Risk factors associated with short-term complications and mortality after pediatric spinal arthrodesis

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OBJECTIVE Spinal arthrodesis is routinely performed in the pediatric population. However, there is limited information on the short-term outcomes of pediatric patients who have undergone spine fusion. Thus, the authors conducted a retrospective review of the Pediatric National Surgical Quality Improvement Program (NSQIP) database to determine the short-term mortality, complication, reoperation, and readmission rates of pediatric patients who underwent spinal arthrodesis for all indications.

METHODS The Pediatric NSQIP database was queried for all patients who underwent spinal arthrodesis between 2012 and 2014. Patient demographics, comorbidities, body mass index, American Society of Anesthesiologists classification, and operative time were abstracted. Short-term mortality, reoperation, and readmission rates and complications were also noted. Univariate and multivariate analyses were performed to delineate patient risk factors that influence short-term mortality, complications, reoperation, and readmission rates.

RESULTS A total of 4420 pediatric patients who underwent spinal fusion were identified. Common indications for surgical intervention included acquired/idiopathic scoliosis or kyphoscoliosis (71.2%) and genetic/syndromic scoliosis (10.7%). The mean patient age was 13.7 ± 2.9 years, and 70% of patients were female. The overall 30-day mortality was 0.14%. Multivariate analysis showed that female sex and pulmonary comorbidities significantly increased the odds of reoperation, with odds ratios of 1.43 and 1.78, respectively.

CONCLUSIONS In the NSQIP database for pediatric patients undergoing spinal arthrodesis for all causes, there was a 3.6% unplanned reoperation rate, a 3.96% unplanned readmission rate, and a 9.0% complication rate. This analysis provides data for risk stratification of pediatric patients undergoing spinal arthrodesis, allowing for optimized care.

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KEY WORDS pediatric; spine; arthrodesis; fusion; short-term outcomes; mortality; reoperation; readmission; complications; NSQIP

SPINAL arthrodesis is commonly performed in the pediatric population for a number of indications, including pediatric deformity, trauma, and tumor-induced instability.^{1,2,5,7,10,13,14,16,17,23–25} Patients undergoing spinal arthrodesis are at significant risk for developing complications and having unplanned readmissions and/or reoperations. These clinical outcomes are undesirable for patients, physicians, and the health care system in gen-

eral, as they can result in increased cost and decreased quality of life. Greater understanding of the risk factors associated with adverse outcomes is needed to more effectively stratify patient populations, identify high-risk groups, and ultimately decrease operative risk. Multiple studies have examined each of these factors in subsets of pediatric patients undergoing spinal fusion. The majority of analyses focus on either one particular population of

ABBREVIATIONS ACS = American College of Surgeons; ASA = American Society of Anesthesiologists; BMI = body mass index; NSQIP = National Surgical Quality Improvement Program; SSI = surgical site infection; UTI = urinary tract infection.

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TABLE 1. Patient preoperative and intraoperative characteristics

Characteristic	Value
Mean age $\pm$ SD, yrs	13.7 $\pm$ 2.9
Sex	
Female	3087 (69.8)
Male	1333 (30.2)
Ethnicity	
White	2947 (66.7)
Black	663 (15)
Hispanic	199 (4.5)
Asian	102 (2.3)
American Indian or Alaskan Native	22 (0.5)
BMI*	
Underweight/normal	19 (0.4)
Overweight	29 (0.7)
Obese	4361 (98.7)
Steroid use w/in 30 days	58 (1.3)
Prior op w/in 30 days	53 (1.2)
Blood transfusion w/in 48 hrs prior to op	127 (2.9)
Inotropic support at time of op	165 (3.7)
Wound classification	
Clean	4382 (99.1)
Clean/contaminated	28 (0.63)
Contaminated	5 (0.11)
Dirty/infected	5 (0.11)
Operative characteristics	
ASA classification	
I–II	2933 (66.4)
$\geq$ III	1478 (33.4)
Unassigned	9 (0.2)
Mean op time $\pm$ SD, mins	296.5 $\pm$ 117.1
Mean anesthesia time $\pm$ SD, mins	404.6 $\pm$ 131.9
Diagnosis	
Adolescent idiopathic/acquired scoliosis &/or kyphoscoliosis	3150 (71.3)
Genetic & syndromic scoliosis	471 (10.7)
Congenital/acquired deformity of the spine (not kyphosis, scoliosis, or lordosis)	256 (5.8)
Neuromuscular disorders other than cerebral palsy	134 (3.0)
Abnormalities of the bone/cartilage	90 (2.0)
Congenital diplegia/hemiplegia/quadruplegia/paraplegia	86 (1.9)
Spondylolisthesis/spondylosis	47 (1.1)
Cerebral palsy	20 (0.45)
Lordosis	11 (0.25)
Tumor	8 (0.18)
Inflammatory/infectious	6 (0.14)

