US regional variations in rates, outcomes, and costs of spinal arthrodesis for lumbar spinal stenosis in working adults aged 40–65 years

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OBJECTIVE It is important to identify differences in the treatment of common diseases over time and across geographic regions. Several studies have reported increased use of arthrodesis to treat lumbar spinal stenosis (LSS). The purpose of this study was to investigate geographic variations in the treatment of LSS by US region.

METHODS The authors reviewed inpatient and outpatient medical claims from 2010 to 2014 using the MarketScan Commercial Claims and Encounters database (Truven Health Analytics), which includes data on commercially insured members younger than 65 years. ICD-9 code 724.02 was used to identify patients aged ≥ 40 and < 65 years who underwent surgery for “spinal stenosis of the lumbar region” and for whom LSS was the only principal diagnosis. The primary outcome was the performance of spinal arthrodesis as part of the procedure. Geographic regions were based on patient residence and defined according to the US Census Bureau as the Northeast, Midwest, South, and West.

RESULTS Rates of arthrodesis, as opposed to decompression alone, varied significantly by region, from 48% in the South, to 42% in the Midwest, 36% in the Northeast, and 31% in the West. After controlling for patient age, sex, and Charlson Comorbidity Index values, the differences remained significant. Compared with patients in the Northeast, those in the South (OR 1.6, 95% CI 1.50–1.75) and Midwest (OR 1.3, 95% CI 1.18–1.41) were significantly more likely to undergo spinal arthrodesis. On multivariate analysis, patients in the West were significantly less likely to have a prolonged hospital stay (> 3 days) than those in the Northeast (OR 0.84, 95% CI 0.75–0.94). Compared with the rate in the Northeast, the rates of discharge to a skilled nursing facility were lower in the South (OR 0.41, 95% CI 0.31–0.55) and West (OR 0.72, 95% CI 0.53–0.98). The 30-day readmission rate was significantly lower in the West (OR 0.81, 95% CI 0.65–0.98) than in the Northeast and similar between the other regions. Mean payments were significantly higher in the Midwest (mean difference \$5503, 95% CI \$4279–\$6762), South (mean difference \$6187, 95% CI \$5041–\$7332), and West (mean difference \$7732, 95% CI \$6384–\$9080) than in the Northeast.

CONCLUSIONS The use of spinal arthrodesis, as well as surgical outcomes and payments for the treatment of LSS, varies significantly by US region. This highlights the importance of developing national recommendations for the treatment of LSS.

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KEYWORDS geographic region; lumbar spinal stenosis; spinal arthrodesis; surgical trends

LUMBAR spinal stenosis (LSS) is often a debilitating condition that is associated with substantial pain and disability related to degenerative bony overgrowth impinging on neural structures in the lumbar spine. The primary goal of LSS surgery is to decompress the compromised neural structures. Several studies have reported similar or superior long-term outcomes af-

ter surgical decompression compared with nonoperative treatment in LSS patients who were candidates for surgery.^{2,10,14,22} However, the role of spinal arthrodesis in these patients is more controversial. Although arthrodesis is often recommended for patients with concomitant scoliosis or spondylolisthesis,¹⁸ it has not been shown to produce better outcomes than decompression alone in patients with

ABBREVIATIONS CCI = Charlson Comorbidity Index; CI = confidence interval; ICD-9 = *International Classification of Diseases, Ninth Revision*; LOS = length of stay; LSS = lumbar spinal stenosis; OR = odds ratio; SD = standard deviation; SNF = skilled nursing facility; USD = US dollars.

