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ORIGINAL ARTICLE

A validated preoperative score for predicting 30-day readmission after 1–2 level elective posterior lumbar fusion

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Abstract

Purpose To develop a model to predict 30-day readmission rates in elective 1–2 level posterior lumbar spine fusion (PSF) patients.

Methods In this retrospective case control study, patients were identified in the State Inpatient Database using ICD-9 codes. Data were queried for 30-day readmission, as well as demographic and surgical data. Patients were randomly assigned to either the derivation or the validation cohort. Stepwise multivariate analysis was conducted on the derivation cohort to predict 30-day readmission. Readmission after posterior spinal fusion (RAPSF) score was created by including variables with odds ratio (OR) > 1.1 and $p < 0.01$; value assigned to each variable was based on the OR and calibrated to 100. Linear regression was performed between readmission rate and RAPSF score to test correlation in both cohorts.

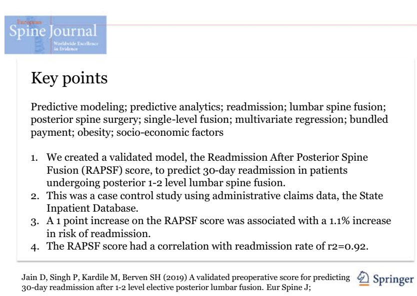
Results There were 92,262 and 90,257 patients in the derivation and validation cohorts. Thirty-day readmission rates were 10.9% and 11.1%, respectively. Variables in RAPSF included: age, female gender, race, insurance, anterior approach, cerebrovascular disease, chronic pulmonary disease, congestive heart failure, diabetes, hemiplegia/paraplegia, rheumatic disease, drug abuse, electrolyte disorder, osteoporosis, depression, obesity, and morbid obesity. Linear regression between readmission rate and RAPSF fits the derivation cohort and validation cohort with an adjusted r^2 of 0.92 and 0.94, respectively, and a coefficient of 0.011 ($p < 0.001$) in both cohorts.

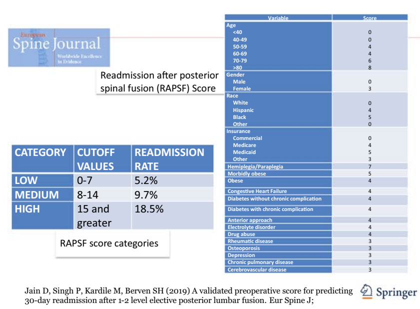
Conclusion The RAPSF can accurately predict readmission rates in PSF patients and may be used to guide an evidence-based approach to preoperative optimization and risk adjustment within alternative payment models for elective spine surgery.

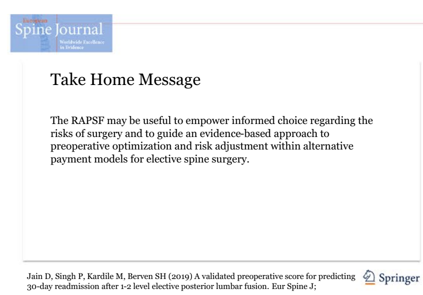
Level of evidence 3.

Graphical abstract

These slides can be retrieved under Electronic Supplementary Material.







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Extended author information available on the last page of the article

Keywords Predictive modeling · Predictive analytics · Readmission · Lumbar spine fusion · Posterior spine surgery · Single-level fusion · Multivariate regression · Bundled payment · Obesity · Socioeconomic factors

Introduction

Posterior lumbar spinal fusion is one of the most commonly performed surgical procedures in the USA, with over 400,000 spinal fusions performed in 2008 [1]. Readmission rates have become an important metric of quality of care, and furthermore, under the Patient Protection and Affordable Care Act, are directly tied to reimbursement. The Centers for Medicare and Medicaid initiated a readmission reduction program which penalizes hospitals up to 3% for each readmission episode [2, 3]. Readmission rates after lumbar posterior spinal fusion are high, with previously reported rates at 30 days of 5% and at 90 days of 25%. [4, 5] It is imperative to understand risk factors for readmission in order to both promote the best possible outcome as well as appropriately risk adjust within alternative payment models.

