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The Spine Journal ■ (2012) ■

THE SPINE JOURNAL

Clinical Study

Thirty-day readmissions after elective spine surgery for degenerative conditions among US Medicare beneficiaries

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Received 28 October 2011; revised 31 August 2012; accepted 20 September 2012

Abstract

BACKGROUND CONTEXT: Readmissions within 30 days of hospital discharge are undesirable and costly. Little is known about reasons for and predictors of readmissions after elective spine surgery to help plan preventative strategies.

PURPOSE: To examine readmissions within 30 days of hospital discharge, reasons for readmission, and predictors of readmission among patients undergoing elective cervical and lumbar spine surgery for degenerative conditions.

STUDY DESIGN: Retrospective cohort study.

PATIENT SAMPLE: Patient sample includes 343,068 Medicare beneficiaries who underwent cervical and lumbar spine surgery for degenerative conditions from 2003 to 2007.

OUTCOME MEASURES: Readmissions within 30 days of discharge, excluding readmissions for rehabilitation.

METHODS: Patients were identified in Medicare claims data using validated algorithms. Reasons for readmission were classified into clinically meaningful categories using a standardized coding system (Clinical Classification Software).

RESULTS: Thirty-day readmissions were 7.9% after cervical surgery and 7.3% after lumbar surgery. There was no dominant reason for readmissions. The most common reasons for readmissions were complications of surgery (26%–33%) and musculoskeletal conditions in the same area of the operation (15%). Significant predictors of readmission for both operations included older age, greater comorbidity, dual eligibility for Medicare/Medicaid, and greater number of fused levels. For cervical spine readmissions, additional risk factors were male sex, a diagnosis of myelopathy, and a posterior or combined anterior/posterior surgical approach; for lumbar spine readmissions, additional risk factors were black race, Middle Atlantic geographic region, fusion surgery, and an anterior surgical approach. Our model explained more than 60% of the variability in readmissions.

CONCLUSIONS: Among Medicare beneficiaries, 30-day readmissions after elective spine surgery for degenerative conditions represent a target for improvement. Both patient factors and operative techniques are associated with readmissions. Interventions to minimize readmissions should

FDA device/drug status: Not applicable.

Author disclosures: ***MCW:*** Grants: Robert Wood Johnson Foundation (F, Paid directly to institution/employer), AANS/CNS Joint Section on Disorders of the Spine and Peripheral Nerves – Sanford Larson Research Award (D, Paid directly to institution/employer); Trips/Travel: Robert Wood Johnson Foundation (B); Research Support (Staff/Materials): AANS/CNS Joint Section on Disorders of the Spine and Peripheral Nerves (C, Paid directly to institution). ***MS:*** Nothing to disclose. ***RAS:*** Nothing to disclose. ***CG:*** Nothing to disclose. ***PWL:*** Grants: Robert Wood Johnson Foundation (F, Paid directly to institution/employer). ***ABN:*** Nothing to disclose.

The disclosure key can be found on the Table of Contents and at www.TheSpineJournalOnline.com.

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1529-9430/$ - see front matter Published by Elsevier Inc.
http://dx.doi.org/10.1016/j.spinee.2012.09.051

be specific to surgical site and focus on high-risk subgroups where clinical trials of interventions may be of greatest benefit. Published by Elsevier Inc.

Keywords: Readmission; Predictors of readmission; Cervical spine surgery; Lumbar spine surgery; Degenerative spine disorders

Introduction

Recent attention has focused on rapidly increasing rates of elective spine surgery for degenerative changes among Medicare beneficiaries [1–4]. The rates of inpatient complications and costs associated with this elective surgery have been topics of intense scrutiny [3,5–9], yet little is known about early readmissions after this surgery. Readmissions within 30 days of hospital discharge are undesirable and costly and have been targeted as a potential area of improvement [10]. According to the Medicare Payment Advisory Committee, Medicare hospital readmissions accounted for $15 billion in spending, and only 10% of these readmissions were considered likely to be planned readmissions [11].

A better understanding of the reasons for and predictors of readmissions after spine surgery may help improve patient counseling for this common elective surgery. In addition, it may elucidate high-risk subgroups that could benefit from targeted strategies to prevent readmissions. Although most studies of spine surgery have focused only on the lumbar spine or grouped cervical and lumbar spine surgeries together, there may be important differences between cervical and lumbar spine surgery patients. Cervical spine degenerative conditions often involve the spinal cord rather than nerve roots alone, and anatomic considerations such as proximity of the airway to the cervical spine may confer higher risk on cervical spine patients.

To better understand short-term readmissions after elective spine surgery, we studied US Medicare beneficiaries undergoing elective cervical and lumbar spine surgery for degenerative conditions to determine rates of 30-day readmissions, the reasons for readmissions, and the predictors of these readmissions.

