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Clinical Studies

Geographic variations in health care resource utilization following elective ACDF for cervical spondylotic myelopathy: A national trend analysis☆,☆☆

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ABSTRACT

Background: As health care expenditures continue to increase, standardizing health care delivery across geographic regions has been identified as a method to reduce costs. However, few studies have demonstrated how the practice of elective spine surgery varies by geographic location. The aim of this study was to assess the geographic variations in management, complications, and total cost of elective anterior cervical discectomy and fusion (ACDF) for cervical spondylotic myelopathy (CSM).
Methods: The National Inpatient Sample database (2016-2017) was queried using the ICD-10-CM procedural and diagnostic coding systems to identify all adult (≥18 years) patients with a primary diagnosis of CSM undergoing an elective ACDF. Patients were divided into regional cohorts as defined by the U.S. Census Bureau: Northeast, Midwest, South, and West. Weighted patient demographics, Elixhauser comorbidities, perioperative complications, length of stay (LOS), discharge disposition, and total cost of admission were assessed.
Results: A total of 17,385 adult patients were identified. While the age (p=0.116) and proportion of female patients (p=0.447) were similar among the cohorts, race (p<0.001) and healthcare coverage (p<0.001) varied significantly. The Northeast had the largest proportion of patients in the 76-100th household income quartile (Northeast: 32.1%; Midwest: 16.9%; South: 15.7%; West: 27.5%, p<0.001). Complication rates were similar between regional cohorts (Northeast: 10.1%; Midwest: 12.2%; South: 10.3%; West: 11.9%, p=0.503), as was LOS (Northeast: 2.2±2.4 days; Midwest: 2.1±2.4 days; South: 2.0±2.5 days; West: 2.1±2.4 days, p=0.678). The West incurred the greatest mean total cost of admission (Northeast: $19,167±10,267; Midwest: $18,903±9,114; South: $18,566±10,152; West: $24,322±15,126, p<0.001). The Northeast had the lowest proportion of patients with a routine discharge (Northeast: 72.0%; Midwest: 84.8%; South: 82.3%; West: 83.3%, p<0.001). The odds ratio for Western hospital region was 3.46 [*95% CI: (2.41, 4.96), p<0.001*] compared to the Northeast for increased cost.
Conclusion: Our study suggests that regional variations exist in elective ACDF for CSM, including patient demographics, hospital costs, and nonroutine discharges, while complication rates and LOS were similar between regions.

Background

United States (U.S.) health care expenditures continue to rapidly increase [1]. Increasing attention has been placed on standardizing health care delivery as a method to reduce health care spending. Despite a rising emphasis on standardizing national health care delivery, geographic variations in surgical outcomes and costs remain evident throughout the U.S. [1–6] These disparities have been well-documented in the field of elective spine surgery, with previous studies demonstrating that hospitals in certain regions are consistently associated with prolonged length of hospital stay (LOS), higher complication rates, and greater resource

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☆☆ This study found regional variations in patient demographics, hospital costs, and discharge disposition following elective ACDF for cervical spondylotic myelopathy.

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use following surgery. [7–10] Therefore, in order to increase the quality of nationwide care and reduce soaring health care costs, it is necessary to understand the differences in post-operative outcomes and health care utilization between the geographic regions in the U.S..

In elective anterior cervical discectomy and fusion (ACDF), regional variations in outcomes and costs continue to exist [8–10] despite an increase in procedure volume over the last two decades. [11] In an analysis of 52,212 patients undergoing elective ACDF for cervical degenerative disease using the 2012-2015 National Inpatient Sample (NIS), Akhras et al. found that hospitals in the West were associated with greater odds of nonroutine discharge, longer LOS, and higher admission cost when compared to hospitals in the Northeast. [9] Similarly, in an observational study of 134,088 patients who underwent elective ACDF in 2011, Kalakoti et al. showed that patients in the West incurred greater hospital costs and longer LOS relative to patients treated in the Northeast. [8] While previous studies have attempted to explore the association of hospital region and post-operative outcomes of elective ACDF, few have investigated this relationship in patients undergoing elective ACDF for cervical spondylotic myelopathy (CSM).

The aim of this study was to assess the geographic variations in management, complications, and total cost after elective ACDF for CSM.

Methods

Data source and patient population

The Healthcare Cost and Utilization Project's National Inpatient Sample (NIS) database is a stratified discharge database representing 20% of all inpatient admissions from community hospitals in the United States. It is the largest all-payer health care database in the US, containing over 7 million hospital admissions (approximately 35 million hospitalizations, weighted) per year. A retrospective study was performed using years 2016 and 2017 of the NIS for all adult inpatient admissions undergoing elective, ACDF for CSM.

The International Classification of Diseases, Tenth Revision, Clinical Modification [ICD-10-CM] diagnosis and procedural coding system was used to identify patients and their respective comorbidities and surgical interventions. All adult patients (≥18 years old) with a primary diagnosis code of CSM (ICD-10-CM M47.12) were identified. ICD-10-CM procedural codes were then cross-matched to identify patients in the cohort undergoing elective, ACDF as coded by "cervical vertebral joint fusion with an interbody fusion device" (ICD-10-PCS 0RG10A0, 0RG20A0). Patients with coding for posterior cervical fusion and/or "cervical spinal cord release" (representing laminectomy), a history of traumatic spine fracture or spinal malignancy were excluded (Appendix Table A.1). Patients were then divided into regional cohorts defined by the U.S. Census Bureau (Northeast, Midwest, South, and West). All patient data is de-identified, so Institutional Review Board evaluation of this study and patient consent were not required.

