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Comparison of Value per Operative Time between Primary and Revision Surgery for Adult Spinal Deformity: A Propensity Score-Matched Analysis

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Study Design: Retrospective cohort study.

Purpose: To compare the relative value units (RVUs) per minute of operative time between primary and revision surgery for adult spinal deformity (ASD).

Overview of Literature: Surgery for ASD is technically demanding and has high risks of complications and revision rates. This common need for additional surgery can increase the overall cost of care for ASD. RVU is used to calculate reimbursement from Medicare and to determine physician payments nationally. In calculating RVUs, the physician's work, the expenses of the physician's practice, and professional liability insurance. Cost effectiveness of surgeries for ASD have been evaluated, except for RVUs per minute compared between primary and revision surgery.

Methods: Data were obtained from the American College of Surgeons National Surgical Quality Improvement Program database. Patients aged ≥18 years who underwent surgery for spinal deformity between 2011 and 2019 were identified and included. To ensure a homogenous patient cohort, those who underwent anterior-only and concurrent anterior-posterior fusions were excluded. Propensity score matching analysis was performed, and Mann-Whitney *U* test, Pearson chi-square test, or Fisher's exact test were used to compare matched cohorts as appropriate.

Results: A total of 326 patients who underwent revision surgery were matched with 206 primary surgery patients via propensity score matching. Demographic characteristics, comorbidities, preoperative laboratory values, and readmission and reoperation rates were not significantly different between groups. The revision surgery group had significantly higher mean RVUs per minute than that of the primary surgery group (0.331 vs. 0.249, $p<0.001$), as well as rates of morbidity and blood transfusion.

Conclusions: Compared to primary surgery, revision surgery for ASD is associated with significantly higher RVUs per minute and total RVUs and higher rates of 30-day morbidity and blood transfusions. Readmission and reoperation rates are similar between surgeries.

Keywords: Scoliosis; Thoracic vertebrae; Lumbar vertebrae; Patient readmission; Reoperation

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Introduction

Adult spinal deformity (ASD) is a common musculoskeletal pathology causing pain, physical limitations, and decreased quality of life [1]. Among patients over 60 years of age, the prevalence of spinal deformity has been as high as 68% [2]. Patients with ASD are often first managed with non-surgical treatment involving pain control, exercise, and physical therapy. However, the efficacy of this approach lacks evidence in the literature [3]. Thus, patients with ASD often require surgical intervention, which involves corrective spinal fusion surgery [4], and achieve better health-related quality of life outcomes compared to those who did not undergo surgery [4].

Surgery for ASD is technically demanding and has a high risk of complications and high revision rates; high complication rates are over 50% [5,6]. Medical and surgical complications commonly include infection, neurologic deficit, cardiopulmonary complications, pseudoarthrosis, proximal junctional kyphosis, and rod fracture [7,8]. Rates of revision surgery for ASD can be as high as 32% [2], commonly caused by pseudoarthrosis, implant failure, adjacent segment disease, and proximal junctional kyphosis/failure [9]. This frequent need for additional surgery can increase the overall cost of care for ASD, compounding the already high cost and morbidity of primary surgery for ASD.

In the United States, the annual expenditure for spine care is approximately $86 billion, majority of which accounts for surgery for ASD [10]. Medicare beneficiaries comprise approximately 10% of patients who underwent surgery for ASD [11]. Relative value unit (RVU) is used to calculate Medicare reimbursement and to determine physician payments nationally. RVUs consider the physician's work, the expenses of the physician's practice, and professional liability insurance [12]. However, in studies on arthroplasty, RVU compensation for revision procedures is lower than that for primary surgery despite the higher difficulty associated with revision surgeries [13,14]. While the cost-effectiveness of surgeries for ASD have been previously evaluated, none have compared RVUs between primary and revision surgeries for ASD. Therefore, this study was aimed to compare the RVUs per minute between primary and revision surgeries for ASD.

