Effect of Resident and Fellow Involvement in Adult Spinal Deformity Surgery

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■ BACKGROUND: **Adult spinal deformity (ASD) operations are complex and often require a multisurgeon team. Simultaneously, it is the responsibility of academic spine surgeons to train future complex spine surgeons. Our objective was to assess the effect of resident and fellow involvement (RFI) on ASD surgery in 4 areas: 1) perioperative outcomes, 2) length of stay (LOS), 3) discharge status, and 4) complications.**

■ METHODS: **Adults undergoing thoracolumbar spinal deformity correction from 2008 to 2014 were identified in the National Surgical Quality Improvement Program database. Cases were divided into those with RFI and those with attendings only. Outcomes were operative time, transfusions, LOS, discharge status, and complications. Univariate and multivariable regression modeling was used. Covariates included preoperative comorbidities, specialty, and levels undergoing instrumentation.**

■ RESULTS: **A total of 1471 patients underwent ASD surgery with RFI in 784 operations (53%). After multivariable regression modeling, RFI was independently associated with longer operations (β = 66.01 minutes; 95% confidence interval [CI], 35.82–96.19; $P < 0.001$), increased odds of transfusion (odds ratio, 2.80; 95% CI, 1.81–4.32; $P < 0.001$), longer hospital stay (β = 1.76 days; 95% CI, 0.18–3.34; $P = 0.030$), and discharge to an inpatient rehabilitation or a skilled nursing facility (odds ratio, 2.02; 95% CI, 1.34–3.05; $P < 0.001$). However, RFI was not associated with any increase in major or minor complications.**

■ CONCLUSION: **RFI in ASD surgery was associated with increased operative time, the need for additional transfusions, longer LOS, and nonhome discharge. However, no increase in major, minor, or severe complications occurred. These data support the continued training of future deformity and complex spine surgeons without fear of worsening complications; however, areas of improvement exist.**

INTRODUCTION

Adult spinal deformity (ASD) surgery can lead to major improvements in quality of life,[1] pain,[2,3] and spinal alignment.[4] However, the risk of perioperative complications can be as great as 70%,[4,5] with 15%–20% of patients requiring revision surgery.[6] Myocardial infarction, sepsis, and pulmonary embolism are some of the major complications that contribute to an overall mortality rate of 0.03%–4.20%.[5,7,8] Furthermore, the presence of comorbidities must be carefully considered, both when deciding to operate and in formulating the operative plan.[9] Several studies have outlined the factors that might improve outcomes and decrease complications in ASD surgery.[4,10,11] One such factor is composition of the operating team.

An evolving area of ASD outcomes research has been the effect of 2-attending surgery. Although some studies have shown that 2-attending surgery is associated with decreased intraoperative complications, blood loss, and operative time,[12-14] others have

Key words
- Adult spinal deformity
- Complications
- Resident fellow training
- Spine outcomes

Abbreviations and Acronyms
AIS: Adolescent idiopathic scoliosis
ASD: Adult spinal deformity
CI: Confidence interval
CPT: Current Procedural Terminology
EBL: Estimated blood loss
LOS: Length of stay
NSQIP: National Surgical Quality Improvement Program
RFI: Resident and fellow involvement

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shown no differences in length of stay (LOS) and postoperative complications.[13] Based on a national survey conducted by Scheer et al.,[15] most deformity surgeons agreed that 2-attending surgeries could benefit patient care but were hindered by reimbursement concerns, access issues, and Medicare billing.[16] Moreover, a competing concern with 2-attending surgery is the responsibility to train future complex spine surgeons.

The effect of resident and fellow involvement (RFI) in ASD surgery has yet to be fully described. In a study of all neurosurgical procedures in >16,000 patients, trainee involvement was shown to have no independent effect on morbidity or mortality.[17] The single study assessing the effect of RFI in ASD surgery concluded that resident participation was associated with greater morbidity than attending-only ASD surgery.[18] Additional investigation in the effect of RFI is, thus, warranted.