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isolated LSS and is therefore not recommended in this patient population.^{5,11,12,16} Arthrodesis has also been shown to be associated with worse postoperative outcomes, including higher complication rates, prolonged length of stay (LOS), and greater resource use.^{5,8,13} Nevertheless, recent studies have reported a dramatic increase in the number of arthrodesis procedures performed for LSS.^{7,8,13,21} This increase was particularly pronounced in the US. Recently, Lønne et al.⁹ showed that, for patients with isolated LSS and similar baseline characteristics, the rate of arthrodesis was 50% in Boston, Massachusetts, compared with 14% in Norway. Studies that assessed temporal trends in and outcomes after the surgical treatment of LSS reported significant variability by geographic region within the US.^{6,19,21} However, geographic variability was analyzed only as a covariate in these studies and not as a primary variable of interest. We believe that a thorough understanding of the geographic variability in surgical trends and outcomes is essential for establishing nationwide consensus on the optimal surgical treatment of LSS.

To our knowledge, no studies have assessed surgical trends and outcomes according to geographic region in the working US population aged 40–65 years, in whom surgery for LSS is most common. Therefore, we compared 1) rates of spinal arthrodesis, 2) outcomes, and 3) temporal trends from 2010 to 2014 in working adults surgically treated for LSS across US geographic regions.

Methods

This study does not qualify as human subjects research and thus is not subject to institutional review board approval.

Patient Sample

Our patient sample is from inpatient and outpatient medical claims for 2010 through 2014 from the MarketScan Commercial Claims and Encounters database (Truven Health Analytics), which includes data on commercially insured members younger than 65 years. Patients whose age was listed as ≥ 40 and < 65 years were included in this study. Patients without a continuous 12 months of coverage were excluded because some long-term outcomes, such as hospital readmission, were analyzed. The *International Classification of Diseases, Ninth Revision* (ICD-9)⁴ code 724.02 was used to identify patients who underwent surgery with “spinal stenosis of the lumbar region” as the only principal diagnosis. Patients with concomitant diagnoses, such as scoliosis or spondylolisthesis, were excluded. The Charlson Comorbidity Index (CCI) with the Elixhauser modification, which is predictive of postoperative outcomes in orthopedic patients, was used for risk stratification.¹⁵

Geographic Regions and States

Geographic regions were based on the location of patient residence and were defined according to the US Census Bureau as the Northeast (Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, and Vermont), Midwest (Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Mis-

souri, Nebraska, North Dakota, Ohio, South Dakota, and Wisconsin), South (Alabama, Arkansas, Delaware, District of Columbia, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia, and West Virginia), and West (Alaska, Arizona, California, Colorado, Hawaii, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming).

Surgical Procedures

Surgical procedures were categorized as decompression alone (ICD-9 code 03.09 or 80.51) or with arthrodesis (ICD-9 code 81.06, 81.07, 81.08, 81.63, or 81.64). Arthrodesis was further classified as simple, which involves a single approach (posterior or anterior) to fuse 1 or 2 spinal levels (ICD-9 code 81.06, 81.07, 81.08, or 81.62), or complex, which involves a combined anteroposterior approach and/or fusion of more than 2 levels (any combination of the following ICD-9 codes: 81.06, 81.07, 81.08, 81.63, or 81.64).

Use of Healthcare Resources

The healthcare resources we analyzed were payments made to hospitals (as opposed to charges) in US dollars (USD) and the LOS after surgery, in days. LOS was analyzed as a binary outcome using the 75th percentile (3 days) as a cutoff. We adjusted for inflation rates according to the Consumer Price Index, and all payments are expressed as 2014 USD equivalents.

Medical Complications and Discharge Status

Inpatient medical complications were assessed using the following ICD-9 codes: cardiopulmonary resuscitation (code 9393 or 9960), endotracheal intubation (code 9604), cardiopulmonary arrest (code 4275 or 9971), acute myocardial infarction (code 410), respiratory failure (code 51881), pulmonary embolism (code 41511), pneumonia (code 482), stroke (code 99702), and wound infection or dehiscence (code 8622, 9981, 9983, or 9985). Patients were categorized as being discharged to home or to a skilled nursing facility (SNF).

