A Predictive Risk Index for 30-day Readmissions Following Surgical Treatment of Pediatric Scoliosis

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Background: Pediatric scoliosis often requires operative treatment, yet few studies have examined readmission rates in this patient population. The purpose of this study is to examine the incidence, reasons, and independent risk factors for 30-day unplanned readmissions following scoliosis surgery.

Methods: A retrospective analysis of the American College of Surgeons National Surgical Quality Improvement-Pediatric database from 2012 to 2013 was performed. Patients undergoing spinal arthrodesis for progressive infantile scoliosis, idiopathic scoliosis, or scoliosis due to other medical conditions were identified and divided between 2 groups: patients with unplanned 30-day readmissions (Readmitted) and patients with no unplanned readmissions (Non-Readmitted). Multivariate logistic regression models were created to determine independent risk factors for readmissions.

Results: A total of 3482 children were identified, of which 120 (3.4%) had an unplanned readmission. A majority of patients had a readmission due to a surgical site complication regardless of scoliosis etiology. Risk factors for readmission included obesity ($P < 0.001$) and posterior fusion of 13 or more vertebrae ($P = 0.029$) for idiopathic scoliosis, impaired cognition ($P = 0.009$) for progressive infantile scoliosis, and pelvic fixation ($P = 0.025$) and American Society of Anesthesiologist ≥ 3 ($P = 0.048$) for scoliosis due to other conditions.

Conclusions: We present 30-day readmissions risk factors based on independent patient and procedural risk factors. This may be useful in the clinical management of patients following scoliosis surgery, specifically for the role of preoperative and predischarge risk stratification.

Level of Evidence: Level III—prognostic.

Key Words: scoliosis, readmissions, NSQIP, spine, pediatric

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Scoliosis is a broad collection of coronal spinal deformities, and is estimated to occur in up to 3% of the pediatric population.[1,2] Patients with advanced disease may have significant disability, and surgical treatment is often warranted to improve pain, prevent curve progression, arrest neurological deficit, decrease cardiopulmonary compromise, and improve cosmesis.[3–5] As with any other operative intervention, a meticulous assessment of risks and potential complications is imperative before surgery. In the last few years, studies analyzing multi-institutional databases reported baseline complications rates ranging from approximately 6% to 18% following these procedures, depending on the etiology of scoliosis.[6–9]

Readmission rate has been labeled a key measure of health care quality by the Centers for Medicare and Medicaid Services, and financial penalties will soon be implemented on institutions that do not meet acceptable postoperative readmission standards.[10] Consequently, the understanding of existing readmission rates and patient-associated and procedural-associated risk factors is paramount in surgical quality improvement initiatives, prevention of financial costs, and reduction in postoperative morbidity.[11] Most recently, a study analyzing the American College of Surgeons (ACS) National Surgical Quality Improvement Program (NSQIP)-Pediatric database demonstrated a 30-day unplanned readmission rate of 3.94% following arthrodesis for pediatric spinal deformities.[9] However, this study was not specific to scoliosis and did not assess causes or independent risk factors for readmission. The purpose of our study is to use the NSQIP-Pediatric database to determine the causes and independent risk factors for readmission following pediatric scoliosis surgery. This database has been frequently used to characterize national trends in pediatric surgery.[12]

The goals of this study are to (1) establish baseline rates of unplanned 30-day readmission following surgical correction of pediatric scoliosis; and (2) identify patient-associated and procedure-associated risk factors for readmissions based on the etiology of scoliosis.

METHODS

Data Source

We conducted a retrospective analysis of the 2012 to 2013 ACS-NSQIP-Pediatric participants' used files. This database contains deidentified patient information from over 50 participating hospitals nationwide, where trained

surgical nurses prospectively collect postoperative data for 30 days following the index surgical procedure. Comprehensive preoperative demographics and comorbidities, operative details, and postoperative complications are recorded for each patient, and collected in 8-day cycles and monitored weekly to ensure adequate data sampling. The reliability of this data have been validated with a low rate of interobserver variability (< 5% as per the 2012 NSQIP-Pediatric database user guidelines). NSQIP has been utilized extensively to analyze trends in orthopaedics, including spine surgery.[13] As per its user guidelines, patient variables are deidentified to comply with the Health Insurance Portability and Accountability Act of 1996 and do not require Institutional Review Board approval. Detailed description of the methodologies of data collection from the NSQIP database has been previously delineated.[14]

Patient Selection

Using *Current Procedural Terminology* (CPT) codes, we identified patients undergoing spinal arthrodesis for spinal deformity. Specifically, patients undergoing posterior fusion of up to 6 vertebral segments (CPT 22800), 7 to 12 vertebral segments (CPT 22802), or 13 or more vertebral segments (CPT 22804) were identified. A concurrent CPT code of 22848, signifying pelvic fixation, was included as an independent variable in our analysis.