The purpose of this study was multifold: (1) to identify the risk factors associated with readmission and quantify the increase in risk, (2) to create a scale that can accurately predict the risk of readmission, and (3) to validate this scale in a separate cohort of patients.

Methods

This was a case control study of an administrative claims database. This study only included the use of de-identified data and thus was exempt from Institutional Review Board approval.

Data sample

We utilized the State Inpatient Database (SID), which is part of the Healthcare Cost and Utilization Project under the Agency for Healthcare Research and Quality. SID is the largest all-payer database and is comprised of all hospital admissions. Each patient is assigned a unique identifying number which can then be tracked across different time points and hospitals. Complete data were available for North Carolina, Nebraska, New York, and Utah from 2005–2009 and California and Florida from 2005–2010.

Inclusion/exclusion criteria

All patients age > 18 undergoing 1–2 level lumbar spine fusion were included in the study. Patients were identified using International Classification of Diseases, and Ninth Revision (ICD-9) procedure codes 81.62 AND 81.07, 81.08, 81.37, or 81.38. Patients were excluded if they had ICD-9 codes for any of the following diagnoses: bone cancer/metastases, infection, and trauma (Table S1).

Data query

Readmission within 30 days of discharge was noted.

Data were extracted for factors previously identified in the literature as risk factors for readmission after lumbar spine fusion, as well as any other factors that the authors deemed might be relevant and available in the database. These factors included: age (categorized into <40, 40-49, 50-59, 60-69, 70-79, 80, or greater years), gender (categorized as male/female), race (categorized as white, Hispanic, black, or other), insurance status (categorized as Commercial, Medicare, Medicaid, or other), the addition of an anterior approach (81.06 and 81.36), revision procedure, and various comorbidities including 17 previously described included as part of the Charlson Comorbidity index, as well as cardiovascular disease, hypothyroidism, alcohol abuse, drug abuse, electrolyte disorder, osteoporosis, smoking, anxiety, depression, malnutrition, underweight, obesity, and morbid obesity (Table S2) [5–8].

Statistical analysis

Patients were randomly assigned to the derivation cohort or the validation cohort with the use of a random number generator with a 50:50 split.

A stepwise multivariate regression was performed. First, univariate analysis was performed using binary logistic regression. Variables with a p value of < 0.05 were considered statistically significant. Multivariate analysis was then performed to create a final model, including variables that were significant on univariate analysis. Odds ratios (OR) and confidence intervals (CI) are reported for each included variable.

Next, the readmission after posterior spine fusion (RAPSF) score was constructed as follows from the derivation cohort: Variables with OR > 1.1 and p value significant according the Holm–Bonferroni method with alpha = 0.05 in the final multivariate model were included. OR of 1.1 was selected as this was considered to be clinically relevant. The contributing value for each variable in the RAPSF was calculated using the following formula: [OR − 1/Sum(OR − 1)] × 100, as previously described [9, 10]. The scale was then recalibrated to 100 by rounding each value to the nearest whole number. This simple formula allows each