Methods

Study population and data source

Medicare Provider Analysis and Review hospital claims and Denominator files were linked by beneficiary identifier and date from 2003 to 2007. This study was approved by our Institutional Review Board. We used published and validated International Classification of Disease, Ninth Revision, Clinical Modification (ICD-9-CM) algorithms to select patients who underwent elective nonurgent spine procedures performed for degenerative conditions in the cervical/cervicothoracic or lumbosacral spine [3,12,13]. Spine procedures performed in an unspecified area of the spine, solely in the thoracic spine, or jointly in the cervical, thoracic, and lumbar spine were excluded; these represented less than 5% of all spine procedures performed.

We excluded beneficiaries who were enrolled in a Health Maintenance Organization because some of their claims may not have been in the Medicare database [1]. In addition, we required that all beneficiaries be continuously enrolled in Medicare for 1 year before the index surgical admission to 30 days after discharge to capture all relevant codes. Beneficiaries whose initial codes indicated a reoperation were also excluded to ensure that patients were not undergoing a repeat spine surgery that might be related to outcome. Because of the lack of sensitivity of the reoperation codes [12], we used the 1 year before the index surgical admission as a ''washout period.'' Beneficiaries who underwent any spine surgery within the year before the index qualifying surgery were excluded.

Patient characteristics

We used Medicare Provider Analysis and Review, Denominator, and Vital Status files linked to US Census and American Community Survey Data to determine patient characteristics, including race/ethnicity, census region, per capita income by zip code of residence, dual Medicare/state buy-in Medicaid eligibility, and high school general education development by zip code of residence. Comorbid conditions were identified using ICD-9-CM diagnosis codes associated with the index hospital admission. We did not analyze individual comorbid conditions; comorbidities were weighted according to Deyo et al.'s [14] adaptation of the Charlson index [15].

Type of surgery and surgical approach

Type of surgery and surgical approach were defined using the same published and validated ICD-9-CM algorithms for cervical and lumbar spine [3,12,13]. For fusion procedures, the number of levels fused and use of bone morphogenetic protein (BMP) were further determined [3,16]. The Food and Drug Administration issued a warning for off-label use of BMP in cervical spine surgery in 2008 [17], after the end of our study period. Therefore, we included BMP to analyze its association with 30-day readmissions. Although some complications previously reported to be associated with BMP, such as delayed radiculitis, retrograde ejaculation, urinary retention, excessive bone growth, and cancer [18], would not be expected to result in 30-day readmissions, other complications, such as severe dysphagia, airway problems, and wound infections or problems would likely be

associated with a readmission within this time frame. Fusion procedures were categorized in six levels: fusion, levels unspecified (no BMP); fusion, levels unspecified with BMP; fusion, two to three levels (no BMP); fusion, two to three levels with BMP; fusion, four or more levels (no BMP); fusion, four or more levels with BMP. The number of levels treated by decompression or instrumentation and the dosing of BMP cannot be identified using ICD-9-CM codes.

Surgical approach was defined as anterior, posterior, or both anterior and posterior [3,12]. Although the discectomy code (ICD-9-CM 80.51) does not specify the approach, when this code was used alone in the lumbosacral spine (without any other procedure code denoting surgical approach), the procedure was classified as posterior.

Thirty-day readmissions and reasons for readmissions

Thirty-day readmissions were defined as all readmissions to a short-term hospital within 30 days of discharge among beneficiaries who were discharged alive from the index admission. Readmissions for rehabilitation were excluded (ICD-9-CM code V57). ICD-9-CM primary diagnosis codes and a standardized coding system (Clinical Classifications Software for ICD-9-CM) were used to categorize reasons for readmissions into clinically meaningful categories [19]. This coding system was developed by the Healthcare Cost and Utilization Project, sponsored by the Agency for Healthcare Research and Quality (AHRQ) and is widely used in research and in AHRQ publications including Statistical Briefs. Agency for Healthcare Research and Quality Patient Safety Indicator ICD-9-CM codes were obtained from the AHRQ Quality Indicators Web site [20].

Data analysis

We compared patient and surgical characteristics between the cervical and lumbar spine surgery groups using univariate analysis (*t* test, Mann-Whitney *U* test, chi-square test, where appropriate). Because large sample sizes are well known to detect very small departures from the null hypothesis [21], we set statistical significance to $p<.01$ to mitigate this effect. To study the associations between patient and surgery characteristics and our primary outcome, 30-day readmissions, we used logistic regression modeling and built separate models for the cervical and lumbar cohorts. Independent variables were selected using a random half of the data and cross-validated by using the remaining half of the data for the cervical and lumbar spine cohorts separately. Reported model estimates were computed with these constructed models applied to the full datasets. Discrimination was measured using the c-statistic. Receiver operating characteristic curve analyses were conducted using the random split-halves method to establish each model's predictive performance. We then used the model to calculate the average predicted probability for 30-day readmission for patient subgroups.

