

effectiveness for decreasing pain improving function and balance in afflicted patients.^{2–5} However, such procedures can be technically challenging, with frequent occurrence of adverse events: substantial peri- and postoperative complications arising from ASD surgery are common, with estimated ranges from 40 to 86%.^{6–8} Surgical management and technical advances have mitigated this figure, yet increasing reports of readmissions and reoperations persist.^{9,10}

Readmission indications point to the evolving nature of ASD treatment. The aging U.S. population, coupled with more refined techniques, translate into a more frail and at-risk population receiving treatment for debilitating ASD.⁶ Broadened surgical indications for ASD management are also important, centering on the restoration of global alignment to improve functional outcomes, which engender increasingly complex surgeries, such as pedicle subtraction osteotomies (PSO).^{11,12}

The increases in spine surgery also pertain to cost-effectiveness analyses. The frequency of readmissions and subsequent procedures place increased burden on patients and hospitals.^{13,14} In 2014, Lucas and Pawlik¹⁵ presented an overall 21.0% 30-day readmission rate for medical conditions, compared with 15.6% for surgical. These rates persist in the context of an estimated \$15 billion spent on rehospitalizations within 30 days in 2007.^{16,17} McCarthy *et al.*¹⁸ reported a 27% readmission rate for ASD surgical patients, with average primary surgical cost of \$103,143, and that for readmission of \$67,262 per patient. Furthermore, incidence of readmission increased ASD surgical cost by 170%. With ASD surgical frequency increases, it is critical to understand factors attributing to ASD readmissions to direct efforts at reducing costs and optimizing outcomes.^{19,20}

Previous studies have examined causes for readmissions in patients undergoing spine surgery, but have not analyzed predictors on the basis of subsequent treatment (medical or surgical) following rehospitalization—a crucial factor for evaluating long-term outcomes and costs.^{10,21} This study aims to identify factors associated with readmission and the impact on health-related quality of life scores (HRQoLs), with special attention given to the treatment method following readmission.

MATERIALS AND METHODS

Data Source

This was a retrospective review of a prospective multicenter database for consecutively enrolled operative and nonoperative ASD patients at 11 nationwide participating sites. Before study initiation, Institutional Review Board approval was obtained at each site. Inclusion criteria were surgical ASD patients: age > 18 years, scoliosis $\geq 20^\circ$ (measured by major coronal Cobb angle), sagittal vertical axis (SVA, distance between C7 plumb line and sacral posterior superior margin) ≥ 5 cm, pelvic tilt $\geq 25^\circ$, and/or thoracic kyphosis $> 60^\circ$.

Study Design

This study included surgical ASD patients with complete demographic, radiographic, HRQoL, and operative data at baseline, 1-year, and 2-year follow-up. Patients were grouped on the basis of readmission: (1) Nonreadmitted: those not readmitted to the hospital subsequent to index surgery, or (2) Readmitted: those that were readmitted. In addition, readmitted patients were assigned to one two subgroups based on subsequent treatment: (1) Medical readmission—readmitted patients without reoperation, or (2) Surgical readmission—readmitted patients who received a reoperation. Surgical readmissions were considered equivalent to revisions procedures.

Data Collection and Analysis

Collected data included patient demographics, operative and complications data, readmission data, re-operation data, and HRQoL outcomes. Complication presence, type, timing [intraoperative (during index procedure), peri-operative (<6 weeks discharge), and postoperative (>6 weeks after discharge)], and treatment (medical *vs.* surgical) were determined by each cases' surgeon. Major and minor complication categorization was done according to previously reported criteria.^{9,22} Specific complications resulting from the index procedure are presented by type and severity (Appendix 1, <http://links.lww.com/BRS/B127>), consistent with prior reports.²² Predictors and causes of readmission were distinguished on the basis of the timing of the readmission relative to the complication: complications resulting in “early” readmissions (occurring <30 days after a complication) were termed “causes,” while complications resulting in “late” readmissions (occurring >30 days after a complication) were termed “predictors,” and retained for analysis. “Drivers of readmission” was a term used for descriptive purposes, without regard for the timing of the rehospitalization.

The following HRQoL measures from index surgery were considered for analysis: Oswestry Disability Index (ODI), Short Form (36) Health Survey Mental (MCS) and Physical (PCS) component summaries, Scoliosis Research Society Patient Questionnaire (SRS-22r) for Activity (AC), Pain (P), Appearance (AP), Satisfaction (S), Mental (M), and Total (T).

