Spine Deformity
www.spine-deformity.org

Spine Deformity 7 (2019) 158–162

Perioperative Complications After Spinal Fusion in Pediatric Patients With Congenital Heart Disease

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Received 27 December 2017; revised 28 April 2018; accepted 5 May 2018

Abstract

Background: Children with congenital heart disease (CHD) have been reported to be at increased risk of developing scoliosis following cardiac surgery. Previous sample studies have reported that these patients may safely undergo posterior spinal fusion (PSF) with low complication rates. The goal of this study is to provide an updated analysis of the perioperative complication profile for posterior spinal fusion in a large cohort of pediatric patients with CHD, using a nationwide database.

Methods: A retrospective cohort study was conducted using 30-day perioperative outcomes data from the NSQIP-P database. Our inclusion criteria were all pediatric patients who underwent posterior spinal fusion by CPT code. Patients were subdivided into two groups: those with a history of cardiac surgery for CHD and those without. Postoperative complications were classified according to the Clavien-Dindo system. Risk factors were assessed in univariate and multivariate logistic regression analyses, with significance set at $p < .05$.

Results: Our results included 3,426 pediatric patients (68.2% female, 31.8% male) with a median age at spinal fusion of 13.7 ± 2.87 years. A CHD diagnosis was present in 312 patients, with 128 having had prior cardiac surgery. The overall complication rate was 6.68%, with a 10.9% rate in the prior cardiac surgery cohort ($p = .068$). The most common overall perioperative complications were unplanned readmission (3.5%), reoperation (2.6%), and superficial wound dehiscence (2.5%). Patients with a history of cardiac surgery were not at increased risk for postoperative complications; however, blood transfusion ($p < .001$), bronchopulmonary dysplasia ($p < .001$), combined bronchopulmonary dysplasia and previous cardiac surgery ($p = .004$), and a neuromuscular diagnosis ($p < .001$) were all risk factors for major postoperative complications in this cohort.

Conclusions: Children with scoliosis who have undergone cardiac surgery to address CHD are not at an increased risk of perioperative complications within 30 days of undergoing a posterior spinal fusion. However, patients who underwent cardiac surgery for CHD who also had bronchopulmonary dysplasia or an associated neuromuscular diagnosis are at increased risk for perioperative complications. It is important for pediatric orthopedic spine surgeons to be familiar with an updated profile of potential perioperative obstacles they may face when treating these patients, as seen in a large and representative cohort.

Level of Evidence: Level III.

Keywords: Congenital heart disease; Scoliosis; Posterior spinal fusion

Introduction

It has previously been reported that patients with congenital heart disease are at increased risk for scoliosis, and that these patients can safely undergo a posterior spinal fusion (PSF) for their spinal deformity [1]. Luke et al. described the association between CHD and scoliosis as early as 1968, an association that has been well supported in the literature by numerous subsequent authors and studies [2]. More recently, Herrera-Soto et al. described a greater than 10-fold increased risk of

IRB approval: This study was reviewed and approved by the Human Research Protection Office, Dwight D. Eisenhower Army Medical Center.

Author disclosures: ABS (none), KAS (none), MS (a consultant for Stryker instrument navigation and design), DPD (other from Medicrea Spine, nonfinancial support and other from K2M Spine, other from SeaSpine, other from SpineCraft, nonfinancial support and other from Mazor Robotics, other from Astura Spine, outside the submitted work), JSM (a consultant for DePuy Spine).

No funding was received for this study.

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https://doi.org/10.1016/j.jspd.2018.05.002

developing scoliosis in children with CHD compared with children with idiopathic scoliosis. In addition to finding a 38% increased incidence of spinal deformities in patients who underwent a combined thoracotomy and sternotomy for CHD, they also found that scoliosis developed at a younger age in these patients, who were therefore at increased risk of progression [3].

