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# Complications After Adult Spinal Deformity Surgeries: All Are Not Created Equal

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## ABSTRACT

**Background:** Data on timing of complications are important for accurate quality assessments. We sought to better define pre- and postdischarge complications occurring within 90 days of adult spinal deformity (ASD) surgery and quantify the effect of multiple complications on recovery.

**Methods:** We performed a review of 1040 patients who underwent ASD surgery (age:  $46 \pm 23$ ; body mass index:  $25 \pm 7$ , American Society of Anesthesiologists [ASA] score:  $2.5 \pm 0.6$ , levels:  $10 \pm 4$ , revision: 9%, 3-column osteotomy: 13%). We assessed pre- and postdischarge complications and risk factors for isolated versus multiple complications, as well as the impact of multiple complications.

**Results:** The 90-day complication rate was 17.7%. 85 patients (8.2%) developed a pre-discharge complication, most commonly ileus (12%), and pulmonary embolism (PE; 7.1%). The most common causes of pre-discharge unplanned reoperation were neurologic injury (12.9%) and surgical site drainage (8.2%). Predictors of a pre-discharge complication included smoking (odds ratio [OR]: 2.2,  $P = .02$ ), higher ASA (OR: 1.8,  $P = .008$ ), hypertension (HTN; OR: 2.0,  $P = .004$ ), and iliac fixation (OR: 4.3,  $P < .001$ ). Ninety-nine patients (9.5%) developed a postdischarge complication, most commonly infection (34%), instrumentation failure (13.4%), and proximal junctional failure (10.4%). Predictors of postdischarge complications included chronic obstructive pulmonary disease (OR: 3.6,  $P < .0001$ ), congestive heart failure (OR: 4.4,  $P = .016$ ), HTN (OR: 2.3,  $P < .0001$ ), and multiple rod construct (OR: 1.8,  $P = .02$ ). Patients who developed multiple complications (9.3%) had a longer length of stay, and increased risk for readmission and unplanned reoperation.

**Conclusions:** Knowledge regarding timing of postoperative complications in relation to discharge may better inform quality improvement measures. PE and implant-related complications play a prominent role in perioperative complications and need for readmission, with several modifiable risk factors identified.

**Level of Evidence:** Level 3.

**Clinical Relevance:** Advances in surgical techniques and instrumentation have improved postoperative radiographic and clinical outcomes after ASD surgery. The rate of complications after complex ASD surgery remains high, both at early postoperative and long term follow-up. This study reviews complications within 90 days of surgery, with an assessment of patient and surgical risk factors. We found that modifiable risk factors for early complications after ASD surgery include COPD, and current smoking. The data presented in this study also provide surgeons with knowledge of the most common complications encountered after ASD surgery, to aid in preoperative patient discussion.

Complications

Keywords: complications, adult spinal deformity, quality improvement

## INTRODUCTION

Adult spinal deformity (ASD) surgeries are inherently complex procedures, and often entail multiple osteotomies, combined anterior/posterior approaches, and long fusions, all of which can confer substantially increased risk for complications and reoperation after index surgery. There is now a vast body of literature investigating and describing complications after ASD surgery with most reports identifying a perioperative complication rate of

approximately 13%–41%.<sup>1,2</sup> In one of the larger studies to date, the rate of medical complications within 6 weeks of ASD surgery was found to be 26.8%.<sup>3</sup> Within 30 days of ASD surgery, the rate of unplanned return to the operating room is reportedly 2.8%, and 24% at 2-year follow-up.<sup>4–6</sup> Previous studies have identified advanced age, smoking, and osteoporosis as important contributors to risk for perioperative complications.<sup>7,8</sup> Surgical factors including fusion of greater than 13 levels, longer operative times, and blood loss are also associated

with an increased risk for complications and unplanned reoperation and readmission.<sup>9–11</sup>