Statistical Analysis

The 4 US regions were compared with respect to baseline patient demographic characteristics and the rates of arthrodesis and complex arthrodesis. Univariate and multivariate logistic regression models controlling for potential confounders were used to compare outcomes and the likelihood of undergoing arthrodesis and complex arthrodesis among the 4 regions. The annual likelihood of undergoing arthrodesis/complex arthrodesis for each region was estimated using logistic regression. Statistical significance was set at $p < 0.05$. Statistical analyses were performed using Stata software (version 15, StataCorp, LLC).

Results

Patient Sample

The enrollment per year in the database was approximately 2.75 million patients in 2010, 2.76 million in 2011,

TABLE 1. Patient and surgical characteristics by US region for 19,885 patients who underwent surgery for LSS, 2010–2014

Variable	Northeast	Midwest	South	West	p Value
LSS surgeries	4004 (20)	5174 (26)	7231 (36)	3476 (18)	
Patient age in yrs, mean	56.4 ± 6.0	56.1 ± 6.1	56.1 ± 6.2	56.4 ± 6.0	0.001
Female patients	1662 (42)	2293 (44)	3336 (46)	1529 (44)	<0.001
CCI					<0.001
0	2652 (66)	3462 (67)	5045 (70)	2477 (71)	
1	940 (24)	1253 (24)	1584 (22)	717 (21)	
>1	412 (10)	459 (9)	602 (8)	282 (8)	
Arthrodesis	1423 (36)*	2172 (42)*	3451 (48)*	1063 (31)*	<0.001
Complex arthrodesis	93 (7)†	160 (7)†	290 (8)†	136 (13)†	<0.001

Data are number of patients or cases (%) unless otherwise indicated. Mean values are presented with SDs.

* Expressed as a percentage of all surgical procedures.

† Expressed as a percentage of all fusion procedures.

2.67 million in 2012, 2.12 million in 2013, and 2.20 million in 2014. The annual incidence of surgery for LSS per 1000 enrollees during that period was 1.7 in 2010, 1.8 in 2011 and 2012, 1.5 in 2013, and 1.2 in 2014. During the study period, 20,279 patients underwent surgery for LSS, of whom 394 were excluded for missing data on geographic location. We included 19,885 patients in our analysis (Table 1). The mean patient age was 56 years (standard deviation [SD] 6.1), and 44% of patients (n = 8820) were women. The CCI value was 0 for 69% of patients (n = 13,636), 1 for 23% of patients (n = 4494), and 2 or more for 9% of patients (n = 1755).

Patient Characteristics by Region

Patient characteristics differed significantly by region. The proportion of women was highest in the South (46%) and lowest in the Northeast (42%). The highest proportion of patients with a CCI of 0 was in the West (71%), and the lowest proportion was in the Northeast (66%).

Arthrodesis Rates by Region and State

The rates of arthrodesis (simple or complex) differed significantly by region as follows: South (48%), Midwest (42%), Northeast (36%), and West (31%). The rates of complex arthrodesis also varied significantly by region as follows: West (13%), South (8%), and Northeast and Midwest (both 7%) (Table 1).

The 4 states with the highest rates of arthrodesis were Delaware (70.4%), Tennessee (59.9%), Indiana (59.0%), and Virginia (57.1%). The 4 states with the lowest rates of arthrodesis were Hawaii (0.00%), Oregon (20.8%), North Dakota (23.1%), and Massachusetts (23.9%) (Table 2). Figure 1 shows a map with shading gradients representing ranges of arthrodesis rates by state.

After we controlled for patient age, sex, and CCI, the differences in arthrodesis rates among the 4 regions were significantly different. Compared with patients in the Northeast, those in the South (odds ratio [OR] 1.6, 95% confidence interval [CI] 1.50–1.75) and Midwest (OR 1.3, 95% CI 1.18–1.41) were significantly more likely to undergo arthrodesis, whereas patients in the West were signifi-

cantly less likely to undergo arthrodesis (OR 0.79, 95% CI 0.73–0.88). For patients who underwent arthrodesis, the likelihood of undergoing complex arthrodesis was similar in the Midwest and Northeast regions and significantly higher (both $p < 0.001$) in the South (OR 1.3, 95% CI 1.04–1.69) and West (OR 2.1, 95% CI 1.61–2.81) (Fig. 2).

