Patient-specific factors affecting hospital costs in lumbar spine surgery

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OBJECTIVE Health care–related costs after lumbar spine surgery vary depending on procedure type and patient characteristics. Age, body mass index (BMI), number of spinal levels, and presence of comorbidities probably have significant effects on overall costs. The present study assessed the impact of patient characteristics on hospital costs in patients undergoing elective lumbar decompressive spine surgery.

METHODS This study was a retrospective review of elective lumbar decompression surgeries, with a focus on specific patient characteristics to determine which factors drive postoperative, hospital-related costs. Records between January 2010 and July 2012 were searched retrospectively. Only elective lumbar decompressions including discectomy or laminectomy were included. Cost data were obtained using a database that allows standardization of a list of hospital costs to the fiscal year 2013–2014. The relationship between cost and patient factors including age, BMI, and American Society of Anesthesiologists (ASA) Physical Status Classification System grade were analyzed using Student t-tests, ANOVA, and multivariate regression analyses.

RESULTS There were 1201 patients included in the analysis, with a mean age of 61.6 years. Sixty percent of patients in the study were male. Laminectomies were performed in 557 patients (46%) and discectomies in 644 (54%). Laminectomies led to an increased hospital stay of 1.4 days ($p < 0.001$) and increased hospital costs by \$1523 ($p < 0.001$) when compared with discectomies. For laminectomies, age, BMI, ASA grade, number of levels, and durotomy all led to significantly increased hospital costs and length of stay on univariate analysis, but ASA grade and presence of a durotomy did not maintain significance on multivariate analysis for hospital costs. For a laminectomy, patient age ≥ 65 years was associated with a 0.6-day increased length of stay and a \$945 increase in hospital costs when compared with patient age < 65 years ($p < 0.001$). A durotomy during a laminectomy increased length of stay by 1.0 day and increased hospital costs by \$1382 ($p < 0.03$). For discectomies, age, ASA grade, and durotomy were significantly associated with increased hospital costs on univariate analysis, but BMI was not. Only age and presence of a durotomy maintained significance on multivariate analysis. There was a significant increase in hospital length of stay in patients undergoing discectomy with increasing age, BMI, ASA grade, and presence of a durotomy on univariate analysis. However, only age and presence of a durotomy maintained significance on multivariate analysis. For discectomies, age ≥ 65 years was associated with a 0.7-day increased length of stay ($p < 0.001$) and an increase of \$931 in postoperative hospital costs ($p < 0.01$) when compared with age < 65 years.

CONCLUSIONS Patient factors such as age, BMI, and comorbidities have significant and measurable effects on the postoperative hospital costs of elective lumbar decompression spinal surgeries. Knowledge of how these factors affect costs will become important as reimbursement models change.

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KEY WORDS cost; lumbar; spine; surgery; outcomes

SURGERY has long been an accepted treatment for symptomatic lumbar degenerative disease. Although outcomes at 2 years are similar with surgery and nonoperative measures, some recent studies have suggested that continued medical management beyond 6 weeks without improvement is not cost-effective.^{11,17} Furthermore, although the upfront costs of operative management

are higher, the overall economic impact (e.g., loss of productivity, continued medical evaluation, and treatment) may be higher in patients who are managed conservatively than in those who undergo surgery.^{7,9,14} Surgery carries risk and, with increasing age and presence of comorbidities, risks of rehospitalization and reoperation increase as well, adding to overall cost of the treatment episode.¹⁰

ABBREVIATIONS ASA = American Society of Anesthesiologists; BMI = body mass index.