Materials and Methods

1. Study design and population

This retrospective cohort study used data obtained from the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) database, which has excellent validity, reliability, and a low rate of reporting error [15,16]. This study is exempt from Institutional Review Board review as this database is de-identified, and no direct patient involvement occurred.

Patients aged ≥18 years who underwent spinal deformity surgery were included based on Current Procedural Terminology (CPT) codes 22800 (arthrodesis, posterior, for spinal deformity, up to 6 levels), 22802 (7–12 levels), and 22804 (≥13 levels). Only data between 2011 and 2019 were used because 2011 was the first year that ACS-NSQIP began collecting certain 30-day outcomes data, including readmission and reoperation. Revision procedures were identified using the CPT codes for re-insertion of spinal fixation device (22830), exploration of spinal fusion (22849), removal of posterior non-segmental instrumentation (22850), and removal of posterior segmental instrumentation (22852) occurring in conjunction with codes for fusion (22800, 22802, and 22804). To ensure that a homogenous cohort of patients who underwent posterior-only fusions, those who underwent anterior-only and concurrent anterior-posterior fusions were excluded. To avoid biases in the results, those with missing demographic or surgical complication data were also excluded.

2. Outcomes and variables

The primary outcome was RVUs per minute, which was compared between the matched primary and revision surgery groups. Secondary outcomes included 30-day readmission, reoperation, and morbidity. Readmission includes any inpatient stay to the same or another hospital related to the surgical procedure. Reoperation includes all major surgical procedures requiring return to the operating room for intervention of any kind. Morbidity includes infectious, pulmonary, cardiac, renal, neurological, hematologic, and thromboembolic complications reported in the ACS-NSQIP dataset [17].

Rates of selected individual complications were also analyzed. Incidences of superficial wound infections, pulmonary embolism, need for ventilator use >48 hours, pro-

gressive renal insufficiency, urinary tract infection, stroke, myocardial infarction, deep venous thrombosis, sepsis, and blood transfusions were compared between the primary and revision groups.

3. Statistical analysis

Propensity score matching analysis was performed with a match tolerance of 0.01 according to demographic characteristics, comorbidities, and procedural factors such as osteotomy. Patients were paired using nearest neighbor approach and without replacement. After matching, the absolute standardized mean difference (ASMD) for each covariate was calculated to obtain sensitivity, with ASMD ≤0.1 representing balance in the covariate between groups [18]. Matched groups were compared via Mann-Whitney *U* test, Pearson chi-square test, or Fisher's exact test as appropriate. All statistical analyses were performed using IBM SPSS software ver. 22.0 (IBM Corp., Armonk, NY, USA). Statistical significance was set at $p \leq 0.05$.

Results

Prior to matching, a total of 3,447 patients were enrolled in this study, comprising the primary group (n=3,121) and the revision group (n=326). We excluded 855 patients

Table 1. Demographic and clinical characteristics before and after propensity score matching