Data collection

Patient demographic information, comorbidities and treating hospital characteristics were collected. Demographic information included age, gender, race, median household income quartile and expected primary payer. Hospital characteristics included the hospital size by bed volume and teaching status. Elixhauser comorbidities were used to evaluate incidence of congestive heart failure (CHF), cardiac arrhythmias, valvular disease, hypertension (HTN), paralysis, other neurological disorders, chronic pulmonary disease, uncomplicated diabetes, hypothyroidism, renal failure, rheumatoid arthritis/ collagen vascular diseases, coagulopathy, obesity, fluid and electrolyte disorders, and deficiency anemias. Nicotine dependence and presence of affective disorders were also assessed (Appendix Table A.2). Data on electrophysiological monitoring, blood transfusion, and perioperative complications were included.

Complications for each admission were collected by indexing additional diagnoses. Complications investigated included acute posthemorrhagic anemia, dysphagia, displacement of internal fixation device of vertebrae, wound disruption, mechanical device complication, hematoma formation, nervous system complication, acute deep vein thrombosis (DVT), and anesthesia-related complications (Appendix Table A.2). We then assessed the regional patient outcomes of discharge disposition and total cost of hospital admission. Disposition was stratified by routine (home), non-routine (short-term hospital, skilled nursing facility, intermediate care facility, home with healthcare services), and other (leaving against medical advice, died in hospital, unknown destination). All-payer inpatient cost-to-charge ratios (CCR) were used to convert total hospital charge to total cost of hospital care.

Statistical analysis

Discharge-level weights were used to calculate national estimates. Parametric data were expressed as mean ± SD and compared via one-way ANOVA test. Nonparametric data were expressed as median (interquartile range) and compared via the Kruskal-Wallis test. Nominal data were compared with the χ^2 test. Univariate and multivariate logistic regressions were then fitted with increased cost as the dependent variable. Increased cost was defined as total cost greater than the 50% percentile (>$17,450). Only those admissions that had total cost available were included in this portion of the analysis. Backward stepwise selection for the multivariate logistic regression analysis was used to select variables in the final model, using 0.1 as entry and stay criteria. We forced hospital region into the model in view of our primary hypothesis, in addition to age and female sex into the model based on the joint biological association between these covariates and their likelihood for confounding. A *P*-value of less than 0.05 was determined to be statistically significant. Statistical analysis was performed using R Studio, Version 3.6.2, RStudio Inc., Boston, MA.

Results

Patient demographics and comorbidities

There were 17,385 adults included in this study, of which 2,025 (11.7%) patients were treated in the Northeast, 3,150 (18.1%) in the Midwest, 8,440 (48.5%) in the South, and 3,770 (21.7%) in the West, Table 1. The age and proportion of female patients were similar among the regional cohorts, with the majority of each cohort being White (*Northeast: 77.2%; Midwest: 86.5%; South: 76.2%; West: 76.7%, p≤0.001*), Table 1. The Northeast had the largest proportion of patients in the 76-100th income quartile compared to the other regional cohorts (*Northeast: 32.1%; Midwest: 16.9%; South: 15.7%; West: 27.5%, p≤0.001*), Table 1. For all regional cohorts, the most common primary healthcare coverage type was Medicare (*Northeast: 41.7%; Midwest: 45.4%; South: 48.0%; West: 43.4%, p≤0.001*), Table 1. Hospital bed size differed between the cohorts, with the Midwest having the greatest proportion of patients treated at large hospitals (*Northeast: 55.3%; Midwest: 65.6%; South: 44.1%; West: 59.9%, p≤0.001*), Table 1. Additionally, when compared to other regional cohorts, the Northeast had the largest proportion of patients treated in an urban teaching setting (*Northeast: 88.6%; Midwest: 76.2%; South: 71.1%; West: 64.9%, p≤0.001*), Table 1.

On comparison of the admission comorbidities between the regional cohorts, the Northeast had the greatest proportion of chronic pulmonary disease (*Northeast: 24.2%; Midwest: 23.5%; South: 18.2%; West: 18.4%, p=0.007*) and obesity (*Northeast: 22.7%; Midwest: 21.3%; South: 16.0%; West: 14.7%, p=0.003*), Table 2. The Midwest had the largest proportion of affective disorder (*Northeast: 28.6%; Midwest: 33.2%; South: 25.6%; West: 25.3%, p=0.006*), nicotine dependence (*Northeast: 16.3%; Midwest: 20.5%; South: 17.8%; West: 14.5%, p=0.040*), and other neurological disorders (*Northeast: 5.9%; Midwest: 6.0%; South: 2.8%;*

Table 1
Patient demographics and hospital characteristics.