Statistical Analysis

Statistical analysis was performed with SPSS version 20.0 (SPSS Inc., Chicago, IL) and R Statistical Package (R Core Team, Vienna, Austria).²³ Univariate analysis involving Chi-square and unpaired Student *t* tests for categorical and continuous variables, respectively, were used to compare readmitted and nonreadmitted patients. Variables with $P < 0.1$ on univariate analysis were considered as potential readmission predictors (and revision in the subanalysis) and were evaluated using multivariate binomial logistic regression modeling. Multivariate repeated measures mixed models measured the impact of readmission and revision on HRQoL at postoperative intervals. $P < 0.05$ was used for

TABLE 1. Distribution of Medical (M) versus Surgical (S) Complication Proportions Leading to Hospital Readmissions at the Five Considered Postoperative Intervals

Post-Op interval	M (n, % of Total)	S (n, % of Total)	Total
1 (0–30 d)	3 (27.3%)	18 (27.7%)	21
2 (30 d–3 mo)	4 (36.4%)	7 (10.8%)	11
3 (3–6 mo)	1 (9.1%)	6 (9.2%)	7
4 (6 mo–1 yr)	0 (0.0%)	16 (24.6%)	16
5 (1 yr–2 yrs)	3 (27.3%)	18 (27.7%)	21
Total	11	65	76

statistical significance; odds ratios are reported as [OR (95% confidence interval, 95% CI), *P* value].

RESULTS

Study Sample

Of 478 surgical ASD patients, 334 met inclusion criteria. Mean age was 57.2 ± 15.1 years, average body mass index (BMI) was 27.4 ± 6.3 kg/m², 83.2% were females, and the average Charlson Comorbidity Index (CCI) Score was 1.67. Mean operative time was 390.6 ± 130.8 minutes, and EBL was 1847.2 ± 1725.8 mL. Posterior was the most common surgical approach (89.2%), with an average 11.8 fused levels overall. BMP-2 use was observed in 40.7% of ASD patients.

Readmitted versus Nonreadmitted Comparison

There were 76 (22.8%) patients' readmissions following index procedure. Of the original 478 operative ASD cases, 105 (19.2%) unique readmissions occurred. The 29 readmitted patients excluded in this study were done so due to missing baseline, 1- and 2-year postoperative follow-up data ($n = 11$), and incomplete 1- and 2-year follow-up and radiographic data ($n = 18$). Table 1 presents readmission timing distributions of the included 76 rehospitalizations: 0 to 30 days ($n = 21$), 30 days to 3 months ($n = 11$), 3 to 6 months ($n = 7$), 6 months to 1 year ($n = 16$), and 1 to 2 years ($n = 21$).

Readmitted and nonreadmitted patients were similar in age, gender, BMI, and CCI score ($P > 0.05$, all cases; Table 2). Readmissions had a higher baseline body mass (77.19 vs. 72.22 kg, $p = 0.047$) and displayed increased pre-operative cervical sagittal malalignment, measured by C2-C7 SVA (39.17 vs. 32.43 mm, $P = 0.010$), and C2-T3 SVA (11.10 vs. 7.76 mm, $P = 0.033$). Readmitted and nonreadmitted cases had similar pre-operative sagittal thoracolumbar profiles, though readmissions had a trend toward larger global SVA (79.94 vs. 61.19 mm, $P = 0.062$). The mean initial LOS for readmitted patients was higher than that for nonreadmissions (8.54 vs. 7.52 days, $P = 0.030$). Readmission groups were similar in number of levels fused (11.17 ± 4.53 vs. 11.13 ± 4.34 , $P = 0.937$), BMP-2 use (55.6% vs. 67.5% , $P = 0.069$), and PSO use (36.7% vs. 22.1% , $P = 0.065$). However, readmitted patients displayed an increased prevalence of the following complication categories associated

with index: major peri-operative, postoperative, major postoperative, implant, infection, and radiographic ($P < 0.001$, all cases).

Nonreadmission Subanalysis

The 258 nonreadmitted ASD cases experienced chiefly operative ($n = 48$, 18.6%; mostly dural tear: $n = 29$, 11.2%), neurologic ($n = 45$, 17.4%; mostly radiculopathy: $n = 15$, 5.8%), and cardiopulmonary ($n = 33$, 12.8%; mostly pleural effusion: $n = 16$, 6.2%) complications. The prevalence of asymptomatic proximal junctional kyphosis (PJK) was 5.4% ($n = 14$). There were no symptomatic nonunions among nonreadmissions.