Balancing the importance of patient safety and complication reduction with teaching responsibilities is an important topic. Using a large, national, administrative database, we sought to describe the effect of RFI on ASD surgery in 4 clinical areas: 1) perioperative outcomes, 2) LOS, 3) discharge status, and 4) complications.

METHODS

Patient Identification

The 2008–2014 American College of Surgeons National Surgical Quality Improvement Program (NSQIP) database was used to collect data from patients who had undergone ASD surgery. More than 600 hospitals participate in the NSQIP registry. Trained data collection specialists prospectively record information in accordance with rigorous definitions that are continually audited.[19] Approximately 150 clinical variables are collected from patients undergoing major surgery from the preoperative, operative, and postoperative periods within 30 days of the index operation, along with select longer term outcomes.[19] To define an exclusively ASD patient population, the following Current Procedural Terminology (CPT) codes were used:

- 22800 (posterior arthrodesis for spinal deformity of ≤6 segments)
- 22802 (posterior arthrodesis for spinal deformity of 7–12 segments)
- 22804 (posterior arthrodesis for spinal deformity of ≥13 segments)
- 22808 (anterior arthrodesis for spinal deformity of 2–3 segments)
- 22810 (anterior arthrodesis for spinal deformity of 4–7 segments)
- 22812 (anterior arthrodesis for spinal deformity of ≥8 segments)
- 22818 (kyphectomy, resection of vertebral segment, 1 or 2 segments)
- 22819 (kyphectomy, resection of vertebral segment, ≥3 segments)
- 22843 (posterior segmental instrumentation, 7–12 segments)
- 22844 (posterior segmental instrumentation, ≥13 segments)
- 22846 (anterior instrumentation, 4–7 segments)
- 22847 (anterior instrumentation, ≥8 segments)

Arthrodesis codes such as 22610 (posterior arthrodesis, single-level thoracic), 22612 (posterior arthrodesis, single-level lumbar), 22830 (exploration of spinal fusion), and 22633 (posterior arthrodesis, interbody technique, single lumbar interspace) were considered inherently within the use of the ASD instrumentation codes. Patients with CPT code 22842 (posterior segmental instrumentation, 3–6 segments) or 22845 (anterior instrumentation, 2–3 segments) were also included if they had had a diagnosis of spinal deformity according to an International Classifications of Diseases code of 737.1, 737.2, 737.3, 737.4, 737.8, or 737.9. Patients who had undergone nonelective surgery, those who had experienced trauma, and those who had undergone previous surgery within 30 days were excluded to narrow our patient population. These coding parameters were determined from previous studies of ASD using the NSQIP database.[18,20,21]

Data Collection

Exposure. The cases were dichotomized into those with RFI compared to those with attendings only. The NSQIP database dichotomizes whether an attending and resident were operating together versus the attending alone, in addition to the level (defined by postgraduate year) of the operating resident. Determining the distribution of junior residents versus senior residents versus fellow was attempted but eventually abandoned owing to the differences in specialty residency length and amount of spine surgery exposure. Furthermore, for the cases without a resident or fellow, we could not determine whether an attending was operating with a second attending level spine surgeon or alone.

Preoperative Data. The selected preoperative demographic and medical history variablesincluded sex, age, body mass index, hypertension requiring medication, diabetes requiring an oral agent or insulin for glucose control, chronic obstructive pulmonary disease, peripheral vascular disease, cardiac history (previous stent, cardiac surgery, or angina), dialysis for chronic kidney disease, previous cerebrovascular accident or transient ischemic attack, a history of cancer, an open wound, steroid use, and a bleeding disorder (a chronic condition that placed the patient at risk of excessive bleeding such as vitamin K deficiency, hemophilia, or continued anticoagulation therapy). Social history factors included cigarette use (in the previous 1 year), functional dependency (independent vs. partially or totally dependent), ventilator use (ventilator-assisted respiration in the 48 hours before surgery), and rapid weight loss (>10% unintentional weight loss in the previous 6 months).