Variables	Northeast(n= 2,025)	Midwest(n= 3,150)	South(n= 8,440)	West(n= 3,770)	P-Value
Age (Years)					
Mean ± SD	60.4 ± 11.3	60.2 ± 10.4	61.3 ± 10.8	60.9 ± 10.5	0.116
Female (%)	51.4	51.3	48.9	47.3	0.447
Race (%)					<0.001
White	77.2	86.5	76.2	76.7	
Black	12.9	10.2	16.6	5.6	
Hispanic	3.0	1.8	3.7	10.5	
Other	6.9	1.5	3.5	7.3	
Income Quartile (%)					<0.001
0-25th	17.0	26.9	31.5	19.7	
26-50th	22.3	28.9	28.1	24.5	
51-75th	28.6	27.3	24.7	28.4	
76-100th	32.1	16.9	15.7	27.5	
Healthcare Coverage (%)					<0.001
Medicare	41.7	45.4	48.0	43.4	
Medicaid	17.0	10.2	6.8	12.4	
Private Insurance	35.1	40.0	37.5	36.5	
Other	6.2	4.4	7.7	7.7	
Elective (%)	100.0	100.0	100.0	100.0	
Hospital Demographics					
Hospital Bed Size (%)					<0.001
Small	23.7	15.9	23.9	13.1	
Medium	21.0	18.6	32.0	26.9	
Large	55.3	65.6	44.1	59.9	
Hospital Type (%)					<0.001
Rural	2.0	4.1	2.2	2.1	
Urban Non-Teaching	9.4	19.7	26.7	33.0	
Urban Teaching	88.6	76.2	71.1	64.9	

Table 2
Admission and patient comorbidities.

Variables (%)	Northeast(n= 2,025)	Midwest(n= 3,150)	South(n= 8,440)	West(n= 3,770)	P-Value
Affective disorder	28.6	33.2	25.6	25.3	0.006
Nicotine dependence	16.3	20.5	17.8	14.5	0.040
Congestive heart failure	2.5	2.1	3.4	2.4	0.310
Cardiac arrhythmias	6.2	5.7	6.9	5.4	0.512
Valvular disease	2.7	1.4	2.7	2.5	0.352
Hypertension, combined	53.3	59.4	61.9	52.3	<0.001
Paralysis	1.0	2.1	1.1	1.9	0.167
Other neurological disorders	5.9	6.0	2.8	2.8	<0.001
Chronic pulmonary disease	24.2	23.5	18.2	18.4	0.007
Diabetes, uncomplicated	14.8	15.6	19.8	12.9	<0.001
Hypothyroidism	11.9	12.9	12.4	13.8	0.751
Renal failure	5.7	5.4	4.9	4.0	0.535
Rheumatoid arthritis/ collagen vascular diseases	4.4	4.6	3.6	4.2	0.675
Coagulopathy	1.5	0.8	0.5	1.1	0.211
Obesity	22.7	21.3	16.0	14.7	0.003
Fluid and electrolyte disorders	2.5	5.2	3.7	4.5	0.130
Deficiency anemias	0.5	1.6	0.6	0.9	0.111

West: 2.8%, p≤0.001), Table 2. The South had the greatest proportion of hypertension (*Northeast: 53.3%; Midwest: 59.4%; South: 61.9%; West: 52.3%, p≤0.001*) and diabetes (*Northeast: 14.8%; Midwest: 15.6%; South: 19.8%; West: 12.9%, p≤0.001*), Table 2. Other baseline comorbidities including congestive heart failure (*p=0.310*), cardiac arrhythmias (*p=0.512*), valvular disease (*p=0.352*), paralysis (*p=0.167*), hypothyroidism (*p=0.751*), renal failure (*p=0.535*), rheumatoid arthritis/collagen vascular diseases (*p=0.675*), coagulopathy (*p=0.211*), fluid and electrolyte disorders (*p=0.130*), and deficiency anemia (*p=0.111*) were similar between the cohorts, Table 2.

Intra- and post-operative variables and complications

There was no difference in electrophysiological monitoring utilization between the regional cohorts (*Northeast: 28.9%; Midwest: 25.2%; South: 24.7%; West: 26.0%, p=0.738),* Table 3. There were also no significant differences in the rates of blood transfusion (*p=0.768*), platelet transfusion (*p=0.677*), or number of fusion levels – one level (*Northeast: 25.7%; Midwest: 27.6%; South: 22.5%; West: 25.5%, p=0.077*) and two levels or more (*Northeast: 74.3%; Midwest: 72.7%; South: 77.8%; West: 74.7%, p=0.071*), Table 3.

There were no significant differences between the cohorts with respect to acute post-hemorrhagic anemia (*p=0.707*), dysphagia (*p=0.111*), wound disruption (*p=0.676*), or hematoma (*p=0.411*), Table 4. While the Midwest trended to have a greater proportion of patients encountering any post-operative complication (*Northeast: 10.1%; Midwest: 12.2%; South: 10.3%; West: 11.9%, p=0.503*), this difference was not statistically significant, Table 4. Also, there was no significant difference when comparing the number of complications encountered (*p=0.637*), Table 4.

Length of hospital stay, hospital cost, and discharge dispositions

The median lengths of stay were identical for all geographic regions (*Northeast: 1 [1 – 2] days; Midwest: 1 [1 – 2] days; South: 1 [1 – 2] days; West: 1 [1 – 2] days, p=0.013*), Table 5. The total cost of admission

Table 3
Intraoperative variables.

