Spine Surgeon Treatment Variability: The Impact on Costs

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Abstract
Study Design: Cross-sectional analysis.
Objectives: Given the lack of strong evidence/guidelines on appropriate treatment for lumbar spine disease, substantial variability exists among surgical treatments utilized, which is associated with differences in costs to treat a given pathology. Our goal was to investigate the variability in costs among spine surgeons nationally for the same pathology in similar patients.
Methods: Four hundred forty-five spine surgeons completed a survey of clinical and radiographic case scenarios on patients with recurrent lumbar disc herniation, low back pain, and spondylolisthesis. Those surveyed were asked to provide various details including their geographical location, specialty, and fellowship training. Treatment options included no surgery, anterior lumbar interbody fusion, posterolateral fusion, and transforaminal/posterior lumbar interbody fusion. Costs were estimated via Medicare national payment amounts.
Results: For recurrent lumbar disc herniation, no difference in costs existed for patients undergoing their first revision microdiscectomy. However, for patients undergoing another microdiscectomy, surgeons who operated <100 times/year had significantly lower costs than those who operated >200 times/year (P < .001) and those with 5-15 years of experience had significantly higher costs than those with >15 years (P < .001). For the treatment of low back pain, academic surgeons kept costs about 55% lower than private practice surgeons (P < .001). In the treatment of spondylolisthesis, there was significant treatment variability without significant differences in costs.
Conclusions: Significant variability in surgical treatment paradigms exists for different pathologies. Understanding why variability in treatment selection exists in similar clinical contexts across practices is important to ensure the most cost-effective delivery of care among spine surgeons.

Keywords
disc herniation, lumbar interbody fusion, degenerative disc disease

Introduction
Substantial variability exists among spine surgeons in treating patients with common lumbar pathologies including low back pain, disc herniation, and spondylolisthesis. This variability is posited to be due to a relative absence of evidence-based guidelines, financial incentives, different specialty and training backgrounds, and different practice cultures based on geographical region and practice setting (eg, academic vs private practices). In the current era of value-based health care, there is increased scrutiny regarding surgical decision making and resource utilization, particularly with regard to cost-effective treatments.
Between 1992 and 2003, Weinstein et al9 found that Medicare spending for all inpatient back surgery more than doubled, and lumbar fusion, specifically, increased 500% from $75 million to $482 million, representing both increased volume and increased costs, and nearly half of total Medicare spending on spine surgery. Variability in operative approaches is a major driver of these costs. This variation stems, in part, from residency training1 and continues throughout practice based on specialty, operative volume, practice duration, and geographic region.2,9

The present study is a cost analysis based on the results of a national survey of US spine surgeons looking at surgical treatment patterns for common lumbar pathologies. Details of this survey have been previously published.2,6 We investigate the variability in costs based on demographic groups of the spine surgeons. Our hypothesis was that there would be significant differences in costs based on geographical location, specialty training, years of experience, and the practice model (academic vs private).

Methods

An online survey was designed using the RedCAP Database (Research Electronic Data Capture; Vanderbilt University, Nashville, TN), to assess surgeon practice patterns for common lumbar pathologies. Details of this survey have been previously published.2,6 In short, the survey was electronically sent to orthopedic and neurologic surgeons in the United States selected from a national spine surgeon database. Those surveyed were asked to provide details regarding the geographical location of their practice (based on regions), their specialty, fellowship training, type of practice (private, academic, hybrid), practice volume, years in practice, use of discograms, and whether or not the surgeon typically surgically treats back pain due to degenerative disc disease. The results of completed surveys were analyzed using R software (version 2.15.0; R Foundation, Vienna, Austria) and SAS software (version 9.3; SAS Inc, Cary, NC). Paired t tests and ANOVA analyses were used to compare cost data. Statistical significance was set at .01 to account for multiple comparisons.

Within this survey, multiple scenarios were posed with respondents having to select a specific treatment (ie, type of surgery vs no surgery) for the patient.2,6 The analyzed pathologies included (1) first-time recurrent disc herniation and second-time recurrent disc herniation,2 (2) low back pain refractory to conservative management with or without concordant discogram findings,6 and (3) spondylolisthesis and neurogenic claudication with or without mechanical low back pain. The costs of the various treatment options were calculated and correlated based on surgeon demographic for a given pathology.

Costs were defined as all hospital charges to the patient undergoing the procedure (ie, the cost of resources used for treating a particular illness, or the direct cost). Medicare national payment amounts, which are publicly available and used nationally across health care systems, were used to estimate all cost data. The Medicare Severity-Diagnosis Related Group (MS-DRG) national Medicare payment amounts for hospitals were referenced in Ingenix’s DRG Expert (institutional-level fees).10 The American Medical Association online database and Center for Medicare and Medicaid Services were queued for Current Procedural Terminology (CPT) code Medicare national payment amounts based on the physician fee schedule (professional-level fees).11,12 Total direct costs were defined as the sum of professional-level fees (CPT) and institutional-level fees (DRG), which were adjusted for inflation to 2016 dollars. Other direct costs, including physical therapy days, outpatient visits, and diagnostic imaging, as well as indirect costs (related to missed work opportunity costs) were not included. For the “No surgery” option, we assumed $0 in comparison to adding costs with a surgery. This does not take into account the real costs associated with nonoperative management.

