Surgeon-Level Variability in Outcomes, Cost, and Comorbidity Adjusted-Cost for Elective Lumbar Decompression and Fusion

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BACKGROUND: The costs and outcomes following degenerative spine surgery may vary from surgeon to surgeon. Patient factors such as comorbidities may increase the health care cost. These variations are not well studied.

OBJECTIVE: To understand the variation in outcomes, costs, and comorbidity-adjusted cost for surgeons performing lumbar laminectomy and fusions surgery.

METHODS: A total of 752 patients undergoing laminectomy and fusion, performed by 7 surgeons, were analyzed. Patient-reported outcomes and 90-d cost were analyzed. Multivariate regression model was built for high-cost surgery. A separate linear regression model was built to derive comorbidity-adjusted 90-d costs.

RESULTS: No significant differences in improvement were found across all the patient-reported outcomes, complications, and readmission among the surgeons. In multivariable model, surgeons #4 ($P < .0001$) and #6 ($P = .002$) had higher odds of performing high-cost fusion surgery. The comorbidity-adjusted costs were higher than the actual 90-d costs for surgeons #1 ($P = .08$), #3 ($P = .002$), #5 ($P < .0001$), and #7 ($P < .0001$), whereas they were lower than the actual costs for surgeons #2 ($P = .128$), #4 ($P < .0001$), and #6 ($P = .44$).

CONCLUSION: Our study provides valuable insight into variations in 90-d costs among the surgeons performing elective lumbar laminectomy and fusion at a single institution. Specific surgeons were found to have greater odds of performing high-cost surgeries. Adjusting for preoperative comorbidities, however, led to costs that were higher than the actual costs for certain surgeons and lower than the actual costs for others. Patients' preoperative comorbidities must be accounted for when crafting value-based payment models. Furthermore, designing intervention targeting "modifiable" factors tied to the way the surgeons practice may increase the overall value of spine care.

KEY WORDS: Spine, 90-d cost, Outcomes, Surgeon variability, Bundled payments

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The current trajectory of the health care expenditure in the United States (US) is unsustainable. According to the Centers for Medicare and Medicaid Services (CMS), projected health spending in the US will be as high as 20% of the gross domestic product by 2021. Low back pain associated with lumbar degenerative pathologies is highly prevalent and an economic burden.[1-5] It is important to investigate costs and to examine the real-world clinical and cost benefit of commonly performed spinal surgeries.

ABBREVIATIONS: ASA, American Society of Anesthesiologists; **AUC,** area under the curve; **BMI,** body mass index; **CI,** confidence interval; **CMS,** Centers for Medicare and Medicaid Services; **CPT,** current procedural terminology; **DRG,** diagnosis-related group; **EQ-5D,** EuroQol-5D; **NRS,** numeric rating scale; **ODI,** Oswestry Disability Index; **OR,** odds ratio; **PRO,** patient-reported outcome; **US,** United States

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In an effort to curb escalating costs, CMS has proposed a pay-for-performance episode-based bundled payment model for hospital and physician reimbursement. The current fee-for-service model, whereby the Medicate reimbursement to the hospital is based on discounted rates payment rates established under the Inpatient Prospective Payment System, is considered a potential source of increasing health care spending. With the proposed bundled payment initiative, the individual physician, hospital, and other providers will be accountable for the quality of care and associated costs from surgery through 90 d after discharge.[6-8] This model mandates all stakeholders to collaborate and investigate optimal strategies for arriving at a target price for a bundled payment. To determine a sustainable bundled cost, it is important to understand the biggest contributors to and variability in the cost at each level of patient care.

The inpatient hospital cost, cost associated with readmission following surgery, and surgeon's professional fee cost are the 3 most important contributors of the cost for spine surgery.[8-11] A number of previous studies have focused on the variations in hospital cost and total cost during the 90-d postdischarge period.[8,9,11,12] Less well studied is the individual surgeon variation in cost, specifically from the same institution and given fairly standardized techniques. Variation in cost, if extant, provides an opportunity to understand the differences and learn from the better practice patterns. Given the wide variation in patient profile, disease process, surgical techniques, and practice patterns, it is prudent to assess the cost variability and to determine the factors driving high cost surgery. Furthermore, it is generally believed that the sicker patients account for higher cost associated with spine care.[13-20] It is vital to understand the variation in cost associated with comorbidities. In this regard, the aims of this study were to define variability in total 90-d cost among the surgeons, to define factors associated with high-cost surgery and to determine the difference in total 90-d cost and cost adjusted for comorbidities for patients undergoing laminectomy and fusion surgery for degenerative spine diseases.

METHODS

Patients undergoing elective decompression and fusion surgery for degenerative spine pathology between 2011 and 2015 at a single comprehensive spine center were enrolled into a single-center prospective longitudinal spine registry. A retrospective review of prospectively collected data was conducted. An approval for the study and wavier of informed consent was obtained from the institutional review board for all the patients entered into the registry. The inclusion criteria were (1) patients age >18 yr; (2) presenting with leg and/or back pain; (3) the correlative imaging findings for the diagnosis of disc herniation, stenosis, and spondylolisthesis; and (4) failed 3-mo of multimodal nonoperative care or patients with progressive neurological deficit. The exclusion criteria were (1) pathological spine disease including tumor, infection, and trauma; (2) any extra-spinal cause of back or leg pain; (3); patients who were unable or unwilling to complete the follow-up questionnaire.