Readmission after surgical procedures is common and can affect between 3% and 25% of patients postoperatively.<sup>12,13</sup> Patients considering surgical interventions are concerned with functional and cognitive outcomes after surgery. Readmission to the hospital and unplanned reoperations represent major events for patients and have considerable impacts on all healthcare stakeholders, particularly when the reoperations occur within 90 days of the initial surgery.<sup>14</sup> Complications have a demonstrated association with increased burden on the healthcare system, resulting in increased resource utilization, longer hospital stay, and higher costs.<sup>15</sup> For this reason, complication rate has been used as a criterion for evaluating surgical department practice and even overall hospital care.<sup>16</sup> A major medical complication can sometimes entail prolonged immobilization, or inability to participate in physical therapy, leading to subsequent complications such as delayed wound healing or wound dehiscence from prolonged bed rest. Although even an isolated complication can deter the overall postoperative recovery, we hypothesize that the effect of some complications is greater than others, and that the effect of concomitant complications is substantially greater. To date, there are few studies that have examined the effect of multiple complications on patient recovery from a large single-institution database. In this regard, we sought to define the most frequent pre- and postdischarge complications occurring within 90 days of ASD surgery using a large single-center database, and define the effects of these complications on readmission, need for unplanned reoperation, and prolonged length of stay.

## MATERIALS AND METHODS

We retrospectively reviewed our institution's prospectively collected database to identify patients who were aged 18 years or older when they underwent posterior spinal fusion for ASD, with a minimum of 4 levels fused, from January 2012 through December 2017. We identified 1040 such patients with complete surgical and inpatient admission data.

### Patient and Surgical Characteristics

The primary indications for surgery were scoliosis or kyphosis with pain and disability for which

prolonged nonoperative treatment had failed. Of the 1040 patients, 90 were patients who had undergone previous spinal surgery (8.8%). We used the clinical database and patients' medical records to ascertain patient characteristics including age, sex, and American Society of Anesthesiologists (ASA) score. Based on a validated 5-item frailty index, a modified frailty index (mFI) was calculated for each patient, with 5 categories of frailty ranging from 1 (lowest) to 5 (highest).

Surgical parameters collected included number of levels fused, the use of pelvic fixation, interbody fusion, and multi-rod construct. Each case was assigned a Mirza invasiveness index, based on published criteria, for the purposes of assessing surgical complexity between the 2 groups.

### Complications and Unplanned Reoperations

Our primary outcome of interest was complications incurred within 90 days of the index surgery. All major and minor complications, as outlined by Glassman et al,<sup>1</sup> were included in this analysis. Complications related to technical details of surgery were categorized retrospectively by one attending spine surgeon, the senior author on the study, through review of operative reports and relevant imaging. Subanalysis was conducted to compare predictors of isolated versus multiple complications, as well as the types of complications that imparted the greatest risk for readmission and unplanned return to the operating room. All clinical information was abstracted from our electronic medical records.

### Statistical Analysis

Univariable regression analyses were used to determine the unadjusted effect of preoperative patient risk factors and operative variables on our primary and secondary outcomes. Covariates associated with a defined outcome, here denoted by a *P* value of less than .20, were included in multivariable logistic regression models. Akaike information criteria, likelihood ratios, and Hosmer-Lemeshow goodness-of-fit tests were used at the addition of each potential covariate to select the most parsimonious model for each outcome.

Complications were separated into isolated (ie, a single complication) and combined complications, depending on whether the individual complication was experienced in isolation or in addition to another complication during the postoperative

**Table 1.** Baseline characteristics for 1040 adults separated by number of complications.

Preoperative Characteristic	Multiple Complications (n = 97)	No Complication (n = 815)	P Value (Multiple Versus No Complications)	Isolated Complication (n = 128)	P Value (Multiple Versus Isolated Complications)
Age, y <sup>a</sup>	60 ± 15 <sup>a</sup>	43 ± 24	<.0001	56 ± 20	.39
BMI <sup>a</sup>	27 ± 7	25 ± 6	.019	28 ± 8	.98
ASA score <sup>a</sup>	2.5 ± 0.5	2.4 ± 0.7	.83	2.5 ± 0.5	.96
mFI <sup>a</sup>	0.67 ± 0.72	0.37 ± 0.65	<.0001	0.71 ± 0.87	.95
Diabetes mellitus <sup>b</sup>	9 (9.3)	63 (7.7)	.59	17 (13.3)	.35
COPD <sup>b</sup>	10 (10.3)	27 (3.3)	.001	14 (10.9)	.88
Hypertension <sup>b</sup>	45 (46)	197 (24)	<.0001	55 (43)	.61
Smoker <sup>b</sup>	13 (13)	52 (6.4)	.011	14 (11)	.57
Revision surgery <sup>b</sup>	13 (13)	61 (7.5)	.044	18 (14)	.89

Abbreviations: ASA, American Society of Anesthesiologists; BMI, body mass index; COPD, chronic obstructive pulmonary disorder; mFI, modified frailty index.