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Surgical costs vary significantly based on procedure types and patient characteristics. It has been shown that patient factors (i.e., age, body mass index [BMI], and presence of comorbidities) have significant effects on overall costs in spine surgery.^{10,15,16} The presence of multiple comorbidities (i.e., obesity and diabetes mellitus) may have an additive effect on overall costs.^{15,16} The Centers for Medicare and Medicaid Services is conducting a pilot study on episode-based bundling of payments whereby the hospital and all providers from 3 days prior to surgery, extending to 30 days postdischarge, receive a single, bundled payment for the care episode.¹³ In this payment model, it will become extremely important to understand patient-specific factors that affect overall treatment costs and to identify areas of potential cost savings, such as postoperative, hospital-related costs. In this study, we sought to identify these potential cost-modifying factors in a cohort of patients undergoing elective lumbar decompressive spine surgery.

Methods

Institutional review board approval was obtained for this study. Surgical records were reviewed retrospectively to identify all surgical cases involving the lumbar spine between January 2010 and July 2012. Patients were excluded if the cervical or thoracic regions were also involved, they underwent fusion operations, the case was performed on an emergency basis, or their information was incomplete or unobtainable (Fig. 1). Demographic data were gathered, as well as hospital length of stay, American Society of Anesthesiologists (ASA) grade, and cost data. ASA grade (Table 1) was used as a surrogate marker for medical comorbidity and coexistent systemic illness classification.^{3,6}

Cost information was obtained using an internal database that calculates total hospital costs from a list of hospital services provided during a hospital stay. These include postoperative antibiotics/other medications, rates for hospital rooms, physical therapy sessions, and other services rendered during a typical hospitalization. These are not patient charges; rather, they are a list of individual medications or services and the corresponding dollar-value cost to the hospital system of providing the specific service to that patient on a particular hospital day. This list does not include professional fees paid to physicians, which can change based on regional and physician variations. It was analyzed this way in an attempt to obtain a “real-world” cost for patient care and to see which patient factors lead to increased use of hospital resources during the postoperative hospital stay. Cost information is generated as a list of costs per hospital day. These data were recorded for each patient. Then, postoperative, hospital-related costs were generated for each patient. All costs and services were reflective of the standard costs for the current fiscal year (which was 2013–2014). Due to institutional policy prohibiting publication of specific cost figures, data are presented as the mean difference in costs, with the actual “parent” values not presented. In the data tables, the parent values are listed as “control” to blind the actual baseline cost value. The change in hospital costs based on

FIG. 1. Flowchart showing patient inclusion/exclusion criteria.

TABLE 1. ASA Physical Status Classification System

ASA Grade	Definition
I	Normal healthy patients
II	Patients with mild systemic disease
III	Patients with severe systemic disease that is limiting but not incapacitating
IV	Patients with severe systemic disease that is a constant threat to life
V	Moribund patients who are not expected to live more than 24 hrs
VI	Patients declared brain dead who are undergoing donation procedures

demographic factors are the data under evaluation in this study, not the parent cost values.

Statistical analysis was performed using SAS software (SAS Institute), and consultation with a departmental statistician was done to guide statistical analysis. Analysis methods included Student t-tests, 1-way ANOVA, and multivariate regression analyses. A p value < 0.05 was reported to be significant, and parameter estimates of the multivariate regression model were included to obtain an equation for prediction of postoperative, hospital-related costs. The cost data for both the laminectomy and discectomy cohorts demonstrated a nonparametric distribution with a right-sided skew. However, the skew was caused by small numbers of outliers (< 5 patients) in each cohort.

Results

We identified 1580 lumbar spine cases performed during the study period. A total of 379 cases were excluded from analysis, including 313 lumbar fusions, 3 emergency cases, and 63 cases without length of stay information. The remaining cohort consisted of 1201 elective, lumbar spine decompression-only procedures via a posterior approach. The mean age of the combined cohort was 61.6 ± 0.45 (SEM), and 715 patients (60%) were male. The average BMI of the cohort was 30.0 ± 0.17 , and the mean hospital length of stay was 2.3 ± 0.05 days. There were 72 patients (6%) classified as ASA Grade I, 703 patients (59%) as ASA Grade II, and 426 patients (35%) as ASA Grade III. Laminectomies were performed in 557 patients (46%) and discectomies in 644 patients (54%).

