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Diagnosis-Related Group—Based Payments for Adult Spine Deformity Surgery Significantly Vary across Centers: Results from a Multicenter Prospective Cohort Study

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BACKGROUND: **To investigate the variation in total episode-of-care (EOC) payment and quality-adjusted life-year (QALY) gain for complex adult spine deformity surgeries in the United States, adjusting for case type and surgeon preferences.**

METHODS: **Patients aged >18 years with adult spine deformity with Medicare Severity—Diagnosis-Related Groups (DRGs) 453—460 and a minimum of 2 years of follow-up from index surgery were included. Index and total payments were calculated using Medicare's Inpatient Prospective Payment System. All costs were adjusted for inflation to 2020 U.S. dollar values. QALYs gained were calculated using baseline, 1-year, and 2-year Short-Form 6D scores. Mixed-effect models were used to estimate the proportion of variation in total EOC payment and QALY gain.**

RESULTS: **A total of 330/543 patients from 6 sites were included. Mean age was 62.4 ± 11.9 years, 79% were women, and 92% were white. The mean index and total EOC payment were $77,302 and $93,182, respectively. Patients gained on average 0.15 QALY (P < 0.0001) 2 years after surgery. In unadjusted analysis, 39% of the variation in total EOC payment across the 6 centers was attributable to relative weight of DRG and base rate. Adjusting for patient and procedural factors increased the proportion of variation in total EOC payments across the centers to 56%. Less than 2% of the variation in QALY gain was observed across the 6 centers.**

CONCLUSIONS: **Medicare-based payments for complex spine deformity fusions are primarily driven by relative weight of the DRG and the hospital's base rate. Patient and procedural factors are unaccounted for in the DRG-based payments made to the providers.**

INTRODUCTION

The Medicare Inpatient Prospective Payment System (IPPS) uses Medicare Severity—Diagnosis-Related Group (DRG) codes to reimburse a fixed amount to hospitals associated with a patient admission. The DRGs assigned to a patient are

Key Words
- Deformity
- DRG
- Medicare
- Payments
- QALY
- Regional variation
- Spine

Abbreviations and Acronyms
3-CO: 3-column osteotomy
BMI: Body mass index
BMP: Bone-morphogenetic protein
CCI: Charlson Comorbidity Index
DRG: Diagnosis-related group
EOC: Episode of care
HRQoL: Health-related quality of life
ICC: Intraclass correlation
IPPS: Inpatient Prospective Payment System
ISSG: International Spine Study Group
LOS: Length of stay
ODI: Oswestry Disability Index
PI: Pelvic Incidence
PROM: Patient-reported outcomes measure
QALY: Quality-adjusted life-year
SRS 22: Scoliosis Research Society 22

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based on their principal diagnosis, primary procedure performed, and underlying comorbidities or complications. The relative weight of the DRG and the hospital's base reimbursement rate calculated from the equation, relative weight of DRG × hospital base rate = hospital payment, determine the final amount paid to providers.[1-3]

Although the DRG-based payment system was intended to increase efficiency in inpatient care and improve transparency in hospital activities, there is criticism that differences in patient characteristics, complexity of the surgical procedures, and surgeon preferences are often ignored in the payment calculations, which introduces geographic and regional variation in payments within a DRG and across hospitals.[1,4] Using 2005–2007 Medicare claims data for 185,954 patients undergoing surgery for spinal stenosis, spondylolisthesis, and lumbar disc herniation, Schoenfeld et al.[5] reported a 2-fold difference in payments between hospitals in the highest quintile and lowest quintile. The difference in payment remained at 47% after controlling for price, case mix, and indication adjustment and at 28% after controlling for procedural choice. Wright et al.[4] reported that the mean hospital cost for spine fusion DRGs 453–460 ranged from $27,153.00 to $75,435.00 among 253,399 spinal fusion discharges in the 2011 National Inpatient Sample data set. Using Medicare and commercial claims data for 196,918 spine fusion DRGs 453–460, 471–473, and 490–491, Ugiliweneza et al.[6] reported that the 30-day bundle payment ranged from $12,518 for DRG 491 to $116,096 for DRG 456.

