasons for exclusion included spinal infection, tumor, fracture, traumatic dislocation, deformity, pseudarthrosis, recurrent multilevel stenosis, and neurological paralysis due to pre-existing spinal disease or injury, age less than 18 years, and incarceration.

Demographic Variables

We recorded the following patient demographic variables when reviewing electronic medical records from the QOD registry: age, gender, body mass index (BMI), American Society of Anesthesiologists (ASA) grade, history of surgery, history of diabetes, coronary artery disease (CAD), osteoporosis, dominant presenting symptom, presence of motor deficit on examination, symptom duration, diagnosis, preoperative ambulatory status, and surgery-specific variables including approach (anterior or posterior), number of levels involved, need for fusion, and presence/absence of an interbody graft. Patient-reported variables, recorded via patient interview and confirmed

through the electronic medical records, were as follows: race, smoking status, anxiety, depression, education, employment status, preoperative employment but not working at the time of surgery (employed patients were further dichotomized as either employed and working at the time of surgery, or employed but not working at the time of surgery), type of occupation (sedentary job, light manual labor job, medium labor, and heavy labor job), workers' compensation, liability insurance, and health insurance status (uninsured, private insurance, uninsured, Medicare, Medicaid, or Veterans Affairs/government).

Interviews and PRO Questionnaires

Baseline (preoperative) and 3-month assessments were conducted either through phone interviews conducted by a data coordinator not involved with clinical care or through self-administration, either during clinic visit or by mail.^{7,48} Interviewers gathered data on employment status and on disability, pain, and QOL. Patients who were employed preoperatively were asked at 3 months whether "they were able to RTW after surgery?" If they responded "yes," they were asked to specify "the date of returning to work" at the 3-month follow-up interview, and the time to RTW was defined as the period spanning the date of the operation and the date on which patients returned to work. Patients responding "no" were considered right-censored on the day of interview. Validated PRO questionnaires were used to collect data on additional outcome measures: 1) disease-specific physical disability (established using the Oswestry Disability Index [ODI]);^{22,23} 2) preference-based QOL status, established using the EQ-5D instrument;²¹ and 3) pain, established using the numeric rating scale (NRS) for back pain (BP) and leg pain (LP).⁴¹ The outcome scores were then entered into a national aggregate database through a secure password-protected web-based portal (Research Electronic Data Capture).³³ At the time of analysis, 48 of 74 total sites had crossed the 3-month patient follow-up timeline and were included in the analysis.

Statistical Analysis

Analysis of prospectively collected data was conducted. Medians and interquartile ranges (IQRs) for continuous variables and frequencies for categorical variables were computed for patient-specific and surgery-specific variables. A multivariable Cox proportional hazards regression model was fitted on an array of patient-specific factors for time to RTW. The variables included in the model were age; gender; race; smoking status; employment; occupation type; number of spinal levels; ASA grade; BMI; diabetes; osteoporosis; CAD; education level; anxiety; depression; dominant symptom; motor deficit; symptom duration; principal spinal diagnosis; workers' compensation; liability insurance for disability; insurance type; ambulatory status; lumbar fusion, anterior, posterior or combined approach; and preoperative ODI, EQ-5D, and NRS-BP/LP scores. We assumed a linear relationship for the surgical level operated on (Level 1–4), and a smooth relationship for other continuous variables using restricted cubic regression splines with 4 knots for age and BMI and 3 knots for preoperative disability, QOL, and pain scores

(the location of knots was chosen based on the upper and lower quartiles for that variable). All the other predictors were included as binary or categorical variables. The effects of predictors on the likelihood of patients returning to work were reported as the hazard ratio (HR) and the corresponding confidence interval (CI) was calculated using Wald statistics. The HRs for the continuous variables in the model were computed using the upper and lower quartile values; p values represent the overall effect over the whole range of the continuous variable. The importance of the individual predictor to the RTW outcome was computed using the following formula: Wald chi-square value minus predictor degree of freedom.