<sup>a</sup>Expressed as mean ± SD.

<sup>b</sup>Expressed as n (%).

hospitalization. Complication combinations with a sample size of fewer than 5 patients were excluded from analysis in the regression model.

Groups were compared with the *t* test statistic or Mann-Whitney nonparametric statistic for continuous parameters. Chi-square tests were used for categorical data when all the expected counts had 5 or more observations, and Fisher exact tests were used for categorical data when any of the expected counts had fewer than 5 observations.

Descriptive statistics were calculated with SPSS version 25 software (IBM, Armonk, New York), R statistical software, and Microsoft Office Excel software (Microsoft Corp, Redmond, Washington).

## RESULTS

### Patient Population

Included in the study were 1040 adults (703 women, 67.8%) who underwent surgery for ASD. Among this group, 1 complication occurred in 242 patients (23.3%), and multiple complications occurred in 97 patients (9.3%): 63 patients (6.1%) with 2 complications, 15 patients (1.4%) with 3 complications, and 19 patients (1.8%) with more than 3 complications.

### Pre- and Postdischarge Complications

Eighty-five patients (8.2%) developed a pre-discharge complication, of which 20% (n = 17) required reoperation. The most common pre-discharge medical complications were ileus (12%, n = 10) and pulmonary embolism (7.1%, n = 6). For the 85 patients who sustained a pre-discharge complication, the most common causes of pre-discharge unplanned return to the operating room were neurologic injury (12.9%, n = 11), surgical site

drainage (8.2%, n = 7), and proximal junctional failure (4.7%, n = 4). Ninety-nine patients (9.4%) developed a postdischarge complication, of which 73 (7%) required readmission for unplanned reoperation (92%, n = 67) or management (8.2%, n = 6). Of the 99 patients, the most common postdischarge medical complications were pneumonia (5.0%, n = 5), pulmonary embolism (4.0%, n = 4), and deep vein thrombosis (DVT; 3.0%, n = 3). For the 67 patients who required unplanned return to the operating room postdischarge, the most common causes were infection (34%, n = 23), neurologic injury (23.9%, n = 16), instrumentation failure including malpositioned pedicle screw or interbody cage migration (13.4%, n = 9), and proximal junctional failure (10.4%, n = 7).

### Isolated Versus Multiple Complications

ASD patients who experienced multiple complications (n = 97, 9.3%) postoperatively revealed substantial differences in preoperative characteristics compared with those who recovered without complications (n = 815, 78.3%) or those with an isolated complication (n = 128, 12.3%) (Table 1). Patients who suffered multiple complications were more commonly older, had a higher body mass index, and a higher modified frailty score. They more commonly had undergone a revision surgery, and more commonly had comorbidities including chronic obstructive pulmonary disease (COPD) and cardiovascular disease, and were smokers. ASD patients who experienced multiple complications postoperatively also revealed substantial differences in intraoperative details, compared with those who recovered without complications or with an isolated complication (Table 2). Surgeries that were associated with multiple postoperative complications had

**Table 2.** Surgical characteristics for 1040 adults separated by number of complications.

Characteristic	Multiple Complication (n = 97)	No Complication (n = 815)	P Value (Multiple Versus No Complications)	Isolated Complication (n = 128)	P Value (Multiple Versus Isolated Complications)
Preoperative Levels <sup>a</sup>	12 ± 5	10 ± 4	<.0001	11 ± 4	.42
Pelvic fixation <sup>b</sup>	59 (61)	236 (29)	<.001	65 (51)	.23
PSO <sup>b</sup>	26 (27)	82 (10)	<.001	30 (23)	.56
Interbody <sup>b</sup>	50 (52)	230 (28)	<.0001	57 (45)	.28
Multiple-rod configuration <sup>b</sup>	20 (21)	108 (13)	.048	29 (23)	.74
Operative time <sup>a</sup>	467 ± 211	389 ± 210	.001	443 ± 147	.95
Estimated blood loss <sup>a</sup>	2358 ± 2015	1470 ± 1338	<.0001	2147 ± 1800	.88
Intraoperative RBCs transfused (U) <sup>a</sup>	2.5 ± 2.4	0.96 ± 1.8	<.0001	1.9 ± 2.2	.06

Abbreviations: PSO, pedicle subtraction osteotomy; RBC, red blood cell.