Changes in Surgical Trends Over Time by Region

From 2010 to 2014, the rates of arthrodesis (complex and simple) increased in all 4 US regions. The rate of complex arthrodesis among patients undergoing arthrodesis similarly increased (Fig. 3). The rates of arthrodesis increased significantly over time in all regions, as follows: Northeast ($p < 0.001$; OR 1.1, 95% CI 1.05–1.15), Midwest ($p < 0.001$; OR 1.1, 95% CI 1.05–1.15), South ($p < 0.001$; OR 1.08, 95% CI 1.04–1.11), and West ($p = 0.001$; OR 1.1, 95% CI 1.04–1.16). For patients who underwent arthrodesis, the likelihood of undergoing complex arthrodesis increased significantly in the Northeast (OR 1.55, 95% CI 1.32–1.81), Midwest (OR 1.45, 95% CI 1.28–1.64), South (OR 1.38, 95% CI 1.26–1.5), and West (OR 1.44, 95% CI 1.25–1.65) (all $p < 0.001$).

Univariate Analysis of Outcomes by Region

The rates of postoperative medical complications were similar among the 4 regions ($p = 0.711$). Patients in the Northeast were most likely to have an LOS longer than 3 days (22.2%, $p = 0.003$). Thirty-day readmission rates were highest in the Northeast (7%, $p = 0.04$), whereas 90-day readmission rates were highest in the South (9.3%, $p = 0.004$). Patients in the Northeast were most likely of those in any region to be discharged to an SNF (2.8%), whereas those in the South were the least likely to be discharged to an SNF (1.1%, $p < 0.001$). The mean payments to hospitals also differed significantly by region. The West had the highest payments (mean \$30,549, SD \$34,740), and the Northeast had the lowest (mean \$22,867, SD \$26,435) ($p < 0.001$; Table 3).

Multivariate Analysis of Outcomes by Region

Patient age, sex, and CCI value were controlled for on

TABLE 2. Rates of spinal arthrodesis for LSS by US state and the District of Columbia, 2010–2014

Rank	State	No. (%)* of Arthrodesis Procedures
1	Delaware	54 (70.4)
2	Tennessee	396 (59.9)
3	Indiana	654 (59.0)
4	Virginia	450 (57.1)
5	South Carolina	878 (56.0)
6	Rhode Island	51 (54.9)
7	Mississippi	144 (54.9)
8	North Carolina	465 (54.8)
9	Kentucky	338 (54.1)
10	Utah	123 (53.7)
11	Nebraska	45 (53.3)
12	Alabama	384 (52.1)
13	Connecticut	336 (50.6)
14	Iowa	109 (50.5)
15	Missouri	395 (48.6)
16	Idaho	106 (48.1)
17	Florida	732 (47.0)
18	Louisiana	250 (46.8)
19	Georgia	850 (46.2)
20	Montana	40 (45.0)
21	Vermont	7 (42.9)
22	New York	833 (41.8)
23	Maryland	127 (41.7)
24	Kansas	121 (41.3)
25	South Dakota	17 (41.2)
26	New Jersey	266 (41.0)
27	Colorado	215 (40.9)
28	Ohio	1353 (40.7)
29	Wisconsin	239 (40.6)
30	District of Columbia	5 (40.0)
31	Arkansas	105 (40.0)
32	Texas	1601 (39.7)
33	Michigan	1145 (39.7)
34	New Hampshire	129 (39.5)
35	Maine	46 (39.1)
36	Wyoming	23 (39.1)
37	Arizona	197 (35.0)
38	Nevada	244 (34.8)
39	Illinois	917 (34.0)
40	Alaska	18 (33.3)
41	New Mexico	145 (33.1)
42	Pennsylvania	2102 (30.5)
43	West Virginia	195 (29.7)
44	California	1744 (27.0)
45	Washington	413 (26.6)
46	Oklahoma	257 (25.3)
47	Minnesota	166 (24.7)
48	Massachusetts	234 (23.9)