Medical Readmission Treatment Data

Eleven patients (14.5%) were readmitted for concerns treated medically, most commonly infections ($n = 4$, 36.4%), treated with antibiotics, which occurred mainly within 30 days postoperative. Medical infections were mostly superficial ($n = 2$, 50.0%). The two other postoperative medical infections were pneumonia and cellulitis. The "other" medical readmission indications included pleural effusion, intraoperative blood loss, and DVT. Neurologic complications (postoperative seizure, neuropathy, radiculopathy; $n = 3$, 27.3%) also drove medical readmissions. Time to medical complications requiring readmission averaged 240 days (range: 4–845 days; Figure 1). Table 3 presents specific medical readmission indications.

Surgical Readmission Treatment Data

Of 76 readmissions, 65 (85.5%) underwent a subsequent reoperation, therefore classified as surgical readmitted cases (radiographic example, Figure 2). An additional seven patients (10.7%) had a second surgical readmission requiring a second rehospitalization. Surgical complications driving readmissions occurred on average 295 days postoperative (range: 0–1643 days). Implant ($n = 24$, 36.9%) and radiographic ($n = 18$, 27.7%) complications were the most common surgical readmission indications (Table 3). Implant complications were mostly due to rod fractures ($n = 13$, 20.0%), occurring most frequently between 1- and 2 years postoperative (average: 487 days); symptomatic PJK ($n = 9$, 13.8%) was the most common radiographic complication cause, occurring most frequently 6 months to 1 year postoperative (average: 182 days). Additional surgical readmission drivers

TABLE 2. Comparison of Baseline Characteristics, Pre-operative Radiographic Parameters, and Surgical Data of ASD Patients Readmitted to the Hospital versus Those Who Were Not

	No Readmission (n = 258)	Readmission (n = 76)	P
Baseline patient demographics			
Age (yrs)	56.76	58.78	0.304
Weight (kg)	72.22	77.19	0.047*
Gender (% Female)	84.2%	79.7%	0.231
BMI (kg/m ²)	27.21	28.13	0.282
CCI score	1.54	1.78	0.286
Diabetes (%)	7.0%	10.5%	0.216
Osteoporosis (%)	12.0%	14.5%	0.347
Baseline radiographic parameters			
PT (°)	23.37	24.89	0.295
PI (°)	55.37	54.36	0.543
PI-LL (°)	15.29	18.67	0.260
C7 SVA (mm)	61.19	79.94	0.062
C2-C7 SVA (mm)	32.43	39.17	0.010*
C2-T3 SVA (mm)	7.76	11.10	0.033*
Surgical factors			
Operative Time (min)	386.16	405.74	0.261
EBL (cc)	1803.67	1997.86	0.401
Length of stay (d)	7.52	8.54	0.030*
Nb levels fused	11.17	11.13	0.937
BMP-2 use (%)	55.6%	67.5%	0.069
PSO use (%)	36.7%	22.1%	0.065
Nb major peri-op Comps	10.9%	35.5%	<0.001*
Nb post-op Comps	25.2%	82.9%	<0.001*
Nb major Post-op comps	9.7%	76.1%	<0.001*
Nb implant comps	10.9%	42.1%	<0.001*
Nb infection comps	4.3%	21.1%	<0.001*
Nb radiographic comps	15.8%	57.9%	<0.001*

*Bolded cells are statistically significant on univariate analysis to $P < 0.05$.

BMI indicates body mass index; CCI Charlson Comorbidity Index Score; EBL, estimated blood loss; PI, pelvic incidence; PI-LL, mismatch between pelvic incidence and lumbar lordosis; PT, pelvic tilt; SVA, sagittal vertical axis.

included infections requiring surgical management ($n = 11$, 16.9%; deep infections: $n = 10$, 15.4%), neurologic complaints ($n = 8$, 12.3%), operative issues ($n = 3$, 4.62%), and “other” ($n = 1$, 1.54%).

Hospital Readmission Causes

Of 32 intra- and peri-operative complications, 12 (37.5%) resulted in “early” readmission and 20 (62.5%) resulted in “late” readmissions. Of 44 postoperative complications, 13 (29.5%) resulted in “early” readmission, while 31 (70.5%) resulted in a “late” readmission. Causes of “early” readmissions were most frequently infections ($n = 8$), specifically deep ($n = 4$). Implant complications ($n = 18$), specifically rod breakages ($n = 10$), were the most frequent causes of “late” readmissions. All complications classified as “causes” of readmission were excluded from the analysis for “predictors” of rehospitalization.