The higher the difference, the higher is the importance of that predictor in the model. The calibration and discrimination of the model was internally validated using the bootstrap resampling to estimate the likely performance of the model on a new sample of patients. The model performance was measured by concordance index (c-index). A c-index of 0.5 is considered a random predication and value of 1 suggests that the model is perfectly discriminating.^{31,32} A 2-sided p value less < 0.05 was considered statistically significant. The analysis was performed using the R statistical program (version 3.1.2, www.r-project.org).

Results

Of a total of 14,985 patients undergoing elective spine surgery for degenerative lumbar disease, 6895 patients (46%) were preoperatively employed and had plans to RTW after surgery. Of those, 5147 patients (75%) completed a 3-month interview, and the 4694 patients (68%) who provided information on RTW form the basis of the current analyses. Eighty-two percent of patients (n = 3855) returned to work within 3 months of surgery.

Patient Demographics and Surgical Characteristics

The median age of the 4694 patients in the study cohort was 52 years (IQR 41–60 years), and 2768 (59%) were male. Nineteen percent (n = 877) of patients were current smokers, and 12% (n = 545) had diabetes at the time of surgery. Median BMI of the cohort was 29.4 (IQR 25.8–34). Thirty-six percent of patients (n = 1696) had leg-dominant symptoms, 18% (n = 839) had back-dominant symptoms, and 46% of patients (n = 2159) had both leg- and back-dominant symptoms. Ninety-three percent of patients (n = 4123) were ambulatory at the time of surgery, and 6% (n = 283) were ambulatory with an assistive device. With regards to diagnosis, 52% (n = 2437) had a disc herniation, 23% (n = 1062) lumbar stenosis, 15% (n = 720) lumbar spondylolisthesis, 7% (n = 339) recurrent disc herniation, 2% (n = 96) adjacent-segment disease, and 0.6% (n = 30) had symptomatic mechanical disc collapse. A history of lumbar surgery was noted in 8% (n = 389) of patients. Twenty-six percent of patients (n = 1232) underwent lumbar fusion surgery. Tables 1 and 2 summarize the patient-specific and surgery-specific variables included in the model for RTW.

Predictive Model for RTW

In a multivariable Cox proportional hazards regression

TABLE 1. Characteristics of patients in the study cohort

Variable	Value
No. of patients	4694
Median age in yrs	52 (41–60)†
% male sex	59 (2768)
Median BMI	29.4 (25.8–34)†
Hispanic	3% (121)
Race	
White	91% (4246)
African American	6% (302)
Other	3% (146)
Education	
< High school	2% (99)
High school diploma	39% (1791)
2-yr college degree	19% (887)
4-yr college degree	24% (1127)
Post-college	16% (748)
Past surgery	8% (389)
Smoker	19% (877)
Diabetes	12% (545)
CAD	6% (269)
Osteoporosis	2% (87)
Anxiety	18% (726)
Depression	18% (726)
Dominant symptom	
Back dominant	18% (839)
Leg dominant	36% (1696)
Back = leg*	46% (2159)
Motor deficit	27% (1244)
Symptom duration	
<3 mos	16% (757)
>3 mos	84% (3884)
Diagnosis	
Disc herniation	52% (2437)
Recurrent disc herniation	7% (339)
Spondylolisthesis	15% (720)
Stenosis	23% (1062)
Adjacent-segment disease	2% (96)
Symptomatic mechanical disc collapse	0.6% (30)
Ambulation	
Independent	93% (4123)
With an assist device	6% (283)
Wheelchair bound (nonambulatory)	0.5% (23)
Occupation	
Sedentary	33% (1554)
Light	24% (1130)
Medium	23% (1083)
Heavy	20% (927)
Workers' compensation	4% (204)
Liability	4% (204)

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TABLE 1. Characteristics of patients in the study cohort

Variable	Value
Insurance status	
Uninsured	0.9% (40)
Medicare	8% (371)
Medicaid	2% (99)
Veterans Affairs/government	3% (120)
Private	87% (4058)
PROs	
ODI score	46 (36–56)†
EQ-5D score	0.60 (0.38–0.77)†
NRS-BP score	7 (4–8)†
NRS-LP score	7 (5–9)†

* Indicates pain is both leg and back dominant.

