

# Predictive Analysis of Healthcare Resource Utilization after Elective Spine Surgery

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## Abstract:

**Introduction:** The management of degenerative spine pathology continues to be a significant source of costs to the US healthcare system. Besides surgery, utilization of healthcare resources after spine surgery drives costs. The responsibility of managing costs is gradually shifting to patients and providers. Patient-centered predictors of healthcare utilization after elective spine surgery may identify targets for cost reduction and value creation. Therefore, our study aims to quantify patterns of healthcare utilization and identify risk factors that predict high healthcare utilization after elective spine surgery.

**Methods:** A total of 623 patients who underwent elective spine surgery at a tertiary academic medical center by one of three fellowship-trained orthopedic spine surgeons between 2013 and 2018 were identified in this retrospective cohort study. Healthcare utilization was quantified including advanced spine imaging, emergency and urgent care visits, hospital readmission, reoperation, PT/OT referrals, opioid prescriptions, epidural steroid injections, and pain management referrals. Patient variables, namely, the Charlson comorbidity index (CCI) and the American Society of Anesthesiologists (ASA) classification system, were assessed as potential predictors for healthcare utilization.

**Results:** Among all patients, a wide range of health utilization was identified. Age, body mass index, Charlson Comorbidity Index, and American Society of Anesthesiology class were identified as positive predictors of postoperative healthcare utilization including emergency department visits, spine imaging studies, opioid and nerve blocker prescriptions, inpatient rehabilitation, any referrals, and pain management referrals.

**Conclusions:** Markers of patient health—such as CCI and ASA class—may be used to predict healthcare utilization following elective spine surgery. Identifying at-risk patients and addressing these challenges prior to surgery is an important step to deliver efficient postoperative care.

**Level of Evidence:** 3

## Keywords:

Spine surgery, cost, utilization, quality, economic

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## Introduction

Degenerative spine conditions are highly prevalent in the general population and have a major impact on patient quality of life<sup>1,2</sup>. Consequentially, the management of these conditions is a significant contributor to the healthcare cost burden<sup>3,4</sup>. As value-based care continues to be a major focus in future healthcare policy, there has been considerable interest in understanding costs of care associated with elective spine surgery<sup>5</sup>.

When compared with the aggregate costs of hospitaliza-

tion following other surgical procedures, spinal fusion comprised nearly 7.1% of the total costs; it has been estimated that the average cost of a hospital stay following spinal fusion is approximately \$27,600<sup>3</sup>. Moreover, the volume of commonly performed spinal procedures in the United States has increased over the last two decades. Martin et al. utilized a national sample to demonstrate that the volume of elective lumbar spinal fusion increased by 62.3%, from 122,679 to 199,140 procedures between 2004 and 2015<sup>4</sup>. Additionally, the aggregate hospital costs following these procedures exceeded \$10 billion in 2015, an increase of

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177% relative to those in 2004<sup>4</sup>). Notably, several studies assessing the costs of spine surgery have strictly focused on aggregate inpatient hospital costs, which is only one component of the cost burden<sup>4,6,7</sup>). Although a useful measurement, this metric alone does not capture the longitudinal health-care costs incurred after spine surgery<sup>8</sup>).

As healthcare costs continue to rise in the United States, there is interest in cost minimization and value-based care. Nevertheless, the ability to accurately measure the quality, total costs, and overall value of surgical procedures has proven to be quite challenging. To thoroughly assess cost, it is important to accurately capture the utilization of health-care resources in the postoperative period. Of particular interest may be the subset of patients with disproportionate levels of healthcare utilization and costs. This study aims to quantify patterns of healthcare utilization and identify risk factors that predict high healthcare utilization after elective spine surgery.

## Materials and Methods

After Institutional Review Board approval, a retrospective review of all patients who underwent elective spine surgery between 2013 and 2018 at a single tertiary academic medical center was performed. All patients were treated by one of three fellowship-trained orthopedic spine surgeons. Patients were eligible if they were at least 18 years of age and underwent decompression or decompression and fusion for degenerative cervical or lumbar spine disorders. Patients were excluded if they had a nondegenerative diagnosis (tumor, trauma, or infection) or were lost to follow-up before 1 year.