For laminectomies, the mean number of operated levels was 2.8 ± 0.04 . A durotomy occurred in 67/557 patients (12%) having a laminectomy and 30/644 patients (5%) having a discectomy. When comparing hospital costs between the laminectomy cohort and the discectomy cohort, we found that a laminectomy was associated with significantly increased hospital costs (mean difference +\$1522.79, $p < 0.001$) and increased length of stay (laminectomy 3.0 ± 0.08 days vs discectomy 1.6 ± 0.05 days, $p < 0.001$) when compared with discectomies. There was a significantly higher rate of durotomy during laminectomies than discectomies (laminectomy 12% vs discectomy 5%, OR 2.8, $p < 0.001$). Patients ≥ 65 years old had a higher rate of durotomies (12%) compared with patients < 65 years old (6%, $p < 0.001$).

TABLE 2. Factors affecting hospital costs and length of stay after laminectomy*

Factor	Costs, Mean Difference (\$)	Length of Stay (days)
BMI, kg/cm ²		
<25	Control†	2.7 ± 0.2
25–29.9	–514.20	2.6 ± 0.1
30–39.9	+906.47	3.2 ± 0.1
≥ 40	+2091.79	3.8 ± 0.3
p Value	<0.001	<0.001
Age, yrs		
<65	Control†	2.5 ± 0.2
≥ 65	+945.33	3.1 ± 0.1
p Value	<0.001	<0.04
ASA grade		
I	Control†	1.8 ± 0.5
II	+984.40	2.6 ± 0.1
III	+1977.08	3.4 ± 0.1
p Value	<0.04	<0.04
Durotomy		
No	Control†	2.8 ± 0.1
Yes	+1382.49	3.8 ± 0.3
p Value	<0.03	<0.03

* Values for length of stay are the mean $\pm$ SEM.

† Institution does not allow publication of “parent” cost values. All listed values are the mean difference compared with the “control” group, for which parent cost values are not reported to comply with institutional policy.

The results of univariate analysis of factors affecting hospital costs and length of stay after a laminectomy are shown in Table 2. A patient age ≥ 65 years was associated with a significant increase in cost (mean difference +\$945.33, $p < 0.001$) and a significant increase in hospital length of stay (≥ 65 years 3.1 ± 0.1 days vs < 65 years 2.5 ± 0.2 days, $p < 0.04$) when compared with patient age < 65 years. There was a statistically significant increase in the number of levels operated during laminectomies in patients ≥ 65 years of age (≥ 65 years 2.9 levels vs < 65 years 2.5 levels, $p < 0.001$). BMI was significantly associated with hospital costs, and whereas there initially was a reduction in cost from a BMI in the normal range (< 25) compared with the overweight category (25–29.9), there was an increase when patients reached the obese (≥ 30) classification (< 25 to 25–29.9 mean difference –\$514.20, < 25 compared with 30–39.9 mean difference +\$906.47, < 25 compared with ≥ 40 mean difference +\$2091.79, $p < 0.001$). Increasing BMI also led to an increase in hospital length of stay (< 25, 2.7 ± 0.2 days; 25–29.9, 2.6 ± 0.1 days; 30–39.9, 3.2 ± 0.1 days; ≥ 40 , 3.8 ± 0.3 days, $p < 0.001$). There was a statistically significant increase in hospital costs with increasing ASA grade (I–II mean difference +\$984.40, I–III mean difference +\$1977.08, $p < 0.04$), as well as a significant increase in length of stay (I, 1.8 ± 0.5 days; II, 2.6 ± 0.1 days; III, 3.4 ± 0.1 days; $p < 0.04$). A durotomy led to a significant increase in hospital costs (mean difference +\$1382.49, $p < 0.03$) and a significant increase in length of stay (durotomy 3.8 ± 0.3 days vs no durotomy 2.8 ± 0.1 days, $p < 0.03$).