Of these, patients with postoperative diagnoses via *International Statistical Classification of Diseases and Related Health Problems* (ICD-9) codes signifying progressive infantile idiopathic scoliosis (ICD-9 737.32), idiopathic scoliosis (ICD-9 737.30), and scoliosis associated with other medical conditions (ICD-9 737.43) were included in the final analysis. All patients who met inclusion criteria were divided between 2 cohorts: patients with all-cause 30-day unplanned readmissions (Readmitted) and patients who did not have any unplanned readmissions 30 days following the index procedure (Non-Readmitted). Readmission data are gathered by each NSQIP participating hospital surgical clinical reviewer through chart abstraction and billing codes, and are crosschecked by interrater reliability reviewers to identify potential reporting errors. Using this methodology, readmission rates have been shown to be significantly higher than those reported solely by physicians.[15]

Comparison of Cohorts

Demographics, comorbidities, and operative characteristics were compared between the Readmitted and Non-Readmitted groups for each of the 3 groups based on scoliosis etiology. A detailed list of preoperative and operative variables that were compared is comprehensively shown in Table 1. Reason for readmission was recorded for the Readmitted cohort.

TABLE 1. Baseline Preoperative and Operative Characteristics

Patient Characteristics	n (%)
Age < 5	49 (1.4)
5 ≤ age < 10	156 (4.5)
10 ≤ age < 15	2060 (59.2)
15 ≤ age ≤ 18	1217 (35.0)
Male	896 (25.7)
Underweight	234 (6.7)
Obese	552 (15.9)
Diabetes	11 (0.3)
Premature birth	271 (7.8)
Ventilator requirement	68 (2.0)
Asthma	288 (8.3)
Cystic fibrosis	1 (0.0)
CLD	106 (3.0)
Oxygen requirement	62 (1.8)
Tracheostomy	42 (1.2)
Structural pulmonary abnormality	161 (4.6)
Esophageal/GI disease	300 (8.6)
Hepatobiliary/pancreatic disease	10 (0.3)
Cardiac risk factors	240 (6.9)
History of cerebrovascular event	126 (3.6)
Childhood malignancy	42 (1.2)
CNS tumor	21 (0.6)
Impaired cognition	618 (17.7)
History of seizure	295 (8.5)
Cerebral palsy	317 (9.1)
Structural CNS abnormality	543 (15.6)
Neuromuscular Disorder	718 (20.6)
History of intraventricular hemorrhage	26 (0.7)
Immunity disorder	17 (0.5)
Chronic steroid use	38 (1.1)
Bone marrow disorder	6 (0.2)
History of organ transplant	6 (0.2)
Open wound	14 (0.4)
Weight loss	39 (1.1)
Nutritional support requirement	268 (7.7)
Bleeding disorder	27 (0.8)
Hematological disorder	51 (1.5)
Chemotherapy	1 (0.0)
Preoperative sepsis	4 (0.1)
Preoperative inotrope requirement	133 (3.8)
Prior operation within last 30 d	29 (0.8)
Preoperative transfusion requirement	111 (3.2)
ASA ≥ 3	925 (26.6)
Operative characteristics	
Posterior fusion up to 6 levels	291 (8.4)
Posterior fusion 7-12 levels	2064 (59.3)
Posterior fusion 13 or more levels	1127 (32.4)
Pelvic fixation	222 (6.4)
Progressive infantile scoliosis	323 (9.3)
Idiopathic scoliosis	2828 (81.2)
Scoliosis due to other condition	331 (9.5)
LOS > 5 d	1031 (29.6)

ASA indicates American Society of Anesthesiologist Class; CLD, chronic lung disease; CNS, central nervous system; GI, gastrointestinal; LOS, length of stay.