Patient demographics as well as ASA classification, BMI, CCI scores, and individual comorbidities were collected. Various 90 day complications were reported, including acute kidney injury acute myocardial infarction (MI), atrial fibrillation, anemia, delirium, deep venous thromboembolism (DVT), hypotension, pneumonia, pulmonary embolism (PE), sepsis, stroke, urinary retention, urinary tract infection (UTI), and wound complications. The health resources that were utilized include advanced spine imaging, surgery-related and nonrelated emergency and urgent care visits, reoperation, PT/OT referrals, pain medication prescriptions (opioid and nerve stabilizing agents), epidural steroid injections, orthopedic surgery referrals, pain management referrals, and inpatient referrals at 90, 180, and 365 days, postoperatively, were measured.

### Charlson comorbidity index

The CCI is a scoring system that was developed in 1987 by Charlson et al. to predict mortality within 1 year of hospitalization<sup>9</sup>). The scoring system considers the number and severity of the comorbid diseases and has been utilized extensively as a summary measure of the comorbidity burden of individual patients in various research applications<sup>10,11</sup>). The CCI considers the following comorbid conditions: age,

**Table 1A.** Charlson Comorbidity Index.

Comorbidity	Score
Prior Myocardial Infarction	1
Congestive Heart Failure	1
Peripheral Vascular Disease	1
Cerebrovascular Disease	1
Dementia	1
Chronic Pulmonary Disease	1
Rheumatologic Disease	1
Peptic Ulcer Disease	1
Mild Liver Disease	1
Diabetes	2
Cerebrovascular (hemiplegia) Event	2
Moderate-to-Severe Renal Disease	2
Diabetes with Chronic Complications	2
Cancer without Metastases	2
Leukemia	2
Lymphoma	2
Moderate-to-Severe Liver Disease	3
Metastatic Solid Tumor	6
Acquired Immuno-Dificiency Syndrome (AIDS)	6

myocardial infarction, congestive heart failure, peripheral vascular disease, cerebrovascular accident, dementia or chronic cognitive deficit, chronic obstructive pulmonary disease, connective tissue disease, peptic ulcer disease, liver disease, diabetes mellitus, hemiplegia, moderate to severe chronic kidney disease, solid tumor, leukemia, lymphoma, and autoimmune deficiency disorders (Table 1A).

### American society of anesthesiologists classification system of physical status

The ASA classification system of physical status was first established by Dr. Robert D. Dripps in 1963<sup>12</sup>). This classification system was designed to be a subjective measure of a patient's overall physical status or health<sup>13</sup>). The scoring system comprised five classes, ranked from I to V, in order of worsening health (Table 1B). The ASA score has been widely used for various applications including health policy, anesthesia reimbursement, risk stratification, and clinical research<sup>13</sup>). Various associations between ASA score and specific outcomes following surgery—particularly short-term outcomes—have been reported in the literature<sup>14-16</sup>).

### Statistical analysis

Descriptive statistics were performed to summarize patient characteristics. As appropriate, the median with interquartile range was used for skewed or nonnormal continuous variables, and frequency with proportions was used for categorical data.

The analyses involved a generalized linear mixed model (GLMM) with either Poisson distribution, log link function, or binary distribution with logit function depending on outcome distribution. The primary variables of interest were CCI, ASA class, age, and BMI. The primary outcome was

**Table 1B.** American Society of Anesthesiologists Classification System.

I.	A patient with completely normal health.
II.	A patient with mild systemic disease.
III.	A patient with severe systemic disease that is not incapacitating.
IV.	A patient with severe systemic disease that is incapacitating and a constant threat to life.
V.	A patient who is not expected to live 24 hours with or without surgery.