† Values presented as the median (IQR).

model, after adjusting for patient- and surgery-specific variables (Fig. 1), the likelihood of returning to work at 3 months after surgery was significantly higher in patients with a higher education level ($p < 0.001$, for patients with postcollege degree vs less than high school education).

The likelihood of returning to work was significantly lower in female versus male patients ($p < 0.001$), African American versus white patients ($p < 0.001$), patients with diabetes versus those without a history of diabetes ($p = 0.0069$), and those with preoperative symptom duration greater than 3 months versus less than 3 months ($p = 0.0007$). With regard to diagnosis, the probability of returning to work within 3 months of surgery did not differ for the diagnosis of stenosis, recurrent disc herniation,

TABLE 2. Surgical variables included in the model

Variable	% (value)
No. of patients	4694
ASA score	
1	13 (588)
2	65 (3018)
3/4	23 (1059)
No. of fused levels	
1	42 (1837)
2	46 (2022)
3	10 (440)
4	3 (113)
Approach	
Posterior	98 (4540)
Anterior	2 (80)
Fusion	
No	74 (3456)
Yes, interbody graft not used	4 (204)
Yes, interbody graft used	22 (1028)

FIG. 1. Adjusted effect of predictors of RTW computed using a multivariable Cox proportional hazards regression model. All the variables in Tables 1 and 2 were included in the model. The HRs for the continuous variables (age, BMI, ODI, EQ-5D, NRS-LP and NRS-BP) in the model were computed based on the upper and lower quartile values. Figure is available in color online only.

spondylolisthesis, adjacent-segment disease, or symptomatic mechanical disc collapse compared with disc herniation. The patients who were preoperatively employed but not actively working at the time of presentation ($p < 0.001$), those employed in manual labor compared with those with a sedentary occupation ($p < 0.0001$), those receiving workers' compensation ($p < 0.001$), and those on liability insurance for disability ($p < 0.001$) had a lower likelihood

of returning to work. The patients with higher preoperative NRS-BP scores had a lower likelihood of returning to work within 3 months of surgery ($p = 0.0265$). Similarly, patients with higher preoperative ODI scores had lower likelihood of returning to work within 3 months of surgery ($p = 0.0031$). The likelihood of RTW was also lower for the patients with a higher ASA score ($p = 0.0022$; ASA score of 2 vs 1 and a score of 3/4 vs 1) and those undergo-

FIG. 2. Importance of predictors, measured by Wald chi-square minus the predictor degree of freedom (df). The relative importance of predictors in the model ($\% \chi^2 - df$) is listed on the right.

ing fusion compared with those undergoing decompression alone ($p < 0.001$).

Fig. 2 displays the adjusted importance of each predictive factor included in the model. The most important predictors of RTW 3 months postoperatively were preoperative employment status, manual labor job, fusion, education level, workers' compensation, liability insurance, race, symptom duration, gender, ASA scores, baseline ODI scores, history of diabetes, and baseline NRS-BP scores. The work-related variables (preoperatively employed but not working, occupation type, workers' compensation, and liability insurance), disease-related variables (diagnosis, symptom duration, dominant symptom, motor deficit, ambulation, prior surgery, baseline ODI score, EQ-5D score, and baseline NRS-BP and NRS-LP scores), surgery-related variables (surgical approach, fusion, number of levels fused), and comorbidity variables (ASA scores, diabetes, anxiety, depression, osteoporosis, and CAD) were grouped

to determine the pooled effect of these variables on RTW. Figure 3 demonstrates the calibration accuracy for RTW estimates based on the model. The bootstrap-validated c-index was 0.71, which suggests that our model is useful in predicting RTW after lumbar spine surgery.

Based on the model, we generated 2 hypothetical patients and predicted their probability of returning to work at 6 weeks and 3 months based on the prediction model. The characteristics and predicted probability are listed in Table 3.