Although studies of variation in spine fusion payments and factors contributing to the variation in payments are well represented in the literature,[4-7] there are limited data on how variation in cost of care corresponds to variation in the patient's health-related quality of life (HRQoL) improvement after surgery across hospitals. The purpose of this study was to quantify the variation in total episode-of-care (EOC) payments for spinal fusion DRGs 453–460 after adjusting for case mix, procedural complexity, and resource utilization across high-volume spine deformity centers in the United States and to determine whether there is significant variation in patient-reported outcome measures (PROMs) across centers. We hypothesize that variation in DRG-based reimbursement exist across spine deformity centers, but that HRQoL improvement is similar across high-volume centers when comparing similar procedures.

METHODS

Study Design and Setting

This study was a retrospective analysis of patient data obtained from the International Spine Study Group (ISSG) registry, which is a prospective multicenter database of consecutive series of patients with adult spine deformity admitted to 14 spine centers from 2008 to 2020 across the United States. Patients were enrolled at each site after institutional review board approval. The study population are a part of the ISSG registry. Patients aged >18 years who underwent corrective spine surgery for adult degenerative or idiopathic scoliosis with a curvature of the spine measuring ≥20°, sagittal vertical axis >5 cm, pelvic tilt > 25°, thoracic kyphosis >60°, >4 vertebrae fused, and a minimum of 2 years of follow-up from surgery were included. Patients diagnosed with spinal deformity secondary to neuromuscular disorders, connective tissue disorders, autoimmune diseases, infection, malignancy, or trauma were excluded.

Main Outcomes

The main outcomes were total EOC cost and PROMs. Cost data for each patient was calculated using Medicare IPPS for DRG codes 453–460 (**Figure 1**).

The total EOC cost includes cost from the index hospitalization and any cost resulting from subsequent complications requiring reoperation. All costs are expressed in 2020 U.S. dollars, discounted at 3% per year based on economic guidelines.[8] PROMs collected include HRQoL scores assessed from Oswestry Disability Index (ODI), Scoliosis Research Society 22 (SRS-22), EuroQol-5D, and Short-Form 6D measures. Cost per quality-adjusted life-year (QALY) was measured as the ratio of total EOC and cumulative QALY gained. The Short-Form 36-item responses at baseline, 1 year, and 2 years were used to calculate Short-Form 6D health utility scores and subsequently transformed to QALY. Cumulative QALYs gained were calculated from summing the discounted incremental health utility changes between baseline and 2 years follow-up Short-Form 6D scores.

Patient, Surgical, Radiographic, and HRQoL Measures

Patient characteristics included were age, sex, race, body mass index (BMI, calculated as weight in kilograms divided by the square of height in meters), Charlson Comorbidity index (CCI), and frailty. Surgical characteristics included were surgical approach (posterior and combined anteroposterior), number of vertebrae fused, interbody fusion (yes/no), decompression (yes/no), 3-column osteotomy (3-CO, yes/no), Smith-Peterson osteotomy (yes/no), operative time (minutes), estimated blood loss (mL), recombinant bone-morphogenetic protein-2 (BMP) used, revision surgery (yes/no), and length of stay (LOS, in days). Radiographic characteristics included were SRS Schwab curve type, coronal balance, thoracic kyphosis, lumbar lordosis, sagittal vertical axis, sacral slope, pelvic tilt, and pelvic incidence (PI). HRQoL measures included were ODI, EuroQol-5D, and SRS-22.

Statistical Analysis

Demographic, surgical, radiographic, and HRQoL measures were compared across the hospitals by 1-way analysis of variance for continuous variables and χ^2 test for discrete variables as appropriate. Variation in total EOC and PROMs across the centers were assessed using a nonparametric Kruskal-Wallis test because of the skewed distribution. A Bonferroni correction was applied to adjust for pairwise comparisons across the centers. Mixed models were used to examine the variation in total EOC payments and 2-year QALY gain across the centers and the contribution of patient, LOS, and surgical factors toward the variation using published methodology.[7] The null model (model 1) includes center as the random effect in the model. This model estimates the intraclass correlation (ICC) coefficient indicating the proportion of variation in the outcome variable accounted for by the center. Models 2–4 were adjusted for patient, LOS, and surgical factors, respectively. Model 5 includes all the factors from model 4 except center as the random effect. We compared models