**Table 2.** Baseline Patient Characteristics.

	N (% of patients)
Age	
18–44	164 (26.3%)
45–54	103 (16.5%)
55–64	143 (23.0%)
65–74	154 (24.7%)
75+	59 (9.5%)
Sex	
Female	281 (45.1%)
Male	342 (54.9%)
Body mass index	
<18.5	7 (1.1%)
18.5–24.9	148 (23.8%)
25.0–29.9	237 (38.0%)
30.0–34.9	127 (20.4%)
35.0–39.9	68 (10.9%)
≥40.0	36 (5.8%)
Charlson Comorbidity Index score	
CCI 0	136 (21.8%)
CCI 1	117 (18.8%)
CCI 2	121 (19.4%)
CCI 3	111 (17.8%)
CCI 4	62 (10.0%)
CCI 5+	76 (12.2%)
American Society of Anesthesiology class	
ASA 1	77 (12.4%)
ASA 2	380 (61.0%)
ASA 3	164 (26.3%)
ASA 4	0 (0.0%)
ASA 5	1 (0.2%)
Three most common diagnoses	
Lumbar disc herniation	204 (32.7%)
Lumbar stenosis	169 (27.1%)
Cervical stenosis	70 (11.2%)

**Table 3.** Incidence of 90 Day Complications.

Complication	N	%
Urinary tract infection	64	10.3
Hypotension	56	9.0
Acute kidney injury	34	5.5
Atrial fibrillation	19	3.0
Urinary retention	16	2.6
Anemia	15	2.4
Wound complication	14	2.2
Acute myocardial infarction	11	1.8
Deep venous thromboembolism	6	1.0
Pulmonary embolism	6	1.0
Delirium	5	0.8
Pneumonia	2	0.3
Stroke	1	0.2
Sepsis	0	0.0

### Results

A total of 623 patients met the inclusion criteria for the study. The mean age of 342 male patients (54.9%) and 281 female patients (45.1%) was 57.0 with an interquartile (Q1-Q3) range of 43.0-68.0. The mean BMI was 28.4 with an interquartile (Q1-Q3) range of 25.0-32.4. Seventy-seven (12.4%) patients had an ASA class of 1, 380 (61.0%) patients had an ASA class of 2, and 165 (26.5%) patients had an ASA class of 3-5. A total of 374 (60.0%) patients had a CCI<3, 173 (27.8%) patients had a CCI of 3 or 4, and 76 (12.2%) patients had a CCI>4. The mean CCI of our population was 2.0. The most common preoperative diagnoses were lumbar stenosis, lumbar disc herniation, and cervical stenosis (Table 2).

The overall reoperation rate was 3.8% within 365 days postoperatively. The most common 90 day complications were UTI (10.3%), hypotension (9.0%), and acute kidney injury (5.5%) (Table 3). Other complications included atrial fibrillation (3.0%), urinary retention (2.6%), anemia (2.4%), wound complication (2.2%), DVT (1.0%), and delirium (0.8%). More severe complications were less common including acute MI (1.8%), PE (1.0%), pneumonia (0.3%), and stroke (0.2%).

Trends in healthcare utilization in the first year following surgery—including emergency department visits, spine imaging studies, and spinal injections—were assessed for the cohort. The mean number of emergency department visits was 0.32±1.04 (mean±standard deviation) with a range of 0-16. The mean number of x-rays was 2.43±2.48, with a range

health care utilization. The GLMM included age, BMI, time point, and either CCI or ASA class as fixed effects variables. The two-way interaction term (e.g., CCI/ASA class by time) was first included in the adjusted model. If this interaction term was insignificant at the 10% level, then it was removed. Additionally, repeated measurements via the inclusion of a random subject effect were accounted for, allowing for the distinction of between and within-subject variance. Bonferroni's correction was performed for pairwise comparisons.