Results

Demographics

A total of 445 spine surgeons completed the survey. Surgeons were characterized according to region, specialty, fellowship training, practice type, yearly surgical volume, and practice length. With respect to regional status, the Midwest, Northeast, and Southeast were most heavily represented with 126 (28%), 109 (24%), and 96 (22%) respondents, respectively, out of the total 445 respondents (331/445, 74%). Of the 445 total respondents, 318 (75%) were orthopedic surgeons and 107 (25%) were neurologic surgeons. The vast majority were fellowship trained, with 340 (78%) reporting additional training. There were 241 (57%) surgeons who practiced in a private practice setting while 99 (22%) chose academia and 85 (20%) combined the two in a hybrid format. At 96 (22%) respondents, most surgeons reported performing 151 to 200 surgeries per year when compared to the other categories. In addition, most surgeons were older, as 163 (38%) respondents described a practice duration of over 20 years.

Direct Costs

The direct costs associated with each management plan are listed in Table 1. As would be expected, costs varied considerably based on the level of surgical involvement. Notably, the most distinguishing cost differences can be attributed to the DRG code associated with the procedure, rather than the CPT code associated costs. For example, DRG code 460 (spinal fusion, excluding cervical, without major complications) added over $11 000 to the direct costs of surgery when compared to DRG code 030 (nonfusion spine surgery without major complications).

Recurrent Lumbar Disc Herniation

Two clinical presentations were considered in the study of recurrent lumbar disc herniation.2 Scenario 1 (Sc1) described a case of recurrent L5-S1 disc herniation after 1 microdiscectomy, whereas Scenario 2 (Sc2) demonstrated a recurrent L5-S1 disc herniation after 2 prior microdiscectomies. In Sc1, there was
relatively widespread agreement among surgeons in choosing another revision microdiscectomy as the preferred surgical treatment, which billed at $10,442 in direct costs. As there was minimal variability in the treatments most surgeons selected, there were no cost implications found (Table 2).

However, Sc2 differed in that surgeons were relatively split in choosing either a third revision microdiscectomy ($10,442) or revision microdiscectomy with posterior lumbar interbody fusion (PLIF)/transforaminal lumbar interbody fusion (TLIF) ($23,713) as the preferred operation. Surgeons with shorter track records (<15 years in practice) and higher volume (>200 surgeries per year) were more likely to select revision microdiscectomy with PLIF/TLIF ($10,442 vs $23,713; P < .01). Yearly surgical volume (P = .001) and surgeon’s practice length (P < .001) were also associated with significant cost implications (Table 3). Further analysis demonstrated that surgeons who operated less than 100 times per year were associated with lower costs than those who operated more than 200 times per year ($10,747 vs $16,178; P < .001). With respect to surgical experience, surgeons with 5 to 15 years were associated with higher costs than those with more than 15 years ($17,288 vs $13,194; P < .001). Less than 5 years of experience was not associated with any statistically significant difference in costs.

Lower Back Pain

Scenario 3 (Sc3) presented a 44-year-old man with mechanical lower back pain refractory to conservative management, no leg pain, and positive discogram at L4-L5 causing concordant pain. Scenario 4 (Sc4) presented a similar patient but with positive discogram at L4-L5 and L5-S1 causing concordant pain.

The most common responses for Sc3 were 1-level anterior lumbar interbody fusion (ALIF; $22,329), 1-level PLIF/TLIF ($22,363), and no surgery. Practice type (P < .001) and discogram use (P < .001) were associated with significant cost implications (Table 4). In particular, academic surgeons selected
treatments that were associated with costs about 55% lower than private practice surgeons ($5334 vs $11,839; P < .001). Moreover, surgeons who never or rarely used discograms were associated with significantly lower costs than those who used discograms more frequently (Supplementary Table 3; all supplementary tables are available at http://journals.sagepub.com/home/gsj).

With regard to Sc4, 2-level ALIF with posterior fixation ($23,473), 2-level PLIF/TLIF ($22,701), and no surgery ($0) were the most preferred management options. No significant cost implications were observed when comparing region, specialty, practice type, volume, fellowship training, or practice length. Using discograms often was associated with significant cost differences compared to rarely or never using them ($19,519 vs $3,587; P < .001; Table 5). In addition, never- or rare-users of discograms tended to select treatment options that had significantly lower costs (Supplementary Table 4).