Patients operated on by 7 surgeons, who are participating in the registry, were analyzed. Patient demographics, comorbidities (diabetes, hypertension, coronary artery disease, myocardial infarction, preoperative anticoagulation, congestive heart failure, chronic obstructive pulmonary disease, and osteoporosis), clinical presentation, operative variables, and postoperative morbidity were reviewed through electronic medical records. The following validated patient-reported outcomes (PROs) were recorded at baseline and 3-mo after surgery: (1) back-related disability: Oswestry Disability Index (ODI)[21]; (2) numeric rating scale (NRS) for back pain and leg pain[22]; and (3) quality of life—EuroQol-5D (EQ-5D).[23]

Cost Data

Total 90-d costs were derived as sum of inpatient hospital stay (hospital cost), surgeons' professional fee (derived based on current procedural terminology [CPT] codes), and postdischarge health care resource utilization. The costs were derived based on Medicare national payment amounts. To standardize and eliminate geographic variations, a unit multiplier was used. The costs were recorded based on resource utilization, derived from patient-reported use and institutional records. Such calculations have been reported previously.[16,17,24-26] The hospital cost was based on the type of surgery performed, the severity of the individual case, and whether in-hospital complications occurred, which collectively determined the diagnosis-related group (DRG). Surgeons' professional fees were derived based on CPT codes. Ancillary postdischarge resource utilization was derived from CPT codes assigned for patient self-reported resource utilization. Low back-related outpatient visits to surgeons or other physicians, chiropractors, physical and occupational therapists, and acupuncturists were captured. The postdischarge need for X-rays, computed tomography scans, magnetic resonance imaging, and electromyography were tracked to derive diagnostic cost. Postoperative devices (braces, canes, and walkers), emergency department visits, epidural steroid injections, back-specific medications (nonsteroidal anti-inflammatory drugs, oral steroids, narcotics, muscle relaxants, antidepressants), and inpatient and outpatient rehabilitation days were assessed. The costs incurred due to readmissions to our institution during the 90-d period were also recorded.

Statistical Analysis

Descriptive data including mean (standard deviation) for continuous variables, and frequency (proportions) for categorical variables were computed. Bivariate analysis was conducted to compare the preoperative, operative, and postoperative variables as well as costs among the surgeons. Baseline and 3-mo PROs were compared using paired *t*-test. Chi-square test and Fisher's exact test for nominal variables and 1-way ANOVA was used for continuous variables. The post hoc test (Bonferroni test) was used to determine the differences in cost between each individual surgeon. The median and standard deviation for total 90-d cost was derived. High cost was defined as total 90-d cost higher than third quartile. Multivariable logistic regression model was built to determine the factors associated with high-cost fusion surgery. The preoperative patient-specific and surgery-specific variables, surgeons as well as complication and readmission, which were selected a priori, were included in the model. The model performance was examined using area under the curve (AUC) for model's receiver operating characteristics curve. To demonstrate the effect of comorbidities on total 90-d cost, we compared the difference in actual 90-d cost and comorbidity adjusted 90-d cost for each surgeon. A separate linear regression model was built for total 90-d cost to derive the comorbidity-adjusted 90-d costs. The variables including age (old age $\geq$65 yr), obesity (body mass index [BMI] $\geq$ 35), ASA (American Society of Anesthesiologists scale) grades, number of comorbidities, each comorbidity including diabetes, hypertension, myocardial infarction, atrial fibrillation, arthritis, osteoporosis, chronic pulmonary disease, congestive heart failure, coronary artery disease, and history of preoperative anticoagulation were included in the model. The difference between the actual 90-d cost and comorbidity adjusted 90-d cost was compared for each surgeon. The analyses were performed using SPSS version 22 (IBM, Armonk, New York) analysis software.

RESULTS

A total of 752 patients undergoing decompression and fusion surgery operated on by 7 surgeons were analyzed. The mean age of 332 male

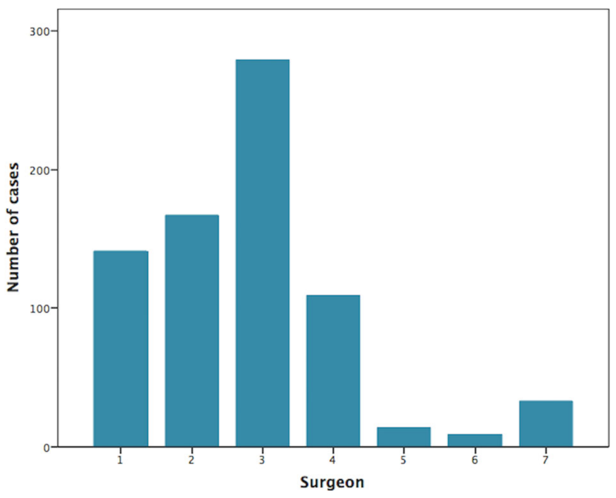

FIGURE 1. *Bar-diagram demonstrating number of patients operated on by each individual surgeon.*

and 418 female patients was 60.8 ± 12.0 yr. Figure 1 demonstrates a bar diagram for frequency of patients operated on by each surgeon.