Results

Patient characteristics

From 2003 to 2007, 343,068 Medicare beneficiaries underwent elective spine surgery for degenerative cervical and lumbar conditions (Table 1). There were significant differences in patient characteristics between the cervical and lumbar cohorts. The cervical cohort was slightly younger (73.2% cervical vs. 61.5% lumbar were younger than 75 years); more often male or of black or other race; and more often had dual eligibility for Medicare/Medicaid, a marker of low socioeconomic status. In addition, cervical spine patients had a higher Charlson Deyo comorbidity index and more often had a diagnosis of myelopathy or spinal cord dysfunction.

Type of surgery and surgical approach

Type of surgery differed between the cervical and lumbar cohorts. Fusions were performed in 81.3% of the cervical cohort compared with 37.3% of the lumbar cohort, and a higher proportion of cervical fusions involved four or more levels. However, BMP-augmented fusions were more common in the lumbar cohort (23% of fusions) compared with the cervical cohort (6.2% of fusions). Surgical approach also differed between the cervical and lumbar spine patients. The cervical cohort most commonly underwent surgery from an anterior approach (67.0%) compared with the lumbar cohort, which more commonly underwent surgery from the posterior approach (98.3%).

Occurrence of outcomes

Length of stay was shorter for the cervical cohort (mean 2.7, standard deviation 3.3 days vs. lumbar mean 3.2, standard deviation 2.5 days; $p<.001$). In addition, a higher proportion of the lumbar cohort was discharged to a subacute nursing facility or long-term care (14.6% cervical vs. 22.2% lumbar; $p<.001$).

Thirty-day readmissions, among those discharged alive from the index hospitalization, were slightly more common in the cervical cohort (7.9% vs. lumbar 7.3%; $p<.001$). About 40% of readmissions occurred within the first week after the index admission, and the median days to readmission was 9 days (interquartile range 4, 18 days) for the cervical cohort vs. 11 days (interquartile range 5, 19 days) for the lumbar cohort ($p<.001$).

Reasons for readmission

Using the Clinical Classifications Software (HCUP), the most common category of reasons for readmission was "injury and poisoning," of which most were classified as complications (23.4% cervical; 31.0% lumbar) (Table 2). Postoperative infections were the most common complication in this category and were more common with lumbar surgeries. Readmissions for a complication of a device,

Table 1
Patient and surgical characteristics

Patient and surgical characteristics	Cervical (n=58,428 [17.0%]), n (%)	Lumbosacral (n=284,640 [83.0%]), n (%)	p*
Age (y)			
Mean (SD)	72.5 (5.2)	74.1 (5.5)	
Age categories (y)			<.001
66–70	25,496 (43.6)	89,579 (31.5)	
71–75	17,302 (29.6)	85,269 (30.0)	
76–80	10,419 (17.8)	68,619 (24.1)	
81 and older	5,190 (8.9)	41,116 (14.4)	
Sex, female	28,990 (49.6)	161,364 (56.7)	<.001
Race/ethnicity			<.001
White	52,560 (90.0)	268,829 (94.5)	
Black	4,087 (7.0)	9,412 (3.3)	
Other	1,731 (3.0)	6,186 (2.2)	
Missing	29	156	
Census region of the United States†			<.001
East North Central	9,705 (16.6)	50,850 (17.9)	
East South Central	4,512 (7.7)	18,314 (6.4)	
Mountain	4,132 (7.1)	20,812 (7.3)	
Middle Atlantic	4,573 (7.8)	27,709 (9.7)	
New England	2,033 (3.5)	11,796 (4.1)	
Pacific	6,233 (10.7)	33,391 (11.7)	
South Atlantic	14,822 (25.4)	62,571 (22.0)	
West North Central	4,353 (7.5)	27,526 (9.7)	
West South Central	8,044 (13.8)	31,614 (11.1)	
Per capita income by zip code of residence			<.001
Median (IQR)	$19,486 ($16,456–$24,543)	$20,146 ($17,028–$25,490)	
Medicare/Medicaid state buy-in	5,095 (8.7)	15,946 (5.6)	<.001
High school GED by zip code of residence			<.001
Median (IQR)	0.83 (0.75–0.89)	0.84 (0.77–0.87)	
Comorbidity, Charlson Deyo index			<.001
0	33,311 (57.0)	167,482 (58.9)	
1	17,373 (29.7)	84,323 (29.6)	
2 or more	7,723 (13.2)	32,778 (11.5)	
Myelopathy	23,567 (40.3)	4,606 (1.6)	<.001
Fusion	47,468 (81.2)	106,119 (37.3)	<.001
2–3 levels	27,614 (58.2)	52,533 (49.5)	<.001
2–3 levels, with BMP	1,796 (3.8)	18,757 (17.7)	
4 or more levels	8,337 (17.6)	9,992 (9.4)	
4 or more levels, with BMP	971 (2.1)	4,054 (3.8)	
No. of levels not specified‡	8,585 (18.1)	19,191 (18.1)	
No. of levels not specified, with BMP‡	165 (0.3)	1,592 (1.5)	
Surgical approach			<.001
Anterior	38,047 (67.0)	1,725 (0.6)	
Posterior	15,815 (27.8)	279,255 (98.3)	
Anterior and posterior	2,949 (5.2)	2,962 (1.0)	
Not defined	1,596	641	