TABLE 3. Multivariate analysis of factors affecting costs and length of stay after laminectomy*

Factor	Parameter Estimate	p Value
Age		
Costs, \$	42.8 ± 20.3	<0.04
Length of stay, days	0.02 ± 0.01	<0.01
BMI		
Costs, \$	159 ± 36	<0.001
Length of stay, days	0.07 ± 0.02	<0.001
ASA grade		
Costs, \$	385.9 ± 396.5	0.33
Length of stay, days	0.46 ± 0.17	<0.01
Number of levels		
Costs, \$	505.3 ± 195.4	<0.01
Length of stay, days	0.37 ± 0.08	<0.001
Presence of a durotomy		
Costs, \$	1041 ± 597.8	0.06
Length of stay, days	0.74 ± 0.26	<0.01
Intercept		
Costs, \$	-7172.7 ± 1979.1	<0.01
Length of stay, days	-3.19 ± 0.8	<0.001

* Values for parameter estimates are the mean ± SEM.

The results of multivariate analysis are shown in Table 3. For hospital costs after a laminectomy, age, BMI, and number of levels remain significant on multivariate analysis, but ASA grade and durotomy do not. However, presence of a durotomy approached significance ($p = 0.06$). Using the statistically significant multivariate linear regression parameter estimates, a formula was created to determine hospital costs after a laminectomy: Postlaminectomy Hospital Cost (\$) = $(42.8 * \text{Age}) + (159 * \text{BMI}) + (505.3 * \text{Number of Levels}) - 7172$. For length of stay, age, ASA grade, BMI, number of levels, and presence of a durotomy all remained significant on multivariate analysis, leading to a formula for hospital length of stay: Postlaminectomy Length of Stay (days) = $(0.02 * \text{Age}) + (0.46 * \text{ASA Grade}) + (0.07 * \text{BMI}) + (0.37 * \text{Number of Levels}) + (0.74 * \text{Durotomy}) - 3.19$.

The results of univariate analysis of factors affecting hospital costs and length of stay after discectomies are shown in Table 4. An age ≥ 65 years was associated with a significant increase in cost (mean difference +\$930.64, $p < 0.01$) and a significant increase in hospital length of stay (≥ 65 years 2.1 ± 0.1 days vs < 65 years 1.4 ± 0.04 days, $p < 0.001$) when compared with age < 65 years. BMI was not significantly associated with hospital costs, but increasing BMI led to a significant increase in hospital length of stay from the overweight to the obese category (< 25 , 1.7 ± 0.1 days; $25-29.9$, 1.5 ± 0.1 days; $30-39.9$, 1.7 ± 0.1 days; ≥ 40 , -1.9 ± 0.3 days, $p = 0.05$). There was a statistically significant increase in hospital costs with increasing ASA grade (I–II mean difference +\$544.07, I–III mean difference +\$980.12, $p < 0.04$), as well as a significant increase in length of stay (I, 1.1 ± 0.2 days; II, 1.6 ± 0.1 days; III, -2.0 ± 0.1 days, $p < 0.04$). A durotomy led to a significant increase in hospital costs (mean difference +\$2101.53, p

TABLE 4. Factors affecting hospital costs and length of stay after discectomy*

Factor	Costs, Mean Difference (\$)	Length of Stay (days)
BMI, kg/cm ²		
<25	Control†	1.7 ± 0.1
25–29.9	-333.48	1.5 ± 0.1
30–39.9	-761.02	1.7 ± 0.1
≥ 40	-63.92	1.9 ± 0.3
p Value	NS	0.05
Age, yrs		
<65	Control†	1.4 ± 0.04
≥ 65	+930.64	2.1 ± 0.1
p Value	<0.01	<0.001
ASA grade		
I	Control†	1.1 ± 0.2
II	+544.07	1.6 ± 0.1
III	+980.12	2.0 ± 0.1
p Value	<0.04	<0.04
Durotomy		
No	Control†	1.6 ± 0.05
Yes	+2101.53	2.7 ± 0.5
p Value	<0.001	<0.03

NS = not significant.