Discussion

Model

Predictive models provide individualized risk-adjusted postoperative outcomes, which have the potential to assist providers in setting realistic expectations for patients and families, adjusting modifiable characteristics preopera-

FIG. 3. Bootstrap estimate of calibration accuracy for RTW estimates from the Cox proportional hazards regression model.

tively, engaging patients in shared decision-making, and having a probabilistic discussion regarding postoperative outcomes during preoperative assessment. To use predictive models in the real-world setting, a robust model with high accuracy in predicting the outcomes is needed. Using a prospective, multicenter, longitudinal registry, we introduce a novel model to predict the likelihood of RTW within 3 months of lumbar spine surgery, which demonstrated good discrimination, with a c-index of 0.71. The most important predictors of RTW at 3 months were preoperative employment status, manual labor job, need for fusion, education level, workers' compensation, liability insurance, race, symptom duration, gender, ASA score, baseline ODI score, history of diabetes, and baseline NRS-BP score.

Work-Related Factors

Work-related factors contributed the most (33.3%) to predicting a patient's chance of returning to work. In particular, preoperative work status was the most important predictor of RTW. Those employed preoperatively but not actively working at the time of surgery had a lower likelihood of returning to work than those who were working at the time of surgery. Previous studies have demonstrated similar associations between preoperative employment status and postoperative RTW.^{2,4,34} Time away from work has a direct negative correlation with RTW.²⁸ Anderson et al. have reported that patients who were working at the time of surgery were 10.5 times more likely to be working at follow-up after fusion surgery.⁴ Type of occupation is another important predictor of postoperative RTW. Compared with those employed in sedentary jobs, the patients working in manual labor (heavy labor jobs < medium labor < light labor jobs) had a lower likelihood of returning to work. One might assume that patients employed and not working at the time of surgery had more severe and/or complicated lumbar spine pathologies (e.g., lumbar spondylolisthesis vs herniated lumbar disc), but the presence

of such conditions does not fully account for the strong independent influence of work-related factors based on our present predictive model. In any event, the association between occupation, employment status, and RTW is likely multifactorial. Previous sociological models have revealed that multiple factors such as psychological state, job satisfaction, availability of modified duty, physical demand at work, employer–employee relations, litigation issues, income, and social support influence the ability to recover and RTW postoperatively.^{4,16,30,47,49}

Active workers' compensation and disability insurance had a negative impact on RTW. Numerous studies have demonstrated that the financial incentives and the adversarial nature of the workers' compensation and liability insurance system may account for worse outcomes and delayed or no RTW.^{9,12,24,30} In our analysis, workers' compensation was a more important predictor for lower likelihood of RTW than liability insurance. Workers' compensation is meant to create a bridge for the injured worker to get back to a level of gainful employment, and liability insurance is a permanent form of compensation. Although both systems are well-intended (i.e., they provide important protections for injured workers), they actually create positive financial incentives for avoiding or delaying RTW, thus influencing this outcome beyond the impact of true functional recovery.

Surgery-Related Factors

Compared with decompression alone, decompression with fusion has been found to be associated with higher complication rates, longer periods of recovery, and delayed RTW.^{51,55,56,65} In our analysis, the likelihood of RTW at 3 months postoperatively was lower for patients undergoing fusion than those undergoing decompression alone. This finding is not surprising, as patients undergoing fusion often have more severe disability, require longer rehabilitation and recovery periods, and have greater postoperative activity restrictions compared with those undergoing decompression alone. Theoretically, the effect of fusion on outcomes may be diagnosis specific. In our analysis, there was no difference in the RTW outcomes for patients with diagnoses of stenosis, spondylolisthesis, adjacent-segment disease, mechanical disc collapse, and recurrent disc herniation, compared those with a diagnosis of disc herniation. Unfortunately, we do not have adequate numbers of patients within each diagnosis category to determine the true effect of fusion based on diagnosis. As patients continue to be enrolled in the QOD lumbar spine registry, we will ultimately accumulate sufficient data to allow for the development of unique RTW models for each diagnosis. Other surgery-related factors, including number of levels and surgical approach, did not contribute significantly to probability of RTW.