SD, standard deviation; GED, general educational development; IQR, interquartile range; BMP, bone morphogenetic protein.
* p Value comparing cervical versus lumbar, chi-square, Mann-Whitney *U* where appropriate.
† Census Regions and Divisions of the United States (www.census.gov/geo/www/us_regdiv.pdf).
‡ Number of levels fused were not specified in the remainder of cases.

implant, or graft were more commonly seen after cervical spine surgery (4.4% vs. lumbar 2.5%). The second most common category of reasons for readmission was ''diseases of the musculoskeletal system and connective tissue,'' which occurred at similar frequency after both cervical and lumbar surgery. Most of these readmissions were for a spine condition in the same area of the spine as the index surgery.

Readmissions for diseases of the heart, gastrointestinal disorders, diseases of the genitourinary system, and infectious and parasitic diseases, including sepsis, were similar in both the cervical and lumbar cohorts. However, readmissions after cervical spine surgery were more often for respiratory reasons, compared with lumbar surgery. Hypovolemia was also more common in the cervical spine cohort (2.2% vs. lumbar 1.4%). Diseases of the nervous system and sensory organs were more common in the cervical spine cohort; this category contained multiple diagnoses with small numbers of beneficiaries. The most common primary diagnosis within this group was acute postoperative pain (0.5%), followed by

Table 2
Top 10 reasons for readmission*

Patient and surgical characteristics	Cervical (n=4,595), n (%)	Lumbosacral (n=20,786), n (%)	p
Injury and poisoning	1,187 (25.8)	6,912 (33.3)	<.001
Complications	1,076 (23.4)	6,452 (31.0)	
Postoperative infection	264 (5.8)	3,155 (15.2)	
Other complications of medical/surgical procedure	207 (4.5)	1,293 (6.2)	
Hemorrhage/hematoma complicating procedure	221 (4.8)	742 (3.6)	
Complication of device, implant, or graft	203 (4.4)	521 (2.5)	
Accidental puncture/laceration	3 (0.1)	79 (0.4)	
Foreign body	0	2	
Diseases of the musculoskeletal system and connective tissue	687 (15.0)	3,274 (15.8)	.176
Cervical	622 (13.5)	61 (0.3)	
Lumbar	120 (2.6)	2,432 (11.7)	
Diseases of the heart	483 (10.5)	2,233 (10.7)	.646
Acute myocardial infarction, coronary atherosclerosis, and other heart disease	124 (2.7)	638 (3.1)	
Atrial fibrillation/flutter	86 (1.9)	364 (1.8)	
Pulmonary heart disease	79 (1.7)	353 (1.7)	
Nonspecific chest pain	78 (1.7)	265 (1.3)	
Congestive heart failure, nonhypertensive	48 (1.0)	393 (1.9)	
Gastrointestinal disorders	405 (8.8)	1,810 (8.7)	.818
Dysphagia	87 (1.9)	6 (0.03)	
Respiratory	486 (10.6)	1,012 (4.9)	<.001
Pneumonia (including aspiration pneumonia)	289 (6.3)	595 (2.9)	
Respiratory failure	78 (1.7)	105 (0.5)	
Diseases of the genitourinary system	220 (4.8)	1,044 (5.0)	.508
Urinary tract infection	93 (2.0)	468 (2.3)	
Acute renal failure	69 (1.5)	240 (1.2)	
Endocrine; nutritional; and metabolic diseases and immunity disorders	202 (4.4)	685 (3.3)	<.001
Hypovolemia	101 (2.2)	289 (1.4)	
Diseases of the nervous system and sense organs	169 (3.7)	618 (3.0)	.013
Infectious and parasitic diseases	116 (2.5)	508 (2.4)	.750
Sepsis	99 (2.2)	448 (2.2)	
Cerebrovascular disease	108 (2.4)	437 (2.1)	.294

Clinical Classifications Software used except for musculoskeletal levels (specific International Classification of Disease, Ninth Revision, Clinical Modification codes used).

Not all subcategories and percentages listed.

* Percentage of total readmissions.

abnormality of gait (0.4%), and other alteration of consciousness (0.3%). Dysphagia was the primary diagnosis for readmission for 1.9% of the cervical spine cohort versus 0.03% of the lumbar cohort.

Agency for Healthcare Research and Quality indicators

We evaluated several other specific conditions that are considered quality indicators [20]: pulmonary embolism, deep venous thrombosis, *Clostridium difficile* infections, and retained foreign body (Table 2). There were no significant differences between the cervical and lumbar cohorts for pulmonary embolism (2.4% vs. 2.8%, respectively; p=.47) or for deep venous thrombosis (1.4% vs. 1.7%, respectively; p=.35). The incidence of *Clostridium difficile* infections was low for both cohorts, although lower in the cervical spine cohort compared with the lumbar cohort (0.5% vs. 0.9%, respectively; p=.01). There were two readmissions because of a retained foreign body; both were in the lumbar cohort.