Hospital Readmission Predictors

Table 4 displays independent predictors of elevated readmission risk: increased number of infections [OR 25.02 (162.00–

3.86), $P < 0.001$], increased radiographic complications [OR 16.94 (49.47–5.82), $P < 0.001$], increased number of implant complications [OR 6.12 (16.41–2.28), $P < 0.001$], increased number of major peri-operative complications [OR 5.13 (18.93–1.39), $P = 0.014$], and PSO use during the index surgery [OR 3.560 (12.08–1.05), $P = 0.042$].

Among these predictive complication categories (infection, implant, radiographic), an analysis evaluating subtype, severity (major vs. minor), and occurrence (intra-, peri-, or postoperative), was performed. Regarding infections, readmitted patients had increased major peri-operative deep infections (5.3%). The most frequent implant complications among readmissions were postoperative minor and major (two complaints: one leading to readmission, one not) rod breakages (14.5% vs. 0.8%, $P < 0.001$). Among radiographic complications, readmitted patients had a higher prevalence of postoperative minor and major PJK (14.5% vs. 0.03%, $P < 0.001$).

Patient-reported Outcomes

Both study cohorts (readmitted and non-readmitted) displayed overall HRQoL improvement at each postoperative

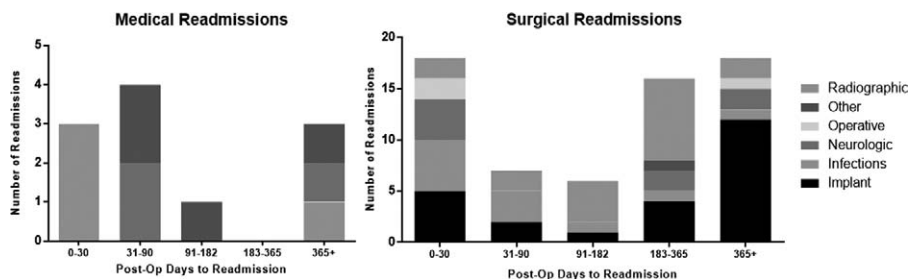


Figure 1. Stacked bar graph showing the absolute numbers of readmissions (medical and surgical) organized by date of unplanned readmission.

interval (6 wks, 1 yrs, 2 yrs), as measured on SF-36 PCS/MCS, ODI, and SRS-22r scores ($P < 0.01$, all cases, Figures 3 and 4). However, the 76 readmissions had statistically reduced improvement overall and at each time interval in all scores, except for their overall ($P = 0.056$) and 6-week SF-36 ($P = 0.12$) MCS score, SRS-22 Mental score ($P = 0.17$), and 6-week SRS-22 Pain score ($P = 0.65$).

Revision (Surgical Readmission) Subanalysis

Average days to re-hospitalization for 65 surgical readmissions were 259 (range: 1–1634 days). Most revisions occurred between 30 days and 1-year postoperative ($n = 29, 44.6\%$). The two frequent revision indications were implant (occurring on average 397 days postoperative) and radiographic (occurring on average 211 days postoperative) complications. The 65 revisions differed from readmissions treated medically in surgical and complications data (Table 5): revisions were more likely to have a fusion extending to S2 ($P = 0.002$), less likely to receive posterior intraoperative allograft (58.5% vs. 90.9%, $P = 0.008$), more frequently sustained postoperative complications overall (84.5% vs. 72.8%, $P = 0.029$), but had fewer cardiopulmonary complications (7.7% vs. 36.4%, $P = 0.006$).

Significant factors identified (Table 6) as elevating surgical readmission odds included increased number of major

postoperative complications [19.64 (356.04–1.08), $P = 0.044$], and lower vertebrae instrumented posteriorly during index [1.75 (2.83–1.08), $P = 0.024$]. More frequent cardiopulmonary complications reduced the odds of a surgical readmission [0.048 (0.956–0.00), $P = 0.014$].

Both revision and nonrevision cohorts improved in postoperative HRQoLs overall and at each time point considered except for at 6 weeks postoperative ($P < 0.01$). Undergoing a reoperation following readmission did not have any impact on HRQoLs ($P > 0.05$ in all cases). Outcome scores were also assessed taking reoperation date in reference to the index procedure into account; however, this analysis did not yield significance ($P > 0.05$ for all HRQoLs).