Statistical Analysis

IBM SPSS, version 22 (Chicago, IL) was used to perform all descriptive and comparative analyses. In all case, a $P \leq 0.05$ was deemed statistically significant. Univariate analysis using Pearson χ^2 test was used to compare preoperative variables and operative characteristics between the Readmitted and Non-Readmitted cohorts for each of the scoliosis groups. Independent multivariate regression analyses were then performed to determine the independent association of preoperative and operative characteristics on readmission. Candidate variables for our multivariate analyses were identified and screened from which only variables with $P < 0.2$ and $P < 10$ incidences in the Readmitted cohort from the univariate

analysis were included.[16] Hosmer-Lemeshow and *C*-statistics were calculated to assess the calibration and goodness-of-fit of the model, respectively.[17]

RESULTS

Baseline Patient Characteristics

A total of 3482 patients were included in the study. Of these, 120 (3.4%) had an unplanned readmission within 30 days of the index procedure. Patient demographics, comorbidities, and operative characteristics are outlined in Table 1. Reasons for readmission are demonstrated in Table 2, where the majority of patients were readmitted due to a surgical site complication (48.2% for idiopathic scoliosis, 53.8% for progressive infantile scoliosis, and 66.7% for scoliosis due to other conditions).

Univariate Analysis

For patients in the idiopathic scoliosis cohort, readmitted patients had significantly higher rates of male sex ($P < 0.001$), obesity ($P < 0.001$), premature birth ($P = 0.008$), tracheostomy ($P = 0.025$), structural pulmonary abnormality ($P = 0.007$), esophageal or gastrointestinal (GI) disease ($P < 0.001$), history of cerebrovascular event ($P = 0.023$), impaired cognition ($P < 0.001$), seizure ($P < 0.001$), structural central nervous system abnormality ($P = 0.012$), nutritional support requirement ($P < 0.001$), bleeding disorders ($P = 0.019$), childhood malignancy ($P = 0.047$), and American Society of Anesthesiologist (ASA) ≥ 3 ($P < 0.001$). These patients also were more likely to have undergone a posterior fusion of 13 or more vertebral levels ($P < 0.001$) and have a length of stay >5 days ($P < 0.001$). All other preoperative and operative characteristics did not statistically differ between the 2 cohorts.

For patients in the progressive infantile scoliosis cohort, readmitted patients had higher rates of ventilator requirement ($P = 0.046$), structural pulmonary abnormality ($P = 0.004$), impaired cognition ($P < 0.001$), seizure ($P = 0.050$), neuromuscular disorder ($P = 0.041$), nutritional support requirement ($P = 0.004$), and ASA ≥ 3 ($P = 0.019$). Readmitted patients also had higher rates of pelvic fixation ($P = 0.027$) with no other differences in preoperative and operative variables.

In patients with scoliosis due to other conditions, readmitted patients had higher rates of ASA ≥ 3 ($P = 0.008$), preoperative inotrope requirement ($P = 0.048$), operative time of >6 hours ($P = 0.004$), pelvic fixation ($P = 0.002$), and length of stay >5 days ($P = 0.018$).

TABLE 2. Reason for Readmission

	Type of Scoliosis [n (%)]		
Reason for Readmission	**Idiopathic Scoliosis (n = 83)**	**Progressive Infantile Scoliosis (n = 13)**	**Scoliosis Due to Other Condition (n = 24)**
Any surgical site complication	40 (48.2)	7 (53.8)	16 (66.7)
Superficial site infection	7 (8.4)	2 (15.4)	1 (4.2)
Deep surgical site infection	13 (15.7)	2 (15.4)	7 (29.2)
Organ space infection	2 (2.4)	0 (0.0)	1 (4.2)
Wound disruption	18 (21.7)	3 (23.1)	4 (16.7)
Seroma	0 (0.0)	0 (0.0)	1 (4.2)
Hematoma	0 (0.0)	0 (0.0)	2 (8.3)
Any gastrointestinal complication	15 (18.1)	0 (0.0)	2 (8.3)
Constipation NOS	4 (4.8)	0 (0.0)	0 (0.0)
Abdominal pain	2 (2.4)	0 (0.0)	0 (0.0)
Noninfectious gastroenteritis and colitis	1 (1.2)	0 (0.0)	0 (0.0)
Other impaction of intestine	1 (1.2)	0 (0.0)	0 (0.0)
Paralytic ileus	2 (2.4)	0 (0.0)	1 (4.2)
Chronic vascular insufficiency of intestine	2 (2.4)	0 (0.0)	1 (4.2)
Acute pancreatitis	1 (1.2)	0 (0.0)	0 (0.0)
Other digestive system complication	1 (1.2)	0 (0.0)	0 (0.0)
Feeding difficulties	1 (1.2)	0 (0.0)	0 (0.0)
Other complications	13 (15.7)	4 (30.8)	2 (8.3)
Mechanical complication of orthopaedic device	1 (1.2)	0 (0.0)	0 (0.0)
Cellulitis or abscess of face	1 (1.2)	0 (0.0)	0 (0.0)
Fever	0 (0.0)	1 (7.7)	1 (4.2)
Dehydration	2 (2.4)	0 (0.0)	0 (0.0)
Acute postoperative pain	1 (1.2)	0 (0.0)	0 (0.0)
Headache	1 (1.2)	0 (0.0)	0 (0.0)
Syncope	1 (1.2)	0 (0.0)	0 (0.0)
Malaise and fatigue	1 (1.2)	0 (0.0)	0 (0.0)
Seizure	1 (1.2)	1 (7.7)	0 (0.0)
Urinary tract infection	2 (2.4)	0 (0.0)	0 (0.0)
Pneumonia	1 (1.2)	2 (15.4)	0 (0.0)
Systemic sepsis	0 (0.0)	0 (0.0)	1 (4.2)
Pressure ulcer, buttock	1 (1.2)	0 (0.0)	0 (0.0)
Unknown	15 (18.1)	2 (15.4)	4 (16.7)