Readmissions after fusion surgery with BMP

Bone morphogenetic protein is used only in fusion surgery (Table 3). Readmissions were significantly higher among beneficiaries who underwent cervical fusion surgery with BMP (cervical 11.2% vs. 7.5% without BMP, p<.001; lumbar 9.1% vs. 9.3% without BMP, p=.191). Again, the most common category of reasons for readmissions using the Clinical Classifications Software was ‘‘injury and poisoning, complication’’ (cervical 33.4%; lumbar 36.0%). The cervical BMP cohort most often had a complication diagnosis of hemorrhage/hematoma complicating a procedure (9.1%), followed by other complications of medical/surgical procedure (5.8%) and postoperative infection (4.3%). In comparison, the lumbar BMP cohort most often had a complication diagnosis of postoperative infection (15.1%), followed by complication of a device, implant, or graft (5.1%) and hemorrhage/hematoma complicating a procedure (4.0%).

Other common reasons for readmission included respiratory reasons, diseases of the musculoskeletal system and

Table 3
Top five reasons for readmission among patients undergoing fusion surgery with and without BMP*

Patient and surgical characteristics	Cervical with BMP (n=329), n (%)	Cervical without BMP (n=3,328), n (%)	p Value
Injury and poisoning	110 (33.4)	838 (25.2)	.001
Complications	106 (32.2)	753 (22.6)	
Hemorrhage/hematoma complicating procedure	30 (9.1)	168 (5.1)	
Complication of device, implant, or graft	24 (7.3)	166 (5.0)	
Other complications of medical/surgical procedure	19 (5.8)	164 (4.9)	
Postoperative infection	14 (4.3)	137 (4.1)	
Respiratory	45 (13.7)	377 (11.3)	.203
Pneumonia (including aspiration pneumonia)	30 (9.1)	215 (6.5)	
Respiratory failure	9 (2.7)	61 (1.8)	
Diseases of the musculoskeletal system and connective tissue	41 (12.5)	513 (15.4)	.154
Diseases of the heart	25 (7.6)	363 (10.9)	.063
Acute myocardial infarction, coronary atherosclerosis, and other heart disease	10 (3.0)	91 (2.7)	
Gastrointestinal disorders	30 (9.1)	292 (8.8)	.833
Dysphagia	10 (3.0)	77 (2.3)	
Patient and surgical characteristics	**Lumbar with BMP (n=2,211)**	**Lumbar without BMP (n=7,626)**	**p Value**
Injury and poisoning	795 (36.0)	2,842 (37.3)	.261
Complications	737 (33.3)	2,706 (35.5)	
Postoperative infection	343 (15.1)	1,451 (19.0)	
Complication of device, implant, or graft	113 (5.1)	299 (3.9)	
Hemorrhage/hematoma complicating procedure	89 (4.0)	256 (3.4)	
Other complications of medical/surgical procedure	80 (3.6)	407 (5.3)	
Diseases of the musculoskeletal system and connective tissue	340 (15.4)	1,023 (13.4)	.019
Diseases of the heart	219 (9.9)	806 (10.6)	.368
Acute myocardial infarction, coronary atherosclerosis, and other heart disease	545 (2.4)	211 (2.8)	
Gastrointestinal disorders	190 (8.6)	621 (8.1)	.498
Respiratory	104 (4.7)	325 (4.3)	.370
Pneumonia (including aspiration pneumonia)	65 (2.9)	185 (2.4)	
Respiratory failure	13 (0.6)	43 (0.6)	

BMP, bone morphogenetic protein.
Clinical Classifications Software used. Not all subcategories and percentages listed.
* Percentage of total readmissions.

connective tissue, diseases of the heart, and gastrointestinal disorders, but readmissions for these reasons were similar among cervical and lumbar fusions with and without BMP, and comparison did not reach statistical significance.

Predictors of 30-day readmissions

We determined patient and surgery characteristics that were significant predictors of 30-day readmissions using multiple logistic regression models (Table 4). The cervical model explained 63.6% of the variability in readmissions; the lumbar model explained 61.0% of the variability in readmissions. The receiver operating characteristic curves using the random half splits were nearly identical visually and by the area under the curve (cervical 0.641 and 0.629; lumbar 0.609 and 0.608).

Patient predictors of readmissions

Several patient characteristics were associated with increased risk of readmission for both the cervical and lumbar spine cohorts: increasing age, a higher Charlson Deyo comorbidity index, and dual eligibility for Medicaid/Medicare status (Table 4). For the cervical cohort, male sex and a diagnosis of myelopathy were also risk factors, and there was a trend for higher readmissions among blacks (p=.03). For the lumbar cohort, sex and a diagnosis of myelopathy were not significant risk factors, but black race and geographic location were, with the highest risk of readmission seen in the Middle Atlantic region.