Values are presented as the number of patients (%) unless stated otherwise.

* Available for 4409 patients.

patients^{1,2,7,16,17,23–25} or a single complication,^{5,10,13–15} while others have been limited to single centers^{5,7,9,10} or to the adult population.^{7,18,20,21} Few studies have provided a comprehensive description of patient characteristics, operative factors, and comorbidities on short-term morbidity and mortality after spinal arthrodesis in children.⁶ With an increasing number of procedures being performed in the United States, further characterization of the short-term outcomes of patients undergoing spinal arthrodesis in the pediatric population is warranted.

The American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP) is a multi-center pediatric database that aims to collect short-term data on pediatric patients undergoing a wide array of procedures for all indications. This database was used to determine clinical outcomes in pediatric patients undergoing spinal arthrodesis. Our objectives were to 1) analyze the short-term mortality rate, complications, reoperation rates, and readmission rates; and 2) identify significant patient risk factors for short-term mortality rate, complications, reoperation rates, and readmission rates. Information from this analysis may bolster continued initiatives to optimize patient care by allowing health care teams to more effectively stratify preoperative risk and counsel patients and their families.

Methods

Patient Selection From NSQIP Database

Pediatric patients (< 18 years) who underwent spinal arthrodesis during the years 2012–2014 were identified from the ACS NSQIP pediatrics database using specified Current Procedural Terminology codes (22800, 22802, 22804, 22840, 22842, 22843, 22844). The methodology and characteristics of the database have been previously described.^{20,21} Patient demographics, including age, sex, race, American Society of Anesthesiologists (ASA) classification, body mass index (BMI), comorbidities, and preoperative serum albumin, were abstracted for analysis. The spinal arthrodesis procedure performed, operative time, 30-day mortality, and postoperative complications were also included.

Statistical Analysis

The primary outcome measures were short-term mortality rate and complications. Secondary outcomes were reoperation and readmission rates. A descriptive analysis was performed detailing the short-term mortality rate, complications, reoperation rates, and readmission rates in patients who underwent the procedures corresponding to the specified Current Procedural Terminology codes. Subsequent univariate and multivariate analyses were done to delineate patient risk factors that influence short-term mortality, complications, reoperation rates, and readmission rates. The multivariate analysis was performed using multivariate logistic regression models adjusting for age, sex, race/ethnicity, comorbidities, BMI, ASA classification, arthrodesis procedure, operative time, blood loss, readmission, infection, reoperation, instrumentation failure, or other complication. A *p* value < 0.05 was considered statistically significant.

TABLE 2. Incidence of mortality and complications

Characteristic	No. of Patients (%)
Short-term mortality	6 (0.14)
Unplanned reop	159 (3.6)
Still admitted >30 days	25 (0.37)
Unplanned readmission	175 (3.96)
Bleeding/transfusion	2969 (67.2)
Complications	398 (9.0)

Results

Patient Demographics and Preoperative Characteristics

Between 2012 and 2014, 4420 pediatric patients in the NSQIP database underwent spinal arthrodesis. The mean patient age was 13.7 ± 2.9 years, and approximately 70% were female. The majority of patients (66.7%) were white, and 15% were black. Overall, 1.3% of the patients received steroids within 30 days of their spinal arthrodesis procedure, while 53 patients (1.2%) had undergone a prior operation within 30 days of the fusion. Blood transfusions were performed in 2.9% of patients within 48 hours prior to the surgery, and 3.7% of them had inotropic support at the time of surgery (Table 1). Preoperative albumin levels were available for 1318 patients (30%), and of those patients, 97% had values ≥ 3.6 g/dl.