Variability in Patient Characteristics

Table 1 compares the preoperative patient characteristics and surgery variables among surgeons. There was a significant variability in patient-specific variables including age at the time of surgery ($P < .0001$), smoking status ($P = .004$), insurance type ($P = .003$), revision surgery ($P = .003$), neurogenic claudication ($P < .0001$), motor deficits ($P = .005$), higher ASA grades (>3, $P = .02$), history of hypertension ($P = .02$), diagnoses ($P < .0001$), estimated blood loss ($P < .0001$), and length of hospital stay ($P < .0001$). The baseline ODI score (ranging from 38.2 ± 12.6 to 53.8 ± 15.7, $P < .0001$) and NRS-leg pain score (LP; ranging from 5.3 ± 2.4 to 7.6 ± 2.7, $P = .02$) was significantly different among the participating surgeons. There were no significant differences in EQ-5D, and NRS-back pain (BP; Table 1).

Variability in Outcomes

There was significant improvement in ODI: 45.9 ± 13.4 vs 25.8 ± 18.3, EQ-5D: 0.55 ± 0.20 vs 0.78 ± 0.17, NRS: BP: 6.6 ± 2.5 vs 3.0 ± 2.7, and NRS: LP: 6.6 ± 3 vs 2.6 ± 3.2 ($P < .0001$) for all patients from baseline to 3 mo after surgery. There were no significant differences in improvement across all the PROs (change score) among the surgeons (Table 2). No significant differences in the complication and readmission rates within 90-d after surgery among the surgeons were observed.

Variability in Cost

The mean total 90-d direct cost for laminectomy and fusion surgery was \$28 947 ± \$9484 (median: \$27 565, interquartile range: \$22 952, \$32 837; Figure 2). The DRG-based hospital cost for these patients was \$24 399 ± \$8190. There were significant differences in the hospital cost, surgeons' professional fee, and costs associated with postdischarge resource utilization among the surgeons (Table 3).

Multivariable Model for High-Cost Fusion Surgery

Twenty-five percent (n = 188) of patients were above the third quartile of the total 90-d cost (Figure 2), and were defined as high-cost fusion surgery. In a multivariable logistic regression analysis, the length of hospital stay (odds ratio [OR]: 1.3, 95% confidence interval [CI]: 1.2-1.5, $P < .0001$), length of surgery (OR: 1.013, 95% CI: 1.01-1.02, $P < .0001$, $P < .0001$), number of levels operated on (OR: 1.4, 95% CI: 1.2-1.5, $P = .023$), occurrence of 90-d complications (OR: 1.8, 95% CI: 1.01-3.5, $P = .0045$) and readmission (OR: 3.7, 95% CI: 1.2-10.9, $P = .019$) were associated with high 90-d costs for fusion surgery. After controlling for all the aforementioned variables, surgeon # 4 (OR: 21.4, 95% CI: 5.2-88.7, $P < .0001$) and surgeon # 6 (OR: 20.5, 95% CI: 2.7-155.7, $P = .003$) had higher odds of having high-cost fusion patients (Table 4). The AUC for models' receiver operating characteristics curve was 0.885.

Multivariable Model to Derive Comorbidity-Adjusted Cost

Table 5 summarizes the comorbidities included in the model to derive the comorbidity-adjusted cost. To adjust for the patients' preoperative health state, we compared the comorbidity-adjusted 90-d cost to the actual 90-d cost for each participating surgeon. Figure 3 demonstrates the 90-d adjusted cost vs actual 90-d cost for each participating surgeon. The vertical axis represents actual median 90-d cost (\$27 565). The black dots represent average comorbidity-adjusted 90-d cost for each surgeon and the colored dot represents the average actual 90-d costs. The line joining the colored and black dots represents the difference between the actual and the adjusted average cost. The adjusted cost was higher than the actual cost for surgeons # 1 ($P = .08$), #3 ($P = .002$), #5 ($P < .0001$), and #7 ($P < .0001$), whereas the adjusted cost was lower for surgeons # 2 ($P = .128$), #4 ($P < .0001$), and #6 ($P = .44$). This suggests that based on the health state of their respective patients, the surgeons #1, #3, #5, and #7 spent lower than expected and surgeons #2, #4, and #6 were costlier than expected.

DISCUSSION

Current trends in strategies to target cost-containment are specially aimed at reducing variability in cost and outcomes. A number of studies have defined the variability in outcomes following spine surgery and a handful of studies have defined the variability in cost within each individual spine-related DRG.[8,9,11,12,27] None of the prior studies have demonstrated the variations in cost and outcomes at the individual surgeon level. In these analyses, utilizing prospectively collected registry data from a single-center, we demonstrate that there were significant differences in total 90-d costs and patient-specific factors among the surgeons. Despite these differences, no significant differences in improvement in the disability, pain, and quality of life outcomes 90 d after surgery were observed. Some surgeons had higher odds of performing high-cost fusion surgery. There was a significant variability in comorbidity-adjusted cost vs actual cost among the surgeons. After adjusting for preoperative comorbidities, the adjusted costs were higher than actual cost for some surgeons and lower than the actual cost for others. Our study provides valuable insights into variations in patient characteristics, outcomes, and costs among the participating surgeons at a single institution. This study can form the basis to stimulate action to improve uniformity and cost-containment for lumbar fusion surgery.