DRG Code	Description
453	Combined anterior and posterior spinal fusion with major complication or comorbidity (MCC)
454	Combined anterior and posterior spinal fusion with complication or comorbidity (CC)
455	Combined anterior and posterior spinal fusion without CC/MCC
456	Spinal fusion except cervical with spinal curvature, malignancy, infection or extensive fusions with MCC
457	Spinal fusion except cervical with spinal curvature, malignancy, infection or extensive fusions with CC
458	Spinal fusion except cervical with spinal curvature, malignancy, infection or extensive fusions without CC/MCC
459	Spinal fusion except cervical with MCC
460	Spinal fusion except cervical without MCC

Figure 1. Diagnosis-related groups and description.

using R^2 values, a measure of model fit that ranges from 0 to 1 and indicates the proportion of variance in the outcome variable explained by the predictor variables. All statistical analyses were conducted using SAS 9.4 (SAS Inc., Cary, North Carolina, USA).

RESULTS

A total of 1493 patients from 14 centers were assessed for eligibility. Of these patients, 528 (35.4%) were excluded because they were not eligible for 2 years follow-up. Of the remaining 965 patients, 57 (5.9%) with missing baseline QALY and 5 centers with 365 patients (37.8%) were excluded because each of the 5 centers had at least 1 missing revision surgery DRG. Of the 543 eligible patients from 9 centers, 201 patients (37.0%) with missing 2-year QALY and 12 patients (2.2%) from 3 centers who had <5 patients enrolled in each site were excluded. The final sample included 330 patients from 6 centers. Overall, the mean age was 62.4 ± 11.9 years, 78.7% were female, and 92.2% were white. The mean BMI was 28.2 ± 5.5, mean frailty was 3.6 ± 1.5, and CCI was 2.0 ± 1.8. Posterior-only procedures were most common (69.4%), with an average of 11.7 ± 3.5 vertebra fused and BMP used in 82% of cases. Smith-Petersen osteotomy was performed in 80.4% of cases and 3-CO in 21.5% of the cases. The average index hospitalization payment was $77,302.56 ± $27,283.46 and the average total EOC payment was $93,182.38 ± $48,738.14. Patients gained on average 0.15 ± 0.20 QALYs ($P < 0.0001$) from baseline to 2 years after surgery.

Variation in Demographics and Surgical Characteristics

Patients treated at center A were on average 8—13 years younger ($P < 0.001$) compared with other centers. Centers F and C had a lower proportion of females treated ($P = 0.001$). The average BMI ranged from 26.3 to 30.4 ($P = 0.002$), frailty ranged from 2.4 to 4.0 ($P <$ 00001), and CCI ranged from 1.4 to 2.9 ($P <$