Surgical predictors of readmission

Several surgical characteristics were associated with increased risk of readmission, but these differed between the cervical and lumbar cohorts (Table 4). For the cervical spine cohort, the posterior approach and a combined anterior and posterior approach were associated with a higher risk of readmission compared with an anterior approach. More invasive fusions (four or more levels) and BMP-augmented two to three and four or more level fusions were also associated with a higher risk of readmission compared with non-fusion procedures.

In contrast, in the lumbar spine cohort, a posterior or combined anterior posterior approach was associated with

Table 4
Associations between patient and surgery characteristics and 30-day readmissions: odds ratios and 95% confidence intervals

Patient and surgical characteristics	30-day readmissions			
	Cervical	p	Lumbar	p
Age (y) (reference: 66–70 y)	—	<.001	—	<.001
71 to 75	1.20 (1.11–1.29)		1.19 (1.14–1.24)	
76 to 80	1.46 (1.34–1.58)		1.40 (1.34–1.45)	
81 and older	1.92 (1.74–2.12)		1.71 (1.64–1.79)	
Sex (reference: female)	1.30 (1.22–1.39)	<.001	1.01 (0.98–1.04)	.514
Race/ethnicity (reference: white)	—	.031	—	<.001
Black	1.12 (1.00–1.25)		1.12 (1.04–1.21)	
Other	0.86 (0.71–1.03)		0.83 (0.75–0.92)	
Medicare/Medicaid status (reference: Medicare only)	1.35 (1.22–1.50)	<.001	1.38 (1.30–1.46)	<.001
Geographic location by census area (reference: West South Central)*	—	NS	—	<.001
East North Central			1.00 (0.95–1.06)	
East South Central			0.98 (0.91–1.05)	
Mountain			1.01 (0.95–1.08)	
Middle Atlantic			1.10 (1.04–1.17)	
New England			0.93 (0.85–1.01)	
Pacific			0.84 (0.79–0.90)	
South Atlantic			0.91 (0.87–0.96)	
West North Central			0.93 (0.88–1.00)	
Comorbidity, Charlson Deyo Index (reference: 0)	—	<.001	—	<.001
1	1.31 (1.22–1.41)		1.30 (1.26–1.34)	
2 or more	1.80 (1.65–1.95)		1.84 (1.77–1.92)	
Diagnosis of myelopathy (reference: no myelopathy)*	1.30 (1.22–1.38)		NS	—
Surgical approach (reference: anterior approach)	—	<.001	—	.001
Posterior approach	1.26 (1.14–1.38)		0.67 (0.58–0.78)	
Anterior and posterior	1.38 (1.22–1.57)		0.81 (0.67–0.98)	
Fusion procedure (reference: nonfusion)	—	<.001	—	<.001
No. of levels not specified	1.16 (1.02–1.33)		1.75 (1.67–1.85)	
No. of levels not specified, with BMP	0.96 (0.51–1.79)		1.50 (1.25–1.79)	
2–3 levels	1.00 (0.89–1.13)		1.49 (1.44–1.55)	
2–3 levels, with BMP	1.51 (1.25–1.82)		1.48 (1.40–1.56)	
4 or more levels	1.45 (1.29–1.63)		1.98 (1.85–2.11)	
4 or more levels, with BMP	2.00 (1.63–2.45)		2.04 (1.85–2.25)	

NS, not significant; BMP, bone morphogenetic protein.
Year of study and per capita income was not significant for any model.
* Geographic location by census area was not significant in the cervical cohort; a diagnosis of myelopathy was not significant in the lumbar cohort.

a lower risk of readmission compared with an anterior approach. In addition, any fusion procedure was associated with higher risk of readmission compared with a nonfusion procedure, and this risk increased with increasing number of levels fused. However, the use of BMP did not appear to confer added risk for 30-day readmission beyond the number of levels treated in this adjusted comparison.

Probability of readmission

Using the same models, we calculated the mean probability of readmission for specific subgroups (Figure). For all patients, the mean probability of readmission increased with older age and with higher Charlson Deyo comorbidity index. More invasive fusions (four or more levels) conferred the highest mean probability of readmission for both cervical and lumbar patients, even after taking age and comorbidity index into account. For example, a patient aged 71 to 75 years with low comorbidity (Charlson Deyo index of 1) had an average predicted probability of readmission of 7.5% after a two- to three-level cervical fusion but 11.6% after a four or more level cervical fusion. An older patient (aged 76–80 years) with greater comorbidity (Charlson Deyo index of 2) and a cervical fusion of four or more levels had an average predicted probability of readmission of 19.1%.

In the lumbar spine, we noted a similar pattern with the lowest average probability of readmission noted in the youngest age group with low comorbidity undergoing a nonfusion procedure or less invasive procedure. For example, a patient aged 66 to 70 years with no comorbid conditions and a non-fusion procedure had an average predicted probability of readmission of 4.2%. However, a patient aged 71 to 75 years with low comorbidity (Charlson Deyo index of 1) and a two- to three-level lumbar fusion had an average predicted probability of readmission of 9.6%, compared with 12.0% for the same patient undergoing a four or more level lumbar fusion. We noted the highest average predicted probability of readmission (18.6%) for a patient aged 76 to 80 years with a comorbidity index of 2 and a four or more level lumbar fusion.