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TABLE 2. Rates of spinal arthrodesis for LSS by US state and the District of Columbia, 2010–2014

Rank	State	No. (%)* of Arthrodesis Procedures
49	North Dakota	13 (23.1)
50	Oregon	207 (20.8)
51	Hawaii	1 (0.00)

* Expressed as a percentage of all surgical procedures in the state for lumbar spinal stenosis.

multivariate regression analysis. LOS was similar in the Midwest, Northeast, and South. Patients in the West were significantly less likely to have a prolonged LOS compared with those in the Northeast ($p = 0.003$; OR 0.84). The rates of postoperative medical complications were similar across all regions ($p > 0.05$). The 30-day readmission rate was significantly lower in the West ($p = 0.039$; OR 0.81) compared with the Northeast, and similar across the other regions. The 90-day readmission rates were similar among regions ($p > 0.05$). The rates of discharge to an SNF were similar in the Northeast and Midwest. However, they were significantly lower in the South ($p < 0.001$; OR 0.41) and West ($p = 0.039$; OR 0.72) compared with the Northeast. The mean payments were significantly higher in the Midwest (mean difference \$5503, 95% CI \$4279–\$6726), South (mean difference \$6187, 95% CI \$5041–\$7332), and West (mean difference \$7732, 95% CI \$6384–\$9080) compared with the Northeast (all $p < 0.001$; Table 4).

Changes in Postoperative Outcomes Over Time by Region

The likelihood of a prolonged LOS did not differ significantly over time in any region ($p > 0.05$). The likelihood of having a postoperative medical complication was significantly higher only in the South ($p = 0.02$; OR 1.19). The rates of 30-day and 90-day readmission, as well as the likelihood of being discharged to an SNF, were similar over time in each region ($p > 0.05$). There was a significant increase in payments to hospitals during the study period in all regions ($p < 0.05$), which was highest in the Northeast (mean difference \$2664/year, $p < 0.001$; Table 5).

Discussion

This study describes variations in surgical trends, outcomes, and costs of surgery to treat isolated LSS in working US adults by geographic region. Even after controlling for potential confounders, there were significant variations in the rates of arthrodesis among the 4 regions, with the highest rates in the South and Midwest and the lowest rate in the West. Further analysis showed that patients who underwent arthrodesis in the West were significantly more likely to undergo a complex arthrodesis procedure compared with their counterparts in the Northeast.

A study by Alosch et al.¹ reported similar results, whereby the highest rates of anterior cervical spine surgery were in the South and the lowest were in the Northeast.

FIG. 1. Map of the US showing rates of spinal fusion surgery for isolated LSS by state.

In an attempt to explain regional variation in procedure choice for the treatment of degenerative lumbar disease in Ontario, Canada, Bederman et al.³ showed that surgeon preference was the dominant factor affecting procedure type. Similar findings were reported for patients undergoing knee replacement surgery in Ontario.²³ Although sur-

geon preferences may have contributed to the differences in surgical trends for the treatment of isolated LSS in our study, we believe that several potential factors, such as cultural expectations, financial reimbursement, and surgeon education, may also play a role. Given the scant research attempting to explain regional variation in surgical trends

FIG. 2. Odds, by US region, of undergoing a spinal fusion procedure (as opposed to decompression alone) (left) or complex fusion procedure (as opposed to a simple fusion procedure) (right) using the Northeast region as referent. Data based on 19,855 patients with a principal diagnosis of LSS, 2010–2014. Error bars indicate 95% confidence intervals.

FIG. 3. Left: Rates of fusion surgery as a percentage of all LSS surgeries from 2010 to 2014. **Right:** Rates of complex fusion during the same period as a percentage of all fusions by US region. Increases were statistically significant for all fusion and complex fusion rates.

in the US, there is a need to investigate this phenomenon further to understand what influences surgeon decisions by region. It is important to note, however, that there was substantial variability in fusion rates within the regions. Therefore, generalization of our findings must be made with that in mind.