Table 1 Demographic and comorbid variables

Variable	Derivation cohort (n = 92,262)	Validation cohort (n = 90,257)
Age		
< 40	12.15	12.16
40–49	18.99	18.82
50–59	22.86	22.86
60–69	23.11	23.20
70–79	17.62	17.61
> 80	5.28	5.36
Gender		
Male	44.20	44.31
Female	55.80	55.69
Race		
White	74.94	74.89
Hispanic	8.68	8.78
Black	5.03	5.21
Other	11.35	11.11
Insurance		
Commercial	42.18	42.04
Medicare	37.42	37.61
Medicaid	3.63	3.66
Other	16.78	16.70
Anterior Approach	10.55	10.76
Revision surgery	11.64	11.59
AIDS/HIV	0.09	0.09
Any Malignancy ex skin	1.62	1.62
Cerebrovascular disease	2.89	2.82
Chronic Pulmonary Disease	17.70	17.47
Congestive Heart Failure	3.36	3.37
Dementia	0.24	0.26
Diabetes without Chronic Comp	15.98	16.07
Diabetes with Chronic Comp	2.14	2.10
Metastatic solid tumor	1.65	1.62
Hemiplegia/Paraplegia	0.15	0.15
Mild Liver Disease	2.22	2.01
Moderate to severe liver disease	0.11	0.11
Myocardial Infarction	4.38	4.52
Peptic Ulcer Disease	1.50	1.44
Peripheral Vascular Disease	3.40	3.38
Renal Disease	2.79	2.82
Rheumatic disease	3.40	3.40
Cardiovascular disease	11.38	11.62
Hypothyroidism	11.28	11.38
Alcohol Abuse	1.87	1.83
Drug abuse	2.78	2.77
Electrolyte disorder	12.65	12.52
Osteoporosis	5.99	5.94
Smoking	29.28	29.33
Anxiety	7.50	7.59
Depression	16.74	16.73
Malnutrition	0.61	0.57
Underweight	0.06	0.07
Obese	10.19	10.28
Morbidly obese	4.27	4.15

All values presented as a percentage

variable to be represented a proportion of the total risk and then recalibrated to facilitate use.

Next, the score was verified first in the derivation cohort. The data were trimmed such that the top 0.1% of the data was excluded as outliers > 3 SD from the mean. A linear regression with ordinary least squares (OLS) was then performed between RAPSF score and readmission rate. The fit is described with r^2 value. These methods have been previously published for similar models [9, 10]. To account for the heteroscedasticity in the data, a variance-weighted least squares regression (WLS) was then performed. Next, the score was similarly validated in the validation cohort, using the RAPSF score created from the derivation cohort.

Finally, cutoff thresholds of RAPSF were established to separate scores as low, medium, and high risk for readmission with decision tree analysis from the derivation cohort. This was done using *ctree* implementation in the *party* package. The code was set with a sensitivity of 0.99 with two nodes. This analysis was performed using R 3.5.0 (R Project, Vienna, Austria).

Results

There were 92,262 patients in the derivation cohort and 90,257 in the validation cohort. The 30-day readmission rates were 10.9% and 11.1%, respectively. Demographic data for each cohort are presented in Table 1. All variables except for AIDS, underweight, and smoking were significant on univariate analysis; all variables except these three were included in the multivariate analysis.

The results of the multivariate analysis are presented in Table 2. The following variables were significantly associated with increased risk for readmission on multivariate analysis: Age 50–59 years, 60–69 years, 70–79 years, and 80 and greater years, female gender, black and Hispanic race, Medicare, Medicaid, and other insurance, anterior approach, cerebrovascular disease, chronic pulmonary disease, congestive heart failure, diabetes without chronic complication, diabetes with chronic complication, hemiplegia/paraplegia, rheumatic disease, drug abuse, electrolyte disorder,