Spondylolisthesis

For the study of spondylolisthesis, the 2 scenarios presented were distinguished based on the presence or absence of mechanical back pain. Sc5 demonstrated L4-L5 spondylolisthesis with stenosis and correlative neurogenic claudication refractory to conservative treatment with mechanical back pain. A similar case was described in Sc6 but of a patient without mechanical back pain.

PLIF/TLIF ($22,363) and laminectomy with posterior lateral fusion ($23,617) were the preferred management options in Sc1. Given that the costs of these procedures are relatively similar and very few surgeons chose not to operate, no significant cost differences were found (Table 6). In Sc6, laminectomy with foraminotomy ($10,243) was another common response in addition to the 2 procedures listed in Sc5. While specialty type trended toward significance, with neurosurgeons posting lower costs than orthopedic surgeons ($18,617 vs $20,518; P = .011), this did not reach statistical significance (Table 7).

Discussion

High-value care is an essential component in health care, and as such, understanding the variability in surgeon treatment decisions and the associated cost implications can allow for
creation of cost-effective treatment paradigms for common lumbar pathologies. A total of $90 billion is spent annually on the treatment of low back pain in the United States.13 Previous studies have shown that there is significant variation in spine surgical treatment across geographic regions, contributing to increased expenditures.1-9 Much of this variability exists due to a lack of high-level evidence and definitive clinical guidelines. In the present study, we analyzed the differences in costs associated with the variable treatment options for the different clinical scenarios.

In Mroz et al2 (Study 1), the authors focused on the variability in treatment patterns for patients with first- and second-time recurrent lumbar disc herniation. Two scenarios were presented to those surveyed. Surgical treatment options included revision microdiscectomy, revision microdiscectomy with in situ fusion, revision microdiscectomy with posterolateral fusion using pedicle screws, revision microdiscectomy with PLIF/TLIF, ALIF with percutaneous screws, ALIF with open posterior instrumentation, or no surgery. Surgeons with shorter track records (<15 years in practice) and higher volume (200+ surgeries per year) were more likely to select revision microdiscectomy with PLIF/TLIF (P < .01). No significant differences existed for region, specialty, fellowship training, or practice type. Similarly, in the present study, average costs per surgeon were significantly (P < .01) different based on surgeon’s volume and practice length. Specifically, those in practice for longer more frequently chose the less costly procedure (repeat discectomy rather than fusion). Interestingly, as volume rose, a parabolic or bimodal pattern was observed whereby both surgeons with the lowest volumes and highest volumes chose lower cost operation (repeat discectomy) than those with mid-tier volumes (who more likely chose the fusion option). Geographic variation in costs trended toward significance (P = .05) with the lowest costs per surgeon found in the Northeast and West (vs the more expensive option in the Midwest).

In Lubelski et al6 (Study 2), the authors focused on surgical treatment variability (same operative choices as Study 1) for low back pain and found substantial clinical equipoise (*75% Table 4. Cost Variability for the Treatment of Lower Back Pain With Positive Discogram at L4-L5 (Scenario 3).)

| Surgeon Characteristics | ALIF (%) | PLIF/TLIF (%) | No Surgery (%) | Average Cost per Surgeon | P Value |
|-------------------------|----------|---------------|----------------|--------------------------|---------|
| Region                  |          |               |                |                          |         |
| Midwest                 | 17 (17)  | 20 (20)       | 65 (63)        | $8106                    | .142    |
| Northeast               | 17 (21)  | 18 (22)       | 47 (57)        | $9538                    |         |
| Southeast               | 15 (20)  | 26 (35)       | 34 (45)        | $12,218                  |         |
| Southwest               | 7 (25)   | 7 (25)        | 14 (50)        | $11,173                  |         |
| West                    | 10 (23)  | 7 (16)        | 27 (61)        | $8632                    |         |
| Specialty               |          |               |                |                          | .320    |
| Neurological surgery    | 15 (18)  | 25 (30)       | 43 (52)        | $10,771                  |         |
| Orthopedic surgery      | 51 (21)  | 53 (21)       | 144 (58)       | $9371                    |         |
| Fellowship training     |          |               |                |                          | .632    |
| Yes                     | 54 (20)  | 60 (23)       | 152 (57)       | $9577                    | <.001*  |
| No                      | 12 (18)  | 18 (28)       | 35 (54)        | $10,315                  |         |
| Practice type           |          |               |                |                          |         |
| Academic                | 8 (9)    | 13 (15)       | 67 (76)        | $5333                    |         |
| Hybrid                  | 15 (26)  | 10 (17)       | 33 (57)        | $9630                    |         |
| Practice type           |          |               |                |                          | <.001*  |
| Yes                     | 43 (23)  | 55 (30)       | 87 (47)        | $11,838                  |         |
| No                      | 12 (18)  | 18 (28)       | 35 (54)        | $10,315                  |         |
| Practice length in years|          |               |                |                          | .322    |
| <5                      | 7 (19)   | 5 (14)        | 25 (67)        | $7246                    |         |
| 5-10                    | 10 (18)  | 12 (21)       | 34 (61)        | $8779                    |         |
| 10-15                   | 11 (24)  | 14 (30)       | 21 (46)        | $12,146                  |         |
| 15-20                   | 14 (20)  | 18 (26)       | 37 (54)        | $10,364                  |         |
| >20                     | 24 (19)  | 29 (24)       | 70 (57)        | $9629                    |         |
| Discogram use           |          |               |                |                          | <.001*  |
| Never                   | 8 (8)    | 8 (8)         | 87 (84)        | $3471                    |         |
| Rarely                  | 18 (15)  | 29 (23)       | 78 (62)        | $8403                    |         |
| Sometimes               | 25 (37)  | 25 (37)       | 17 (26)        | $16,676                  |         |
| Often                   | 15 (42)  | 16 (44)       | 5 (14)         | $19,243                  |         |