<sup>a</sup>Expressed as mean ± SD.

<sup>b</sup>Expressed as n (%).

a greater number of levels fused, and 3-column osteotomy (3CO), interbody, and pelvic fixation procedures performed, and use of a multiple-rod construct. Surgeries that were associated with multiple postoperative complications demonstrated a longer operative time, higher estimated blood loss, and greater number of intraoperative packed red blood cells (pRBCs) transfused.

Multiple patient characteristics including current smoking status, COPD, hypertension, history of DVT, and a higher mFI score were independently associated with increased risk for sustaining multiple complications (Table 3). Surgical characteristics including undergoing 3CO, pelvic fixation, or interbody fusion; having an increased volume of pRBCs transfused intraoperatively; and undergoing a multiple-rod construct were independently associated with increased risk for sustaining multiple complications (Table 4).

### Impact on Readmission and Unplanned Return to the Operating Room

Seventy-three patients (7.0%) required readmission to the hospital for unplanned return to the operating room or management of medical and surgical complications. Of the patients who developed multiple complications, 44/97 (45%) required readmission to the hospital for further investigation

**Table 3.** Patient characteristics associated with development of multiple complications after adult spinal deformity surgery.

Parameter	Odds Ratio (95% CI)	P Value
Current Smoker	2.1 (1.05–3.8)	.03
COPD	2.5 (1.2–5.0)	.01
Hypertension	2.4 (1.5–3.6)	<.0001
mFI	1.5 (1.2–2.0)	.001

Abbreviations: CI, confidence interval; COPD, chronic obstructive pulmonary disorder; mFI, modified frailty index.

and observation, and 54/97 (56%) required unplanned reoperation. Of patients who developed only 1 complication, 26/128 (20%) required readmission to the hospital, and 27/128 (21%) required unplanned reoperation.

By regression analysis, there were no medical complications that were independently associated with increased risk for readmission within 90 days. Physical exam documentation during the index inpatient stay of a new postoperative motor or sensory deficit was independently associated with increased risk for readmission to the hospital within 90 days of surgery (odds ratio [OR]: 15.4, 95% confidence interval: 6.4–37.4).

### Impact on Length of Stay

The mean ± SD length of stay at index hospitalization in patients who did not incur any complication was 5.9 ± 3.0 days, while the length of stay for patients who incurred a single complication was 8.9 ± 7.5 days, and that for patients with multiple complications was 9.6 ± 6.8 days. The difference in length of stay between patients with no complications versus those with an isolated or multiple complications was significantly different ( $P < .0001$ ).

## DISCUSSION

In the present study, we found that 9.3% of ASD patients experienced multiple major postoperative

**Table 4.** Surgical characteristics associated with development of multiple complications after adult spinal deformity surgery.

Parameter	Odds Ratio (95% CI)	P Value
Pelvic fixation	2.3 (1.6–3.3)	<.0001
3CO	2.7 (1.6–4.4)	<.0001
Interbody fusion	2.5 (1.7–3.9)	<.0001
Intraoperative pRBC transfusion	3.7 (2.4–5.9)	<.0001

Abbreviations: 3CO, 3-column osteotomy; pRBC, packed red blood cells.

complications, with an associated risk for readmission to the hospital of 45%, and a risk for unplanned return to the operating room of 56%. Patients who developed multiple complications experienced a significantly longer length of hospital stay and had a higher rate for readmission and reoperation compared with those who did not develop any complications. Predictors of sustaining multiple complications included current smoking, COPD, hypertension, history of DVT, higher mFI, and undergoing surgeries with increased complexity.