NOS indicates not otherwise specified.

Multivariate Analysis and Risk Stratification

Independent risk factors for readmissions included obesity [odds ratio (OR) 3.09; 95% confidence interval (CI), 1.83-5.21; $P < 0.001$] and posterior fusion of 13 or more vertebral segments (OR 1.86; 95% CI, 1.07-3.23; $P = 0.029$) for idiopathic scoliosis, impaired cognition (OR 10.08; 95% CI, 2.78-14.23; $P = 0.009$) for progressive infantile scoliosis, and pelvic fixation (OR 2.80; 95% CI, 1.14-6.89; $P = 0.025$) and ASA ≥ 3 (OR 5.92; 95% CI, 1.02-10.74; $P = 0.048$) for scoliosis due to other conditions. The *C*-statistics of 0.760 to 0.769 confirmed adequate predictive models.

DISCUSSION

Hospitals, physicians, health systems, and patients have begun to use readmission rates as an indicator of quality of care that patients receive during hospitalization and following discharge.[18,19] Because of the wide variation of 30-day readmission rates among hospitals, a substantial proportion of readmissions are thought to be preventable.[20] Although considerable research focuses on readmission in the elderly, the pediatric population has received far less attention.[21–23] Readmission rates following scoliosis surgery in the pediatric population is scarce, with 2 recent studies delineating complications and readmissions following all pediatric spinal deformity surgery as well as posterior arthrodesis for adolescent idiopathic scoliosis.[8,9] However, these studies did not assess the independent effects of patient comorbidities on readmission rates, which are vital for pediatric orthopaedic surgeons for the purpose of risk stratification as well as closer attention following hospital discharge. Other than these 2 studies utilizing NSQIP, we are unaware of any previous multi-institutional literature analyzing readmission rates following operative spinal intervention in the pediatric population.

Our study found a nationwide readmission rate of 3.4% following scoliosis surgery, with the highest readmission rate (7.3%) in patients with scoliosis secondary to other medical conditions, and the lowest in patients with idiopathic scoliosis (2.9%). The readmission rates between these different patient populations have implications for risk stratification. Namely, the outcomes for scoliosis surgery for idiopathic scoliosis and progressive infantile scoliosis should be considered separately from the outcomes associated with scoliosis surgery secondary to medical conditions. Potential explanations for this discrepancy may be due to a higher comorbidity burden, underlying diagnoses such as cerebral palsy and muscular disorders, and more involved procedures in patients with scoliosis due to medical conditions, creating a higher risk for adverse events in this group. Our readmission rate is slightly lower than that shown by Pugely and colleagues (3.9%) likely secondary to the exclusion of pediatric spine deformities other than scoliosis requiring arthrodesis, which may have higher readmission rates. Basques and colleagues found a lower readmission rate of 1.5% following patients undergoing posterior arthrodesis for adolescent idiopathic scoliosis, which may be because of the stricter exclusion criteria, including numerous comorbidities.