Abbreviations: ALIF, anterior lumbar interbody fusion; PLIF, posterior lumbar interbody fusion; TLIF, transforaminal lumbar interbody fusion.

*Statistically significant at P < .01.
disagreement) among surgeons. Surgeons working in academic practices were 4 times as likely to select “no surgery” or just continue conservative management as compared to their colleagues in hybrid and private practice. Disagreement was highest in the Southwest and there was least disagreement in the Midwest (82% vs 69%). In the present study, we found that this translated into an average cost per surgeon that was more than double ($11 838 vs $5333; \(P < .01\)) for private practice surgeons versus academic surgeons. No significant differences in cost were found based on geographic region or other surgeon variable.

In the third study, the authors focused on surgical treatment pattern variability for patients with grade 1 lumbar spondylolisthesis with and without mechanical low back pain (Lubelski et al, unpublished data, 2017). For patients without mechanical back pain, neurosurgeons were significantly (\(P < .01\)) more likely to select decompression-only as compared to orthopedic surgeons who more commonly fused. In addition, for patients with mechanical back pain, significant (\(P < .01\)) geographic, practice type, volume, and practice length variation existed. In the present study, when evaluating the financial implications, the average costs per surgeon for orthopedic surgeons trended toward significance ($20 518 vs $18 617; \(P = .011\)). No other differences in costs were discovered based on other surgeon variables. While there was substantial variability in surgical choices, the lack of cost differences is likely related to the similarity in costs between the various fusion options.

Overall, we found that there is variation in costs based on spine surgeon specialty, practice duration, operative volume, and practice model. However, there was no consistent surgeon-specific variable that explained the cost differences. Geographic variation in procedures and associated costs has been observed previously. Cook et al\(^7\) examined (\(n = 23 143\) from the Nationwide Inpatient Sample, years 1990-2000) the total

### Table 5. Cost Variability for the Treatment of Lower Back Pain With Positive Discogram at L4-L5 and L5-S1 (Scenario 4).