DISCUSSION

The burden of unplanned hospital readmissions in ASD surgery is realized in recent reports of elevated hospital costs and undesirable patient outcomes.¹⁸ Reducing readmissions and revisions are tangible measures of improving outcomes and can drive planning and patient counseling. This interest is demonstrated in recent cost-effective studies in the context of different orthopedic surgical procedures.^{24–26} Although somewhat limited in ASD literature, analyses focusing on immediate postoperative patient

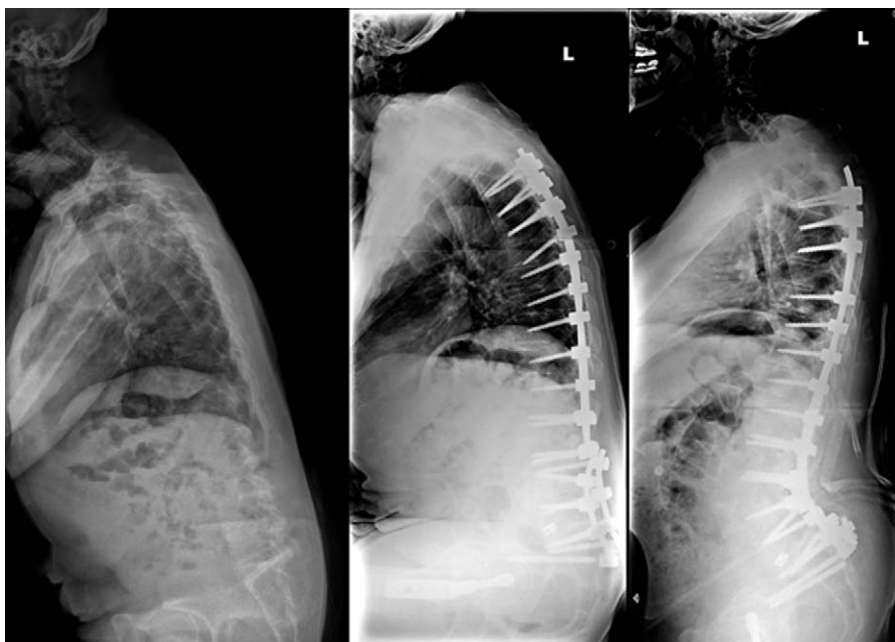


Figure 2. Case illustration of an ASD patient required revision surgery following a surgical complication (hardware failure) requiring a hospital readmission: pre-operative (left), postoperative before revision (middle), postrevision (right).

TABLE 3. Distribution of Medical and Surgical Readmission Indications and Subset Descriptors for Each Individual Indications Among Readmitted ASD Patients

Readmission Indication	Subset Type	N, % of Readmitted Pts
Medical readmissions		
Infection	Pneumonia	4 (36.4%)
	Superficial*	
	Other	
Neurologic	Pain (radiculopathy)	3 (27.2%)
	Other*	
Other	Pleural effusion	4 (36.4%)
	Intra-op blood loss	
	DVT*	
Total medical readmissions		11
Surgical readmissions		
Implant	Painful implants	24 (36.9%)
	Prominence	
	Rod breakage*	
	Screw breakage	
	Interbody dislodgement/migration	
	Set screw dislodgement	
	Screw bone interface Loosening	
	Other	
Infection	Deep*	11 (16.9%)
	Other	
Neurologic	Motor deficit	8 (12.3%)
	Motor deficit/paralysis	
	Pain (Radiculopathy)*	
Operative	Dural tear	3 (4.62%)
	Implant failure	
	Pedicle fracture	
Radiographic	Adjacent segment degeneration	18 (27.7%)
	Coronal imbalance	
	DJK	
	PJK*	
	Pseudoarthrosis	
	Sagittal imbalance	
Other	Other	1 (1.54%)
Total surgical readmissions		65

Percentages of patients are listed in relation to the total number of readmitted patients (medical: n = 11; surgical: n = 65).

*Denotes the most frequent specific complaint upon readmission within each category.

DJK indicates distal junctional kyphosis; DVT, deep vein thrombosis; PJK, proximal junctional kyphosis.

TABLE 4. Multivariate Analysis Results for Identified Significant Independent Predictors of Hospital Readmission Among All ASD Patients

Predictive Variables	OR	95% Confidence Interval		P
		Lower	Upper	
Nb PSO osteotomies	3.560	1.046	12.076	0.042
Nb major peri-op comps	5.128	1.389	18.931	0.014
Nb implant comps	6.116	2.280	16.405	<0.001
Nb infection comps	25.02	3.86	162.000	<0.001
Nb radiographic comps	16.964	5.817	49.469	<0.001

OR indicates odds ratio; PSO, pedicle subtraction osteotomy.