Variables (%)	Northeast(n= 2,025)	Midwest(n= 3,150)	South(n= 8,440)	West(n= 3,770)	P-Value
Electrophysiological monitoring	28.9	25.2	24.7	26.0	0.738
Fusion Levels					
One level	25.7	27.6	22.5	25.5	0.077
Two levels or more	74.3	72.7	77.8	74.7	0.071
Transfusion					
Blood	0.7	0.3	0.4	0.5	0.768
Platelet	0.0	0.0	0.1	0.0	0.677
Complications					
Cerebrospinal fluid leak or dural tear	1.0	0.5	0.4	N<10*	-

* Signifies that the count number is <10 and cannot be reported.

Table 4
Postoperative complications.

Variables (%)	Northeast(n= 2,025)	Midwest(n= 3,150)	South(n= 8,440)	West(n= 3,770)	P-Value
Acute post-hemorrhagic Anemia	1.5	2.7	2.4	2.4	0.707
Dysphagia	7.4	9.5	7.0	9.5	0.111
Displacement of internal fixation device of vertebrae	0.0	N<10*	0.2	0.3	-
Wound disruption	0.0	0.0	0.1	0.0	0.676
Mechanical device complication	N<10*	N<10*	0.2	0.3	-
Hematoma	0.0	0.0	0.4	0.3	0.411
Nervous system complication	0.7	N<10*	0.2	N<10*	-
Acute deep vein thrombosis	N<10*	0.0	0.1	N<10*	-
Anesthesia-related	0.0	N<10*	0.0	0.0	-
Any complication	10.1	12.2	10.3	11.9	0.503
Number of Complications					0.637
0	89.9	87.8	89.7	88.1	
1	9.1	11.1	9.7	10.7	
>1	1.0	1.1	0.6	1.2	

* Signifies that the count number is <10 and cannot be reported.

Table 5
Postoperative inpatient outcomes.

Variables	Northeast(n= 2,025)	Midwest(n= 3,150)	South(n= 8,440)	West(n= 3,770)	P-Value
Length of stay (days)					
Mean ± SD	2.2 ± 2.4	2.1 ± 2.4	2.0 ± 2.5	2.1 ± 2.4	0.678
Median [IQR]	1 [1 – 2]	1 [1 – 2]	1 [1 – 2]	1 [1 – 2]	0.013
Total Cost of Admission ($)					
Mean ± SD	19,167 ± 10,267	18,903 ± 9,114	18,566 ± 10,152	24,322 ± 15,126	<0.001
Median [IQR]	16,680 [12,314 – 22,876]	17,101 [13,022 – 21,750]	16,383 [12,368 – 21,786]	20,717 [16,170 – 28,432]	<0.001
Disposition (%)					<0.001
Routine	72.0	84.8	82.3	83.3	
Non-Routine					
SH/SNF/ICF	8.2	8.7	7.0	6.9	
Home Health Care	19.8	6.2	10.3	9.4	
Other	0.0	0.3	0.4	0.4	

SH = Short-term Hospital; SNF = Skilled Nursing Facility; ICF = Intermediate Care Facility.

was largest in the West (*Northeast: $16,680 [12,314 – 22,876]; Midwest: $17,101 [13,022 – 21,750]; South: $16,383 [12,368 – 21,786]; West: $20,717 [16,170 – 28,432], p≤0.001*), Table 5. The Northeast had the smallest proportion of routine discharges (*Northeast: 72.0%; Midwest: 84.8%; South: 82.3%; West: 83.3%, p≤0.001*), with proportionally twice as many patients being discharged to Home Health Care compared to the other cohorts (*Northeast: 19.8%; Midwest: 6.2%; South: 10.3%; West: 9.4%, p≤0.001*), Table 5. These data are summarized in Figure 1.

Multivariate regression for increased costs

On weighted, multivariate regression analysis, Western geographic location compared to hospitals in the Northeast [*odds ratio (OR): 3.46, 95% Confidence Interval (CI): (2.41, 4.96), p≤0.001*], 76-100th median household income quartiles compared to 0-25th [*OR: 1.76, 95% CI: (1.30, 2.38), p≤0.001*], and two levels of more fusion compared to one level [*OR: 3.94, 95% CI: (3.20, 4.85), p≤0.001*] were all found to be independent risk factors associated with increased cost, Table 6. Furthermore, compared to those with no complications, patients encountering one complication [*OR: 1.40, 95% CI: (1.06, 1.85), p≤0.019*] and greater than one complication [*OR: 3.30, 95% CI: (1.22, 8.92), p≤0.019*] showed a stepwise, increased likelihood for increased cost, Table 6. Deficiency anemias and LOS were also statistically significant risk factors, Table 6. Contrarily, Female sex and diabetes were found to be protective factors for normal cost, Table 6.