A key finding in our analysis is that the majority of readmissions following scoliosis surgery are secondary to wound complications. In a study of readmissions following spine and total joint procedures, Maslow et al[24] reported that 60% of the readmissions were due to wound complications as well. Our multivariate analyses demonstrated that different preoperative characteristics were risk factors for readmissions based on underlying scoliosis etiology. For patients with idiopathic scoliosis, high body mass index and larger number of fused vertebrae place patients at increased risk for readmissions. Both these factors have been extensively demonstrated to increase rates of surgical site complications in spine arthrodesis.[25–27] Obese patients have a thick subcutaneous adipose layers that may form dead space following closure, increasing the risk of site infection through necrosis of local fat while more invasive procedures have higher degrees of exposure, placing patients at risk.[28] In progressive infantile scoliosis patients, impaired cognition was independently associated with readmission risk. Although the reason for this is unclear, it may stem from other neurological comorbidities not recorded in our data set, which may play a role in postoperative morbidity. Finally, in scoliosis due to other conditions, high ASA class and pelvic fixation were risk factors for readmission. Increased ASA class indicates greater comorbidity burden, which subsequently lends itself to higher risk of infection.[29] One caveat, however, is that in children, although ASA class has been shown to be significantly associated with perioperative outcomes, interreliability in accurately documenting scores has been moderate due to clinical practice variability as with many other score classifications.[30] The most frequent reason for pelvic fixation in scoliosis surgery is to provide a solid and aligned spinopelvic unit to provide firm sitting balance in nonambulatory neuromuscular patients with significant pelvic obliquity.[31] However, high complication rates—particularly deep wound infections and early failure rate—have been reported with this technique.[32]

Novel methods of postoperative prophylaxis may also be useful in this patient population.[26,33] Hence, pediatric spine surgeons should be focused on the reduction of postoperative surgical site infection burden, particularly in obese patients, patients with high ASA class, impaired cognition, and patients who undergo pelvic fixation or more vertebral fusions to reduce unplanned readmissions. Although numerous other postoperative complications can contribute to unplanned readmissions, our data suggest that particular attention should be focused on preventing and monitoring wound infection and disruption, which plays the most significant role in reasons for readmission as it pertains to spinal arthrodesis for pediatric scoliosis.

Our results also demonstrate the fundamental finding that GI complications contribute to a significant portion of readmissions in idiopathic scoliosis patients (18.1%) and in patients with scoliosis due to other conditions (8.3%). Postoperative GI morbidity—most notably postoperative

ileus—has been previously shown to occur in over 3.5% of patients undergoing lumbar arthrodesis, yet few studies have further broached this topic.[34] Regardless, based on our results, physicians should place increased emphasis on proper nutrition, hydration, and maintaining a healthy bowel regimen to both patients and parents following scoliosis surgery, and should be vigilant about potential gastric or intestinal complaints on follow-up.

Our study is not without several limitations. First, like other national databases, the ACS-NSQIP database does not include geographic information, hospital type, or surgeon experience, all of which have been shown to affect complication rates following spine surgery.[35] Furthermore, socioeconomic factors and ambulatory status are also not recorded. In addition, although the pediatric NSQIP database includes a fairly comprehensive list of demographics and comorbidities, some comorbidities may not be recorded which may also be independent risk factors for readmission such as previous spine surgery. Also, with our data on readmissions, patients with complications that occurred during their hospital stay before discharge are not captured, and hence we do not have an accurate estimate of true complication rates. The true readmission rate may in fact be higher than what we report due to the possibility of readmissions after the 30-day window that NSQIP tracks, and while we have done our best to incorporate all diagnoses of scoliosis via ICD-9 coding, some codes may have been inaccurately listed by practitioners or excluded by us due to ambiguity, thus underestimating the number of patients as well as readmission cases in our study. Finally, the 30-day window of NSQIP does not take into account 90-day unplanned readmissions, which is important as many surgical site infections occur after 30 days. Variations in practices of antibiotic prophylaxis, intraoperative irrigation and additives, and postoperative care such as types of dressing and drain placement exist are based on surgeon and institutional preference, and hence is a confounder for not only surgical site complications, but also the readmission rates we see with this patient population.

CONCLUSIONS

In conclusion, we report a comprehensive analysis of 30-day readmissions following operative treatment of pediatric scoliosis through a large national cohort. We note that in idiopathic scoliosis, progressive infantile scoliosis, and scoliosis due to medical conditions, different risk factors were associated with an increased rate of unplanned readmissions. This information can greatly aid surgeons to effectively reduce postoperative morbidity and hospital costs, and improve surgical quality metrics as it pertains to scoliosis.

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