Characteristic	Total cohort			Propensity matched cohort		
	Primary	Revision	*p*-value	Primary	Revision	*p*-value
No. of subjects	3,121	326		206	326	
Age (yr)	56.7±18.4	60.3±15.3	0.001*	60.6±14.4	60.3±15.3	0.818
Female sex	1,917 (61.4)	205 (62.9)	0.635	121 (58.7)	205 (62.9)	0.339
Non-white race	282 (10.3)	28 (11.3)	0.588	19 (9.2)	28 (11.3)	0.463
Hispanic ethnicity	120 (4.3)	8 (3.3)	0.511	6 (2.9)	8 (3.3)	0.824
Body mass index (kg/m^2)	28.3±6.5	29.6±6.6	<0.001*	29.5±6.3	29.6±6.6	0.835
Comorbidities						
Diabetes mellitus	449 (14.4)	44 (13.5)	0.739	28 (13.6)	44 (13.5)	0.975
Current smoker within 1 year	586 (18.8)	54 (16.6)	0.369	42 (20.4)	54 (16.6)	0.264
Dyspnea	141 (4.5)	20 (6.1)	0.212	14 (6.8)	20 (6.1)	0.761
Independent prior to surgery	2,901 (93.0)	289 (88.7)	0.008*	187 (90.85)	289 (88.7)	0.436
Severe COPD	123 (3.9)	9 (2.8)	0.362	12 (5.8)	9 (2.8)	0.077
Hypertension requiring medication	1,454 (46.6)	170 (52.1)	0.062	124 (60.2)	170 (52.1)	0.069
Dialysis	14 (0.4)	1 (0.3)	1.000	0	1 (0.3)	0.426
Disseminated cancer	74 (2.4)	3 (0.9)	0.113	18 (8.7)	3 (0.9)	0.764
Open wound/wound infection	29 (0.9)	7 (2.1)	0.076	3 (1.5)	7 (2.1)	0.568
Chronic steroid use	166 (5.3)	31 (9.5)	0.004*	18 (8.7)	31 (9.5)	0.764
Bleeding disorders	86 (2.8)	13 (4.0)	0.220	7 (3.4)	13 (4.0)	0.728
Sepsis or SIRS	50 (1.6)	3 (0.9)	0.478	6 (2.9)	3 (0.9)	0.083
ASA ≥3	1,718 (55.3)	234 (71.8)	<0.001*	139 (67.5)	234 (71.8)	0.291
Preoperative laboratory values						
Elevated creatinine	282 (10.0)	25 (8.2)	0.362	16 (7.8)	25 (8.2)	0.869
Elevated white blood cells	240 (8.2)	19 (6.2)	0.269	6 (2.9)	19 (6.2)	0.093
Decreased hematocrit	455 (15.5)	52 (16.8)	0.564	45 (21.8)	52 (16.8)	0.149
Decreased platelet count	160 (5.5)	24 (7.8)	0.093	17 (8.3)	24 (7.8)	0.850

Values are presented as number, mean±standard deviation, or number (%). Fisher's exact test performed for categorical variables; independent *t*-test performed for continuous variables.
COPD, chronic obstructive pulmonary disease. SIRS, systemic inflammatory response syndrome. ASA, American Society of Anesthesiologists.
*$p<0.05$ (statistically significant).

who underwent anterior fusion procedures or had missing clinical or demographic data. By propensity score matching, 326 patients who underwent revision surgery were matched with 206 patients who underwent primary surgery. Based on ASMD, all covariates were adequately balanced (ASMD <0.1). There was no significant difference on demographic characteristics, comorbidities, and preoperative laboratory values as well as the length of hospital stay between groups after matching; however, non-home discharge disposition was more common among revision surgery patients (58.6% versus 35.4%, p=0.031) (Table 1). In the revision group, 152 patients (46.6%) included osteotomy codes, and 61 cases (18.7%) used interbody devices. In the primary group, 55 patients (26.7%) had osteotomy codes, while 23 cases (15.1%) used interbody devices.

The mean total RVUs (97.9±42.2 versus 75.4±36.6, p<0.001) and mean RVUs per minute (0.331±0.214 versus 0.249±0.132, p<0.001) were significantly higher in the revision surgery group than in the primary surgery group. The 30-day outcomes such as readmission (11.7% versus 7.1%, p=0.069) and reoperation (4.9% versus 5.5%, p=0.737) were not significantly different between the primary and revision groups. However, morbidity (57.7% versus 42.7%, p<0.001) and incidence of blood transfusion (53.4% versus 39.8%, p=0.002) were significantly higher in the revision surgery group than in the primary surgery group. There were no differences between groups in the rates of other complications, including superficial wound infections, pneumonia, pulmonary embolism, prolonged ventilator requirement, renal insufficiency, urinary tract infection, stroke, myocardial infarction, deep venous thrombosis, and sepsis (Table 2).