Table 1. Summary of Demographic and Surgical Characteristics by Spine Center

	Center						
Metrics	A (n = 45)	B (n = 45)	C (n = 54)	D (n = 28)	E (n = 62)	F (n = 96)	*P* Value
Demographics							
Age (years), mean ± SD	52.1 ± 12.7	63.1 ± 8.6	65.1 ± 9.4	60.3 ± 17.7	63.6 ± 10.6	65.3 ± 10.4	<0.0001
Female, n (%)	42 (93.3)	42 (93.3)	38 (70.4)	24 (85.7)	48 (77.4)	65 (68.4)	0.001
Body mass index (kg/m^2), mean ± SD	26.3 ± 4.5	30.4 ± 6.5	28.0 ± 5.5	26.4 ± 4.7	27.6 ± 5.3	29.1 ± 5.5	0.002
Frailty, mean ± SD	2.4 ± 1.6	3.8 ± 1.4	4.0 ± 1.5	3.0 ± 1.5	3.9 ± 1.3	3.9 ± 1.4	<0.0001
Charlson Comorbidity Index, mean ± SD	1.4 ± 1.7	1.6 ± 1.3	2.9 ± 1.8	1.7 ± 1.5	1.5 ± 1.8	2.2 ± 1.8	<0.0001
Surgical							
Levels fused, mean ± SD	12.6 ± 3.2	11.1 ± 3.0	11.6 ± 3.1	10.2 ± 3.9	13.0 ± 3.9	11.2 ± 3.2	<0.0001
Approach, n (%)							
Posterior only	16 (35.6)	33 (73.3)	39 (72.2)	12 (42.9)	41 (66.1)	88 (91.7)	<0.0001
Anteroposterior	29 (64.4)	12 (26.7)	15 (27.8)	16 (57.1)	21 (33.9)	8 (8.3)	
Smith-Peterson osteotomy, n (%)	38 (100.0)	28 (84.8)	39 (86.7)	20 (100.0)	17 (39.5)	76 (82.6)	<0.0001C
Pedicle subtraction osteotomy, n (%)	0 (0.0)	6 (18.2)	8 (17.8)	1 (5.0)	22 (51.2)	19 (20.7)	<0.0001F
Vertebral column resection, n (%)	3 (7.9)	0 (0.0)	1 (2.2)	0 (0.0)	1 (2.3)	8 (8.7)	0.24F
Operating time (minutes), mean ± SD	382.1 ± 137.7	477.1 ± 66.7	488.4 ± 143.1	337.7 ± 91.2	302.3 ± 124.1	374.4 ± 97.2	<0.0001
Estimated blood loss (mL), mean ± SD	1047.8 ± 827.6	1628.6 ± 1178.2	2038.4 ± 2028.0	892.1 ± 983.1	1371.8 ± 1378.2	2497.3 ± 1824.4	<0.0001
Revision surgery, n (%)	8 (17.8)	6 (13.3)	11 (20.4)	13 (46.4)	18 (29.0)	15 (15.6)	0.005
Length of stay (days), mean ± SD	6.4 ± 1.9	9.4 ± 7.0	9.0 ± 5.2	7.5 ± 4.2	8.6 ± 4.6	8.3 ± 3.9	0.03

SD, standard deviation.

Table 2. Summary of Baseline and Two-Year Radiographic Measurements

	Center						
Metrics	**A (n = 45)**	**B (n = 45)**	**C (n = 54)**	**D (n = 28)**	**E (n = 62)**	**F (n = 96)**	***P* Value**
Coronal balance, mean ± SD							
Baseline	−8.3+44.5	7.0+43.5	2.1+49.2	6.0+64.5	−2.8+49.5	6.1+51.7	0.58
2 years	2.9+34.5	11.0+30.7	−3.9+42.2	4.0+38.3	0.5+29.5	−2.2+35.8	0.35
Delta	11.3+32.3	1.1+50.3	−4.6+45.0	−6.3+52.9	4.1+42.7	−6.5+46.3	0.28
Thoracic kyphosis, mean ± SD							
Baseline	−36.2+18.6	−30.3+15.6	−40.1+16.0	−40.1+19.6	−34.2+20.0	−37.8+20.2	0.10
2 years	−49.1+16.2	−45.2+19.0	−58.2+16.4	−49.0+16.2	−53.8+19.2	−57.5+17.0	0.0004
Delta	−13.1+12.9	−15.3+12.1	−18.3+14.5	−9.6+14.3	−19.6+13.7	−20.0+14.5	0.003
Lumbar lordosis, mean ± SD							
Baseline	46.6+19.7	31.2+19.7	37.3+19.6	45.8+16.9	37.4+17.9	30.7+20.3	<0.0001
2 years	52.7+13.1	45.7+14.6	53.2+11.5	56.3+14.2	58.2+13.5	50.7+12.1	<0.0001
Delta	6.4+16.7	14.1+12.5	15.7+18.4	10.1+13.3	20.8+16.7	20.4+17.4	<0.0001
Sagittal vertical axis, mean ± SD							
Baseline	18.3+51.1	81.1+70.3	71.0+65.1	55.7+69.2	82.5+62.6	89.8+77.7	<0.0001
2 years	−1.1+38.6	43.7+53.3	32.2+46.1	27.9+53.2	26.1+50.0	39.6+56.6	0.0004
Delta	−20.6+48.6	−39.0+56.9	−38.1+70.3	−26.3+61.5	−55.5+76.4	−55.4+64.6	0.027
Sacral slope, mean ± SD							
Baseline	32.0+11.1	29.1+12.4	29.7+10.6	36.2+9.1	32.2+9.5	27.0+11.3	0.0008
2 years	32.5+9.5	32.0+10.4	32.0+9.2	38.5+10.9	38.4+8.6	30.0+9.9	<0.0001
Delta	0.6+7.1	2.7+7.6	2.0+8.3	1.9+6.8	5.9+7.5	3.1+7.3	0.013
Pelvic tilt, mean ± SD							
Baseline	18.6+8.4	27.8+8.9	23.3+11.6	23.0+12.2	25.6+10.3	28.1+10.3	<0.0001
2 years	18.0+8.9	25.8+9.1	21.2+10.3	22.5+14.5	20.2+9.8	24.6+10.6	0.0016
Delta	−0.9+7.2	−2.2+7.3	−2.0+8.4	−0.5+7.0	−5.3+6.7	−3.6+7.1	0.014
Pelvic incidence, mean ± SD							
Baseline	50.6+12.9	57.0+13.7	53.0+11.3	59.2+11.9	58.0+13.0	55.0+13.2	0.016
2 years	50.5+12.5	57.8+13.6	53.1+11.4	61.0+12.6	58.7+13.0	54.6+13.3	0.002
Delta	−0.3+2.0	0.5+3.8	0.1+1.5	1.4+5.1	0.6+4.0	−0.5+2.1	0.035
Pelvic incidence—lumbar lordosis, mean ± SD							
Baseline	4.0+16.6	25.8+18.8	15.6+19.9	13.4+21.5	20.6+17.8	24.4+19.8	<0.0001
2 years	−2.2+12.2	12.1+15.4	−0.1+12.4	4.7+17.8	0.5+13.9	4.0+14.0	<0.0001
Delta	−6.6+17.2	−13.6+12.8	−15.6+18.3	−8.8+14.5	−20.2+15.7	−20.9+17.5	<0.0001