Modifiers. In an attempt to control for case complexity, the invasiveness of ASD surgery was weighed as an important factor, and constructs were divided into small (≤6 levels), medium (7–11 levels), and large (≥12 levels) according to the CPT codes. Procedures such as anterior or posterior arthrodesis and kyphectomy

were distributed appropriately among the 3 levels of invasiveness. Specialty was also collected as a binary variable as orthopedics versus neurosurgery.

Outcomes. The outcomes used in the present study spanned the intraoperative and postoperative periods and consisted of 4 domains: 1) perioperative: operative time in minutes and number of transfusions given; 2) LOS: number of days in the hospital; 3) discharge status: binary variable of discharge to home versus inpatient rehabilitation or skilled nursing facility; and 4) complications: defined as major or minor in accordance with previous neurosurgical NSQIP studies,[18,21,22] in addition to more serious complications such as surgical site infection, pneumonia, deep vein thrombosis, pulmonary embolism, stroke, myocardial infarction, or sepsis.

Statistical Analysis

Descriptive statistics were compiled for all demographic, preoperative, and postoperative variables. Cases with large amounts of missing data for any of the variables were excluded using a list-wise deletion method. Univariate logistic and linear regression analyses were performed to test the association between the exposure of RFI and the 4 primary outcomes. Variables that resulted in an association of $P < 0.10$ were then incorporated into a multivariable regression model to identify independent predictors of each outcome. For each multivariable model, several confounding variables were controlled for, including surgical invasiveness, specialty, demographic data, medical history, and social variables. For the perioperative, LOS, and discharge status domains, we did not control for additional covariates. However, for the complications domain, operative time and transfusions were controlled for, in accordance with previous studies.[23,24] All statistical analyses were performed in STATA, version 14 (StataCorp LP, College Station, Texas, USA).

RESULTS

Demographic Data

A total of 1471 patients underwent ASD surgery with attendings only in 687 cases (47%) and had RFI in 784 cases (53%). Both groups were similar in sex, age, and body mass index. In terms of the size of the construct, smaller constructs were seen in 57% of attending-only cases versus 54% of the RFI cases. The RFI cases had a slightly greater proportion of medium-size constructs (25% vs. 17%), with the reverse trend seen in larger constructs (21% vs. 27%). With respect to specialty, 707 operations (48%) were performed by orthopedics and 754 (51%) by neurosurgery (51%). The remaining demographic, medical history, and social variables are summarized in Table 1. Owing to the nature of the administrative database, missing data were seen sparingly. Complete data were available for all demographic variables except for the following, which had missing data points: sex ($n = 4$), peripheral vascular disease ($n = 86$), functional status ($n = 6$), specialty ($n = 10$), and complete CPT codes ($n = 338$).

Table 1. Demographic Data From Cases with Attending Only Versus Resident or Fellow Involvement (Total $n = 1471$)

Variable	Attending Only ($n = 687$)	RFI ($n = 784$)
Male gender*	288 (42)	310 (40)
Age (years)	58.1 ± 14.8	58.2 ± 15.6
BMI (kg/m^2)	28.8 ± 6.7	27.8 ± 7.2
MH		
HTN	367 (53)	402 (51)
Diabetes	92 (13)	103 (13)
COPD	23 (3)	30 (4)
PVD*	6 (1)	4 (1)
Cardiac	55 (8)	57 (5)
Dialysis	5 (1)	3 (0)
TIA/CVA	33 (5)	38 (5)
Cancer	13 (2)	33 (4)
Open wound	11 (2)	17 (2)
Steroid	24 (3)	38 (5)
Bleeding disorder	8 (1)	23 (3)
Social		
Smoker	134 (20)	130 (17)
Independent*	633 (93)	698 (89)
Ventilator	2 (0)	7 (1)
Weight loss	5 (1)	14 (2)
Operative CPT code*		
Smaller construct (<6 levels)	284 (57)	342 (54)
Medium construct (7–11 levels)	83 (17)	156 (25)
Large construct (>12 levels)	135 (27)	133 (21)