Operative Characteristics

Adolescent idiopathic/acquired scoliosis and/or kyphoscoliosis were the most common indications for spinal arthrodesis, representing 71.2% of the patient population. Genetic/syndromic scoliosis was the primary diagnosis in 10.7% of cases; 5.8% of patients had congenital/acquired deformity of the spine other than kyphosis, scoliosis, or lordosis (i.e., fusion of the vertebrae, hemivertebrae, or absence of a vertebrae, among others); 3% had a primary diagnosis of neuromuscular disorders other than cerebral palsy; and 2% had abnormalities of the bone or cartilage. Tumor and trauma as indications for surgery represented a minority of the patients, accounting for 0.18% and 0.11%, respectively (Table 1). Other operative indications are also presented in Table 1. A significant number of cases were elective; 66% of patients had an ASA classification $\leq$ II. Patients' wounds were classified as clean in the majority of patients (Table 1). The mean operative time was 296.5 ± 117.1 minutes, with a mean anesthesia time of 404.6 ± 131.9 minutes.

Postoperative Outcome

The short-term mortality rate was 0.14%, 3.6% of the patients underwent unplanned reoperations within the 30-day period, and 3.96% had unplanned readmissions. A bleeding or transfusion event was documented in 67.2% of the patients, and a significant number of patients (9.0%) sustained a variety of complications (Table 2). Surgical site infections (SSIs) complicated a number of cases, with 1% of patients having superficial SSIs, 1.1% having deep incisional SSIs, 0.27% sustaining organ/space SSI, and 0.84% having wound disruption. Pneumonia occurred in

TABLE 3. Incidence of complications

Complication	No. of Patients (%)
Superficial SSI	44 (1.0)
Deep incisional SSI	48 (1.1)
Organ/space SSI	12 (0.27)
Wound disruption	37 (0.84)
Pneumonia	61 (1.4)
Unplanned intubation	60 (1.4)
Pulmonary embolism	1 (0.02)
Progressive renal insufficiency	6 (0.14)
Acute renal failure	3 (0.07)
UTI	51 (1.2)
Coma >24 hrs	1 (0.02)
Stroke	2 (0.05)
Seizure	2 (0.05)
Nerve injury	16 (0.36)
Cardiac arrest requiring CPR	8 (0.18)
Graft/prosthetic/flap failure	2 (0.05)
VT requiring therapy	5 (0.11)
Systemic sepsis	36 (0.81)
Central-line associated bloodstream infection	3 (0.007)

CPR = cardiopulmonary resuscitation; VT = venous thromboembolism.

1.4% of patients, another 1.4% had an unplanned intubation, and 1.2% had a UTI. The incidence of complications, including SSI, seizure, stroke, nerve injury, and thromboembolic events, among others, is reported in Table 3.

Of the unplanned readmissions ($n = 134$) with an indicated reason, deep incisional SSI, wound disruption, superficial SSI, and organ/space SSI were the most common, representing 25.4%, 19.4%, 10.4%, and 3.7%, respectively (Fig. 1). Reoperations were frequently performed for complex wound infections (13.8%), incision and drainage of a deep abscess (18.7%), hematoma/seroma fluid collection (8.2%), reinsertion of a spinal fixation device (6.9%), and posterior arthrodesis (6.9%). Reoperation indications and procedures are presented in Table 4.

Univariate and Multivariate Analyses of Risk Factors for Reoperation

Univariate analysis revealed a number of significant risk factors ($p < 0.05$) for reoperation, including pulmonary comorbidities (ventilator dependence, pneumonia, oxygen support, and structural pulmonary/airway abnormality), esophageal/gastric/intestinal disease, CNS conditions (cerebrovascular accident/stroke or traumatic/acquired brain injury with resulting neurological deficit, developmental delay/impaired cognitive status, seizure disorder, cerebral palsy, structural CNS abnormality, and intraventricular hemorrhage), neuromuscular disorder, nutritional support, blood transfusion, acute renal failure, and wound complications (including open wounds, superficial SSI, deep incisional SSI, organ/space SSI, and wound disruption) (Table 5).