Given the continuously improving surgical and medical treatment of congenital heart disease and, consequently, the improved survival of CHD patients, indications for operative management of spinal deformity with posterior spinal fusion are expanding, and a need for familiarity with the postoperative complication profile is becoming increasingly relevant. The goal of this study is to provide a robust and updated analysis of the perioperative complication profile for posterior spinal fusion procedures in pediatric patients, specifically for pediatric CHD patients with previous cardiac surgery, using the 30-day quality outcomes from the National Surgical Quality Improvement Program, Pediatric (NSQIP-P).

Materials and Methods

After obtaining approval from the Institutional Reviewi Board, a retrospective cohort study was conducted using data from the NSQIP-P database, a multi-institutional surgical outcomes database for pediatric subspecialties sponsored by the American College of Surgeons. The database contains preoperative, surgical, and 30-day postoperative outcome variables that are collected using a systematic sampling process of patients under 18 years of age undergoing major surgical procedures at more than 60 participating pediatric institutions [4]. The sampling process consists of identifying patients undergoing surgery every 8 days, at 46 time points throughout the year, for data collection. NSQIP-P data are continuously audited, validated, and compiled into Participant User Files (PUFs) for use in quality improvement and surgical outcomes research. The 2015 NSQIP-P PUF was used in this study. The PUF data contains no patient identifiers and this research was deemed exempt from Institutional Review Board review by the Human Subjects Protection Office.

Patients were identified using current procedural terminology (CPT) codes for posterior spinal fusion (22800, 22802, and 22804). Patients who had undergone previous cardiac surgery for CHD before PSF for their scoliosis were selected as the study population, with the remaining PSF patients serving as the control group. Other variables of interest included operative time, length of hospital stay, neuromuscular diagnosis, use of preoperative inotropic medication, bronchopulmonary dysplasia, and patients with combined prior cardiac surgery and bronchopulmonary dysplasia. Bronchopulmonary dysplasia may be considered a proxy in this study for pulmonary hypertension, given its association with pulmonary hypertension in both preterm and at term infants [5,6].

Postoperative complications were stratified according to the modified Clavien-Dindo classification system [7] for orthopedic procedures, with the modification of omitting blood transfusion from the Grade II complications (Table 1), given that prior studies do not consider perioperative blood transfusion a complication. Complications with a Clavien-Dindo Grade II or less were classified as minor, whereas Grade III or higher complications were classified as major. The primary outcomes of interest in our study cohort were the overall number of major perioperative complications within 30 days of surgery. Specific complications such as the total blood transfusion and the incidence of cardiac arrest requiring cardiopulmonary resuscitation were each analyzed individually.

Table 1
List of surgical complications as defined using Sink's modification of the Clavien-Dindo classification system.

Complication class	Defined criteria
I	None recorded
II	Superficial infection, urinary tract infection, seizure, venous thromboembolism, pneumonia
III	Wound dehiscence, neurologic deficit, system sepsis, reoperation, readmission, pulmonary embolism
IV	Reintubation, coma, septic shock, implant failure, cerebrovascular accident
V	Death

Statistical analysis was performed using SPSS statistical software, package version 24 (SPSS; Chicago, IL). Significance was set at $p < .05$. Univariate analyses using the chi-square test were performed to assess for relationships between categorical predictor variables and the occurrence of postoperative complications. Continuous variables for total blood volume transfused, operative time, and length of stay were assessed for interaction using Pearson correlation coefficient. Univariate factors identified as having statistically significant associations with the occurrence of any and major complications were entered in a stepwise multivariable binary logistic regression model to determine independent contributions to the occurrence of complications. A Bonferroni correction was used based upon identified univariate predictors to generate level of significance for multivariate analysis.

Results

A total of 3,426 pediatric patients underwent posterior spinal fusion (2,335 [68.2%] female, 1,091 [31.8%] male; median age 13.7 ± 2.87 years) with 759 patients having a neuromuscular diagnosis, 160 with a congenital spinal anomaly, 2,218 classified as idiopathic scoliosis, and 110 with a mixed syndromic etiology (osteochondrodysplasia, muscular dystrophy, Marfan syndrome, osteogenesis imperfecta, and spinal muscular atrophy). Of the remaining 179 patients, no listed preoperative diagnosis was available. Underlying CHD was present in 312 children, the most common being atrial septal defect (14.5%) and mitral valve deficiency (11.2%) (Table 2). Of the 312

Table 2
Underlying cardiac diagnoses, defined by ICD-9 code, for children undergoing posterior spinal fusion who had previously undergone cardiac surgery.