Data presented as n (%) or mean ± standard deviation.
RFI, resident and fellow involvement; BMI, body mass index; MH, medical history; HTN, hypertension; COPD, chronic obstructive pulmonary disease; PVD, peripheral vascular disease; TIA, transient ischemic attack; CVA, cerebrovascular accident; CPT, Common Procedural Terminology.
*Data missing for some variables; see text for details.

Predictors of Outcomes

The 4 outcome domains are summarized in Table 2. Missing data were seen for the following outcome variables: operation time ($n = 2$), LOS ($n = 2$), and discharge status ($n = 593$). After multivariable regression modeling, 5 outcomes remained significant (Table 3). RFI was associated with longer operative times ($\beta = 66.01$ minutes; 95% confidence interval [CI], 35.82–96.19; $P < 0.001$), an increased odds of transfusion (odds ratio, 2.80, 95% CI, 1.81–4.32; $P < 0.001$), longer hospital stay ($\beta = 1.76$ days; 95% CI, 0.18–3.34; $P = 0.030$), and discharge to an inpatient rehabilitation or a skilled nursing facility (odds ratio, 2.02; 95% CI, 1.34–3.05; $P < 0.001$). However, RFI was not associated with any increase in major or minor complications nor the specific

Table 2. Outcomes of Cases with Attending Only Versus Resident or Fellow Involvement (Total $n = 1471$)

Variable	Attending Only ($n = 687$)	RFI ($n = 784$)
Perioperative		
Operative time (minutes)*	250.9 ± 154.9	337.6 ± 158.7
Transfusion	154 (22)	354 (45)
LOS (days)*	5.5 ± 6.2	8.1 ± 14.7
Discharge to IPR/SNF*	82 (21)	179 (37)
Complications		
Major	70 (10)	117 (15)
Minor	174 (25)	374 (48)
SSI	9 (1)	33 (4)
Pneumonia	12 (2)	19 (2)
DVT	11 (2)	16 (2)
PE	5 (1)	10 (1)
Stroke	4 (1)	4 (1)
MI	0 (0)	4 (1)
Sepsis	13 (2)	31 (4)

Data presented as mean ± standard deviation or *n* (%).
RFI, resident and fellow involvement; LOS, length of stay; IPR/SNF, inpatient rehabilitation or skilled nursing facility; SSI, surgical site infection; DVT, deep vein thrombosis; PE, pulmonary embolism; MI, myocardial infarction.
*Data missing for some variables; see text for details.

complications of infection, pneumonia, deep vein thrombosis, pulmonary embolism, stroke, myocardial infarction, or sepsis.

DISCUSSION

Optimal construction of the spine surgery team in order to maximize efficiency, patient safety, and education is a formidable task. In a preliminary, pilot study using a large, administrative database, RFI in ASD surgeries was associated with increased operative times, transfusions, LOS, and nonhome discharge. However, no increase was found in the incidence of major, minor, or severe complications. These data represent a preliminary investigation into an important topic and support the continued training of future complex spine surgeons without fear of worsening complications. However, areas of improvement exist.

Studies that assess the effect of RFI in ASD surgery are sparse because most of the available data compares outcomes between 2- versus 1-attending surgery. Ames et al.[12] evaluated 78 patients who underwent pedicle subtraction osteotomies with either 2 or 1 attending surgeon. Patients who had surgery by 2 attendings had a decreased operative time (5.0 vs. 7.6 hours), lower estimated blood loss (EBL; 2.0 vs. 5.3 L), and decreased complication rates (25% vs. 45%) compared with those who had undergone surgery with 1 attending. Furthermore, Gomez et al.[13] compared 2- versus 1-attending ASD surgical procedures and found that 2-attending surgical procedures were associated with fewer intraoperative complications, including neuromonitoring changes, screw misplacements, and excessive blood loss. Gomez et al.[13] reported a greater postoperative complication rate in the 2-attending group; however, they attributed this to a greater mean age and increased complexity compared with the single attending group.