**Table 4.** Healthcare Utilization with 1 Year after Surgery.

	N (%)
Emergency Department visits	
0	506 (81%)
1	81 (13%)
2	16 (3%)
3+	16 (3%)
X-ray studies	
<2	276 (44%)
2-5	285 (46%)
6-10	59 (9%)
11-15	3 (0%)
CT imaging studies	
0	522 (84%)
1-2	90 (14%)
3+	11 (2%)
MRI studies	
0	465 (75%)
1-2	144 (23%)
3+	14 (2%)
Epidural/other spinal injections	
0	562 (90%)
1	33 (5%)
2	15 (2%)
3	6 (1%)
4	5 (1%)
Pain management referrals	
0	560 (90%)
1	56 (9%)
2	7 (1%)

of 0-15. The mean number of CT imaging studies was  $0.24 \pm 0.66$ , with a range of 0-6. The mean number of MRI studies was  $0.34 \pm 0.69$ , with a range of 0-5. The mean number of epidural or other spinal injections was  $0.16 \pm 0.58$ , with a range of 0-4. The mean number of pain management referrals was  $0.11 \pm 0.35$ , with a range of 0-2 (Table 4).

The univariate analysis, controlling for age and BMI, demonstrated that both CCI, ASA scores, BMI, and age were predictive of various markers of higher healthcare utilization in the 365 days following surgery. *ED visits*: 12% increase per one-point CCI, 4.98-fold for ASA 3 at all time points, and 3% per 1-year increase in age. *Spine imaging studies*: 5% increase per one-point CCI increase at 180 and 365 days; 2.99-fold increase for ASA 2 and 4.56-fold increase for ASA 3 at 365 days; 3%, 4%, and 5% increases per one point in BMI at 90, 180, and 365 days, respectively. *Opioid prescriptions*: 17% increase per one-point CCI increase, and 2-fold increase for ASA 3 at 365 days. *Nerve blocking prescriptions*: 1.78-fold increase for ASA 2 and 1.98 in ASA 3 at 90 days; 6-fold increase for ASA 3 at 365 days; 4% and 6% increases per one-point increase in BMI at 90 and 365 days, respectively. *Inpatient rehabilitation admissions*: 21% increase per one-point CCI increase; 2.39-fold increase for ASA 3 compared to ASA 2 at 365 days; 6% increase per 1-year increase in age; 4% increase per

one-point increase in BMI. *Orthopedic, nonorthopedic, and physical therapy referrals*: 12% increase per one-point CCI increase; 5.9-fold increase for ASA 2 and 9.9-fold increase for ASA 3 at 365 days; 2% increase per one-point increase in BMI. *Pain management referrals*: 9% increase per one-point CCI increase at 365 days (Table 5).

## Discussion

With a shift toward value-based care, understanding the patterns and predictors of cost around surgical care has become critical to surgeons and health systems. Besides the direct costs of the surgical episode, the impact of postsurgical care is becoming a focal point for care improvement. This study highlights the variability in postoperative health resource utilization after elective spine surgery, this small subgroup of patients accounted for 80% of health utilization. The practice of spine care frequently proves particularly difficult to generalize, both in its effectiveness in providing optimal patient outcomes and in the standardization of cost for patients and health systems<sup>17</sup>. This study identified patient-specific factors, including comorbidities and ASA class, which correlated with a rise in healthcare utilization after surgery.

Overutilization, defined as healthcare provided at a higher volume or cost than is appropriate, accounted for as much as \$226 billion spent on healthcare in the United States in 2011<sup>18</sup>. Consequently, efforts to identify factors that can predict overutilization have become increasingly important as a means of defraying the associated costs. Although surgeon-driven decisions are often a focus, patient-based factors may also affect health utilization and costs. However, there has been considerably less discussion regarding patient factors that may influence short-term outcomes, quality of care, and healthcare utilization. Identifying patients that are at risk for high utilization of healthcare resources following surgery is an opportunity for cost reduction. Several studies have found trends in utilization wherein a small percentage of back pain patients account for the majority of expenditures<sup>19,20</sup>. Consequently, identifying specific risk factors that are predictive of healthcare utilization following spine surgery is an important step in optimizing the quality of care and cost-effectiveness.