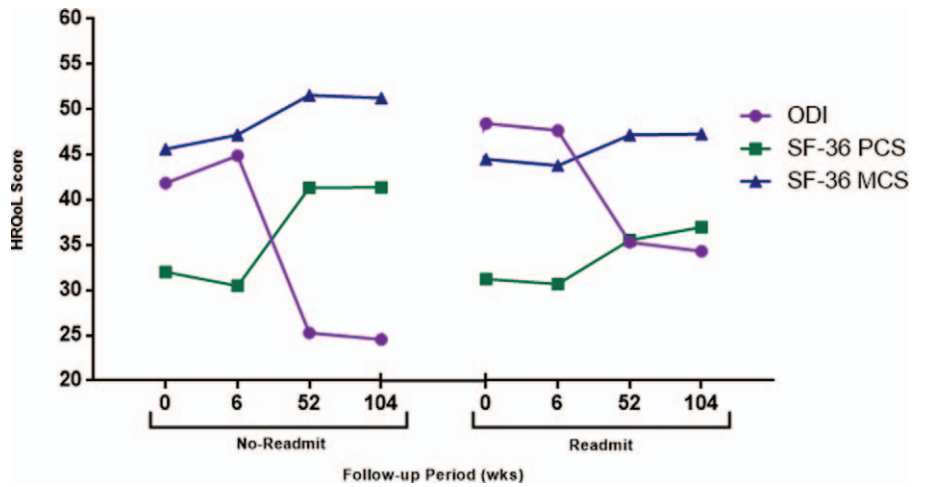


Figure 3. Pre-operative and postoperative HRQoL scores (ODI, SF-36 PCD, SF-36 MCS) for readmitted and nonreadmitted patients.

outcomes related to readmission and revision are important. Minimizing 30-day readmission rates have involved preliminary studies investigating unplanned readmissions and predisposing factors, such as infections or postoperative pain. Building on this foundation, this study identifies risk factors for readmission and reoperation, and quantifies the impact on HRQoLs in ASD correction, with attention given to treatment method following readmission.

Within 2 years following index ASD surgery, 22.8% of patients underwent unplanned readmissions, 6.3% of which occurred within 30 days. Rehospitalizations within 30 days of discharge are relevant for policy-makers, as this period is more indicative of surgical success and acute complications effects.²⁷ Our reported value is comparable with other series evaluating similar spinal procedures: Akamnonu *et al.*²⁸ observed unplanned readmission rates varying between 2.1% and 7.1%, depending on lumbar pathology; Schairer *et al.*¹⁰ reported a 8.4% 30-day readmission rate for ASD cases. In this study, a similar percentage of patients (6.3%) were also readmitted between 1- and 2 years postoperative, signifying the negative impacts of both acute and extended complications inherent in ASD surgery. Extended unplanned readmission have been less thoroughly investigated in the literature compared with early rehospitalization.¹⁵

Readmitted and nonreadmitted patients were comparable regarding baseline demographics, differing only in total body mass and upper alignment measures: readmitted patients displayed pre-operative cervical sagittal malalignment based on C2-T3 SVA and C2-C7 SVA, measures that have been previously correlated with global sagittal parameters indicative of more severe ASD.^{29,30} Surgical complications, though, chiefly increased readmission odds in this study: positive predictors were increased number of infections, radiographic complications, implant complications, major peri-operative complications, and PSO use. With respect to these complication group predictors, readmitted patients had more peri-operative deep infections (5.7%), and postoperative major and minor rod breakages (14.5%), and PJK (14.5%). That instrumentation failures were the principal surgical readmission drivers re-emphasizes the importance of effective pre-operative planning; optimizing surgical planning tools may thus be beneficial from both a radiographic and patient-outcome standpoint.³¹ Furthermore, identifying major peri-operative complications as a readmission risk factor may discern those ASD patients who are intrinsically predisposed to rehospitalizations. This association may serve as a marker for overall patient frailty or