| Surgeon Characteristics | Two-level ALIF With Posterior Fixation (%) | Two-Level PLIF/TLIF (%) | No Surgery (%) | Average Cost per Surgeon | \(P\) Value |
|-------------------------|-------------------------------------------|-------------------------|----------------|--------------------------|------------|
| **Region**              |                                           |                         |                |                          |            |
| Midwest                 | 12 (14)                                   | 16 (19)                 | 58 (67)        | $7499                    | .256       |
| Northeast               | 15 (19)                                   | 23 (29)                 | 41 (52)        | $11 066                   |            |
| Southeast               | 9 (12)                                    | 21 (28)                 | 46 (61)        | $9052                     |            |
| Southwest               | 7 (26)                                    | 6 (22)                  | 14 (52)        | $11 130                   |            |
| West                    | 9 (21)                                    | 6 (14)                  | 28 (65)        | $8081                     |            |
| **Specialty**           |                                           |                         |                |                          |            |
| Neurological surgery    | 10 (12)                                   | 31 (36)                 | 44 (52)        | $11 041                   | .075       |
| Orthopedic              | 42 (19)                                   | 41 (18)                 | 143 (63)       | $8481                     |            |
| **Fellowship training** |                                           |                         |                |                          | .260       |
| Yes                     | 47 (19)                                   | 49 (20)                 | 155 (62)       | $8827                     |            |
| No                      | 5 (8)                                     | 23 (38)                 | 32 (53)        | $10 658                   |            |
| **Practice type**       |                                           |                         |                |                          | .110       |
| Academic                | 16 (19)                                   | 10 (12)                 | 60 (70)        | $7007                     |            |
| Hybrid                  | 12 (20)                                   | 14 (24)                 | 33 (56)        | $10 161                   |            |
| Private                 | 24 (14)                                   | 48 (29)                 | 94 (57)        | $9958                     |            |
| **Surgeries per year**  |                                           |                         |                |                          | .572       |
| 0-100                   | 2 (6)                                     | 9 (29)                  | 20 (65)        | $8105                     |            |
| 101-150                 | 13 (23)                                   | 9 (16)                  | 34 (61)        | $9097                     |            |
| 151-200                 | 9 (13)                                    | 20 (30)                 | 38 (57)        | $9929                     |            |
| 201-250                 | 13 (23)                                   | 12 (21)                 | 32 (56)        | $10 133                   |            |
| 251-300                 | 10 (20)                                   | 12 (24)                 | 27 (55)        | $10 350                   |            |
| >300                    | 5 (10)                                    | 10 (20)                 | 36 (71)        | $6752                     |            |
| **Practice length in years** |                                         |                         |                |                          | .247       |
| <5                      | 6 (17)                                    | 4 (11)                  | 26 (72)        | $6434                     |            |
| 5-10                    | 10 (17)                                   | 9 (16)                  | 39 (67)        | $7570                     |            |
| 10-15                   | 10 (22)                                   | 13 (28)                 | 23 (50)        | $11 518                   |            |
| 15-20                   | 8 (13)                                    | 12 (20)                 | 41 (67)        | $7544                     |            |
| >20                     | 18 (20)                                   | 15 (16)                 | 58 (64)        | $8385                     |            |
| **Discogram use**       |                                           |                         |                |                          | <.001*     |
| Never                   | 5 (5)                                     | 10 (10)                 | 81 (84)        | $3587                     |            |
| Rarely                  | 19 (15)                                   | 22 (18)                 | 82 (67)        | $7686                     |            |
| Sometimes               | 17 (29)                                   | 23 (39)                 | 19 (32)        | $15 491                   |            |
| Often                   | 11 (33)                                   | 17 (52)                 | 5 (15)         | $19 519                   |            |

Abbreviations: ALIF, anterior lumbar interbody fusion; PLIF, posterior lumbar interbody fusion; TLIF, transforaminal lumbar interbody fusion.

*statistically significant at \(P < .01\)
inflation-adjusted charges associated with surgical care post-lumbar spine fusion for degenerative disc disease. The Northeast had the lowest charges (mean $24,405) followed by the Midwest, South, and West (mean $40,157; \( P < .01 \)). In the present study, we only investigated direct costs of the procedures and did not include inpatient/outpatient costs or other indirect costs. It is certainly possible that the cost of perioperative care may be the major driver in variation observed in the study by Cook et al, rather than the difference in operative cost.

The results of the study by Cook et al showing the Northeast as the region with the lowest costs are contrasted by those of Goz et al, who retrospectively analyzed the Medicare Provider Utilization and Payment database (CPT and DRG cost data) to determine the geographic variation in costs of anterior cervical discectomy and fusion (ACDF), posterolateral fusion (PLF), and total knee arthroplasty (TKA). Statistically significant (\( P < .01 \)) differences in total costs among geographic regions existed for PLF and TKA with the lowest costs in the Midwest and highest in Northeast (\( P < .01 \)). No significant differences in costs were found for ACDF. On a state level, however, Illinois and Minnesota, despite being in the Midwest and seen regionally as part of the low-cost conglomerate, serve as outliers as 2 states with the highest ACDF costs in the country. Finally, cost of living correlated strongly to procedure cost, but not enough to fully explain the cost trends. In addition to cost of living, 2 studies by Walid et al show an impact of patient comorbidities, age, and body mass index on operative cost as well.

Epstein et al showed a 10-fold variation in instrumentation costs ($4062 to $40,409) and 4.8-fold variation in total costs ($26,653 to $129,220) to patients undergoing single-level anterior cervical discectomies with fusion within a single year at one institution. Differences were largely attributed to length of stay and surgeon’s choice of instrumentation. Specifically, the instrumentation charges for performing single-level ACDF varied from $4062 to $40,409.

This suggests that even for similar surgeries, the specific surgeon and the associated surgical instruments can have a