Cardiac diagnosis	Occurrence
Atrial septal defect	45
Congenital mitral valve insufficiency	35
Aortic valve insufficiency	24
Other diagnosis (ICD-9 747)	24
Endocardial disease	23
Pulmonary valve insufficiency	20
Tetralogy of Fallot	17
Cardiomyopathy	14
Ventricular septal defect	13
Pulmonary valve stenosis	13
Chronic pulmonary heart disease	9
Aortic coarctation	8
Cardiac dysrhythmia	6
Atrioventricular septal defect	5
Hypoplastic left heart	5

patients with CHD, 128 (41%) underwent a prior cardiac surgery. Inotropic medications were used in 95 patients before their spinal surgery and were used significantly more often in the patient cohort who had a history of cardiac surgery (6.25% vs. 2.6%, p = .015). A total of 184 patients were found to have bronchopulmonary dysplasia, 45 combined bronchopulmonary dysplasia and CHD, and 19 had combined bronchopulmonary dysplasia and previous cardiac surgery.

Patients in the prior cardiac surgery cohort were statistically similar to the idiopathic cohort in terms of age (p > .05); however, there was a significantly higher percentage of males (45.3% vs. 31.2%, p < .001) and neuromuscular patients (35.1% vs. 21.6%, p < .001) in the prior cardiac surgery cohort. Operative times were similar between groups (p = .262), although a higher total volume of blood was transfused in the prior cardiac surgery cohort (463.41 mL, 95% confidence interval 420.96–505.87, vs. 233.90 mL, 95% confidence interval 220.67–247.12; p < .001). A blood transfusion was performed in 64% of the non–cardiac surgery cohort versus 67.9% for the cardiac surgery cohort (p = .298). Increased operative time was significantly correlated with an increased blood transfusion requirement (correlation coefficient [CC] 0.384, p < .001), as well as longer hospital admissions (CC 0.141, p < .001). Increased operative time was further associated with increased risk for any complication and any major complication (CC 0.244, p < .001, and CC 0.111, p < .001, respectively).

Overall, 229 patients (6.68%) undergoing PSF had a perioperative complication reported within 30 days after surgery, 6.5% in the idiopathic cohort and 10.9% in the cardiac surgery cohort (p = .068). Of the total complications reported, 84 (2.45% of all patients) were classified as Grade II, 175 (5.1%) were Grade III, 28 (0.8%) were Grade IV, and 4 (0.012%) were Grade V. A summary of all complications is presented in Table 3. Among the 128 patients in the prior cardiac surgery cohort, 16 postoperative complications occurred in 14 patients (10.9%). Of these complications, four were classified as Grade II (3.1%), nine Grade III (8.9%), and three Grade IV (2.97%).

Table 3
Summary of all complications experienced within the 30-day perioperative period following posterior spinal fusion.

Complication	Occurrence in overall patient population, %	Occurrence in cardiac surgery cohort, %
Clavien-Dindo Class II		
Blood transfusion	64	67.9
Urinary tract infection	0.8	0
Superficial infection	0.8	0.7
Pneumonia	0.8	2.3
VTE	0.1	0
Clavien-Dindo Class III		
Unplanned readmission	3.47	2.34
Unplanned reoperation	2.6	3.1
Superficial dehiscence	2.5	6.2
Sepsis	0.5	0.7
Deep infection	0.6	0.7
Deep dehiscence	0.6	1.5
Nerve injury	0.2	0
Clavien-Dindo Class IV		
Unplanned re-intubation	0.7	2.3
Cardiac arrest	0.2	0.7
Implant failure	0.1	0
Septic shock	0.2	0.7

The most common complications were blood transfusion (96% of all complications), unplanned readmission, unplanned reoperation, and superficial wound dehiscence (Table 3). The most commonly stated reasons for readmission were wound disruption (n = 19), deep surgical site infection (n = 12) and superficial surgical site infection (n = 8). No patients were readmitted for any cardiac complication. Unplanned reoperations were performed on 72 patients; irrigation and debridement for surgical site infection was the most common cause of reoperation (n = 25) followed by soft tissue debridement for wound dehiscence (n = 7), instrumentation revision (n = 6), and revision arthrodesis (n = 6).