Multivariate analysis revealed only 2 characteristics as significant risk factors ($p < 0.05$) for reoperations, namely,

FIG. 1. Bar graph showing the reasons for unplanned readmissions in 134 patients. Postoperative systemic sepsis, pulmonary embolism, seizure, septic shock, and venous thromboembolism each accounted for 1% of unplanned readmissions.

female sex and pulmonary comorbidities (i.e., ventilator dependence, current pneumonia, asthma, cystic fibrosis, history of chronic lung disease, oxygen support, and structural pulmonary abnormalities) with ORs of 1.43 and 1.78, respectively (Table 6).

Discussion

Understanding the risk factors and patient characteristics associated with unexpected outcomes has become increasingly important as health care agencies seek to implement quality control measures. Readmissions, reoperations, and complications can result in a significant burden on the health care system, with increased costs associated with patient morbidity. While a number of studies have reported on the short-term outcomes of pediatric patients undergoing spinal arthrodesis for spinal deformity or specific complications after spinal arthrodesis, few have investigated patient characteristics; comorbidities; and mortality, reoperation, and readmission rates in pediatric patients undergoing spinal arthrodesis for all indications. In this study, we used the ACS NSQIP database to identify pediatric patients undergoing spinal fusion surgeries for all indications to better characterize short-term outcomes in patients.

In this analysis, we were able to identify 4420 pediatric patients who underwent spinal arthrodesis with scoliosis and/or kyphoscoliosis being the most frequent indication for operation. We found that our analysis was comparable to those of other studies with similar populations.⁹ Furthermore, in our analysis the overall mortality was 0.14% with an overall complication rate of 9.0%. The values obtained for overall morbidity and mortality are comparable to those reported in the literature for pediatric patients undergoing spinal fusion, particularly for spinal deformity.^{3,4,8,16,19} SSIs and wound dehiscence were the most common complications and also accounted for a majority of the indications for readmission and/or reoperations. Several studies have

TABLE 4. Reoperation indications and procedures (n = 159)

Procedure/Indication	No. of Patients (%)
Complex wound infection	22 (13.8)
Incision & drainage, deep abscess	25 (18.7)
Hematoma/seroma/fluid collection	13 (8.2)
Reinsertion of spinal fixation device	11 (6.9)
Posterior arthrodesis	11 (6.9)
Debridement of subcutaneous tissue	9 (5.7)
Removal of instrumentation	7 (4.4)
Debridement of bone, muscle, or fascia	4 (2.5)
Exploration of spinal fusion	4 (2.5)
Tube thoracostomy	4 (2.5)
Debridement of open wound	4 (2.5)
Closure of superficial wound dehiscence	3 (1.9)
Tracheostomy	3 (1.9)
Secondary closure of surgical wound	2 (1.3)
Posterior segmental instrumentation	2 (1.3)
Laminectomy of >2 thoracic vertebral segments	2 (1.3)
Repair of dural/CSF leak/pseudomeningocele w/ laminectomy	2 (1.3)
Other	31 (19.5)

also demonstrated that wound infections and wound dehiscence represent the most common complications following spinal arthrodesis in this population.^{11,15,16}

We found that the unplanned readmission and reoperation rates were 3.96% and 3.6%, respectively. Pugely et al.¹⁶ recently reported similar readmission (3.94%) and reoperation (3.74%) rates in patients undergoing arthrodesis for pediatric spinal deformities, and Minhas et al.¹⁵ reported a 30-day readmission rate of 3.4% in pediatric patients in the NSQIP database who underwent surgical treatment of pediatric scoliosis. Li et al.¹² also reported a 30-day reoperation rate of 2.1% in a single institution of patients undergoing fusion for spinal deformity. Jain et al.,⁹ utilizing information from a single institution, reported a 90-day readmission rate of 8.0%, with a similar unplanned reoperation rate of 4% in patients undergoing spinal fusion for all indications. The unplanned readmission rates were higher in their cohort, which might be explained by the longer follow-up of their patients or the complexity of the cases seen at the tertiary institution. Notwithstanding, our reported values are comparable to those reported in the literature.