### Table 6. Cost Variability for the Treatment of Spondylolisthesis With Mechanical Back Pain (Scenario 5).

| Surgeon Characteristics | PLIF/TLIF (%) | Laminectomy With PLF (%) | No Surgery (%) | Average Cost per Surgeon | \( P \) Value* |
|-------------------------|---------------|--------------------------|----------------|--------------------------|--------------|
| Region                  |               |                          |                |                          | .783         |
| Midwest                 | 69 (64)       | 35 (32)                  | 4 (4)          | $21,941                  |              |
| Northeast               | 46 (48)       | 46 (48)                  | 3 (4)          | $22,264                  |              |
| Southeast               | 54 (68)       | 21 (27)                  | 4 (5)          | $21,564                  |              |
| Southwest               | 22 (63)       | 11 (31)                  | 2 (6)          | $21,480                  |              |
| West                    | 32 (67)       | 15 (31)                  | 1 (2)          | $22,289                  |              |
| Specialty               |               |                          |                |                          | .484         |
| Neurological surgery    | 67 (71)       | 25 (27)                  | 2 (2)          | $22,221                  |              |
| Orthopedic surgery      | 156 (58)      | 103 (38)                 | 12 (4)         | $21,850                  |              |
| Fellowship training     |               |                          |                |                          | .846         |
| Yes                     | 181 (61)      | 103 (35)                 | 11 (4)         | $21,967                  |              |
| No                      | 42 (60)       | 25 (36)                  | 3 (4)          | $21,853                  |              |
| Practice type           |               |                          |                |                          | .189         |
| Academic                | 47 (51)       | 41 (45)                  | 4 (4)          | $21,950                  |              |
| Hybrid                  | 48 (68)       | 23 (32)                  | 0 (0)          | $22,770                  |              |
| Private                 | 128 (63)      | 64 (32)                  | 10 (5)         | $21,654                  |              |
| Surgeries per year      |               |                          |                |                          | .448         |
| 0-100                   | 11 (28)       | 26 (65)                  | 3 (7)          | $21,501                  |              |
| 101-150                 | 33 (60)       | 20 (36)                  | 2 (4)          | $22,006                  |              |
| 151-200                 | 46 (55)       | 32 (38)                  | 6 (7)          | $21,244                  |              |
| 201-250                 | 48 (76)       | 15 (24)                  | 0 (0)          | $22,662                  |              |
| 251-300                 | 39 (67)       | 17 (29)                  | 2 (4)          | $21,960                  |              |
| >300                    | 46 (71)       | 18 (28)                  | 1 (1)          | $22,367                  |              |
| Practice length in years|               |                          |                |                          | .929         |
| <5                      | 27 (77)       | 7 (20)                   | 1 (3)          | $21,975                  |              |
| 5-10                    | 48 (72)       | 18 (27)                  | 1 (1)          | $22,366                  |              |
| 10-15                   | 40 (67)       | 18 (30)                  | 2 (3)          | $21,994                  |              |
| 15-20                   | 44 (65)       | 21 (31)                  | 3 (4)          | $21,764                  |              |
| >20                     | 64 (47)       | 64 (47)                  | 7 (6)          | $21,798                  |              |
| Discogram use           |               |                          |                |                          | .917         |
| Never                   | 58 (56)       | 41 (39)                  | 5 (5)          | $21,782                  |              |
| Rarely                  | 77 (60)       | 47 (37)                  | 4 (3)          | $22,125                  |              |
| Sometimes               | 51 (61)       | 30 (36)                  | 3 (3)          | $22,012                  |              |
| Often                   | 37 (76)       | 10 (20)                  | 2 (4)          | $21,706                  |              |

Abbreviations: PLIF, posterior lumbar interbody fusion; TLIF, transforaminal lumbar interbody fusion; PLF, posterolateral fusion.

*Statistically significant at \( P < .01 \).
major impact on the associated costs/charges. Similarly, Kazberouk et al\textsuperscript{13} retrospectively analyzed intersurgeon variation for 1241 elective spine procedures at one institution over 3 years. When adjusted for patient characteristics, intersurgeon variation in cost per procedure was modest (factor of 1.31 between lowest and highest cost surgeons). They found that for different surgical procedures, the cost drivers varied. For example, for spinal fusions, instrumentation costs were the major driver of cost. On the other hand, for spinal decompressions, the cost varied by surgeon: for some the hospital length of stay was the major cost driver, whereas for others it was the operating room cost.

Given the variability in costs, the next question to consider, though not analyzed in this study, is differences in patient outcome (ie, are higher costs associated with better outcomes?). High-value care consortiums and hospital groups have already taken steps to reduce variability for non–spine-related procedures while maintaining standard of care for patients, such as with total knee replacements.\textsuperscript{18,19} The overarching goal is to reduce unwarranted variation while maintaining or benefitting the standard of care for all patients. For example, implementation of a co-managed inpatient postoperative care consortium led to decreased complication rates and, as a result, shorter hospital stays.\textsuperscript{18} Other hospitals have utilized pay for performance and nonblinded performance feedback tactics to normalize surgeon variation.\textsuperscript{19} This may limit surgeon variability in costs substantially. By identifying significant variations in costs, surgical groups and hospital organizations can initiate discussions targeting value-based spine care and appropriate care-paths, when indicated.

Limitations of the present study include the relatively low response rate, which limits the generalizability of the study conclusions. In addition, the surveys enable broad evaluation of surgical costs, without allowing for more granular evaluation of intersurgeon variability for a given procedure, charges versus costs to the hospital, other hospital-related costs such as hospital length of study, as well as evaluation of indirect costs.