Univariate analysis of postoperative complications in each group (those that did and did not have prior cardiac surgery) revealed that patients with a history of cardiac surgery were not at increased risk for any complication or a major complication. Inotropic medication use was significantly associated with the incidence of any postoperative complication (85% vs. 64.7%, p < .001). Neither previous cardiac surgery nor bronchopulmonary dysplasia individually influenced the rate of any postoperative complication within 30 days of surgery.

Risk factors for major postoperative complications included increased blood transfusion requirement (4% with vs. 6.6% without, p = .002), bronchopulmonary dysplasia (12.4% with vs. 4.95% without, p < .001), combined bronchopulmonary dysplasia and previous cardiac surgery (21.05%

with vs. 5.57% without, p = .004), and neuromuscular diagnosis (3.78% vs. 12.5% with neuromuscular diagnosis, p < .001). When investigating cardiac-specific complications, including blood transfusion requirements and cardiac arrest requiring cardiopulmonary resuscitation (CPR), the use of inotropic medications was significantly associated with an increase in total blood transfusion (p < .001), whereas bronchopulmonary dysplasia was associated with a higher incidence of cardiac arrest (1.6% vs. 0.09%, p < .001). Patients who necessitated blood transfusion were at a significantly increased risk for a major complication with a significantly higher total blood volume transfused in patients who had a major postoperative complication (p < .001, 95% confidence interval 412.43–620.14 mL vs. 257.16–284.53 mL). A multivariate analysis was performed using bronchopulmonary dysplasia, inotropic medications, previous cardiac surgery, neuromuscular diagnosis, and combined bronchopulmonary dysplasia and previous cardiac surgery. Only neuromuscular diagnosis was predictive of a major postoperative complication (p < .001, OR 3.2).

Discussion

There was a trend toward increased major and minor complications in our cardiac surgery cohort relative to the overall complication rate. Although there was no significant association with cardiac surgery in patients with CHD undergoing PSF, we identified several risk factors for major postoperative complications, such as blood transfusion, bronchopulmonary dysplasia, combined bronchopulmonary dysplasia and previous cardiac surgery, and neuromuscular diagnosis. There were no perioperative deaths in our cohort, thereby strengthening prior authors' conclusions that PSF in CHD patients is an overall safe procedure. Our finding that CHD patients undergoing PSF have an increased complication rate, in particular with the above risk factors, is significant because this is the largest and most updated patient cohort as of this writing describing the complication profile of this patient population.

Scoliosis has been found to be more prevalent in children with CHD with an incidence of up to 34%, compared with ⩽3% in children with idiopathic scoliosis without CHD [8,9]. In 1991, Farley et al. described similar rates of progression in children with scoliosis both with and without CHD, which suggests that indicating a patient for surgical intervention should be performed independently, whether or not that patient also has CHD [10]. Taggart et al. [1] reported a complication rate of 27% (not including blood transfusion) after spinal fusion in CHD patients, compared with our rate of 10.9%. Taggart et al. concluded that although spinal fusion for scoliosis was generally safe in patients with CHD, children with a history of pulmonary hypertension were at increased risk for postoperative complications [1]. Further, they found a significant difference in complication rates in patients with pulmonary hypertension—a finding that was replicated in this study as a significant risk factor for major postoperative complications. It stands to reason that patients with a diagnosis of CHD in addition to prior cardiac surgical history would have an increased perioperative complication risk.