TABLE 1. Variation in Patient-Specific and Surgery-Specific Factors Among the Participating Surgeons

	1 (n = 141)	2 (n = 167)	3 (n = 279)	4 (n = 109)	5 (n = 14)	6 (n = 9)	7 (n = 33)	*P*-value
Age [mean ± SD]	60.4 ± 13.2	61.1 ± 11.4	63.5 ± 10.3	57.5 ± 11.3	71.1 ± 9.1	52.0 ± 11.9	66.1 ± 11.4	<.0001
Gender: male	36 (43%)	42 (39%)	75 (36%)	51 (54%)	4 (67%)	4 (57%)	15 (52%)	.07
BMI [mean ± SD]	30.1 ± 6.4	30.8 ± 6.8	31.8 ± 7.7	31.2 ± 6.1	28.9 ± 6.2	28.4 ± 5.4	31.0 ± 6.9	.47
Smoker	18 (22%)	23 (21%)	27 (13%)	20 (21%)	0	0	1 (3%)	.004
Insurance								.03
Medicaid/uninsured	17 (20%)	24 (22%)	40(20%)	25 (27%)	1 (17%)	0	4 (14%)	
Medicare	29 (35%)	36 (34%)	91 (44%)	26 (28%)	4 (67%)	0	13(45%)	
Private	37 (45%)	47 (44%)	75 (36%)	43 (46%)	1(16%)	7 (100%)	12 (41%)	
Prior surgery	23 (28%)	53 (50%)	58 (28%)	36 (38%)	2 (33%)	3 (43%)	13 (45%)	.003
Neurogenic claudication	10 (12%)	17 (16%)	72 (34%)	18 (19%)	1 (17%)	0	1 (4%)	<.0001
Motor deficits	12 (14%)	30 (28%)	68 (33%)	40 (42%)	3 (50%)	2 (29%)	7 (24%)	.005
Duration of symptoms ≥ 12 m	50 (60%)	77 (72%)	132 (64%)	60 (64%)	5 (83%)	3 (42%)	15 (52%)	.31
Duration of preoperative opioid use [mean ± SD]	425.7 ± 1048	470 ± 1045	364 ± 1082	585 ± 1139	451 ± 1449	304 ± 716	224 ± 455	.55
Comorbidities								
ASA grades > 3	56 (67%)	68 (64%)	159 (77%)	66 (70%)	4 (67%)	4 (57%)	23 (79%)	.02
Diabetes	22 (27%)	21 (20%)	57 (28%)	22 (23%)	1 (17%)	1 (14%)	10 (34%)	.59
Hypertension	47 (57%)	65 (61%)	142 (69%)	59 (63%)	6 (100%)	1 (14%)	20 (69%)	.02
MI	3 (4%)	7 (7%)	12 (6%)	6 (6%)	1 (17%)	0	2 (7%)	.85
CAD	14 (17%)	28 (26%)	46 (22%)	22 (23%)	2 (33%)	0	9 (31%)	.43
COPD	3 (4%)	2 (2%)	8 (4%)	3 (3%)	2 (33%)	0	1 (3%)	.59
Osteoporosis	3 (4%)	2 (2%)	9 (4%)	2 (2%)	0	0	1 (3%)	.88
Preoperative anticoagulation	2 (2%)	2 (2%)	5 (2%)	2 (2%)	0	0	4 (14%)	.03
Primary diagnosis								<.0001
Disc herniation	20 (24%)	7 (7%)	14 (7%)	14 (16%)	0	1 (14%)	0	
Stenosis	29 (35%)	63 (59%)	89 (43%)	29 (31%)	1 (17%)	2 (29%)	0	
Spondylolisthesis	34 (41%)	37 (35%)	103 (50%)	51 (54%)	5 (83%)	4 (57%)	16 (100%)	
Number of levels [mean ± SD]	1.8 ± 0.83	1.9 ± 0.87	1.9 ± 0.85	1.7 ± 0.86	2.0 ± 1.1	1.3 ± 0.76	1.8 ± 0.97	.31
EBL [mean ± SD]	469 ± 302	553 ± 434	709 ± 513	512 ± 363	320 ±124	471 ± 496	509 ± 342	< .0001
Length of surgery [mean ± SD]	240 ± 63	245 ± 79	229 ± 72	235 ± 65	274 ± 76	239 ± 53	253 ± 61	.001
Length of hospital stay [mean ± SD]	4.3 ± 2.2	4.7 ± 3.1	3.6 ± 1.7	4.1 ± 1.8	3.5 ± 1.9	3.7 ± 1.9	2.7 ± 1.1	.29
Interbody graft	61 (44%)	70 (42%)	119 (45%)	69 (65%)	4 (31%)	6 (67%)	15 (47%)	.001

MI, myocardial infarction; CAD, coronary artery disease; COPD, chronic obstructive pulmonary disease; EBL, estimated blood level; SD, standard deviation.

Number of factors can result in variations in the cost associated with fusion surgery. It is possible that the interplay of patient-specific factors and surgery-specific factors may also induce variation in the utilization of health care services and therefore induce variability in total 90-d costs. Prior studies have demonstrated that the patients' comorbidity burden influence 90-d costs.[13-17] In this study, we have sought to take one step further, however, and simulate a workflow for surgeon-level process improvement. Figure 3 reveals which surgeons incurred average costs exceeding risk-adjusted predictions, and which surgeons were less costly than predicted. This finding highlights that there may be several exogenous factors, in addition to the patient-specific comorbidities that are tied to the way surgeons practice that influences the total 90-d costs. We can now turn our attention to a particular surgeon who was costlier than expected and investigate his or her specific cost distribution. For example, surgeons #4 and #6 had higher frequency of performing interbody graft fusion compared to other surgeons. However, after adjusting for interbody graft and other surgery-specific variables the surgeons #4 and #6 were high-cost surgeons. This suggests that there might be confounders beyond the variables included in the model. For example, surgeon #6 had higher postdischarge health care visit associated costs and surgeon #4 had higher hospital cost. Further, granular data with details on type of implant used, additional intraoperative costs, and breakdown of the cost associated with inpatient hospital stay is needed to accurately determine the practice pattern of high-cost surgeons. A habitual practice of examining surgeon-level cost variability in this manner, when coupled with evaluations of modifiable risk factors within surgeons' high-cost patient populations, can provide the makings of a true "learning health care system" as imagined by the Institute of Medicine.[28]