Table 7. Cost Variability for the Treatment of Spondylolisthesis Without Mechanical Back Pain (Scenario 6).

| Surgeon Characteristics | PLIF/TLIF (%) | Laminctomy With PLF (%) | Laminctomy With Foraminotomy (%) | No Surgery (%) | Average Cost per Surgeon | P Value* |
|------------------------|--------------|-------------------------|---------------------------------|---------------|-------------------------|--------|
| Region                 |              |                         |                                 |               |                         |        |
| Midwest                | 49 (45)      | 47 (43)                 | 10 (9)                          | 4 (4)         | $20,984                 | .451   |
| Northeast              | 28 (31)      | 44 (48)                 | 14 (15)                         | 5 (5)         | $19,876                 |        |
| Southeast              | 36 (45)      | 26 (33)                 | 16 (20)                         | 2 (3)         | $19,788                 |        |
| Southwest              | 17 (41)      | 14 (34)                 | 8 (20)                          | 2 (5)         | $19,336                 |        |
| West                   | 22 (38)      | 23 (40)                 | 9 (16)                          | 4 (7)         | $19,437                 |        |
| Specialty              |              |                         |                                 |               |                         | .011   |
| Neurological surgery   | 42 (45)      | 24 (26)                 | 22 (24)                         | 5 (5)         | $18,617                 |        |
| Orthopedic surgery     | 110 (38)     | 130 (45)                | 35 (12)                         | 12 (4)        | $20,518                 |        |
| Fellowship training    |              |                         |                                 |               |                         | .271   |
| Yes                    | 126 (41)     | 125 (41)                | 41 (13)                         | 14 (5)        | $20,228                 |        |
| No                     | 26 (35)      | 29 (39)                 | 16 (22)                         | 3 (4)         | $19,327                 |        |
| Practice type          |              |                         |                                 |               |                         | .271   |
| Academic               | 33 (35)      | 47 (51)                 | 10 (11)                         | 3 (3)         | $20,972                 |        |
| Hybird                 | 32 (45)      | 24 (34)                 | 12 (17)                         | 3 (4)         | $19,794                 |        |
| Private                | 87 (40)      | 83 (38)                 | 35 (16)                         | 11 (5)        | $19,742                 |        |
| Surgeries per year     |              |                         |                                 |               |                         | .326   |
| 0-100                  | 7 (18)       | 19 (48)                 | 12 (30)                         | 2 (5)         | $18,205                 |        |
| 101-150                | 20 (34)      | 26 (45)                 | 8 (14)                          | 4 (7)         | $19,711                 |        |
| 151-200                | 30 (33)      | 47 (51)                 | 8 (9)                           | 7 (8)         | $21,222                 |        |
| 201-250                | 35 (56)      | 20 (32)                 | 8 (13)                          | 0 (0)         | $19,734                 |        |
| 251-300                | 30 (48)      | 20 (32)                 | 10 (16)                         | 2 (3)         | $20,091                 |        |
| >300                   | 30 (46)      | 22 (34)                 | 11 (17)                         | 2 (3)         | $20,048                 |        |
| Practice length in years |            |                         |                                 |               |                         | .525   |
| <5                     | 21 (53)      | 13 (33)                 | 6 (15)                          | 0 (0)         | $20,953                 |        |
| 5-10                   | 34 (55)      | 18 (29)                 | 7 (11)                          | 3 (5)         | $21,028                 |        |
| 10-15                  | 28 (43)      | 22 (34)                 | 12 (18)                         | 3 (5)         | $19,518                 |        |
| 15-20                  | 28 (42)      | 26 (39)                 | 8 (12)                          | 5 (7)         | $19,734                 |        |
| >20                    | 41 (28)      | 75 (51)                 | 24 (16)                         | 6 (4)         | $20,096                 |        |
| Discogram use          |              |                         |                                 |               |                         | .326   |
| Never                  | 37 (37)      | 42 (42)                 | 18 (18)                         | 4 (4)         | $19,839                 |        |
| Rarely                 | 58 (41)      | 57 (41)                 | 19 (14)                         | 6 (4)         | $20,270                 |        |
| Sometimes              | 33 (37)      | 42 (47)                 | 11 (12)                         | 3 (3)         | $20,703                 |        |
| Often                  | 24 (48)      | 13 (26)                 | 9 (18)                          | 4 (8)         | $18,719                 |        |

Abbreviations: PLIF, posterior lumbar interbody fusion; TLIF, transforaminal lumbar interbody fusion; PLF, posterolateral fusion.