Table 2. RVUs per minute and 30-day outcomes in propensity score matched groups

Variable	Primary	Revision	*p*-value
Total RVUs	75.4±36.6	97.9±42.2	<0.001*
Operative time (min)	334.3±141.9	345.3±158.4	0.419
RVUs (/min)	0.249±0.132	0.331±0.214	<0.001*
30-Day outcomes			
Readmission	24 (11.7)	23 (7.1)	0.069
Reoperation	10 (4.9)	18 (5.5)	0.737
Morbidity	88 (42.7)	188 (57.7)	<0.001*
Complications			
Superficial wound infection	3 (1.5)	7 (2.1)	0.568
Pneumonia	8 (3.9)	10 (3.1)	0.612
Pulmonary embolism	3 (1.5)	5 (1.5)	0.943
Ventilator >48 hr	8 (3.9)	10 (3.1)	0.612
Renal insufficiency	0	1 (0.3)	0.426
Urinary tract infection	4 (1.9)	14 (4.3)	0.144
Stroke	0	2 (0.6)	0.26
Myocardial infarction	2 (1.0)	2 (0.6)	0.642
Deep venous thrombosis	4 (1.9)	5 (1.5)	0.722
Sepsis	8 (3.9)	5 (1.5)	0.087
Blood transfusions	82 (39.8)	174 (53.4)	0.002*

Values are presented as mean±standard deviation or number (%). Fisher's exact test performed for categorical variables; independent *t*-test performed for continuous variables.
RVUs, relative value units.
*p<0.05 (statistically significant).

Discussion

This study was aimed to compare the RVUs per minute between primary and revision surgeries for ASD and to evaluate the differences in 30-day outcomes. Based on the study findings, compared to primary surgery, revision surgery for ASD is associated with a higher mean RVUs and RVUs per minute and higher rates of morbidity and blood transfusions; between groups, readmission and reoperation rates were not significantly different. To the best of our knowledge, this is the first study that evaluated the RVUs associated with surgery for ASD, as this was not adequately assessed by prior cost-effectiveness studies that focused on overall hospital costs and resource utilization rather than physician reimbursement rates [11,19].

In recent decades, reimbursement for medical care has undergone significant changes in response to the continually rising medical expenses [20]. As healthcare becomes increasingly more value-driven, reimbursement systems have transitioned toward productivity-based compensation by using RVUs to more objectively quantify performance [21]. This is in contrast to the traditional fee-for-service payment model, which has been criticized for escalating healthcare costs in the United States [22]. Higher RVUs are assigned to more complex procedures which require greater degrees of physician work. Satarasinghe et al. [23] recently reviewed the literature and reported that the integration of RVU payment model was viewed largely favorably by neurosurgeons despite the several areas for improvement.

For example, the assigned RVU does not appropriately capture the complexity of the patient and the procedure

[12]. As ASD is a complex and heterogeneous spinal disorder with varying types of deformity and etiology [24], surgery is associated with high frequencies of perioperative complications, which can worsen the outcome and reduce the overall cost-effectiveness [25]. ASD presents an increasingly significant burden on the US healthcare economy, with the incidence of surgery for ASD recently increasing by 112.5% within 7 years [26]. To better understand the economic implications of ASD, a thorough assessment of the reimbursement for ASD surgery is necessary.

Our data highlight the differences in RVUs between primary and revision surgeries for ASD. The matched cohort included 532 patients, of which 61% were women, consistent with the well-established female predominance in cases of spinal deformity [2]. The RVUs per minute was significantly greater for revision surgery than for primary surgery (0.331 versus 0.249, $p<0.001$). Revision surgery is associated with increased complexity, in which existing devices should be removed and the spine, scarred dura, and neural elements should be dissected, therefore typically prolonging operative time [27]. Moreover, in this study, osteotomies were more frequently performed in the revision group than in the primary surgery group (46.6% versus 26.7%). Previous studies have also reported appropriately greater compensation for more complex surgeries. Childers et al. [28] evaluated work RVU assignments in various surgical specialties and found operative time is positively corrected with RVUs.