Consistent with previous studies, in our analysis, the high cost for fusion surgery was also associated with postoperative complication and readmission, increased surgery duration, and extended length of hospital stay. Complications and readmission within 90 d global period occur at a consistent frequency, specifically when analyzing the larger data sets.[20,29-32] The factors including patient age, obesity, associated comorbidities, primary diagnosis, and surgical invasiveness and complexity are associated with higher likelihood of developing complications and also influence the cost and outcomes following surgery.[18,19,30,33-38] We

TABLE 2. Variation in Complication, Readmission Within 90-day After Surgery, and PROs Among the Participating Surgeons

	1 (n = 141)	2 (n = 167)	3 (n = 279)	4 (n = 109)	5 (n = 14)	6 (n = 9)	7 (n = 33)	*P*-value
Complication	13 (16%)	22 (21%)	30 (15%)	16 (17%)	1 (17%)	0	4 (14%)	.75
Readmission (spine related)	4 (5%)	3 (3%)	8 (4%)	3 (3%)	0	0	2 (7%)	.93
Baseline PROs								
ODI [mean ± SD]	45.9 ± 13.5	45.6 ± 13.9	47.4 ± 14.3	53.8 ± 15.7	45.7 ± 15.9	38.2 ± 12.6	43.6 ± 13.5	<.001
EQ-5D [mean ± SD]	0.55 ± 0.20	0.57 ± 0.19	0.55 ± 0.21	0.49 ± 0.22	0.56 ± 0.22	0.62 ± 0.16	0.58 ± 0.18	.06
NRS-BP [mean ± SD]	6.5 ± 2.6	6.9 ± 2.3	6.9 ± 2.4	7.2 ± 1.8	6.4 ± 2.4	7.3 ± 0.87	7.5 ± 1.8	.34
NRS-LP [mean ± SD]	6.6 ± 3.0	6.2 ± 2.9	6.9 ± 2.6	6.5 ± 2.8	6.6 ± 2.4	5.3 ± 2.4	7.6 ± 2.7	.02
3-mo PROs								
ODI [mean ± SD]	26.01 ± 18.5	29.8 ± 16.8	28.4 ± 15.9	36.2 ± 19.5	25.6 ± 17.3	29.3 ± 16.1	26.2 ± 16.7	<.001
EQ-5D [mean ± SD]	0.77 ± 0.17	0.74 ± 0.17	0.75 ± 0.16	0.68 ± 0.21	0.77 ± 0.13	0.75 ± 0.17	0.78 ± 0.16	<.001
NRS-BP [mean ± SD]	3.0 ± 2.6	3.7 ± 2.5	3.5 ± 2.6	4.1 ± 2.8	2.7 ± 2.1	4.0 ± 2.7	3.3 ± 2.8	.06
NRS-LP [mean ± SD]	2.6 ± 3.3	2.9 ± 3.3	2.6 ± 3.0	3.1 ± 3.3	1.7 ± 2.7	3.3 ± 3.0	3.0 ± 3.1	.03
Change score for PROs								
ODI [mean ± SD]	20.2 ± 17.2	15.4 ± 16.4	18.4 ± 16.7	17.1 ± 21.6	20.1 ± 17.7	8.8 ± 13.2	16.3 ± 17.1	.18
EQ-5D [mean ± SD]	0.23 ± 0.22	0.17 ± 0.20	0.20 ± 0.22	0.18 ± 0.24	0.22 ± 0.20	0.13 ± 0.24	0.20 ± 0.23	.45
NRS-BP [mean ± SD]	3.6 ± 3.1	3.2 ± 2.7	3.4 ± 3.1	3.1 ± 3.1	3.6 ± 2.9	3.3 ± 3.0	3.9 ± 3.3	.71
NRS-LP [mean ± SD]	3.9 ± 4.1	3.2 ± 3.9	4.3 ± 3.8	3.3 ± 3.9	4.9 ± 3.2	2.0 ± 4.4	4.7 ± 3.4	.15

SD, standard deviation.