Table 2 Multivariate analysis

Variable	OR	95% CI		*p* value
Age				
<40	1 (reference)			
40–49	1.08	0.98	1.19	0.12
50–59	1.29	1.18	1.42	**<0.001**
60–69	1.52	1.38	1.67	**<0.001**
70–79	2.04	1.84	2.27	**<0.001**
>80	2.91	2.58	3.29	**<0.001**
Gender				
Male	1 (reference)			
Female	1.13	1.08	1.19	**<0.001**
Race				
White	1.05	0.98	1.12	0.201
Hispanic	1.31	1.19	1.44	**<0.001**
Black	1.60	1.44	1.78	**<0.001**
Other	1 (reference)			
Insurance				
Commercial	1 (reference)			
Medicare	1.44	1.36	1.55	**<0.001**
Medicaid	1.74	1.56	1.94	**<0.001**
Other	1.18	1.10	1.27	**<0.001**
Anterior Approach	1.33	1.24	1.42	**<0.001**
Revision	1.04	0.98	1.11	0.215
Any Malignancy ex skin	1.06	0.91	1.22	0.473
Cerebrovascular disease	1.15	1.04	1.28	**0.008**
Chronic Pulmonary Disease	1.11	1.05	1.17	**<0.001**
Congestive Heart Failure	1.26	1.14	1.39	**<0.001**
Dementia	1.07	0.78	1.48	0.676
Diabetes without Chronic Comp	1.20	1.13	1.26	**<0.001**
Diabetes with Chronic Comp	1.32	1.17	1.48	**<0.001**
Metastatic solid tumor	1.26	0.82	1.94	0.287
Hemiplegia/Paraplegia	2.24	1.98	2.54	**<0.001**
Mild Liver Disease	1.14	1.00	1.29	0.049
Moderate to severe liver disease	1.18	0.72	1.93	0.512
Myocardial Infarction	1.05	0.95	1.16	0.367
Peptic Ulcer Disease	1.13	0.97	1.30	0.109
Peripheral Vascular Disease	0.96	0.86	1.06	0.396
Renal Disease	1.13	1.01	1.25	0.027
Rheumatic disease	1.15	1.04	1.28	**0.006**
Cardiovascular disease	1.05	0.98	1.12	0.207
Hypothyroidism	1.02	0.96	1.09	0.55
Alcohol Abuse	1.04	0.90	1.21	0.597
Drug abuse	1.37	1.21	1.54	**<0.001**
Electrolyte disorder	1.44	1.36	1.53	**<0.001**
Osteoporosis	1.15	1.06	1.24	**0.001**
Anxiety	1.08	1.00	1.16	0.059
Depression	1.17	1.11	1.24	**<0.001**
Malnutrition	1.23	1.00	1.51	0.049
Obese	1.23	1.15	1.31	**<0.001**
Morbidly obese	1.57	1.44	1.72	**<0.001**

Bold values indicate statistical significance

Table 3 Readmission after posterior spinal fusion (RAPSF) Score

Variable	Score
Age	
<40	0
40–49	0
50–59	4
60–69	4
70–79	6
>80	8
Gender	
Male	0
Female	3
Race	
White	0
Hispanic	4
Black	5
Other	0
Insurance	
Commercial	0
Medicare	4
Medicaid	5
Other	3
Hemiplegia/Paraplegia	7
Morbidly obese	5
Obese	4
Congestive Heart Failure	4
Diabetes without chronic complication	4
Diabetes with chronic complication	4
Anterior approach	4
Electrolyte disorder	4
Drug abuse	4
Rheumatic disease	3
Osteoporosis	3
Depression	3
Chronic pulmonary disease	3
Cerebrovascular disease	3

osteoporosis, depression, obesity, and morbid obesity. These variables were included in the RAPSF.

The RAPSF score is presented in Table 3. The RAPSF score is calculated for each individual patient by assigning the respective point value if the demographic or comorbid variable is present, and summing them. Average RAPSF in the derivation cohort was 11.6 with a standard deviation of 6.8.