SD, standard deviation.

0.0001) across the 6 centers. A posterior surgical approach was less common at centers A and D ($P < 0.0001$). Patients in center D on average had 3 fewer vertebrae fused ($P < 0.0001$) and patients in center E had the lowest rate of BMP use ($P < 0.0001$). Patients in center E had the lowest rates of Smith-Peterson osteotomy ($P < 0.0001$) but the highest rate of 3-CO ($P < 0.0001$). Operative time ($P < 0.0001$) and blood loss ($P < 0.0001$) were significantly different across the centers. Center D had the highest revision rate of 46.4%, compared with the lowest revision rate of 13.3% at center B ($P = 0.005$). Center A discharged patients on average 1–2 days earlier compared with other centers ($P = 0.03$). Table 1 shows the distribution of demographic and surgical characteristics of patients across the centers.

Table 3. Summary of Cost and Quality-Adjusted Life-Year Metrics Across Spine Centers

	Center						
Metric	**A (n = 45)**	**B (n = 45)**	**C (n = 54)**	**D (n = 28)**	**E (n = 62)**	**F (n = 96)**	***P* Value**
Cost							
Index	54618.9+11521.0	60649.9+12530.0	96339.4+21836.0	57977.5+8750.4	110199.5+23734.3	69423.8+18277.9	<0.0001
Total	66997.1+34310.2	66396.4+20726.7	112963.7+45030.4	86719.4+40273.3	138477.6+61136.8	79517.5+32602.4	<0.0001
Cost/QALY	35225.3+17883.8	39955.5+14767.9	69179.0+32863.2	48083.1+26469.5	98358.1+58674.2	46951.4+22088.7	<0.0001
QALY							
Baseline	0.65+0.12	0.53+0.12	0.54+0.11	0.60+0.14	0.52+0.09	0.54+0.10	<0.0001
2 years QALY	0.69+0.13	0.64+0.11	0.60+0.14	0.65+0.14	0.59+0.14	0.60+0.11	0.0003
QALY gain	0.04+0.13	0.10+0.10	0.06+0.13	0.06+0.13	0.08+0.13	0.06+0.11	0.13

QALY, quality-adjusted life-year.

Variation in Deformity Characteristics

Table 2 summarizes the baseline, 2-year, and change in deformity characteristics across coronal plane and sagittal spinopelvic parameters. Coronal alignment and thoracic kyphosis was not significantly different across the centers. However, lumbar lordosis ($P < 0.0001$), sagittal vertical axis ($P < 0.0001$), sacral slope ($P = 0.0008$), pelvic tilt ($P < 0.0001$), PI ($P = 0.016$), and PI—lumbar lordosis ($P < 0.0001$) parameters significantly differed across the centers. Across all the centers, patients showed significant improvement in sagittal spinopelvic parameters from baseline to 2 years after surgery.