Previous studies have shown an increase in rates of arthrodesis performed for various degenerative lumbar disease conditions.^{8,13} This study supports these results and further shows that this trend is consistent across all 4 US regions. Furthermore, we show that the rise in the rates of arthrodesis in the various regions was not accompanied by a rise in medical complications. In an attempt to explain this phenomenon, the US Department of Health and Human Services conducted a nationwide study in 2013.²⁰ They found that the rise in arthrodesis rates (both simple and complex) from 1997 to 2012 was accompanied by a rise in the purchasing of spinal instrumentation by hospitals from physician-owned distributors. However, the study's results on the geographic variation in the use of physician-owned distributors were based on very small sample sizes (21 states had fewer than 20 patients each), and no conclusions were drawn with regard to this factor.

Although all of the outcomes we analyzed in this study varied significantly by region on univariate analysis, most did not differ after we controlled for patient age, sex, and

general health status, which highlights these factors as potential confounders. On multivariate analysis, patients in the West were significantly less likely to have a prolonged LOS, to be readmitted to the hospital (at 30 or 90 days), or to be discharged to an SNF. Although the worse post-operative outcomes associated with arthrodesis compared to decompression alone^{8,13} may partially explain why the West had lower complication rates, such speculation about our findings in the Northeast may not be justified. Despite the relatively low rates of arthrodesis in the Northeast, the rates of discharge to an SNF and medical complications were relatively high.

Medicare reimbursement for spinal surgery procedures varies significantly by geographic region.¹⁷ Our results support this finding in private insurer payments for working US adults. Interestingly, the West had the highest payments to hospitals after adjustment for covariates, despite having the lowest rates of arthrodesis. When examining factors affecting differential reimbursement by Medicare for spinal procedures, Schoenfeld et al.¹⁷ concluded that some hospitals were inherently more "expensive," and that this was not affected by regional variation in salaries, diagnosis, procedure, demographic characteristics, or health-care use. This inherent difference might partially explain the differences in hospital payments that we found in our study. However, other factors, such as physician salaries,

TABLE 3. Postoperative outcomes by US region for 19,885 patients who underwent surgical correction of LSS, 2010–2014

Variable	Northeast	Midwest	South	West	p Value
LOS >3 days	887 (22.2)	1080 (20.9)	1552 (21.5)	663 (19.1)	0.008
Medical complication	64 (1.6)	81 (1.6)	101 (1.4)	47 (1.4)	0.711
30-day readmission	237 (5.9)	286 (5.5)	434 (6.0)	163 (4.7)	0.04
90-day readmission	388 (9.7)	474 (9.2)	745 (10)	284 (8.2)	0.004
Discharge to SNF	111 (2.8)	110 (2.1)	82 (1.1)	68 (2.0)	<0.001
Payments in USD*	22,867 ± 26,435	28,459 ± 28,511	29,161 ± 29,722	30,549 ± 34,740	<0.001

Data are presented as number of patients (%) unless otherwise indicated.

* Expressed as mean ± SD in 2014 USD equivalents.

TABLE 4. Adjusted odds/mean difference of postoperative outcomes by US region using the Northeast as referent after adjusting for patient age, sex, and CCI for 19,885 patients who underwent surgery for lumbar spinal stenosis, 2010–2014

Outcome	Midwest		South		West	
	OR (95% CI)	p Value	OR (95% CI)	p Value	OR (95% CI)	p Value
LOS >3 days	0.93 (0.84–1.03)	0.157	0.97 (0.88–1.07)	0.516	0.84 (0.75–0.94)	0.003
Medical complication	1 (0.72–1.40)	0.963	0.93 (0.67–1.27)	0.634	0.9 (0.62–1.32)	0.6
30-day readmission	0.94 (0.79–1.12)	0.502	1.04 (0.88–1.22)	0.652	0.81 (0.65–0.98)	0.039
90-day readmission	0.95 (0.83–1.1)	0.502	1.1 (0.97–1.25)	0.151	0.85 (0.73–1.0)	0.057
Discharge to SNF	0.78 (0.59–1.02)	0.066	0.41 (0.31–0.55)	<0.001	0.72 (0.53–0.98)	0.039
Difference in mean payment, USD*	5503 (4279–6726)	<0.001	6187 (5041–7332)	<0.001	7732 (6384–9080)	<0.001

* Mean difference expressed in 2014 USD equivalents.