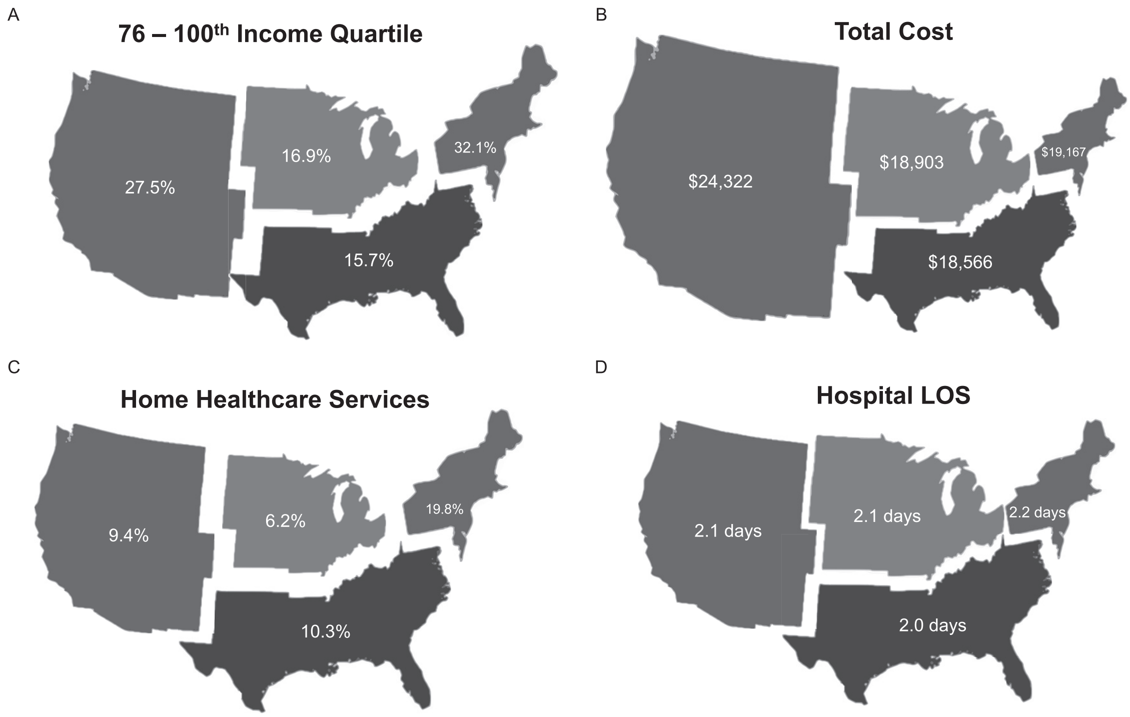

Fig. 1. Cartogram Census Bureau maps showing the relative percentage of patients in the 76-100th median household income quartile (A), mean total cost (B), patients discharged with home healthcare services (C), and mean hospital length of stay (D). Compared across all regions, there were significant differences in the proportions of patients in the 76-100th median household income quartile ($p<0.001$), total cost ($p<0.001$) and home healthcare services ($p<0.001$). The mean LOS was similar amongst all cohorts ($p=0.678$).
LOS = Length of Stay.

Table 6
Logistic multivariate regression analysis on increased costs.

	Univariate Model	Multivariate Model	P - Value
Hospital Region			
Northeast	REFERENCE		
Midwest	1.12 (0.79, 1.58)	1.33 (0.91, 1.95)	0.147
South	0.96 (0.69, 1.33)	1.11 (0.79, 1.58)	0.544
West	**2.51 (1.78, 3.52)**	**3.46 (2.41, 4.96)**	<0.001
Age	0.99 (0.99, 1.01)	0.99 (0.99, 1.00)	0.166
Female sex	**0.89 (0.77, 1.02)**	**0.85 (0.72, 0.99)**	0.044
Race			
White	REFERENCE		
Black	1.19 (0.98, 1.47)	1.24 (0.97, 1.57)	0.081
Hispanic	**1.44 (1.03, 2.03)**	1.13 (0.74, 1.72)	0.577
Other	**1.62 (1.15, 2.29)**	1.36 (0.93, 1.99)	0.115
Income Quartile			
0-25th	REFERENCE		
26-50th	0.84 (0.70, 1.02)	0.87 (0.70, 1.09)	0.227
51-75th	1.14 (0.93, 1.39)	1.20 (0.95, 1.50)	0.124
76-100th	**1.62 (1.26, 2.07)**	**1.76 (1.30, 2.38)**	<0.001
Comorbidities			
Paralysis	**1.89 (1.05, 3.44)**	*Removed*	
Diabetes, uncomplicated	**0.79 (0.67, 0.95)**	**0.81 (0.66, 0.99)**	0.048
Fluid and electrolyte disorders	**2.97 (2.01, 4.41)**	*Removed*	
Deficiency anemias	**2.88 (1.21, 6.86)**	**3.42 (1.37, 8.58)**	0.009
Fusion Levels			
One level	REFERENCE		
Two levels or more	**3.59 (2.97, 4.34)**	**3.94 (3.20, 4.85)**	<0.001
Number of Complications			
0	REFERENCE		
1	**2.39 (1.89, 3.02)**	**1.40 (1.06, 1.85)**	0.019
>1	**7.83 (3.03, 20.19)**	**3.30 (1.22, 8.92)**	0.019
Length of stay	**1.54 (1.39, 1.70)**	**1.49 (1.33, 1.66)**	<0.001

Discussion

In this retrospective NIS study assessing the impact of hospital region on 17,385 adult patients undergoing elective ACDF for CSM, we identified geographic variations in patient demographics, overall hospital costs, and discharge dispositions between the Northeast, South, West, and Midwest regions of the United States. On multivariate regression analysis, Western geographic region compared to the Northeast was an independent predictor of increased costs.