Variation in Cost of Care and Quality-of-Life Characteristics

Payments for index hospitalization and total EOC to center F were higher by 102% ($P < 0.0001$) and 108% ($P < 0.0001$), respectively, compared with the center with lowest reimbursement. Baseline QALY ($P < 0.0001$) and 2-year QALY ($P = 0.0003$) across the centers was significantly different. Yet, the QALY gain at 2 years after surgery was not significantly different across the centers ($P = 0.10$). Similarly, the baseline to 2-year improvement in ODI ($P = 0.41$), SRS-22-pain ($P = 0.16$), SRS-22-activity ($P = 0.22$), SRS-22-appearance ($P = 0.34$), SRS-22-satisfaction ($P = 0.36$), and SRS-22-total ($P = 0.50$) scores was not significantly different across the centers. Tables 3 and 4 summarize cost of care and quality-of-life characteristics across the centers.

Mixed Model Analyses

Total EOC Payments. In the unadjusted model (model 1), the ICC coefficient was 39%, indicating that 39% of the variation in total EOC payments was attributable to the center at which treatment was provided. Adjusting for patient demographics (model 2) and LOS (model 3) marginally decreased the proportion of variation in total EOC payments across the centers from 39% to 37%. Further adjusting for surgical factors (model 4) increased the proportion of variation in total EOC payments across the centers from 37% to 56%. Model 4, which accounted for patient, LOS, surgical, and center effects, had an R^2 value of 42.3%, compared with an R^2 value of 28% for Model 5 which did not account for center effects. This suggests that the center at which the patient received treatment was a significant factor in explaining the variation in total EOC payments.

QALY Gain at 2-years. In the unadjusted model (model 1), the ICC coefficient was 1.6%, indicating that only 1.6% of the variation in QALY gain at 2 years was attributable to the center at which treatment was provided. Adjusting for patient (model 2), LOS (model 3), and surgical factors (model 4) resulted in an ICC of 5.8%. Model 4, which accounted for patient, LOS, surgical, and center effects, had an R^2 value of 1.5%, compared with an R^2 value of 2.7% value for model 5, which did not account for center effects. The low R^2 value suggests that the center at which the patient received treatment had no significant impact on patient's QALY gain at 2 years. Table 5 shows results from mixed model analyses of total EOC payments and QALY gain at 2 years.

DISCUSSION

Medicare reimbursement based on DRG weight and hospital base rate provides a simple and convenient method to capture a patient's inpatient EOC payments that can be generalizable across medical and surgical specialties.[1,2,9] However, there is criticism that Medicare reimbursements do not capture the true cost incurred by providers and that the payments across hospitals have significant variance that is not explained by patient and surgical factors. We estimated the proportion of variation in total EOC payments for spine fusion DRGs 453—460 across 6 major spine deformity centers in the United States and assessed whether variation in payments corresponded to variation in HRQoL improvement.

Across the 6 centers, 39% of the variation in total EOC payments was attributable to regional variation in Medicare DRG reimbursement. After adjusting for patient and surgical factors, regional reimbursement differences accounted for 56% of reimbursement variation. This finding suggests that the relative weight of DRG and base hospital rate are the primary drivers of