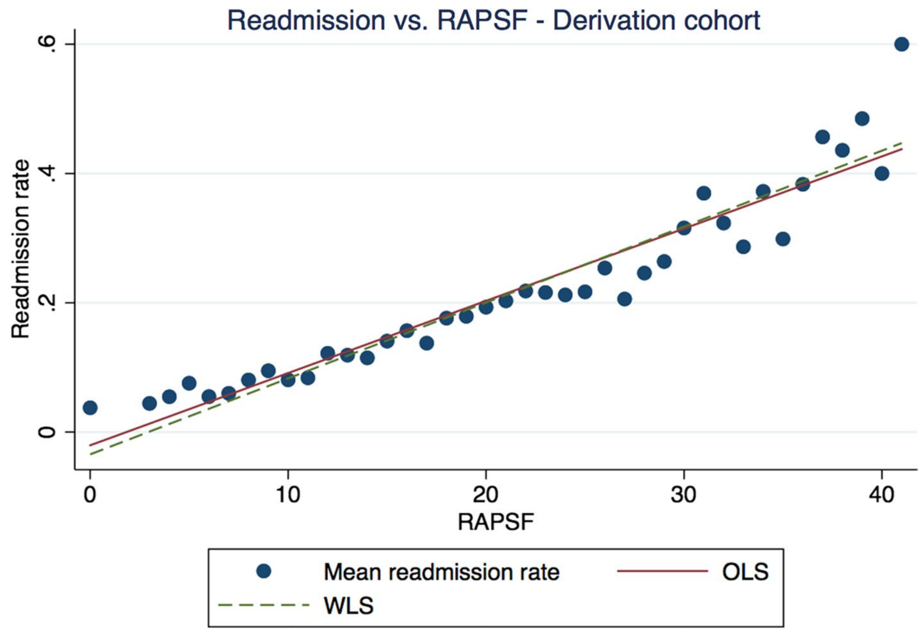

Fig. 1 Linear regression using ordinary least squares (OLS) and variance-weighted least squares (WLS) of Readmission rate versus RAPSF in the derivation cohort. Slope = 0.011 ($p < 0.001$) in both analyses

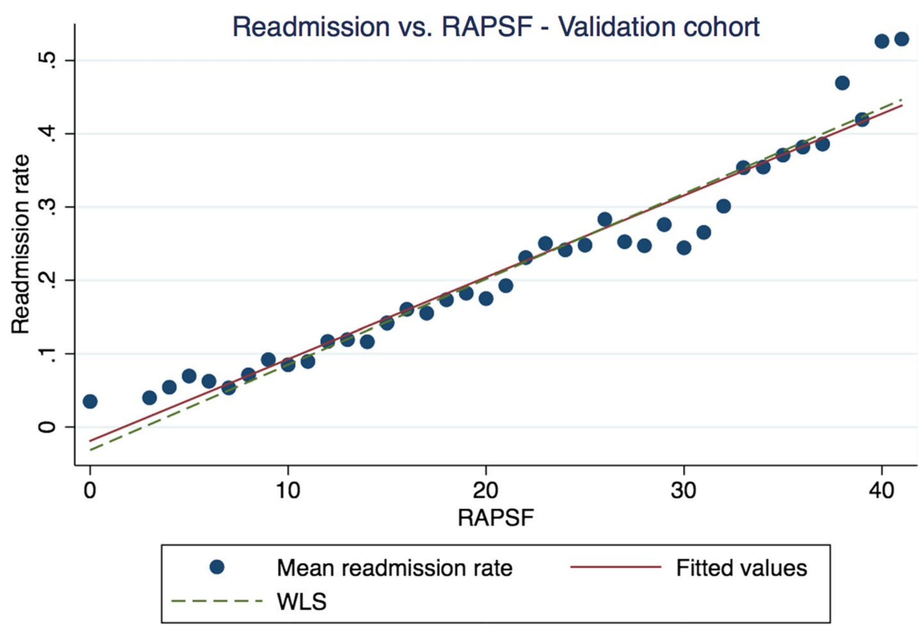

Fig. 2 Linear regression using ordinary least squares (OLS) and variance-weighted least squares (WLS) of Readmission rate versus RAPSF in the validation cohort. Slope = 0.011 ($p < 0.001$) in both analyses

The RAPSF was first tested in the derivation cohort. On OLS analysis, readmission rate was significantly correlated with RAPSF with a beta = 0.011 ($p \leq 0.001$) and an adjusted $r^2 = 0.92$ (Fig. 1). On WLS analysis, readmission rate significantly correlated with RAPSF with a beta = 0.011 ($p \leq 0.001$) and an adjusted $r^2 = 0.88$. It was then tested in the validation cohort. Again, on OLS analysis, readmission rate was significantly correlated with RAPSF, with beta = 0.011 ($p < 0.001$) and an adjusted $r^2 = 0.94$ (Fig. 2). On WLS analysis, readmission rate significantly correlated with RAPSF with a beta = 0.011 ($p \leq 0.001$) and an adjusted $r^2 = 0.92$.