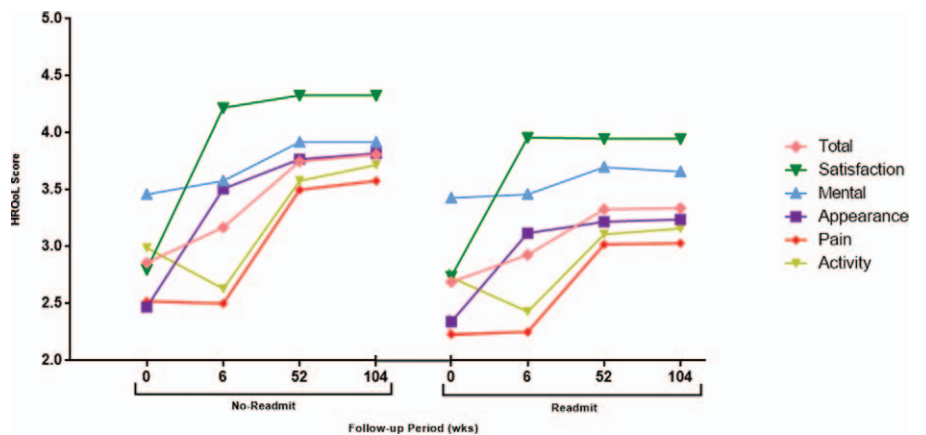


Figure 4. Preoperative and postoperative SRS-22r (Appearance, Pain, Activity, Mental, Satisfaction, Total) scores for readmitted and nonreadmitted patients at each follow-up time interval.

TABLE 5. Univariate Analysis for Differences in Baseline Demographic, Radiographic, and Surgical Variables for All Readmitted ASD Patients (n = 76) on the Basis of Their Subsequent Treatment (Medical vs. Surgical)

	Readmitted: Medical (n = 11)	Readmitted: Surgical (n = 65)	P
Baseline patient demographics			
Age (yrs)	54.48 (14.54)	59.51 (14.64)	0.295
Gender (% Female)	90.9%	77.8%	0.324
BMI (kg/m ²)	29.21 (8.43)	27.92 (5.74)	0.532
Baseline bladder incontinence (%)	0.0%	22.0%	0.099
Baseline diabetes (%)	18.2%	9.2%	0.378
Baseline osteoporosis (%)	9.1%	15.4%	0.589
Radiographic parameters			
Baseline PT (°)	21.29 (9.11)	25.50 (12.07)	0.274
Baseline PI (°)	53.61 (10.37)	54.48 (13.33)	0.837
Baseline PI-LL (°)	15.62 (21.59)	19.18 (23.80)	0.643
Baseline C7 SVA (mm)	79.83 (89.03)	79.95 (77.34)	0.996
Baseline T1S-CL (°)	15.92 (10.54)	16.89 (12.26)	0.817
Baseline C2-C7 SVA (mm)	31.72 (17.33)	40.62 (17.79)	0.150
Baseline C2-T3 (°)	8.26 (12.53)	11.66 (17.43)	0.250
Surgical factors			
Posterior LIV	24.45 (2.81)	26.28 (1.46)	0.002*
Length of stay (d)	6.82 (2.68)	8.83 (5.13)	0.061
EBL (cc)	2052.27 (2225.04)	1988.05 (2041.49)	0.930
Posterior allograft (%)	90.9%	58.5%	0.008*
Nb post-op comps (%)	72.8%	84.5%	0.029*
Nb major post-op comps (%)	45.5%	81.5%	0.014*
Nb cardiopulmonary comps (%)	36.4%	7.7%	0.006*
Nb neurologic comps (%)	45.5%	15.3%	0.070

*Bolded cells are statistically significant to P < 0.05.

BMI indicates body mass index; CCI, Charlson Comorbidity Index Score; EBL, estimated blood loss; LIV, lowest instrumented vertebrae; PI, pelvic incidence; PI-LL, mismatch between pelvic incidence and lumbar lordosis; PT, pelvic tilt; SVA, sagittal vertical axis.

susceptibility to postoperative complications. Interestingly, our results identified PSO use during index procedure as increasing medical, not necessarily surgical, complication odds driving readmission. Although Auerbach *et al.*³² also reported a similar observation: major medical complications (most frequently cardiopulmonary events, myocardial infarction, and optical deficits)

occurred in 38% of PSO patients and 24.8% experienced major surgical complications.

To effectively quantify ASD readmissions, we considered both medical and surgical indications for rehospitalization. Medical complications are defined as pathologic processes affecting patients that occur during or around surgery for spinal deformity, though that are not directly related to

TABLE 6. Multivariate Analysis Results for Significant Independent Predictors for Surgical Revision Upon Readmission, Controlling for Confounding Significant Variables Identified on the Univariate Analysis in the Following Significance Range: P < 0.1