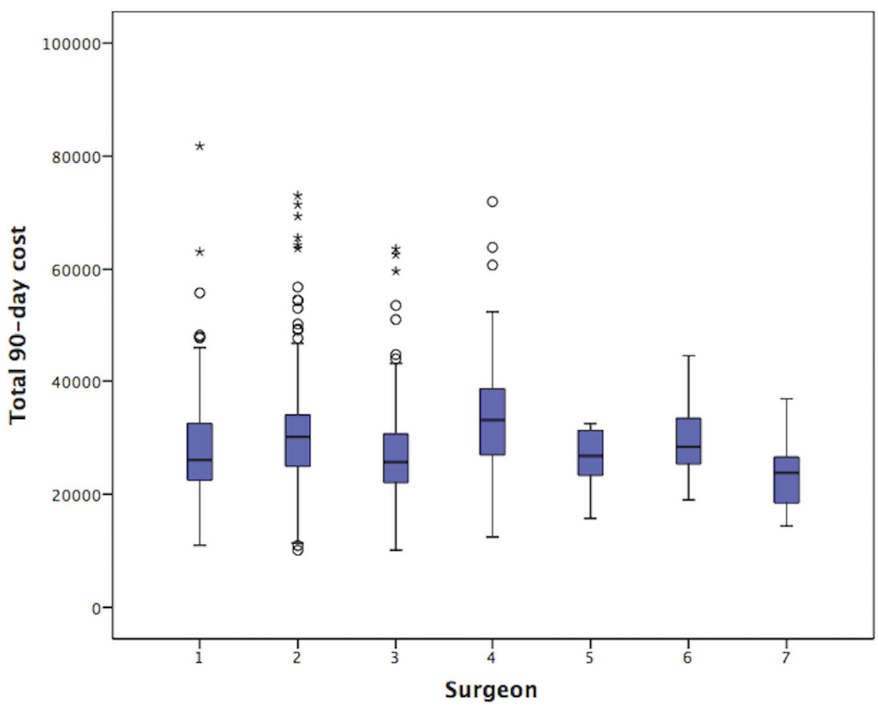

FIGURE 2. *Box-plot representing total 90-day cost among the participating surgeons. The empty circle and asterisk represent the outliers above third quartile or below first quartile. The outliers above third quartile were defined as high-cost patients.*

TABLE 3. Variations in Total 90-day Cost Including Hospital Cost, Surgeon Profession Costs, Postdischarge Health Care Resource Utilization (Health Care Visits, Medication Costs, Diagnostic Imaging Costs), and Readmission Costs Among the Participating Surgeons

Mean (SD)	1 (n = 141)	2 (n = 167)	3 (n = 279)	4 (n = 109)	5 (n = 14)	6 (n = 9)	7 (n = 33)	*P*-value
Direct cost 90 d	$28 345	$32 272	$26 810	$33 674	$26 310	$29 805	$23 103	<.0001
	($9472)	($11 272)	($7536)	($9776)	($7665)	($7665)	($5912)	
	(*P* < .0001)	(*P* = .328)	(*P* < .0001)		(*P* = .067)	(*P* = .884)	(*P* < .0001)	
Hospital cost	$24 134	$26 464	$22 481	$28 256	$23 746	$25 495	$18 529	<.0001
	($8676)	($9713)	($6236)	($8118)	($4545)	($7651)	($5535)	
	(*P* = .128)	(*P* = .390)	(*P* = 0.001)		(*P* = .1)	(*P* = .999)	(*P* = .004)	
Surgeon professional fee	$3138	$3342	$3053	$3355	$3068	$2993	$3046	.001
	($706)	($812)	($663)	($872)	($547)	($341)	($685)	
	(*P* = .291)	(*P* = .1)	(*P* = 0.007)		(*P* = .939)	(*P* = .836)	(*P* = .354)	
Post-discharge health care visits	$703	$966	$834	$908	$337	$1207	$977	.002
	($701)	($1133)	($1186)	($1053)	($610)	($795)	($760)	
	(*P* = .729)	(*P* = .999)	(*P* = 0.996)		(*P* = .01)	(*P* = .987)	(*P* = .1)	
Medication cost	$376	$470	$351	$478	$254	$442	$263	<.0001
	($282)	($310)	($303)	($329)	($198)	($313)	($244)	
	(*P* = .109)	(*P* = 1.0)	(*P* = 0.004)		(*P* = .122)	(*P* = 1.0)	(*P* = .006)	
Diagnostic costs	$149	$160	$71	$244	$219	$132	$53	<.0001
	($282)	($309)	($179)	($413)	($341)	($281)	($95)	
	(*P* = .1)	(*P* = .089)	(*P* = 0.104)		(*P* = .972)	(*P* = .1)	(*P* = .545)	
Readmission costs	$7822	$14 800	$11 980	$16 260	–	–	$7708 (–)	.479
	($5255)	($10 740)	($7904)	($4103)				

demonstrate that complications do contribute to higher cost for fusion surgery; however, there was no difference in the complication rate among the participating surgeons. This suggests that occurrence of complication alone might not explain the variation in cost among surgeons. Clearly, measures focused on prevention of complications will be able to decrease the cost and therefore increase the cost-benefit ratio.

Analogous to the previous studies, extended duration of surgery and length of hospital stay were significant drivers of the total 90-d cost. The surgery duration and length of hospital stay were significantly different among the participating surgeons. Identifying the factors associated with this variability might be able to precisely determine and remedy the modifiable factors and contain the escalating costs associated with fusion. In our study, surgeons #4 and #6 had higher odds of performing high-cost fusion surgery. There is a tendency for a surgeon to account for the high cost by stating that they care for sicker patients. In a retrospective study, Walid et al[13] demonstrated that the comorbidities additively increase the cost associated with spine surgery. Several other authors have emphasized the importance of considering the patients' comorbidities as a driver of cost and outcomes following spine surgery.[13-20] None of the previous studies have demonstrated the surgeon level variability in cost accounted for the comorbidities. In our study after adjusting for comorbidities, surgeon #4 was found to be costlier than expected and surgeon #6 was found to be less costly than expected, based on the health state of their respective patients. Furthermore, surgeon #2 was not a high-cost surgeon overall; however, this surgeon was found to be costlier than expected, when adjusting for comorbidities. This suggests that there is no doubt that preoperative comorbidities should be accounted for when deriving the aggregate total cost. However, as mentioned above, there are other factors beyond comorbidities that influence the total 90-d cost.