* Values for length of stay are the mean ± SEM.

† Institution does not allow publication of "parent" cost values. All listed values are the mean difference compared to the "control" group, for which parent cost values are not reported to comply with institutional policy.

< 0.001) and a significant increase in length of stay (durotomy 2.7 ± 0.5 days vs no durotomy 1.6 ± 0.05 days, $p < 0.03$).

The results of multivariate regression analysis of patients undergoing discectomies are shown in Table 5. On multivariate analysis, age and presence of a durotomy remained significant, but ASA grade and BMI did not. Using the parameter estimates, a formula for postoperative hospital costs after discectomy was obtained: Postdiscectomy Hospital Costs (\$) = $(27.3 * \text{Age}) + (1954.7 * \text{Durotomy})$. For length of stay, age and presence of a durotomy remained significant, but BMI and ASA grade did not. Using these estimates, a formula could be created: Postdiscectomy Length of Stay (days) = $(0.02 * \text{Age}) + (1.01 * \text{Durotomy})$.

Discussion

Understanding factors associated with costs in elective spine surgery is becoming increasingly important as reimbursement models continue to undergo significant change. In this study, we demonstrated how demographic variables affect postoperative hospital-related costs and hospital length of stay based on procedure type. When comparing procedure type, patients who underwent laminectomies spent more time in the hospital by 1.4 days, and had increased hospital costs by approximately \$1500. Durotomies are more than twice as likely to occur during a laminectomy than a discectomy. These findings are

TABLE 5. Multivariate analysis of factors affecting costs and length of stay after discectomy*

Factor	Parameter Estimate	p Value
Age, yrs		
Cost, dollars	27.3 ± 7.03	<0.001
Length of stay, days	0.02 ± 0.003	<0.001
BMI, kg/cm ²		
Cost, dollars	7.2 ± 17.9	0.68
Length of stay, days	0.013 ± 0.008	0.12
ASA grade		
Cost, dollars	153.7 ± 205.8	0.45
Length of stay, days	0.14 ± 0.09	0.14
Presence of a durotomy		
Cost, dollars	1954.7 ± 502.4	<0.001
Length of stay, days	1.01 ± 0.25	<0.001
Intercept		
Cost, dollars	-508.3 ± 665.9	0.4
Length of stay, days	-0.24 ± 0.3	0.42

* Values for parameter estimates are the mean ± SEM.

not meant to adjust surgical decision making, because these procedures are performed for different pathologies. However, they may suggest that even within the subset of decompression-only procedures in the lumbar spine performed through a posterior approach, as the procedure becomes larger, so does postoperative use of hospital resources, a finding that is not unexpected.

Patient age greatly affects hospital costs and length of stay for both procedure types. Following a laminectomy, a patient ≥ 65 years old will stay in the hospital approximately a half day (0.6) longer and cost the hospital \$945 more than a patient < 65 years old. It was noted that significantly more levels were being operated on in the ≥ 65 years of age patient group (2.9 vs 2.5), and this could be underlying some of the increase in hospital costs for this cohort. Similarly, age increases hospital costs and length of stay for discectomies. Again, the increase is just over a half day (0.7) longer, with an increased cost of \$930.

Patients with a BMI in the obese category and above (≥ 30) demonstrated an increase in hospital costs and length of stay for laminectomies, but only an increase in length of stay for discectomies. In all analyses, there was a decrease in hospital costs and length of stay when moving from the normal BMI group (< 25) to the overweight group (25–29.9), and this was probably due to the small number of patients in the normal BMI range (38/1201 patients). For laminectomies, BMI in the obese category (30–39.9) led to an increase in hospital costs of \$906 compared with patients with normal weights. Furthermore, a BMI associated with medical complications (≥ 40) increased costs by \$2091 compared with normal-weight patients. Similarly, when comparing obese patients with medical complications (≥ 40) to normal-weight patients, the hospital length of stay increased by 1.1 days. Hospital costs were not significantly increased with increasing BMI in discectomies; although there was an increase in length of stay, it was far less pronounced than in laminectomies. Patients with a