Pulmonary, CNS, gastrointestinal, and cardiac conditions were the most common comorbidities among this patient population. Univariate analysis revealed a number of significant factors associated with reoperation, including pulmonary comorbidities, esophageal/gastric/intestinal disease, CNS conditions, neuromuscular disorder, nutritional support, blood transfusion, acute renal failure, and wound complications. Interestingly, however, multivariate analysis demonstrated that female sex and the presence of pulmonary comorbidities significantly increased the odds of reoperation. The literature has shown that there is a higher rate of readmission and reoperation among patients with con-

TABLE 5. Significant risk factors for reoperation (univariate analysis)

Risk Factor	p Value
Ventilator dependence	<0.001
Current pneumonia	<0.001
Oxygen support	<0.001
Structural pulmonary/airway abnormality	<0.001
Esophageal/gastric/intestinal disease	<0.001
CVA/stroke or traumatic/acquired brain injury with resulting neurological deficit	<0.001
Developmental delay/impaired cognitive status	<0.001
Seizure disorder	<0.001
Cerebral palsy	<0.001
Structural CNS abnormality	0.002
Neuromuscular disorder	<0.001
Intraventricular hemorrhage	<0.001
Nutritional support	<0.001
Blood transfusion w/in 48 hrs prior to surgery	0.032
Open wound	<0.001
Superficial SSI	<0.001
Deep incisional SSI	<0.001
Organ/space SSI	<0.001
Wound disruption	<0.001
Acute renal failure	<0.001

CVA = cerebrovascular accident.

genital, genetic/syndromic, or neuromuscular scoliosis, as well as pulmonary complications.^{9,16} Respiratory complications represent a small percentage of the complications that can occur following spinal fusion, especially in the setting of the high prevalence of pulmonary comorbidities among pediatric patients who undergo such procedures. Sullivan et al.²² recently developed a model that demonstrated that preoperative pulmonary function increased the likelihood of patients requiring a higher level of postoperative care. Taken together, these results suggest that optimizing pulmonary function prior to a spinal arthrodesis procedure can potentially lead to decreased morbidity in this patient population. Female sex, on the other hand, has not been reported to affect the reoperation or readmission rate of spinal fusion patients. Females represented approximately 70% of the patients in our analysis, and, therefore, further investigation into this finding is warranted to ensure the best possible outcomes for these patients.

While the NSQIP database allows for an analysis of patients from multiple centers, there are nonetheless a number of limitations inherent in its use for this study. These include information bias with a short-term follow-up of 30 days, which constrains our assessment of long-term patient outcomes. Additionally, even though NSQIP provides a wealth of data on numerous surgical variables, there is a distinct lack of specific variables addressing spinal surgeries, such as the hardware—including screws, rods, plates and cages—used during arthrodesis and the exact number of levels fused, and the implications these have on patient outcomes. There is also the potential for sample bias giv-

TABLE 6. Significant risk factors for reoperation (multivariate analysis)

Risk Factor	p Value	OR (95% CI)
Female sex	0.035	1.43 (1.03–2.0)
Pulmonary comorbidities*	0.002	1.8 (1.2–2.6)

* Pulmonary comorbidities included ventilator dependence, current pneumonia, asthma, cystic fibrosis, history of chronic lung disease, oxygen support, and structural pulmonary abnormality.

en that the data collected may not be representative of all hospitals in the United States. Also, these comparisons are limited to available hospital characteristics and collected outcome measures. As such, there may be other unknown risk factors that better predict morbidity and mortality associated with spinal arthrodesis in the pediatric population.

Conclusions

Spinal arthrodesis is commonly performed in the pediatric population for pediatric spinal deformity and rarely for spinal tumors and trauma, among others. Understanding the patient factors that lead to undesired outcomes is essential for decreasing morbidity and mortality of pediatric patients undergoing these procedures. The use of the NSQIP database provides an avenue to assess patients from multiple centers. Our analysis revealed a 3.6% rate of unplanned reoperation, a 3.96% rate of unplanned readmission, and a 9.0% complication rate. Furthermore, the presence of pulmonary comorbidities and female sex represent significant risk factors for reoperation.

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Supplemental Information

Videos

Video Abstract. <https://vimeo.com/233474294>.

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