Table 4. Summary of Health-Related Quality of Life Scores Across Spine Centers

	Center						
Metrics	**A (n = 45)**	**B (n = 45)**	**C (n = 54)**	**D (n = 28)**	**E (n = 62)**	**F (n = 96)**	***P* Value**
Oswestry Disability Index							
Baseline	30.6+28.9	48.7+48.0	51.349.0	38.7+40.0	51.6+52.0	48.3+48.0	<0.0001
2 years	16.0+10.0	25.7+27.0	33.6+36.0	19.3+11.0	33.7+31.0	31.6+32.0	<0.0001
Delta	−14.5+16.4	−22.4+−22.0	−17.9+−18.0	−19.4+−21.0	−18.0+−17.0	−16.6+−18.0	0.41
EuroQol-5D							
Baseline	0.8+0.8	0.7+0.7	0.7+0.7	0.8+0.8	0.8+0.7	0.7+0.7	0.04
2 years	1.0+1.0	0.8+0.8	0.8+0.8	0.8+0.8	0.8+0.8	0.8+0.8	0.11
Delta	0.2+0.2	0.1+0.1	0.0+0.0	0.0+0.0	0.1+0.0	0.1+0.1	0.35
SRS-22 pain							
Baseline	3.0+3.0	2.2+2.0	1.9+1.8	2.5+2.4	2.2+2.1	2.2+2.2	<0.0001
2 years	4.0+4.2	3.6+3.8	3.3+3.4	3.5+3.8	3.3+3.2	3.3+3.4	0.006
Delta	1.0+1.0	1.4+1.4	1.4+1.6	1.1+1.1	1.0+1.0	1.1+1.0	0.16
SRS-22 activity							
Baseline	3.4+3.4	2.7+2.6	2.6+2.6	3.2+3.3	2.5+2.6	2.7+2.6	<0.0001
2 years	4.0+4.2	3.6+3.8	3.3+3.2	3.8+4.1	3.1+3.1	3.4+3.3	<0.0001
Delta	0.6+0.6	1.0+0.8	0.6+0.8	0.6+0.8	0.6+0.6	0.7+0.8	0.22
SRS-22 appearance							
Baseline	2.7+2.6	2.2+2.0	2.3+2.4	2.5+2.7	2.2+2.1	2.3+2.4	0.01
2 years	4.0+4.2	3.7+3.6	3.5+3.6	3.6+3.8	3.3+3.4	3.4+3.4	0.0006
Delta	1.4+1.4	1.4+1.6	1.1+1.0	1.2+1.4	1.1+1.2	1.1+1.2	0.34
SRS-22 mental							
Baseline	3.9+4.0	3.3+3.4	3.4+3.3	3.5+3.9	3.0+3.0	3.4+3.3	0.0005
2 years	4.1+4.4	3.9+4.0	3.8+3.8	3.9+4.2	3.7+4.0	3.9+4.0	0.44
Delta	0.2+0.2	0.6+0.4	0.4+0.4	0.4+0.2	0.7+0.6	0.5+0.4	0.04
SRS-22 satisfaction							
Baseline	2.7+3.0	3.0+3.0	2.8+2.5	2.4+2.5	2.6+2.5	2.7+3.0	0.17
2 years	4.4+5.0	4.4+4.5	4.0+4.5	4.1+4.5	3.9+4.0	4.2+4.5	0.03
Delta	1.7+2.0	1.4+1.5	1.2+1.5	1.7+2.0	1.3+1.5	1.5+1.5	0.36
SRS-22 total							
Baseline	3.2+3.2	2.6+2.5	2.6+2.6	2.9+3.0	2.5+2.5	2.6+2.6	<0.0001
2 years	4.0+4.3	3.7+3.8	3.5+3.6	3.8+4.1	3.4+3.5	3.6+3.5	0.0003
Delta	0.9+0.9	1.1+1.1	0.9+1.0	0.9+1.1	0.9+0.9	0.9+1.0	0.50

SRS-22, Scoliosis Research Society 22.

the variation in payments. In contrast to the 56% variation in total EOC payments across the centers, less than 2% of the variation was observed in QALY gain at 2 years, reflecting a high degree of consistency in patient outcomes across high-volume U.S. deformity centers. In addition, 2-year improvements in ODI, SRS-22-pain, SRS-22-acitvity, SRS-22-appearance, SRS-22-satisfaction, and SRS-22-total scores were also consistent across the centers.