Previous studies have investigated the regional variations in the prevalence of ACDF for cervical degenerative disease. In a retrospective analysis of 4,506 patients undergoing ACDF for cervical radiculopathy, Virk et al. found that the majority of patients were treated in the South (52.73%), followed by the Midwest, West, and Northeast.[10] Similarly, in a retrospective cohort study of 28,813 patients who underwent a one or two-level primary ACDF for degenerative cervical pathology, Harris et al. found that their Southern cohort had the highest proportion of patients (47%) relative to Northeastern, North Central, and Western hospitals. [12] Furthermore, in a retrospective study of 35,962 CSM patients that aimed to compare outcomes of different surgical approaches, Veeravagu et al. found that the majority of ACDF procedures were performed in Southern hospitals (51.48%) as opposed to Northeastern, North Central, or Western hospitals. [13] Analogous to the aforementioned studies, our study found that the South had the greatest rate of elective ACDF for CSM (48.5%) compared to the other geographic regions. This regional variability emphasizes the need to examine geographic variations in post-operative outcomes and develop evidence-based guidelines to help standardize treatment.

Regional differences in patient demographics, and their associated impact on surgical outcomes, have been relatively understudied in the elective ACDF population. Better elucidating these factors may help clarify the observed regional discrepancies in outcomes. For example, in a retrospective cohort study of 15,400 patients undergoing elective ACDF for CSM using the NIS from 2016 to 2017, Elsamadicy et al. found that hospital region differed significantly between their African American and Caucasian cohorts (p<0.001). [14] Likewise, in an observational study of 134,088 patients who underwent elective ACDF in 2011, Kalakoti et al. reported significant differences in U.S. hospital region between their comorbid and no comorbidity cohorts. [8] Similarly, our study found that race, median household income quartile, and healthcare coverage all varied significantly between the North, South, West, and Midwest regions. Additionally, our study found that patient comorbidities, including affective disorder, nicotine dependence, diabetes, and obesity, varied significantly for patients treated in different geographic regions. Future studies assessing the impact of such patient demographics on outcomes and resource utilization may lead to regionally-based changes in health care that allow for pre-operative risk stratification and optimization of patient care.

In addition to patient demographics, there is a dearth of literature on the association of geographic region and post-operative outcomes such as LOS. In an analysis of 52,212 patients undergoing elective ACDF for cervical degenerative disease using the NIS from years 2012 to 2015, Akhras et al. found that Western hospital region was associated with a longer LOS when compared to the Northeast (p<0.001). [9] Conversely, in a retrospective study of 144,514 patients undergoing ACDF for CSM using the NIS from 2010 to 2014, Elsamadicy et al. showed that hospital region was similar between the extended LOS (>3 days) and normal LOS cohorts. [15] Analogously, our study found that LOS was similar between the different regional cohorts. Further investigations are warranted to definitively determine the impact of hospital region on post-operative outcomes following elective ACDF for CSM.

As health care costs continue to rise, previous studies have focused on the regional differences in resource utilization following ACDF for CSM. In the study of 52,212 elective ACDF patients by Akhras et al., the authors demonstrated that hospital region in the West was associated with a $4,812.14 increase in admission cost when compared to the Northeast. [9] Similarly, in a retrospective analysis of 4,506 patients undergoing ACDF for cervical radiculopathy, Virk et al. showed that the mean reimbursement per patient significantly differed by U.S. geographic region, with the highest reimbursement occurring in the West ($16,098 ± $970). [10] Akin to the aforementioned studies, our study found that the West incurred the greatest total cost of hospital admission compared to the other regional cohorts ($24,322 ± $15,126). Additional studies analyzing the breakdown of admission costs by geographic region may allow for targeted cost-reduction strategies and decreased health care spending.

Few reported studies have explored regional variations in discharge disposition following elective ACDF for CSM. The Akhras et al. study demonstrated that the West (OR: 1.71), South (OR: 1.34), and Midwest (OR: 1.25) were all associated with greater odds of nonroutine discharge when compared to the Northeast. [9] Contrarily, our study found that patients in the Northeast encountered the highest proportion of nonroutine discharges (28.0%). Further studies are necessary to elucidate the effects of hospital region on discharge disposition to minimize unanticipated non-routine discharges and lower the burden of associated costs.

This study has several limitations inherent to all administrative databases, including the NIS. First, the analysis is retrospective, with data available only by ICD-10-CM codes, which may contain coding and reporting biases. Second, data may be misclassified or incomplete. Third, pre-operative factors such as the severity of CSM or degree of stenosis were not available, which may have implications on our results. Also, we are unable to comment on the rate of procedures performed per statewide population, nor on important variables such as special group care and independent practice, all which can impact outcomes of ACDF surgery. Finally, as the NIS has information specific to only one inpatient admission, we cannot comment on long-term functional outcomes or treatment durability. Despite these limitations, this study provides important findings on the geographic variations in post-operative outcomes and health care utilization for patients undergoing elective ACDF for CSM.