BMI > 40 stayed in the hospital 0.4 day longer than overweight patients (BMI 25–29.9) and only 0.2 day longer than obese patients (BMI 30–39.9). These findings are in line with other studies that also suggest that obese patients use more operative resources and are at increased risk for systemic complications, specifically when BMI is in the ≥ 40 range.²

The ASA grade, a marker used for comorbidities, was associated with increased costs and length of stay for both procedures. For laminectomies, costs and length of stay increased by approximately \$1000 and 0.8 days, respectively, when increasing from an ASA Grade I to Grade II, as well as for the increase from an ASA Grade II to Grade III. For discectomies, there was a similar increase. However, the cost increase was approximately \$500, and the length of stay increase was a half day when moving from an ASA Grade I to Grade II, as well as for an ASA Grade II to Grade III.

Incidental durotomy, which is more common in laminectomies, increases hospital costs and length of stay for both procedures. When a durotomy occurs in a laminectomy, the hospital length of stay increases by 1 day and the costs increase by \$1382. When a durotomy occurs during a discectomy, the length of stay again increases by 1.1 days, but the hospital costs increase by \$2102.

Using findings on multivariate analysis, formulas were created to predict both hospital costs and length of stay for each procedure. For laminectomies, the cost formula is Postlaminectomy Hospital Cost (\$) = (42.8 * Age) + (159 * BMI) + (505.3 * Number of Levels) = -7172 and the length of stay formula is Postlaminectomy Length of Stay (days) = (0.02 * Age) + (0.46 * ASA Grade) + (0.07 * BMI) + (0.37 * Number of Levels) + (0.74 * Durotomy) = -3.19. For discectomies, the cost formula is Postdiscectomy Hospital Costs (\$) = (27.3 * Age) + (1954.7 * Durotomy) and the length of stay formula is Postdiscectomy Length of Stay (days) = (0.02 * Age) + (1.01 * Durotomy).

Although the present study illustrates the effects that age, ASA grade, body habitus, and durotomies can have on hospital costs and length of stay, it reflects solely the immediate perioperative period. It is probable that these individual factors lead to increased complications and readmissions, as recently demonstrated in 2 independent studies conducted by Whitmore et al.¹⁸ and Kim et al.⁸ In addition, this study does not factor in long-term outcomes, which are equally important to consider and review in the subsets when considering reimbursement for surgery, as each cohort will probably still benefit.^{1,5,12} The advantages of this study compared with large inpatient samples are the uniformity in practice and the accuracy of data collection. However, only trends in costs and length of stay can be generalized because these probably vary among centers.⁴ Even if all patients had been treated at 1 center, there would remain significant practice variation regarding postoperative hospital management. Development of a standardized postoperative-care algorithm could help institutions decrease length of stay and hospital costs. In this study, the cost data do not demonstrate a parametric distribution and show a right-sided skew. Given the extremely small number of outliers causing this skew (< 5 patients) when compared with the respective cohort sizes (557 and

644 patients), we do not believe that the skew significantly alters the final findings.

Conclusions

Patient factors, such as age, BMI, and comorbidities, have significant and measurable effects on the costs of elective lumbar-decompression surgeries. Knowledge of how these factors affect costs will become important as reimbursement models change.

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Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributions

Conception and design: Puffer, Mallory. Acquisition of data: Puffer, Planchard. Analysis and interpretation of data: Puffer, Planchard. Drafting the article: Puffer, Mallory. Critically revising the article: Clarke, Puffer, Mallory. Reviewed submitted version of manuscript: Clarke. Approved the final version of the manuscript on behalf of all authors: Clarke. Statistical analysis: Puffer, Mallory. Study supervision: Clarke.

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