In this study, we examined a single-center cohort of several hundred patients to identify risk factors for healthcare utilization following elective spine surgery. Well-established metrics of overall health—age, BMI, CCI, and ASA scores—were assessed as predictors for the utilization of healthcare resources in the year following surgery. Age, BMI, CCI, and ASA scores were predictive of incremental healthcare utilization across metrics including emergency department visits, spine imaging studies, opioid prescriptions, and inpatient rehabilitation. These scoring systems are easily calculated and may have utility as a marker of patients at high risk for excessive healthcare utilization following surgery.

**Table 5.** Univariate Analysis of CCI, ASA Class, Age, and BMI as Predictors for Healthcare Utilization.

	CCI score <sup>a</sup>	ASA score <sup>b</sup>	Age <sup>c</sup>	BMI <sup>d</sup>
Emergency department visits				
Within 365 days	1.12 [1.06–1.19]	ASA 2: n.s. ASA 3: 4.98 [1.53–16.21]	0.03 [0.01–0.06]	n.s.
Spine imaging studies				
Within 90 days	n.s.	ASA 2: 1.76 [1.28–2.40] ASA 3: 2.0 [1.42–2.82]	n.s.	0.03 [0.01–0.05]
Within 180 days	1.05 [1.01–1.11]	ASA 2: 2.98 [1.44–6.17] ASA 3: 3.51 [1.65–7.45]	n.s.	0.04 [0.01–0.06]
Within 365 days	1.05 [1.01–1.11]	ASA 2: 2.99 [1.50–5.97] ASA 3: 4.56 [2.20–9.45]	n.s.	0.06 [0.02–0.10]
Opioid Rx				
Within 365 days	1.17 [1.05–1.30]	ASA 2: n.s. ASA 3: 2.0 [1.06–3.76]	n.s.	n.s.
Nerve blocker Rx				
Within 90 days	n.s.	ASA 2: 1.78 [1.08–2.96] ASA 3: 1.98 [1.17–3.36]	n.s.	0.04 [0.02–0.06]
Within 365 days	n.s.	ASA 2: n.s. ASA 3: 6.03 [1.51–24.05]	n.s.	0.06 [0.02–0.08]
Inpatient rehabilitation				
Within 365 days	1.21 [1.15–1.28]	ASA 2: n.s. ASA 3: 2.39 [1.09–5.23]	0.06 [0.02–0.10]	0.04 [0.01–0.08]
Any referrals				
Within 365 days	1.21 [1.15–1.28]	ASA 2: n.s. ASA 3: 2.39 [1.09–5.23]	n.s.	0.02 [0.01–0.03]
Pain management referrals				
Within 365 days	1.09 [1.01–1.17]	ASA 2: n.s. ASA 3: n.s.	n.s.	n.s.

\*Brackets [ ] indicate 95% confidence interval.

<sup>a</sup>Reported per 1 unit increase in CCI score.

<sup>b</sup>Reported relative to ASA score 1 as a baseline. ASA 4 and 5 were not included given the limited number of patients with ASA score of >3.

<sup>c</sup>Reported per 1 unit increase in BMI.

<sup>d</sup>Reported per 1 year increase in age.

n.s.=Did not achieve statistical significance.

As complications after surgery increase, so does healthcare resources utilization. Whitmore et al. found that both higher CCI and ASA scores were predictive of increased minor, major, and overall complications rates after spine surgery within the 6-month postoperative period. The author also noted that elevated ASA scores were associated with increased direct costs<sup>14</sup>. Sheha et al. found that a CCI greater than 1 was associated with increased ED visits within 30 and 90 days after undergoing an elective anterior cervical discectomy and fusion<sup>21</sup>. Moreover, Borja et al. retrospectively analyzed patients undergoing lumbar discectomy and identified that single-point increases in CCI scores were significantly correlated to a higher risk of readmission within 90 days, revision surgery within 90 days, and increased outpatient office visit rates within 30 days of surgery leading to increased healthcare utilization<sup>22</sup>. A retrospective cohort study by Elsamadicy et al. reported that patients greater than or equal to 80 years old had significantly higher complication rates, longer hospital lengths of stay, and nonhome discharges than their 50-79-year-old counterparts. They also