Conclusion

Our study identified regional variations in patient demographics, total admission cost, and discharge disposition following elective anterior cervical discectomy and fusion for cervical spondylotic myelopathy. On multivariate regression analysis, Western geographic region was an independent predictor of increased costs. These findings underscore the need to standardize treatment nationwide for ACDF surgery.

Appendix

Table A1, Table A2

Table A1
ICD-10-CM malignancy, fracture trauma, posterior decompression and/or fusion codes excluded.

Variable	ICD-10 Code
Neoplasms of vertebral column, spinal cord, and meninges of spinal cord	C41.2, C41.9, C70.1, C70.9, C72.0, C72.1, C72.9
Fracture of cervical vertebra and other parts of neck	S12.0, S12.00, S12.000-S12.001, S12.01-S12.03, S12.030-S12.031, S12.04, S12.040-S12.041, S12.09, S12.090-S12.091, S12.000X, S12.001X, S12.01XX, S12.02XX, S12.030X, S12.031X, S12.040X, S12.041X, S12.090X, S12.091X, S12.1, S12.10, S12.100, S12.101, S12.11, S12.110-S12.112, S12.12, S12.120-S12.121, S12.13, S12.130-S12.131, S12.14-12.15, S12.150-S12.151, S12.19, S12.190-S12.191, S12.100X, S12.101X, S12.110X, S12.111X, S12.112X, S12.120X, S12.121X, S12.130X, S12.131X, S12.14XX, S12.150X, S12.151X, S12.190X, S12.191X, S12.2, S12.20, S12.200, S12.201, S12.23, S12.230, S12.231, S12.24-S12.25, S12.250-S12.251, S12.29, S12.290-S12.291, S12.200X, S12.201X, S12.230X, S12.231X, S12.24XX, S12.250X, S12.251X, S12.290X, S12.291X, S12.3, S12.30, S12.300, S12.301, S12.33, S12.330, S12.331, S12.34-S12.35, S12.350-S12.351, S12.39, S12.390-S12.391, S12.300X, S12.301X, S12.330X, S12.331X, S12.34XX, S12.350X, S12.351X, S12.390X, S12.391X, S12.4, S12.40, S12.400, S12.401, S12.43, S12.430, S12.431, S12.44-S12.45, S12.450-S12.451, S12.49, S12.490-S12.491, S12.400X, S12.401X, S12.430X, S12.431X, S12.44XX, S12.450X, S12.451X, S12.490X, S12.491X, S12.5, S12.50, S12.500, S12.501, S12.53, S12.530, S12.531, S12.54-S12.55, S12.550-S12.551, S12.59, S12.590-S12.591, S12.500X, S12.501X, S12.530X, S12.531X, S12.54XX, S12.550X, S12.551X, S12.590X, S12.591X, S12.6, S12.60, S12.600, S12.601, S12.63, S12.630, S12.631, S12.64-S12.65, S12.650-S12.651, S12.69, S12.690-S12.691, S12.600X, S12.601X, S12.630X, S12.631X, S12.64XX, S12.650X, S12.651X, S12.690X, S12.691X, S12.8, S12.8XXX, S12.9, S12.9XXX
Crushing injury of neck	S17, S17.0, S17.8, S17.9, S17.0XXX, S17.8XXX, S17.9XXX
Fracture of thoracic vertebrae	S22.0, S22.00, S22.000, S22.001-S22.002, S22.008-S22.009, S22.01, S22.010-S22.012, S22.018-S22.019, S22.02, S22.020-S22.022, S22.028-S22.029, S22.03, S22.030-S22.032, S22.038-S22.039, S22.04, S22.040-S22.042, S22.048-S22.049, S22.05, S22.050-S22.052, S22.058-S22.059, S22.06, S22.060-S22.062, S22.068-S22.069, S22.07, S22.070-S22.072, S22.078-S22.079, S22.08, S22.080-S22.082, S22.088-S22.089, S22.000X, S22.001X, S22.002X, S22.008X, S22.009X, S22.010X, S22.011X, S22.012X, S22.018X, S22.019X, S22.020X, S22.021X, S22.022X, S22.028X, S22.029X, S22.030X, S22.031X, S22.032X, S22.038X, S22.039X, S22.040X, S22.041X, S22.042X, S22.048X, S22.049X, S22.050X, S22.051X, S22.052X, S22.058X, S22.059X, S22.060X, S22.061X, S22.062X, S22.068X, S22.069X, S22.070X, S22.071X, S22.072X, S22.078X, S22.079X, S22.080X, S22.081X, S22.082X, S22.088X, S22.089X
Fracture of lumbar spine and pelvis	S32.0, S32.00, S32.000-S32.002, S32.008-S32.009, S32.01, S32.010-S32.012, S32.018-S32.019, S32.02, S32.020-S32.022, S32.028-S32.029, S32.03, S32.030-S32.032, S32.038-S32.039, S32.04, S32.040-S32.042, S32.048-S32.049, S32.05, S32.050-S32.052, S32.058-S32.059, S32.000X, S32.001X, S32.002X, S32.008X, S32.009X, S32.010X, S32.011X, S32.012X, S32.018X, S32.019X, S32.020X, S32.021X, S32.022X, S32.028X, S32.029X, S32.030X, S32.031X, S32.032X, S32.038X, S32.039X, S32.040X, S32.041X, S32.042X, S32.048X, S32.049X, S32.050X, S32.051X, S32.052X, S32.058X, S32.059X, S32.1, S32.10, S32.14-S32.17, S32.19, S32.11, S32.110-S32.112, S32.119, S32.12, S32.120-S32.122, S32.129, S32.13, S32.130-S32.132, S32.139, S32.10XX, S32.110X, S32.111X, S32.112X, S32.119X, S32.120X, S32.121X, S32.122X, S32.129X, S32.130X, S32.131X, S32.132X, S32.139X, S32.14XX, S32.15XX, S32.16XX, S32.17XX, S32.19XX, S32.2XXX
Posterior cervical fusion and/or “cervical spinal cord release” (representing laminectomy)	0RG2071, 0RG207J, 0RG20AJ, 0RG20J1, 0RG20JJ, 0RG20K1, 0RG20KJ, 0RG2371, 0RG237J, 0RG23AJ, 0RG23J1, 0RG23JJ, 0RG23K1, 0RG23KJ, 0RG2471, 0RG247J, 0RG24AJ, 0RG24J1, 0RG24JJ, 0RG24K1, 0RG24KJ, 0RG1071, 0RG107J, 0RG10AJ, 0RG10J1, 0RG10JJ, 0RG10K1, 0RG10KJ, 0RG1371, 0RG137J, 0RG13AJ, 0RG13J1, 0RG13JJ, 0RG13K1, 0RG13KJ, 0RG1471, 0RG147J, 0RG14AJ, 0RG14J1, 0RG14JJ, 0RG14K1, 0RG14KJ, 00NW0ZZ