Education Level

Patients with a higher level of education had greater likelihood of postoperative RTW. Patients with 4-year college and postcollege levels of education were more likely to have desk or nonlaborious jobs, which increased their likelihood to RTW. Patients with a higher educational status are more likely to be engaged in professional ca-

TABLE 3. The probability of a hypothetical Patient A and Patient B returning to work at 6 weeks and 3 months postoperatively

Variable	Patient A	Patient B
Age (yrs)	35	55
BMI	27	35
Gender	Female	Male
Hispanic	No	No
Race	White	White
Education	Less than high school	High school diploma
Prior surgery	No	No
Smoker	Yes	Yes
Diabetes	No	Yes
CAD	No	Yes
Osteoporosis	No	No
Anxiety	Yes	No
Depression	Yes	No
Dominant symptom	LP dominant	BP dominant
Motor deficit	No	No
ASA score	2	3
Symptom duration	>3 mos	<3 mos
Diagnosis	Stenosis	Spondylolisthesis
No. of surgical levels	1	2
Interbody graft	No	Yes
Arthrodesis	No	Yes
Approach	Posterior	Posterior
Insurance	Private	Medicare
Ambulation	Independent	With assistance
Occupation	Medium labor job	Heavy labor job
Employed and working	Employed but not working	Employed but not working
Compensation	Yes	Yes
Liability	No	Yes
Baseline ODI score	60	80
Baseline EQ-5D score	0.7	0.3
Baseline NRS-BP score	7	9
Baseline NRS-LP score	9	8
Probability of RTW at 6 wks (95% CI)	69.1% (56.4%–81.0%)	32.4% (17.6%–33.5%)
Probability of RTW at 3 mos (95% CI)	99.8% (98.7%–99.9%)	90.9% (63.7%–88.1%)

reers, which theoretically makes RTW easier due to less demanding physical work.⁶⁸ Furthermore, a higher education level may also allow for a better understanding of disease processes, which may result in these patients forming more realistic postoperative expectations, being more treatment compliant, and achieving better recoveries.^{40,53}

Diagnosis-Related Factors

Patients with longer preoperative symptom duration (> 3 months) had a lower likelihood of returning to work. Grøyle et al. have reported that duration of sciatica more than 3 months in patients with disc herniation is associated with longer time to RTW.²⁹ Radcliff et al.⁵⁷ have reported that the patients with stenosis and symptom duration less than 12 months have significantly better outcomes; how-

ever, in patients with spondylolisthesis, the preoperative symptom duration was not associated with outcomes.⁵⁷ Patients with greater baseline disability (i.e., high ODI scores) and back pain were less likely to RTW at 3 months. Previous studies have demonstrated that the patients who start out with worse disability and pain scores are less likely to RTW postoperatively. The Maine Lumbar Spine Study data indicated that less-severe low-back pain at presentation was associated with higher RTW rates at 4 years after lumbar discectomy.⁸ Patients with poor functional status preoperatively have higher needs for postoperative rehabilitation, which prolongs the recovery period. This finding highlights the importance of adjusting for varying degrees of symptom duration, baseline disability, and pain when assessing RTW outcomes.

Patient Demographic Factors and Comorbidities

The demographic factors female gender and African American race were associated with lower likelihood of returning to work. A number of studies have reported the effect of gender and racial differences on outcomes and RTW after lumbar spine surgery.^{18,37,59,61} The racial disparity in returning to work can be partly explained by the barriers in education, attitudes toward health care, and economic status.^{3,36,61} The issue of racial disparity and association with outcomes and RTW, however, is multidimensional and complex; further studies focused on this parameter are clearly needed.

Consistent with our findings, several previous studies have reported that preoperative comorbidities are significantly associated with delayed postoperative recovery and hence are associated with a lower likelihood of returning to work.^{10,39,44,64} Our model suggests that preoperative history of diabetes and ASA scores in particular should be accounted for when evaluating the probability of 3-month postoperative RTW outcome.

Study Limitations and Strengths

The c-index of model performance was 0.71, which can be considered a “good” discrimination index. One intrinsic limitation of predictive models is the discrete number of variables that are inputted into their creation. In the present analysis, we included 28 patient-specific and surgery-specific variables collected as a part of the multicenter QOD registry. It is possible that variables not collected and therefore not accounted for in this analysis will play a significant role in an RTW outcome. Previously reported variables that contribute to RTW missing from our registry include the following: marital status and family support, preoperative willingness of returning to work, and working conditions, including employer–employee relationship and work-related stress. Such missing data could affect the performance of statistical models in discriminating accurately between observed and predicted outcomes.