found via a multivariate regression analysis that octogenarian age status was an independent predictor of extended hospital length of stay and nonhome discharges<sup>23</sup>. Furthermore, Puvanesarajah et al. reported that Octogenarians had 1.6 times greater odds of having postoperative complications, 4 times greater odds of mortality, and had significantly more than patients aged 65-79 years<sup>24</sup>. Importantly, these predictor variables could potentially be used to create more comprehensive care plans that maximize the benefit to patients while simultaneously reducing overutilization.

Enhanced Recovery After Surgery (ERAS) protocols involve a multidisciplinary and multimodal evidence-based approach to enhance patient outcomes after surgery<sup>25</sup>. Sivaganesan et al. demonstrated that a postoperative ERAS protocol for elective cervical and lumbar fusion patients leads to a decreased hospital length of stay, 90 complication rates, and readmission rates. Older patients, higher ASA, and BMI score were associated with increased length of stay as well<sup>26</sup>. Moreover, there is a paucity of literature pertaining to randomized controlled trials (RCT) of ERAS protocols.

However, Ali et al. provided a comprehensive protocol for a future RCT to assess healthcare quality associated with a specific ERAS protocol for patients undergoing elective spine surgery<sup>27)</sup>. Identifying these at-risk patients with multiple comorbidities preoperatively could allow providers to apply targeted interventions concerning preoperative medical optimization and prehabilitation, discharge pathways, patient education, surgical expectations, and home healthcare to ensure that these patients are receiving appropriate and efficient delivery of care in the postoperative period.

Besides this being a single-center study of several hundred patients, several limitations should be noted. The study is retrospective in design. Although patient data were collected prospectively, the retrospective nature of the study creates a bias and allows only for a predictive analysis based on correlation. Furthermore, the utilization of healthcare resources was identified via chart review. Inherently, this only captures data points that are available within the electronic medical record that is utilized by our 10-hospital healthcare system. It is possible that there were visits to emergency departments, ambulatory centers, imaging centers, and other providers that were not captured. Another limitation is that this study is reflective of an academic center in the United States; however, our results are applicable to tertiary care centers in other countries that also provide care for patients with severe pathology and increased comorbidities. A large portion of spine surgery occurs in the community setting. This study is pertinent to surgeons in community practice because, as the global population ages, spine surgery is occurring on older and more medically complex patients in the community setting and not only at academic centers. Surgeons in community practice can enhance their preoperative patient health optimization even further and improve their postoperative discharge pathway to prevent healthcare overutilization. For future studies, it would be valuable to incorporate cost data and measures of quality or performance, such as patient-reported outcomes. These metrics would enable direct estimation of the overall quality of elective spine surgery for individual patients. When estimating the value of surgical procedures, the utilization, and costs of postoperative care should then be considered.

## Conclusion

High utilization of healthcare resources after surgery represents a key source of costs and a cause of uncertainty regarding the effectiveness and value of elective spine surgery. This study identified variability in health utilization after surgery. Additionally, patient variables and established scoring systems—CCI and ASA scores—are associated with incrementally increasing utilization of various healthcare resources after surgery. These scoring systems may be used to identify patients at risk for healthcare overutilization. Future research should focus on targeted interventions (e.g., patient education, establishing expectations, social work interventions, and home health) that can be implemented to mitigate

overutilization and optimize postoperative care in this patient population.

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**Author Contributions:** All authors wrote the manuscript. Dr. Gerlach and Dr. Arpey queried the literature. Dr. Gerlach, Dr. Arpey, and Dr. Plantz generated the tables. Dr. Gerlach and Dr. Patel supervised the study.

**Ethical Approval:** IRB was approved (#: STU00208163) by Northwestern University Institutional Review Board

**Informed Consent:** Consent was not required because of the retrospective study design.

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