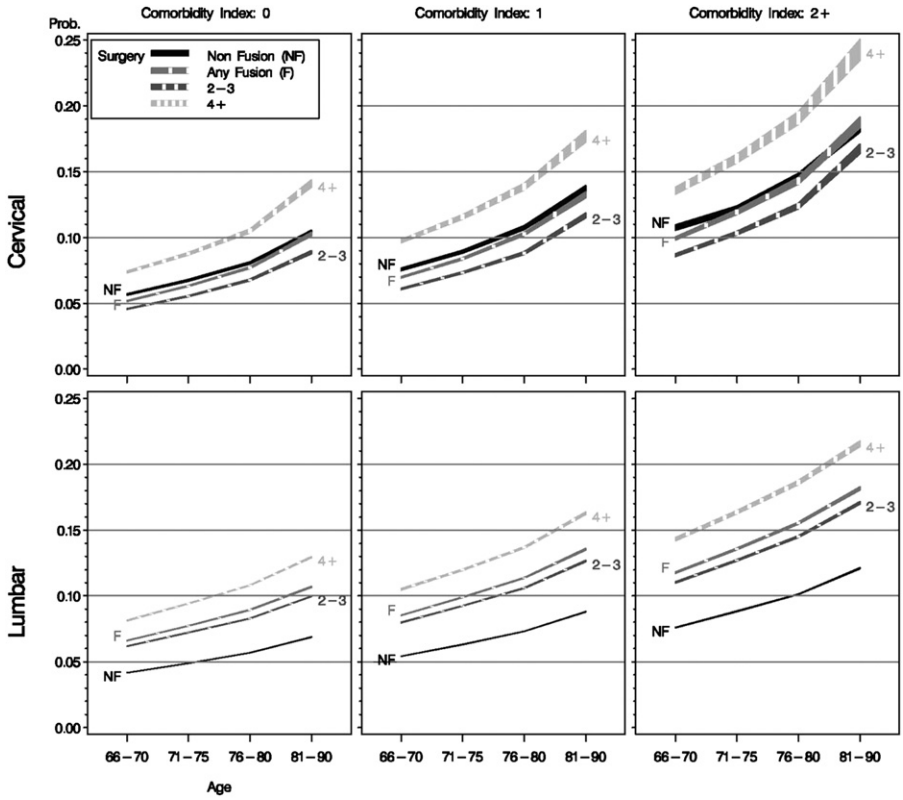

Figure. Probability of readmission by age, comorbidity index, and type of surgery.

Discussion

Thirty-day readmissions after elective cervical and lumbar spine surgery for degenerative conditions are 7.9% and 7.3%, respectively, and represent a target for potential improvement. The most common reason for readmission by primary ICD-9-CM diagnosis codes was a complication of care. The second most common reason for readmission was a musculoskeletal diagnosis most often in the same area of the spine as the index surgery. In comparing cervical and lumbar readmissions, postoperative infections were higher in the lumbar cohort. However, readmissions for respiratory reasons and for hypovolemia were higher in the cervical cohort.

Overall, there were significant differences in patient and surgery characteristics between the cervical and lumbar cohorts. The cervical cohort, although slightly younger, had more risk factors for poor outcome such as higher comorbidity index and a diagnosis of myelopathy or spinal cord dysfunction. Type of surgery and surgical approach also differed between the cohorts, with cervical spine patients more often undergoing fusion surgery and surgery from an anterior approach.

There were several predictors of readmission that were consistent for both the cervical and lumbar cohorts: increasing patient age, higher comorbidity index, dual Medicare/Medicaid eligibility, and more invasive fusions (four or more levels fused). For cervical spine patients, male sex, a diagnosis of myelopathy, and a posterior surgical approach were also associated with increased risk of readmission in our multivariate model. In addition, we found increased risk of readmission with the use of BMP, potentially modifiable factor. Of note, in 2008, after our study time period, the Food and Drug Administration issued a warning for off-label use of BMP in the cervical spine because of complications of dysphagia and breathing problems [17]. In contrast, in the lumbar cohort, fusion procedures were associated with higher risk of readmission compared with nonfusion procedures, but the use of BMP did not add a significantly increased risk beyond the number of levels fused. Given our 30-day readmission time frame, this is not surprising because many of the complications reported for lumbar spine surgery, such as radiculitis, retrograde ejaculation, and delayed implant displacement or subsidence [18], would not have been expected to result in a short-term readmission unlike the complications seen among cervical spine surgery patients. Among lumbar patients, we also found an association between readmissions and black race, and with geographic location (Middle Atlantic Region).