“Returning to work” was defined as any RTW within 3 months after surgery. It is possible that patients did not RTW at full preoperative capacity, which is not captured in the present analysis. Future analyses will include a more granular evaluation of actual work capacity, as well as extending the follow-up duration of this outcome to 1 year, particularly in patients undergoing more invasive procedures such as fusion surgery. With exponentially increasing numbers of patients enrolled in the QOD registry, and with further refinement of variables collected, we will be able to continuously update our predictive model to increase its performance and accuracy. Furthermore, discovery of potential interactions between already collected variables will further improve performance and accuracy.

In spite of these potential limitations, our current novel, risk-adjusted predictive model for RTW provides significant value as a starting point for patient-level predictive analytics to guide shared decision-making with the goal of optimizing outcomes at the individual patient and population levels. This value is derived from 2 major sources: first, this national project has, by design, included a diverse

range of practice and patient types, which allows for a true representative sampling of patients undergoing elective lumbar spinal surgery. Specifically, the patients included in the QOD registry are enrolled from 74 centers across the US representing a roughly equal number of academic and private practices, and including small, medium, and large centers in both rural and metropolitan settings.^{5,27,50} These structural features enhance the generalizability of registry results, which is to say, the relevance of the results to a broad range of patients undergoing spine surgery. Second, as has been mentioned above, even this preliminary model exhibits good discrimination, and it can therefore be used in its present form to generate the probabilities of returning to work within 3 months after surgery in a fashion that can be meaningful to individual patients, care providers, and other health care stakeholders.

As calculations such as those involved in deriving individual RTW probabilities from this present model can be difficult to perform in a real-world clinic setting, we have created an online application that can be more easily used in the spine clinic to predict 3-month RTW (http://statcomp2.vanderbilt.edu:37212/app_0/). We are currently testing a variety of health information technology models to further simplify the use of this predictive model in the clinic, with the objective of embedding this methodology in daily practice workflows. By enabling patient-specific probabilistic counseling at the point of care, we seek to facilitate the involvement of all stakeholders in true shared decision-making which, among other potential benefits, can help set appropriate expectations prior to surgery (with the potential to improve patient satisfaction), modify correctable factors that could help improve the potential for RTW, and possibly reduce health care expenditures in situations in which surgical care is deemed unlikely to achieve satisfactory outcomes. Furthermore, outcome prediction modeling can be used by self-insured companies and workers' compensation groups to identify the patients who will RTW and those who will not within 3 months of surgery.

Conclusions

We present a novel predictive model for the probability of returning to work after lumbar spine surgery. Spine care providers can use this model to educate patients and encourage them in shared decision-making regarding the RTW outcome. This evidence-based decision support will result in better communication between patients and clinicians and improve postoperative recovery expectations, which will ultimately increase the likelihood of a positive RTW trajectory.

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Appendix

Quality and Outcomes Database (QOD) Vanguard Sites

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Dr. Devin has served as a consultant to Exparel and Medtronic, and has received support of non-study-related clinical or research effort from Stryker Spine. Dr. Shaffrey has served as a consultant to Medtronic, NuVasive, K2M, and Zimmer-Biomet; has direct stock ownership in NuVasive; and is a patent holder for Medtronic, NuVasive, and Zimmer-Biomet. Dr. Foley has served as a consultant to Medtronic; has direct stock ownership in BioD, Discgenics, Medtronic, NuVasive, Spinewave, and TrueVision; and is a patent holder for Discgenics, Medtronic, and NuVasive.

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Supplemental Information

Companion Papers

McGirt MJ, Bydon M, Archer KR, Devin CJ, Chotai S, Parker SL, et al: An analysis from the Quality Outcomes Database, Part 1. Disability, quality of life, and pain outcomes following lumbar spine surgery: predicting likely individual patient outcomes for shared decision-making. DOI: 10.3171/2016.11.SPINE16526.

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