Variation in Medicare payments across hospitals has been observed in several medical and surgical specialties. Birkmeyer et al.[10] reported a difference in average Medicare payments of $16,668 for coronary artery bypass graft, $18,762 for back

Table 5. Mixed Model Analyses of Total Episode-of-Care Payments and Quality-Adjusted Life-Year Gain at 2 years

Random Effect	Fixed Effects	ICC—Total Episode-of-Care Payments (%)*	R^2	ICC—QALY Gain at 2 years (%)†	R^2
Center	— (unadjusted)	39.2	—	1.4	—
Center	Patient factors	37.1	0.04	1.0	0.05
Center	Patient factors and LOS	37.3	0.009	0.97	0.00
Center	Patient, LOS, and surgical factors	56.1	0.42	1.6	0.013
—	Patient, LOS, and surgical factors	—	0.28	—	0.007

ICC, intraclass correlation; QALY, quality-adjusted life-year; LOS, length of stay.
*ICC coefficient explaining the proportion of variation in total episode-of-care payments by center.
†ICC coefficient explaining the proportion of variation in QALY gain at 2 years by center.

surgery, $10,615 for hip fracture repair, and $12,988 for colectomy between the highest and lowest costing hospitals. Grenda et al.[11] determined that the average Medicare payments for bariatric surgery differed by 16.5% between the highest and lowest costing hospital. Cram et al.[12] observed that the median variation in payments for total knee replacement varied from $623 to $21,870. In our study, variation in index EOC payment across the centers was 61% and index hospitalization accounted for >80% of total EOC payment. Across all these studies, index procedure accounted for the largest variation in total EOC payment across hospitals. Patient characteristics, hospital characteristics, post—acute care service, and physicians' services were the other sources of variation. Because of the inherent limitations of IPPS, we could not capture payments attributed to physician's services or post—acute care services.

A common criticism of Medicare-based payments is their inability to account for volume of hospital activity, case mix, and procedural complexity. The IPPS system assumes that patients assigned to a DRG group undergo similar clinical evolution, thus incurring comparable treatment costs.[1] Yet, studies have shown that there is significant variation in payments within a given DRG. Ugiliweneza et al.[6] observed significant variation in average payments within each DRG 453—460, 471—473, and 490—491. Lowest variation for 30-day bundle payment was observed for DRG 491, with minimum of $566 to a maximum of $160,002 in payments. The highest variation in 30-day bundled payment was observed for DRG 456, with a minimum of $587 to a maximum of $222,514 in payments. Wright et al.[4] reported the lowest variation in mean payments of $26,230—$28,076 for DRG 460 and $71,976—$83,954 for DRG 456. In our study, we observed 51%—98% of variation in index payment across the centers based on the spine fusion DRG.

There are several limitations to the study. First, the cost data were obtained from the Medicare IPPS and did not include payments resulting from physician services and post—acute care services. Second, we could not assess the impact of hospital-centric factors such as location (urban vs. rural), teaching status, hospital volume of cases, or region on variation in payments. Although the Medicare payment system conveniently allows cost-effectiveness studies to be conducted comparing interventions in medical and surgical specialties, the payment system significantly undermines the cost incurred by the providers. Gum et al.[13] reported that hospitals lose on average $12,000—$20,000 for every adult spine deformity surgery performed on a patient receiving Medicare. Third, more than one third of the patients from 5 centers were excluded from the analysis to minimize selection bias. Including the centers with missing revision DRG code would indicate that the center's overall readmission rate and total cost of surgery are lower compared with other centers with complete data on revision surgery DRG codes. Consequently, that center would erroneously be considered a better performing center, despite having more revision surgeries. We believe that the variation across centers would have been more profound had we included data from all the centers that did not have missing revision surgery DRG codes. Fourth, data in our study were obtained from the ISSG deformity registry, indicating some clinical homogeneity. Although the homogeneity of the centers allows for more direct and less biased comparisons of costs, it also limits the external validity of results. Results from our study can be generalizable only to other sites performing high-volume complex deformity surgeries. Fifth, although we adjusted for several patient, surgical, and resource utilization factors, we did not account for deformity characteristics. Unlike cost of care, HR-QoL outcomes are associated with deformity characteristics, and not controlling for this measure may have introduced confounding.

CONCLUSIONS

Results from our study show that Medicare-based payments for spine fusion DRGs 453—460 are primarily driven by relative weight of the DRG and the hospital's base rate. The 60% variation in index payments and 39% variation in total EOC payments across the centers are minimally affected by patient factors, LOS, and surgical characteristics. Variation in hospital base rate reimbursement accounts for a large percentage of the observed variation in total EOC payments and should be considered when making health economic comparisons between centers.

CRediT AUTHORSHIP CONTRIBUTION STATEMENT

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