Outside an ASD population, the effect of 2- versus 1-attending surgery in the adolescent idiopathic scoliosis (AIS) population has been studied. Halanski et al.[25] reported no differences in EBL or operative time between the 2 groups, but 2-attending surgeries were associated with less of a decrease in hemoglobin (2.8 vs. 3.8 g/L), lower transfusion rates (4% vs. 29%) and a greater Cobb angle improvement (46° vs. 35°). Similarly, using a prospective propensity score-matched cohort in an AIS population, Kwan and Chan[14] showed decreased operative time, EBL, transfusion rates, and LOS in the 2-attending surgeon group. Despite the vastly different nature of ASD and AIS surgery, these results add helpful background information.

Perhaps the most similar study to the present analysis, Kothari et al.[18] used the same database 2 years earlier and found that resident involvement was associated with increased overall morbidity, wound complications, transfusions, and LOS for patients undergoing fusion for ASD but not for other complications, including mortality. Although the investigators controlled for length of construct as a surrogate for complexity, the disparate results between the current study and their results might be related to not controlling for specialty, as the resident experience differs vastly between orthopedics and neurosurgery, in addition to the extra 2 years of data to 2014. Similarly, Auerbach et al.[26] used a single-surgeon series to investigate the perioperative outcomes related to having residents and fellows as opposed to junior or senior attending physicians as first assistants for both AIS and ASD surgery. The investigators found no significant differences in operative times, curve corrections, transfusion rates, LOS, or early complication rates.[26] Various studies have also found no difference in surgeries with residents or fellows,[27] and 1 study of orthopedic procedures found that resident participation was associated with decreased overall complication rates and mortality.

To assess the attitudes and opinions of surgeons regarding 2-attending surgery, Scheer et al.[15] surveyed the Scoliosis Research Society membership — 199 surgeons across 27 countries. All respondents believed that having 2 attendings participating improved the outcomes and decreased complication risk. However, 52% of the respondents expressed that 2-attending operations could negatively affect resident and fellow training. Furthermore, a significant number of respondents expressed logistical difficulty in having a second surgeon, including reimbursement and access (33%) and surgeon availability (52%). In contrast to the Medicare reimbursements for physicians for elective spine procedures as estimated by patients, the actual reimbursements for spine surgeries were found to be much lower than expectations and have continued to decline annually.[28] Although 2-attending surgeon operations might improve patient outcomes, the financial and scheduling issues must be addressed.

Given the increased transparency seen in all of medicine and an increasing ASD prevalence projected to be >60 million by 2050,[29]

Table 3. Regression Analysis Results of Cases with Attending Only Versus Resident and Fellow Involvement

	Univariate Analysis		Multivariable Analysis	
Outcome	**OR (95% CI)**	***P* Value**	**OR (95% CI)**	***P* Value**
Perioperative				
Operative time (min)	86.7 (70.63—102.83)	<0.001	66.01 (35.82—96.19)	<0.001*
Transfusions	2.84 (2.27—3.58)	<0.001	2.80 (1.81—4.32)	<0.001*
LOS (days)	2.55 (1.37—3.73)	<0.001	1.76 (0.18—3.34)	0.030*
Discharge to home vs. IPR/SNF	2.22 (1.63—3.01)	<0.001	2.02 (1.34—3.05)	0.001*
Complications				
Major	1.56 (1.13—2.13)	0.006	0.960 (0.65—1.42)	0.840
Minor	2.69 (2.15—3.36)	<0.001	0.634 (0.27—1.47)	0.288
SSI	3.31 (1.57—6.97)	0.002	1.69 (0.72—3.94)	0.225
Pneumonia	1.40 (0.67—2.90)	0.369	0.42 (0.17—1.07)	0.069
DVT	1.28 (0.59—2.78)	0.532	0.62 (0.25—1.52)	0.296
PE	1.76 (0.60—5.18)	0.303	0.67 (0.17—2.65)	0.559
Stroke	0.88 (0.22—3.51)	0.851	0.34 (0.05—2.28)	0.268
MI	1 (omitted)	NA	1 (omitted)	NA
Sepsis	2.13 (1.11—4.11)	0.023	1.49 (0.69—3.20)	0.312