These findings warrant further study. Some predictors, such as older age and comorbid conditions, are associated with increased risk of 30-day readmissions after surgery for other conditions including hip replacement [22] and coronary artery bypass graft surgery [23]. More invasive

lumbar fusions are associated with higher complications and mortality after spine surgery for lumbar spinal stenosis [3]. However, geographic location and socioeconomic or demographic predictors such as race/ethnicity may represent differences in factors such as social support systems, processes of care, or practice environment. The role of patient preference and provider characteristics is not known.

There are several limitations to our study. These results may not be generalizable beyond the fee-for-service Medicare population, and some variables, such as race/ethnicity, may lack accuracy. However, black race may be more reliably coded and misclassification is likely nondifferential [24,25]. The ICD-9-CM codes used in this study lack detail about specific surgical techniques and use of devices or instrumentation [12] and may be subject to coding errors [26]. Although we used validated ICD-9-CM code algorithms to select cervical and lumbar surgery admissions, and readmissions were classified using the AHRQ Clinical Classifications Software (ICD-9-CM codes), chart adjudication was not performed in this large dataset. The indications for surgery and progression of symptoms cannot be determined using administrative data, nor can other outcomes, such as function or quality of life. However, these data allow for near population–based measurements of the general practice of spine surgery in the United States. Although complications are likely underreported using these data [27], we studied hospital readmissions and the primary diagnoses associated with these readmissions. We would not have captured secondary diagnoses; for example, a readmission associated with a primary diagnosis of musculoskeletal disease, cervical spondylosis with myelopathy; and a secondary diagnosis of complication of surgery, postoperative infection, would be classified under the musculoskeletal heading. Although a portion of these readmissions may have been planned readmissions for reasons such as a staged surgical procedure, this is difficult to determine using ICD-9-CM codes. Analysis of surgeon claims data using Current Procedural Terminology codes may provide more information in this regard because Current Procedural Terminology modifiers indicating a staged procedure are used within the 90-day global period after a surgery, and these may provide data about planned reoperations. Use of BMP in fusion surgery is also not well quantified because dose cannot be determined. In addition, complications associated with the use of BMP may occur after the 30-day window of our study or may not result in a readmission to the hospital. These complications would not have been captured in our study.

Despite these limitations, this is the first study to report near population–based 30-day readmissions, reasons for readmissions, and predictors of readmissions among Medicare beneficiaries undergoing elective cervical and lumbar spine surgery for degenerative conditions. In comparison with the findings of Jencks et al. [10] of 19.6% readmissions within 30 days of discharge among Medicare beneficiaries rehospitalized after both medical and surgical index admissions, we found lower readmissions in this elective surgery group. However, our 30-day readmissions are also lower than the 12.3% reported by Deyo et al. [13] in their study of initial and revision spinal fusion surgery for lumbar stenosis. In part, this may be because of the differences in inclusion and exclusion criteria. We included all degenerative diagnoses and all types of spine surgery in our study, but restricted inclusion to those beneficiaries undergoing elective surgeries that were not coded as reoperations, and those who did not have any spine surgery for the year before the index admission. Likewise, we also strictly defined 30-day readmissions to exclude admissions for rehabilitation. Our findings are more similar to the 8.5% 30-day readmissions after total hip arthroplasty in US Medicare beneficiaries reported by Cram et al. [28]. Similarly, Zhan et al. studied hip arthroplasty in a general adult population in five states and found 30-day readmissions of 4.9% and 12.2% for total and partial hip arthroplasty, respectively [22].

Better understanding of predictors of readmission may help improve risk stratification and patient counseling. Our regression models allow calculation of the average probability of 30-day readmissions among various subgroups, and these data could be used to improve patient counseling in regard to risk of readmission associated with particular cervical or lumbar spine procedures. Our findings suggest that cervical and lumbar spine surgeries be studied separately because there are significant differences in patient and surgery characteristics and in the reasons for readmission.

Further study of the most common reasons for readmissions may help providers target high-risk subgroups for clinical trials of preventative interventions to reduce readmissions. For example, hospitals could provide specialized support to high-risk patients. In addition, the reasons for readmission may suggest modifications in care pathways. Postoperative infections are one of the most common reasons for readmission after lumbar spine surgery and may represent a target for intervention. Respiratory reasons for readmissions were higher in the cervical spine cohort than the lumbar spine cohort and may present another area for improvement. Future studies of specific surgical techniques that are not distinguished using ICD-9-CM codes, such as number of levels treated by decompression or instrumentation, processes of care, and indications for surgery may help further improve our identification of subgroups at higher risk for readmissions, improve patient counseling and risk stratification, and highlight opportunities to reduce readmission rates.

Acknowledgments

Grant support was received from Robert Wood Johnson Physician Faculty Scholars Program and the American Association of Neurological Surgeons/Congress of Neurological Surgeons Joint Section on Disorders of the Spine and Peripheral Nerves Larson Award. The authors wish to thank

Richard Deyo, MD, MPH, for his input and use of the lumbar ICD-9-CM algorithm and Nadia Malik, MBBS, CPC, for her assistance and coding expertise.

This study was approved by the Institutional Review Board of the Medical College of Wisconsin.

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