Predictive Variables	OR	95% Confidence Interval		P
		Lower	Upper	
Posterior LIV	1.745	1.076	2.831	0.024
Nb major post-op comps (%)	19.641	1.084	356.039	0.044
Nb cardiopulmonary comps (%)	0.048	0.000	0.959	0.014

surgical technique.⁸ Peri-operative medical complications after spine surgery have been well described in elevated ranges.²⁸ The most prevalent medical complications observed here were superficial infections (36.4%), most of which occurred within 10 days postoperative, indicating the importance in detecting early onset infections associated with major spinal surgeries. Schairer *et al.*¹⁰ also identified SSIs as comprising the predominant cause for the majority of early readmissions subsequent to ASD surgery in 57.1% cases. Similarly, Akamnonu *et al.*²⁸ evaluated common lumbar pathologies and also identified SSIs (42%) and wound-related complications (30%) as the most common readmission indicators. Ganocy *et al.*³³ identified urinary tract infections (UTIs) in approximately 9% of patients following adult scoliosis surgery and reported that post-operative UTIs increased length of stay by about 4 days and nationwide treatment costs by about \$500 million. From a long-term outcomes standpoint, both readmission patient cohorts improved in overall HRQoLs and at each recorded time interval. Readmitted patients' recovery was significantly lower, however, than nonreadmissions (except for 6-week SF-36 MCS, SRS-Mental and Pain), suggesting a sustained long-term impact of readmissions on patients, likely due to the complications experienced by these patients. This worsening of overall patient-reported outcomes requires further study, notably in the indication for readmission and ultimate treatment.

For this study, surgical complications associated with index ASD correction that drove readmissions were classified synonymously as revision procedure indications. In doing so, we do not underestimate ASD's revision frequency: following unplanned readmission, the majority of patients in our series (85.5%) underwent subsequent surgical treatment caused by a surgical complication. This study's overall revision rate is 19.5%, consistent with prior ranges of 7.61% to 21%.^{34–37} The most common causes of surgical readmissions were implant (36.7%) and radiographic (27.7%) complications. The timing of these complications is noteworthy—most implant complications ($n = 12$) occurred between 1 and 2 years postoperative, and most radiographic complications ($n = 8$) occurred between 6 months and 1-year postoperative. Kelly *et al.*³⁷ also identified both implant-related issues and pseudarthroses occurring 12 to 36 months postoperative as a principle driver for ASD revisions.³⁸ Rod breakages were the primary causes of implant complications, which are relatively commonly associated with complex ASD correction in the sagittal plane—Smith *et al.*³⁹ reported symptomatic rod breakages in 6.8% of surgical ASD patients that took place on average 6.4 months postoperative.⁴⁰ Adjacent segment pathologies, notably PJK, accounted for most of the radiographic complications in our series, which has also been supported in recent literature.^{10,34,41}

Limitations

This study's limitations arise principally from the database's design. Despite quality control and data collection assurance, the results presented reflect variety in practice; this,

combined with the retrospective analysis, introduces bias and lack of standardization into our results, particularly with regard to readmission indications and subsequent decision-making. Despite extensive internal audits for verification of database accuracy that are performed by our group, the difficulty of identifying medical readmissions also presents a limitation. It was difficult to take into account readmissions not on the enrolling surgeons' service, those that occurred at alternate hospitals, which were not recorded in our database, and any potential complications or readmissions that may have occurred to patients lost to follow-up. Furthermore, there are additional possible medical drivers of readmission, unrelated to the index ASD surgery, which may have contributed to rehospitalizations, which were not captured in our dataset. Further, complications unrelated to the index ASD surgery that may have resulted in a readmission were not captured in our database.

CONCLUSION

Although ASD correction carries risk, potentially modifiable factors may attenuate this. Patients with major peri-operative complications, implant complications, infections, and radiographic complications associated with index surgery had greater readmission odds, which were predominantly surgically driven. The most common reoperation causes were implant complications. Readmitted patients improved, although less, compared with the overall cohort, yet displayed reduced 6-week SF-36 MCS. Risk factors associated with readmission/revision indicate increased case complexity and identify patients more susceptible to postoperative issues.

➤ Key Points

- ❑ Hospital readmission among adult spinal deformity (ASD) surgical patients occurred most often within 30 days (6.3%) and between 1 and 2 years postoperative (6.3%), for an overall readmission rate of 22.8%; readmissions were driven predominantly by surgical (85.5%) compared with medical indications.
- ❑ Medical readmissions were largely to treat infections (superficial infections, 50.0%), while surgical readmissions (revisions) were mostly due to implant (rod fractures, 20.0%) and symptomatic radiographic (PJK, 13.8%) complications.
- ❑ Both patients who were readmitted and those that were subsequently revised improved in most health-related quality of life (HRQoL) outcome scores at all follow-up intervals (6 wk, 1 yr, 2 yrs postoperative), but they improved less compared to non-readmissions.

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