OR, odds ratio; CI, confidence interval; LOS, length of stay; IPR/SNF, inpatient rehabilitation or skilled nursing facility; SSI, surgical site infection; DVT, deep vein thrombosis; PE, pulmonary embolism; MI, myocardial infarction.
*Statistically significant after multivariable regression analysis.

the training of future complex spine surgeons is critical. Our study found that RFI did not increase complication rates but was associated with longer operative times, increased odds for transfusions, and nonhome discharge. We also suspect these findings are representative of the increased complexity at training centers. Although we attempted to control for case complexity by construct size, undoubtedly we were unable to fully control for this essential confounding variable.

Although concrete conclusions should not be drawn from the present administrative database study, we believe several important lessons for future studies can be realized. First, the topic of 2- versus 1-attending surgery should be enfolded with RFI as a variable. Both issues are inherently related. Thus, in future studies, exposure groups could be divided into: 1) 2 attendings, 2) 1 attending and 1 fellow or senior resident, 3) 1 attending and 1 nontrainee first assistant, and 4) 1 attending alone. In future studies, comprehensive data demonstrating the different surgical teams and how they each correspond to important outcomes such as deformity correction, blood loss, LOS, and complications would be useful. Second, randomization would be helpful to control for unmeasured confounders, such as the effect of a private hospital versus an academic institution and comorbidity management. Third, physician-managed databases are needed to further investigate this topic, rather than administrative databases. Complications should be specific, especially those related to surgical technique, including screw malposition, direct neural injury, and postoperative deficits. Moreover, which part of each case is performed by the attending alone, the trainee alone, or both together, should be reported. These case components could include exposure, cervical/lumbar/thoracic screw placement, iliac fixation, decompression, interbody work, rod bending, and closure, among others, according to the case details. This level of detail could lead to major strides in assessing the most complex and time-consuming parts of a case. Fourth, the type of ASD operation should also be weighed. Having 2 experts working on a 13-level all-posterior operation requiring a 3-column osteotomy is vastly different than having 1 surgeon working at a time on a staged, anterior/lateral or minimally invasive deformity intervention.

The present study was limited in several capacities. The analysis of the present prospectively collected data set was performed retrospectively, which presents an intrinsic risk of selection bias. Additionally, we used a large, administrative, non—spine-focused database lacking specific spine surgery variables. Pertinent details regarding specific comorbidities, such as cancer status and treatment course, were not available in the NSQIP database. Moreover, data were missing for several demographic and outcome variables. Finally, given the rarity of some postoperative complications, the large number of covariates could have limited the discriminate capacity of the multivariable logistic regression model. Overall, we have acknowledged these limitations, because the present study was viewed as an early pilot study that could lead to more spine-focused study of RFI in complex spine surgery.

CONCLUSION

Using a large, administrative database as a preliminary analysis to investigate RFI in ASD surgeries, RFI was associated with increased operative times, transfusions, LOS, and nonhome discharge; however, no increase in major, minor, or severe complications was seen. The results of the present early, pilot analysis support the continued training of future deformity and complex spine surgeons without fear of worsening the incidence of complications, yet areas in need of improvement exist.

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