Decision tree analysis resulted in low risk as RAPSF 0–7, medium risk as 7–14, and high risk as 15 and above ($p < 0.001$) (Table 4). Low-risk RAPSF patients had a readmission rate of 5.2%, medium risk of 9.7%, and high risk of 18.5%.

Discussion

In this case control study, we created and validated a useful tool, the RAPSF, to accurately predict 30-day readmission in patients undergoing elective 1–2 level posterior lumbar

Table 4 Categories of risk based on the readmission after posterior spinal fusion score (RAPSF)

Category	Cutoff values	Readmission rate (%)
Low	0–7	5.2
Medium	8–14	9.7
High	15 and greater	18.5

fusion. The RAPSF score accounted for approximately 90% of the variability in the readmission rate as demonstrated by the r^2 values. This scale can be rapidly calculated preoperatively to identify patients at high risk for readmission and thus target preoperative optimization to mitigate this risk.

Readmission rates after posterior spinal fusion are high in this study 11% at 30 days. This is higher than previously reported rates of approximately 5% [8, 11]. This is likely due to prior underreporting of readmissions and highlights one of the advantages of SID; SID includes all inpatient admissions in the state and thus captures readmission at other hospitals even if the index procedure was performed at another hospital.

The results of the linear regression between readmission rate and RAPSF demonstrated a correlation coefficient of 0.011, indicating that a 1 point increase in the RAPSF is associated with a 1.1% risk increase in 30-day readmission. This value was the same in both in the derivation cohort and the validation cohort, further confirming the validity of the RAPSF.

This study identified important socioeconomic variables as risk factors for readmission: race and insurance status. Previous studies have confirmed black and Hispanic race to be risk factors for readmission after both elective spine surgery and general medical admission [5, 7, 12–14]. One hypothesis for this finding suggests that minority patients may receive lower quality care; patients who live in areas with high concentration of minorities receive care at similarly underperforming hospitals [15, 16]. Previous studies have also confirmed Medicare and Medicaid insurance status to be a risk factors for readmission [5, 17]. Medicare and Medicaid insurance status likely represents poorer economic backgrounds as compared to private insurance status; this finding may be related to education barriers as well as decreased access to follow-up care [18, 19].

Williams discussed the importance of coordination of care with a patient-centric approach, as opposed to a disease-centered approach, in order to reduce readmission rates [20]. Recent literature has emphasized both preoperative identification and postoperative transitional care as means of reducing readmission rates after hospitalization of other surgical and medical problems. Examples of transitional care that have been successful include nurse transition guides and an early clinic visit prior to the routinely scheduled postoperative visit [21, 22]. While similar protocols have not been studied in spine surgery, a recent study by Pak et al. [23] demonstrated that outpatient spine clinic utilization is associated with reduced emergency department utilization, and might also translate to reduced readmission rates. Future studies will involve implementation of a targeted protocols to reduce readmission rates after spine surgery.

The limitations of this study are primarily attributable to those suffered by any study of administrative claims data; it is subject to errors in coding. Another limitation is that the top 0.1% of RAPSF scores was excluded (score > 41). While this was done because the number of patients reaching such high RAPSF was too few to have an accurate representation of the readmission rate, it might mean that the RAPSF is less predictable at very high scores, or that there is a point where the relationship between RAPSF is no longer linear, but rather, the readmission rate approaches 100% very quickly.

In conclusion, rates of readmission after lumbar spine fusion are high; thus identifying patients at risk are critical for preoperative targeting. The RAPSF is an easy to use, validated tool to assess this risk. Future studies will focus on interventions aimed at reducing readmission rates in high-risk patients to promote the best patient outcomes and ease the financial burden suffered by the healthcare system.

Compliance with ethical standard

Conflict of interest Drs. Jain, Singh, and Karile have no conflicts of interest. Dr. Berven has financial relationships with Medtronic, Stryker, Globus, Medicrea, Providence Medical, and GreenSun.

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