The value-based pay-per-performance for an episode of care (30- or 90-d) initiatives are conceptually simple and have potential to improvise the health-care quality and contain escalating costs.[39-45] The ideal episode of care model should be well designed to accommodate the highs and lows in each component of total 90-d cost. Given the heterogeneity of patient-specific and surgeon-specific factors, implementation of these models in real-world practice is complex and challenging. As demonstrated in our analyses, there is significant variation in the cost and characteristics of the patients managed by each surgeon at a single institution. Without fuller accountability of these variations in each component of the cost, the episode of care model can potentially be seen as an infringement of the individual surgeons' autonomy. Therefore, it is imperative to involve surgeons in the decision-making and to consider variability in cost at the individual surgeon level after adjusting for complexity of the patient population managed by each surgeon.

Limitations

There are several limitations associated with this study. This is a single-institution study, and the costs were adjusted based for Medicare allowable 2013 national payments amount. The institution costs may vary for private payers and if a different geographical multiplier is used. We used unit multiple to eliminate any geographical variation. Furthermore, we do not have granular data on different types of instrumentation, use of infuse, or type of biologics used by each surgeon. This will certainly be important as hospitals try to better understand cost saving measures to improve profit margin. This will require a partnership with surgeons, so the costs are cut but care is not compromised. Our institution, similar to other institutions will not allow detailed information regarding unique cost arrangements with companies to be published. The data on postdischarge utilization is gleaned from the electronic medical records and augmented by patient interview (to capture care outside of the facility) and is subject to recall bias. Furthermore, the indirect cost from societal perspective including patient workday losses, family work day loss, caregiver cost was not included in the cost calculation,

TABLE 4. Multivariable Logistic Regression Analysis for High-Cost Fusion Surgery

			95% CI for OR	
	P-value	OR	Lower	Upper
Age	.975	0.99	0.97	1.03
BMI	.451	1.01	0.98	1.05
Smoker	.246	1.40	0.79	2.49
Insurance				
Medicaid vs private	.427	1.25	0.72	2.2
Medicare vs private	.711	0.89	0.47	1.67
Neurogenic claudication	.811	0.93	0.53	1.64
Duration of symptoms	.134	0.71	0.45	1.11
Revision surgery	.226	1.33	0.84	2.09
Number of comorbidities	.309	1.1	0.92	1.32
ASA grades >3	.116	0.65	0.38	1.11
Length of surgery (minutes)	<.0001	1.01	1.01	1.02
EBL (mL)	.051	1.0	1	1.01
Number of levels	.023	1.41	1.04	1.78
Interbody fusion	.105	1.43	0.93	2.21
Length of hospital stay	<.0001	1.3	1.2	1.5
Surgeon				
Surgeon #1 vs #7	.092	3.36	0.82	13.77
Surgeon #2 vs #7	.073	3.59	0.89	14.49
Surgeon #3 vs #7	.258	2.21	0.56	8.77
Surgeon #4 vs #7	<.0001	21.4	5.2	88.7
Surgeon #5 vs #7	.998	0	0	–
Surgeon #6 vs #7	.003	20.5	2.7	155.7
90-day complication	.045	1.8	1.01	3.5
90-day readmission	.019	3.7	1.2	10.9

BMI, body mass index; EBL, estimated blood loss.

TABLE 5. Multivariable Linear Regression Model to Derive Comorbidity-Adjusted Cost

			95% CI for beta	
	Beta coefficient	*P*-value	Lower bound	Upper bound
Intercept	26832	<.001	22871	30793
Number of comorbidities	321	.736	–1550	2191
Age > 65 yr	1566	.028	165	2966
Smoker	1952	.037	116	3789
ASA grade	343	.652	–1148	1833
Diabetes	712	.58	–1810	3234
Hypertension	–856	.506	–3386	1673
Myocardial infarction	2698	.23	–1712	7108
Congestive heart failure	–1119	.701	–6841	4603
Chronic obstructive pulmonary disease	–117	.955	–4206	3972
Atrial fibrillation	–1974	.325	–5906	1958
Obesity (BMI > 65)	1044	.407	–1425	3513
Arthritis	–503	.697	–3033	2027
Osteoporosis	–1755	.41	–5933	2424
Preoperative anticoagulation	–75	.976	–5016	4866

BMI, body mass index.