Generally, past literature has shown surgery to be safe in patients with CHD, although the perioperative complication profile in CHD patients undergoing PSF has previously only been reported in small sample sizes. As reported by Warner et al., they found a 6% incidence of perioperative complications in pediatric and adult patients with CHD undergoing both inpatient and ambulatory noncardiac surgery [11]. Given the significant advances in medical technology and perioperative care over the past two decades, these complication profiles are in need of an update. Ideally this update and future research in this area will be reported in a standardized fashion, namely, through widespread use of complication classification systems such as the Clavien-Dindo system used in this study.

Perez-Caballero et al. described complications after scoliosis surgery in a very small cohort of 18 CHD patients who had previously been surgically corrected, and found a 39% complication rate, including one perioperative death; however, their small sample size also calls into question the general applicability of their results [12]. In Taggart and colleagues' previously mentioned cohort of 64 patients with CHD who underwent spinal fusion for spinal deformity, the authors found a complication rate of 27%, the majority of which were minor (such as anemia, asthma, or pleural effusion), in the first month after spinal fusion, and were primarily seen in patients with pulmonary hypertension. Although their complications included one perioperative death, the authors ultimately concluded that spinal fusion is a safe procedure for most pediatric patients with CHD [1]. This is in contrast to the much lower postoperative complication rate seen in the adolescent idiopathic scoliosis population of 2.6% [13].

With respect to cardiac-specific complications, we found that the use of inotropic medication was significantly associated with postoperative complications and that their use was more common in patients who had undergone cardiac surgery, although we did not find that use of inotropic medications significantly increased the risk of complications in CHD patients who had previously undergone cardiac surgery. Our results show that the use of inotropic medications was significantly associated with an increased risk of total blood transfusion, which is notable given that we also found patients requiring blood transfusions were at a significantly greater risk for a major complication. We also found that bronchopulmonary dysplasia, although not associated with a higher incidence of overall complications, was associated with a higher incidence of cardiac arrest requiring CPR. In general, although causality cannot be implied, these results confirm that more complicated patients are at greater risk for perioperative complications.

Strengths of our study include our large cohort size of patients undergoing posterior spinal fusion for spinal deformity, specifically with a CHD diagnosis, using a standardized and up-to-date NSQIP-P database that is constantly audited and validated. Additionally, these data have high external validity given that it is a compilation of patient populations from around the United States, collected from numerous high-volume pediatric institutions without the regional bias or lack of patient heterogeneity that can be introduced in single-institution studies.

As a retrospective study, there are inherent limitations to this study, as well as limitations associated with database studies, specifically with data extraction from NSQIP-P database. The data are highly dependent on the quality and accuracy of the variables recorded by the host institutions. Inaccurate or omitted data points cannot be excluded and have the potential to significantly affect the reported outcomes. As NSQIP-P uses an eight-day sample cycle for data inclusion, data are collected from a small portion of patients undergoing surgery each year (46 days/annum) which holds the potential of selection bias. Additionally, institutions included within NSQIP-P consist predominately of tertiary care referral centers and treated patient may not accurately represent the overall patient population. As data are only collected up to 30 days postoperatively, this information is only a small snapshot of each patient's overall treatment course and may not be representative of their long-term complication profile. Further, our finding that use of inotropic medications was significantly associated with an increase in total blood transfusion may be attributable to a multifactorial cause and therefore we recommend further research exploring this relationship between inotropic medication administration and blood transfusion during PSF before attributing causality.

Conclusions

In summary, our results suggest that pediatric patients with a history of cardiac surgery may not have an increased risk of 30-day perioperative complications after spinal fusion surgery. Based on a comprehensive, broadly applicable, and updated complication profile, we identified blood transfusion, bronchopulmonary dysplasia, combined bronchopulmonary dysplasia with prior cardiac surgery, and a neuromuscular diagnosis as risk factors for postoperative complications in patients undergoing posterior spinal fusion. Further randomized controlled studies are needed to better identify causality between these risk factors and complications after spinal fusion in CHD patients.

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