Postoperative complications and hospital readmissions within a short period after the initial surgery contribute significantly to overall healthcare costs and resource utilization.<sup>17</sup> Complex ASD surgery is of particular interest in this regard, because it has relatively high readmission and reoperation rates compared with other surgeries. A study of 718 ASD patients with greater than 2-year follow-up demonstrated a 17.9% reoperation and 17.7% readmission rate.<sup>18</sup> Similar analyses among ASD surgical populations have demonstrated an inverse relationship between number of complications incurred after the operation and patient quality of life.<sup>19–21</sup> Despite some discrepancies between complications defined by investigators in those studies, as well as differences in methodology and patient sample among studies, the principle remains the same. Major postoperative complications are associated with increased length of stay, increased need for subsequent procedures, and worse health-related quality of life scores.<sup>22</sup>

We found that risk factors for the development of multiple complications included patient characteristics such as current smoking status, COPD, hypertension, history of DVT, and a higher mFI score. The strong association between these factors and development of a complication after ASD surgery is consistent with the findings of previous studies.<sup>23–25</sup> A few studies have reported that diabetes and smoking are risk factors for infection and cardiopulmonary and other medical complications after ASD surgery.<sup>3,26</sup> Interestingly, our findings that smoking is an independent risk factor for development of multiple complications after ASD surgery are different than those of De la Garza Ramos et al,<sup>27</sup> who found that smoking was not associated with a higher 30-day complication rate in a study utilizing the American College of Surgeons National Surgical Quality Improvement Program database. The difference in findings may be ex-

plained by the longer perioperative follow-up in our study of 90 days, as well as the equivalent complexity of surgery that smokers and nonsmokers in the present study underwent, with no significant difference in number of levels fused (10 in both groups) or Mirza invasiveness index (20 in the nonsmoking group, 21 in the smoking group).

COPD is a described risk factor for increased 30-day readmission after 1- or 2-level lumbar fusion.<sup>28</sup> Karikari et al<sup>29</sup> reported that patients with COPD had increased length of stay and higher rates of postoperative pneumonia after spine fusion surgery greater than 3 levels. Similarly, we found that COPD increased the risk of incurring multiple complications postoperatively in this large cohort. While the need to maintain adequate oxygen levels may require prolonged postoperative mechanical ventilation, we did not find any difference in this study in rates of prolonged ventilation postoperatively, or rate of unplanned reintubation, between patients who had COPD or those that did not.

Undergoing 3CO and receiving a higher volume of intraoperative pRBCs intraoperatively are known risk factors for complications after ASD surgery.<sup>26,30</sup> We further found that undergoing pelvic fixation and interbody fusion conferred increased risk for undergoing multiple complications. Fusion to the pelvis and osteotomies routinely appear in studies on this topic, as predictors of complications and higher risk for infection.<sup>31–33</sup> These are likely surrogates for increased complexity of a given case, and more research is needed to understand what proportion of risk is conferred by each of these components of the surgical plan.

We evaluated prolonged length of hospital stay as an outcome to better elucidate the incremental cost of care associated with multiple postoperative complications, because the literature supports a correlation between health care spending and hospital length of stay.<sup>34,35</sup> Previous investigations have found that an increased number of intraoperative complications was associated with extended length of stay.<sup>34</sup> Similar to these observations, postoperative hospital length of stay increased from 5.9 days for those with no complications to 8.9 days with an isolated complication and 9.6 days for those with 2 or more complications in our study. While most surgeons will agree that patient care be the first priority in determining the length of stay in the hospital, the financial impact of an extended length

of hospital stay must be understood in the current healthcare climate.<sup>35</sup>

The strengths of this study are the relatively homogenous population of ASD patients with long fusion constructs and equivalent case complexity. The retrospective nature of our study could be perceived as a weakness; however, most data were collected prospectively. All patients were from a single institution and treated by surgeons who treat a large volume of adults with spinal deformity, which may limit the generalizability of our results. However, the exclusivity also conferred uniformity, and one might expect these types of surgical procedures to be performed at a tertiary care center by surgeons with similar experience.

This single-institution analysis is one of the first studies to demonstrate the impact of multiple major complications on readmission and revision after ASD surgery. Knowledge of preoperative and intraoperative risk factors for multiple complications will enable providers to better identify those at risk and individualize treatment strategies that afford patients the best chance of uncomplicated recovery. This will also improve prognostication and provide realistic expectations for families regarding expected length of stay and risk of requiring revision surgeries. This may ultimately also help reduce institutional variation in ASD complication rates and improve outcomes.

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