TABLE 5. Annual OR/mean difference in postoperative outcomes by US region for 19,885 patients who underwent surgery for LSS, 2010–2014

Outcome	Northeast		Midwest		South		West	
	OR (95% CI)	p Value	OR (95% CI)	p Value	OR (95% CI)	p Value	OR (95% CI)	p Value
LOS >3 days	0.99 (0.94–1.04)	0.7	0.99 (0.94–1.04)	0.82	1.02 (0.98–1.06)	0.33	1 (0.94–1.06)	0.99
Medical complication	1.07 (0.89–1.27)	0.48	1.07 (0.90–1.26)	0.45	1.19 (1.03–1.37)	0.02	1.03 (0.83–1.28)	0.79
30-day readmission	1.06 (0.96–1.16)	0.26	1.03 (0.95–1.13)	0.44	1.02 (0.95–1.09)	0.63	0.94 (0.83–1.06)	0.3
90-day readmission	0.98 (0.91–1.06)	0.67	1 (0.93–1.08)	0.93	0.98 (0.93–1.04)	0.48	0.97 (0.88–1.06)	0.49
Discharge to SNF	1.08 (0.94–1.23)	0.23	1.05 (0.91–1.21)	0.5	1.15 (0.98–1.35)	0.076	1.15 (0.96–1.38)	0.13
Difference in mean payment, USD*	2664 (2074–3253)	<0.001	1641 (1046–2235)	<0.001	1090 (578–1601)	<0.001	1518 (652–2383)	<0.001

* Mean difference expressed in 2014 USD equivalents.

regional variation in instrument prices, and other financial factors, could not be assessed and likely play a substantial role in this variability. Furthermore, payments to hospitals increased significantly over time in all regions, with the most pronounced increase in the Northeast and the lowest in the West. These findings were true after we controlled for patient age, which is a known determinant of hospital costs.

This study has several potential limitations. It is a large national database study, and medical billing codes were used to determine patient diagnoses. Medical billing codes do not reflect disease severity, and some surgeons might not have coded for concomitant diagnoses, such as scoliosis or spondylolisthesis. However, the use of a consistent billing code across all regions likely minimized the regional differences in disease severity. This study has a similar potential limitation in coding for procedures; however, the use of a consistent code inherently controlled for that variation as well. As with other large national database studies, risk adjustment across the 4 regions was incomplete because some relevant variables, such as body mass index, were unavailable. However, we attempted to address that problem by adjusting for known and available risk factors such as age, sex, and CCI value. Unlike the regions, some states had very small sample sizes and the results for these states might not reflect accurate arthrodesis rates. Nevertheless, we believe that our results highlight

important trends in the surgical treatment of working US adults with LSS.

Conclusions

Given the large discrepancy (31%–48%) in arthrodesis rates for the same diagnosis across the 4 US regions, there is a need for further investigation into the causes of this variation. A better understanding of this regional variation is important to inform attempts to create national consensus guidelines for the treatment of isolated LSS.

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Author Contributions

Conception and design: Skolasky, Raad, Reidler. Acquisition of data: Skolasky, Raad. Analysis and interpretation of data: Raad. Drafting the article: Raad, Reidler, El Dafrawy. Critically revising the article: Reidler, Amin, Jain, Neuman, Riley, Sciubba, Kebaish. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Skolasky. Statistical analysis: Skolasky, Raad, Reidler. Administrative/technical/material support: Skolasky. Study supervision: Skolasky

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