*Statistically significant at $P < .01.$
such as missed work days, physical therapy, and so on. We analyzed each operation’s costs by the type of surgery alone, not including differences in instrumentation use, which, as described above, may have had a significant impact on costs. As discussed, our study cost data is unique to the Medicare population given the lack of readily available cost data from private insurers. Even Medicare payment data has been shown to vary widely across hospitals for various spine surgical procedures.20 Finally, we did not analyze differences in patient outcome based on cost and specific clinical scenarios where guidelines for management may be controversial or highly variable. Nonetheless, this study signifies the first to provide a comprehensive evaluation of differences in costs associated with variability for treatment of common lumbar spine pathology. It provides an important starting point for which more substantive efforts can be built upon in the future.

Conclusions

Significant variation exists in surgical treatments of common lumbar pathologies. Variability in associated costs is seen based on geographical location, surgeon’s specialty, practice type, and surgical volume. Understanding the underlying reasons for the variability in treatment selection is important for ensuring the most cost-effective delivery of care among spine surgeons.

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Supplemental Material

The supplemental material is available in the online version of the article.

References

1. Daniels AH, Ames CP, Smith JS, Hart RA. Variability in spine surgery procedures performed during orthopaedic and neurological surgery residency training: an analysis of ACGME case log data. J Bone Joint Surg Am. 2014;96:e196.
2. Mroz TE, Lubelski D, Williams SK, et al. Differences in the surgical treatment of recurrent lumbar disc herniation among spine surgeons in the United States. Spine. 2014;39:1380-1389.
3. Irwin ZN, Hilibrand A, Gustavel M, et al. Variation in surgical decision making for degenerative spinal disorders. Part I: lumbar spine. Spine (Phila Pa 1976). 2005;30:2208-2213.
4. Irwin ZN, Hilibrand A, Gustavel M, et al. Variation in surgical decision making for degenerative spinal disorders. Part II: cervical spine. Spine (Phila Pa 1976). 2005;30:2214-2219.
5. Hussain M, Nasir S, Moed A, Murtaza G. Variations in practice patterns among neurosurgeons and orthopaedic surgeons in the management of spinal disorders. Asian Spine J. 2011;5:208-212.
6. Lubelski D, Williams SK, O’Rourke C, et al. Differences in the surgical treatment of lower back pain among spine surgeons in the United States. Spine (Phila Pa 1976). 2016;41:978-986.
7. Cook C, Santos GCM, Lima R, Pietrobon R, Jacobs DO, Richardson W. Geographic variation in lumbar fusion for degenerative disorders: 1990 to 2000. Spine J. 2007;7:552-557.
8. Weinstein JN, Lurie JD, Olson PR, Bronner KK, Fisher ES. United States’ trends and regional variations in lumbar spine surgery: 1992-2003. Spine (Phila Pa 1976). 2006;31:2707-2714.
9. Deyo RA, Mirza SK. Trends and variations in the use of spine surgery. Clin Orthop Relat Res. 2006;443:139-146.
10. Schmidt K, Hart AC, eds. DRG Expert: A Comprehensive Reference to the DRG Classification System. 2012 Edition. Eden Prairie, MN: Ingenix; 2012.
11. Center for Medicare and Medicaid Services. CMS covers 100 million people [home page]. www.cms.gov. Accessed May 1, 2017.
12. American Medical Association. Coding online. https://commerce.ama-assn.org/ocm/index.jsp. Accessed May 1, 2017.
13. Kazberouk A, Sagy I, Novack V, McGuire K. Understanding the extent and drivers of interphysician cost variation for spine procedures. Spine (Phila Pa 1976). 2016;41:1111-1117.
14. Goz V, Rane A, Abtahi AM, Lawrence BD, Brodke DS, Spiker WR. Geographic variations in the cost of spine surgery. Spine (Phila Pa 1976). 2015;40:1380-1389.
15. Walid MS, Robinson JS Jr. Economic impact of comorbidities in spine surgery. J Neurosurg Spine. 2011;14:318-321.
16. Walid MS, Sanoufa M, Robinson JS. The effect of age and body mass index on cost of spinal surgery. J Clin Neurosci. 2011;18:498-499.
17. Epstein NE, Schwall G, Reilly T, Insinna T, Bahnken A, Hood DC. Surgeon choices, and the choice of surgeons, affect total hospital charges for single-level anterior cervical surgery. Spine (Phila Pa 1976). 2011;36:905-909.
18. Tomek IM, Sabel AL, Froimson MI, et al. A collaborative of leading health systems finds wide variations in total knee replacement delivery and takes steps to improve value. Health Aff (Millwood). 2012;31:1329-1338.
19. Gauld R, Horwitt J, Williams S, et al. What strategies do US hospitals employ to reduce unwarranted clinical practice variations? Am J Med Qual. 2011;26:120-126.
20. Schoenfeld AJ, Harris MB, Liu H, Birkmeyer JD. Variations in Medicare payments for episodes of spine surgery. Spine J. 2014;14:2793-2798.