Table A2
Covariates and corresponding ICD-10 codes.

Variables	ICD-10 Codes
Affective disorders	F30, F30.1, F30.10, F30.11, F30.12, F30.13, F30.2, F30.3, F30.4, F30.8, F30.9, F31, F31.0, F31.1, F31.10, F31.11, F31.12, F31.13, F31.2, F31.3, F31.30, F31.31, F31.32, F31.4, F31.5, F31.6, F31.60, F31.61, F31.62, F31.63, F31.64, F31.7, F31.70, F31.71, F31.72, F31.73, F31.74, F31.75, F31.76, F31.77, F31.78, F31.8, F31.81, F31.89, F31.9, F32, F32.0, F32.1, F32.2, F32.3, F32.4, F32.5, F32.8, F32.81, F32.89, F32.9, F33, F33.0, F33.1, F33.2, F33.3, F33.4, F33.40, F33.41, F33.42, F33.8, F33.9, F34, F34.0, F34.1, F34.8, F34.81, F34.89, F34.9, F39, F41, F41.0, F41.1, F41.3, F41.8, F41.9
Nicotine dependence	F17, F17.2, F17.20, F17.200, F17.201, F17.203, F17.208, F17.209, F17.21, F17.210, F17.211, F17.213, F17.218, F17.219, F17.22, F17.220, F17.221, F17.223, F17.228, F17.229, F17.29, F17.290, F17.291, F17.293, F17.298, F17.299
Cervical vertebral joint fusion with an interbody fusion device	0RG10A0, 0RG20A0
Transfusion	30233N1, 30230N0, 30233R1
Electrophysiological monitoring	4A1004G, 4A1034G, 4A1074G, 4A1084G, 4A10 × 4G, 4A1104G, 4A1134G, 4A1174G, 4A1184G, 4A11 × 4G
Cerebrospinal fluid leak or dural tear	G96.0, G96.1, G96.11
Acute post-hemorrhagic anemia	D62
Dysphagia	R13.1, R13.10, R13.11, R13.12, R13.13, R13.14, R13.19
Displacement of internal fixation device of vertebrae	T84.226A
Wound disruption	T81.30, T81.30XA, T81.31, T81.31XA, T81.32, T81.32XA
Mechanical complication	T84.216, T84.216A, T84.218, T84.218A, T84.226, T84.226A, T84.228, T84.228A, T84.296, T84.296A, T84.298, T84.298A, T84.31, T84.310, T84.310A, T84.318, T84.318A, T84.32, T84.320, T84.320A, T84.328, T84.328A, T84.39, T84.390, T84.390A, T84.398, T84.398A
Hematoma	L76.32
Nervous system complication	G97.82
Acute deep vein thrombosis	I82.4, I82.40, I82.401, I82.402, I82.403, I82.409, I82.41, I82.411, I82.412, I82.413, I82.419, I82.42, I82.421, I82.422, I82.423, I82.429, I82.43, I82.431, I82.432, I82.433, I82.439, I82.44, I82.441, I82.442, I82.443, I82.449, I82.45, I82.451, I82.452, I82.453, I82.459, I82.46, I82.461, I82.462, I82.463, I82.469, I82.49, I82.491, I82.492, I82.493, I82.499, I82.4Y, I82.4Y1, I82.4Y2, I82.4Y3, I82.4Y9, I82.4Z, I82.4Z1, I82.4Z2, I82.4Z3, I82.4Z9
Anesthesia-related	T88.59XA

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