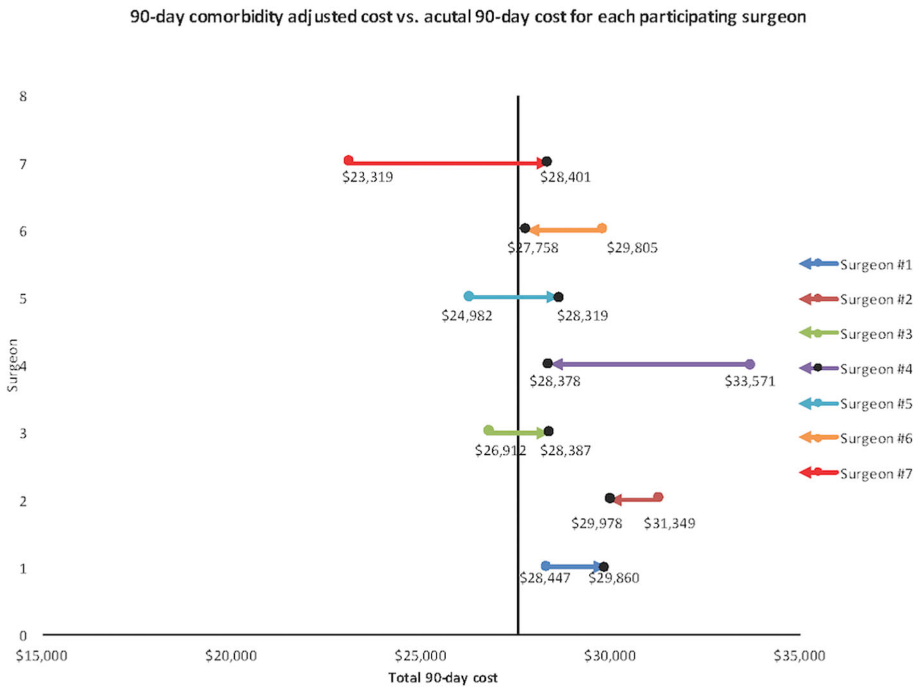

FIGURE 3. *The 90-day adjusted cost vs actual 90-day cost for each participating surgeon. The vertical axis represents actual median 90-day cost ($27 565). The black dots represent mean comorbidity-adjusted 90-day cost for each surgeon and the colored dot represents the mean actual 90-day costs. The line joining the colored and black dots represents the difference between the actual and the adjusted cost. The adjusted cost was higher than the actual cost for surgeons #1 ($P = .08$), #3 ($P = .002$), #5 ($P < .0001$), and #7 ($P < .0001$), suggesting these surgeons were less costly than predicted. In contrast, the adjusted cost was lower for surgeons #2 ($P = .128$), #4 ($P < .0001$), and #6 ($P = .44$), which suggests that these surgeons were more costly than predicted after adjusting for comorbidities.*

as the goal of this study was to define variability in cost from payers' and providers' perspective. The confounding variables included in the analysis may not be exhaustive, therefore adding more variables might account for other variation in the 90-d costs. Finally, the number of patients operated on by each surgeon was different. Sensitivity analysis was performed. A separate model was fitted excluding patients operated on by surgeons #5 and #6. There were no differences in the effect size and model performance (AUC—0.881) between this model and all-inclusive model (AUC—0.885; **Tables, Supplemental Digital Content 1 and 2**). The generalized application of these data needs to consider these limitations. Nonetheless, utilizing comprehensive list of variables captured in a single-center prospective longitudinal spine registry, we present the variations in 90-d cost and outcomes for laminectomy and fusion for lumbar degenerative pathology.

CONCLUSION

Our study provides valuable insight into variations in 90-d costs among the surgeons performing elective lumbar laminectomy/fusions at a single institution. Specific surgeons were found to have greater odds of performing high-cost surgeries. Adjusting for preoperative comorbidities, however, led to costs that were higher than the actual costs for certain surgeons and lower than the actual costs for others. Patient's preoperative comorbidities must therefore be accounted for when crafting value-based bundled payment models. More broadly, this study demonstrates that the designing intervention targeting "modifiable" factors tied to the way surgeons practice may increase the overall value of lumbar laminectomy and fusion.

Disclosure

The authors have no personal, financial, or institutional interest in any of the drugs, materials, or devices described in this article.

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COMMENTS

In this manuscript, the authors have presented a cost-utilization and outcome analysis of inter-surgeon variability for elective lumbar decompression and fusion. The authors have outlined the variations in patient profile, cost, and outcomes for each surgeon performing laminectomy and fusion for degenerative spine disease at a single center. The authors found that when adjusted for preoperative comorbidities, the costs for certain surgeons were found to be higher than the comorbidity-adjusted 90-day cost.

As a per surgeon utilization study, the manuscript represents an important addition to the literature. Single center studies such as this are uniquely situated to assess per surgeon costs as they control for institutional variables. With that said, a multi-center study would provide insight into cost factors that remain out of the surgeons control. In one of the supplemental tables, the authors provide an analysis that suggests that the higher cost surgeons fused more levels and had longer Operating Room time, indicating that they were doing more involved cases than the low-cost surgeons. How much of the cost difference does this explain? In addition to adjusting for preoperative morbidities, the authors should consider adjusting for intraoperative factors (type of fusion surgery, length of construct, etc). Moreover, 3 of 7 surgeons did 33 or fewer cases between 2011 and 2015, with 1 surgeon doing only 9 cases in that period. The other surgeons in the study did well over 100 cases each. Although in some analyses 2 of the 3 lower-volume surgeons were excluded, it is unclear the relationship this had to the overall cost driver analysis.

In future analyses, the authors may consider delving into the reasons that explain the cost variations. For instance, what aspects of patient care or operative factors (implantable devices, etc) drive the costs for each surgeon? It would also be interesting to see how the publication of the article has impacted the cost decisions of the surgeons identified as higher cost relative to their colleagues. Overall, this article highlights an important topic: surgeon variability and its relationship to costs.

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The authors examined a longitudinal registry from a single institution for 90-day costs and outcomes for 752 patients undergoing laminectomy and fusion surgery. They found that while there were no differences in the complication rate, 90-day readmission rate, or measurements of clinical outcome, 2 of the 7 surgeons incurred significantly higher costs. The subject relates to critical analysis of the cost for the care that spinal surgeons deliver—a matter universally recognized as an area we as a society need to better understand to permit the best care that we can afford.

The study is limited in providing any practical information about the value of any particular surgeon's approach to operative management of degenerative spine disease; as the authors note that they lacked any "granular data" to assess the various surgeons with regard to use of particular spinal implants, biologics, or costs associated with the inpatient stay. Still, the study is useful in providing needed data to validate the importance of considering the preoperative morbidities in creating bundled payment models.

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