However, the correlation between case complexity and RVU is better defined in general surgery subspecialties than in orthopedic surgery; 58% of orthopedic procedures were assigned lower-than-expected work RVUs [28]. Other studies have noted discrepancies between expected and actual RVUs when comparing primary and revision surgeries. Sugarman et al. [29] determined that although revision total elbow arthroplasty (TEA) is generally considered more complex than primary TEA, revision TEA was associated with lower RVUs per minute. Peterson et al. [13] found that primary total knee arthroplasty (TKA) had higher RVUs per minute despite revision TKA having additional complications and longer operative times. These findings suggest a need for adjustment to the assigned RVUs to more accurately represent the complexity level of each procedure, particularly in the field of orthopedic surgery.

The secondary outcomes of the present study included 30-day readmission, reoperation, morbidity, and individual complications. Rates of morbidity and blood transfusions were higher in the revision surgery group than in the primary surgery group, while the rates of readmission, reoperation, and other individual complications were not significantly different between groups. The readmission and reoperation rates were not worse for the revision group possibly because revisions were more likely focal procedures that may generate more CPT codes per segment due to the need for decompression, osteotomy, reinstrumentation, and fusion. While the findings of the present study are consistent with several previous studies, the outcomes of primary and revision spinal deformity surgery remain controversial. Qureshi et al. [30] determined that patients undergoing primary and revision surgeries for ASD had statistically similar 30-day readmission and complication rates. However, Malik et al. [31] evaluated 30-day outcomes in primary and revision posterior spinal fusion for pediatric spinal deformity and reported higher readmission and reoperation rates in patients who underwent revision surgery. Lapp et al. [9] found that major complications were slightly more frequent following primary surgery for ASD than after revision surgery. Evidently, despite the common clinical sense in assuming worse outcomes after revision surgery, findings reported in the previous studies remain highly variable. Thus, further investigations evaluating the differences in outcomes and complications following primary and revision ASD surgeries are warranted.

This study had some limitations. First, the ACS-NSQIP database consists mainly of academic medical centers, which therefore could result in generalizability bias. Nevertheless, the use of the ACS-NSQIP database allowed for an adequate sample size to increase the power of this study. Second, the ACS-NSQIP database does not allow for follow-up of individual patients throughout multiple surgeries, thereby making it impossible for us to assess the intervals between primary and revision surgeries and specify the reasons for revision surgery among this patient cohort. Third, the number of patients who underwent revision ASD surgery was disproportionately smaller than those who underwent primary surgery. While propensity score-matching analysis adequately balanced the observed baseline covariates between the groups, unmeasured characteristics and confounders would remain unbalanced. Fourth, radiographic parameters could not be evaluated and surgical indications for revision were not determined.

Therefore, it is possible that patients undergoing revision had more "focal procedures" as previously noted, which may explain why the rates of 30-day readmission and reoperation were not worse for revision surgery. Fifth, the operative times used to calculate RVUs per minute may vary depending on the presence of trainees and the frequency of ASD surgeries performed by the surgeon. Sixth, the retrospective design of the study further limits the level of evidence and the conclusions that can be drawn.

Despite these limitations, the present study provides valuable evidence highlighting the differences in RVUs per minute and outcomes between primary and revision ASD surgery.

Conclusions

Revision surgery for ASD is associated with a significantly higher RVUs per minute and total RVUs compared to primary surgery, as well as higher rates of 30-day morbidity and blood transfusions. Readmission and reoperation rates were not significantly different between patients who underwent primary and revision surgeries for ASD. This study provides useful evidence for evaluating the reimbursement of ASD surgery and directs future research to better understand its outcomes.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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