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30-day Outcomes in Primary vs. Revision Posterior Spinal Fusion for Pediatric Spinal Deformity

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ABSTRACT

Objectives: Current evidence, with regard to primary vs. revision spinal fusions in pediatric spine deformities, is limited to inpatient outcomes only. The current study aims to analyze and compare 30-day outcomes in pediatric spine deformity patients undergoing a primary vs. a revision posterior spinal fusion.

Patients and methods: The 2012–2016 American College of Surgeons – National Surgical Quality Improvement Program (ACS-NSQIP) Pediatric database was queried using *Current Procedural Terminology* (CPT) codes for patients undergoing posterior spinal fusions (22800, 22802 and 22804). Patients undergoing concurrent anterior fusion/combined fusion and anterior-only fusions were removed from the study. Revision spinal fusions were captured using CPT codes for re-insertion of spinal fixation device (22830), exploration of spinal fusions (22849), 22850 and 22852 (removal of posterior instrumentation).

Results: Out of a total of 13,398 patients, 332 (2.5%) underwent a revision posterior spinal fusion and the remained underwent primary spinal fusion. Following adjustment for baseline clinical characteristics, patients undergoing revision posterior spinal fusions were at a higher risk of deep surgical site infections (OR 2.43 [95% CI 1.10–5.35]; p = 0.028), organ/space surgical site infections (OR 4.09 [1.19–14.04]; p = 0.025) and 30-day unplanned re-operations (OR 1.87 [95% CI 1.17–3.00].

Conclusions: Pediatric spine deformity patients undergoing revision spinal fusions are at a higher risk of experiencing wound-complications and subsequent unplanned re-operations within 30-days of surgery. Providers should promote careful wound-care and/or awareness among care-givers to minimize the risks and costs associated with these specific adverse outcomes.

1. Introduction

Spinal deformities in the pediatric population can pose a significant obstacle in a growing child's life, by negatively influencing physical function as well as causing possible emotional impact due to the psychological perception of an impaired body image [1,2]. While most cases of mild scoliosis can be managed conservatively, a growing number of patients with significant curve progression [3] and cardiopulmonary compromise [4] ultimately require spinal fusion for relief of symptoms. While spinal fusions have been shown to improve the quality-of-life in these patients [5,6], the procedure is associated with significant morbidity [7,8].

A recently published review in the *Journal of American Academy of Orthopaedic Surgeons* reported that nearly 10% of pediatric patients who undergo surgery for spinal deformity ultimately require a revision procedure [9]. Recent evidence-based literature has concluded that infections, implant-related complications, pseudoarthrosis and curve-progression are the most likely indications for undergoing a revision surgery following the index procedure for pediatric spine deformity [10]. While revision surgery has been shown to be associated with higher risks of adverse outcomes as compared to index procedures in adult spinal deformities [11], current evidence regarding differences in outcomes between primary vs. revision pediatric spine deformity surgery is scarce. To our knowledge, only one study has compared outcomes between primary and revision spinal fusions for pediatric deformities using an inpatient-only database, with the study authors concluding that spinal refusion procedures in pediatric spinal deformities have significantly higher complication rates as compared to primary surgeries [12]. With the inherent limitations associated with utilization of an inpatient-only database, as well as a relative absence of clinically beneficial literature on the relevant topic-of-interest, the current study, using a national surgical database with a 30-day follow-

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Table 1
Baseline clinical characteristics.

Clinical characteristic	Primary Fusion	Revision Fusion	P-value
Demographics			
Age (years)			**< 0.001**
< 12	1381 (10.6%)	82 (24.7%)	
12-14	3857 (29.5%)	83 (25.0%)	
15-17	3588 (27.5%)	59 (17.8%)	
> 17	4240 (32.5%)	108 (32.5%)	
Gender			**< 0.001**
Male	3939 (30.1%)	134 (40.4%)	
Female	9127 (69.9%)	198 (59.6%)	
BMI (kg/m2)			**< 0.001**
< 20	6119 (46.8%)	198 (59.6%)	
20-30	5857 (44.8%)	105 (31.6%)	
> 30	1090 (8.3%)	29 (8.7%)	
Race			0.107
White	9289 (71.1%)	252 (75.9%)	
Black or African American	2096 (16.0%)	50 (15.1%)	
Asian	308 (2.4%)	8 (2.4%)	
Native Hawaiian or Pacific Islander	31 (0.2%)	2 (0.6%)	
American Indian or Alaska Native	32 (0.2%)	0 (0%)	
Unknown/Not Reported	1310 (10.0%)	20 (6.0%)	
Co-morbidities			
Chronic steroid use	144 (1.1%)	8 (2.4%)	**0.026**
Ventilator dependence	365 (2.8%)	24 (7.2%)	**< 0.001**
Asthma	1189 (9.1%)	43 (13.1%)	**0.016**
Chronic lung disease	565 (4.3%)	41 (12.3%)	**< 0.001**
Oxygen support	232 (1.8%)	15 (4.5%)	**< 0.001**
Tracheostomy	203 (1.6%)	15 (4.5%)	**< 0.001**
Structural pulmonary abnormality	754 (5.8%)	48 (14.5%)	**< 0.001**
Esophageal/Gastric/Intestinal disease	1287 (9.8%)	57 (17.2%)	**< 0.001**
Previous cardiac surgery	497 (3.8%)	27 (8.1%)	**< 0.001**
Development delay	2639 (20.2%)	133 (40.1%)	**< 0.001**
Seizure disorder	117 (9.0%)	40 (12.0%)	0.057
Cerebral palsy	1162 (8.9%)	45 (13.6%)	**0.003**
CNS abnormality	1725 (13.2%)	83 (25.0%)	**< 0.001**
Neuromuscular disorder	2798 (21.4%)	127 (38.3%)	**< 0.001**
Pre-operative transfusion	156 (1.2%)	3 (0.9%)	0.630
Nutritional support requirement	938 (7.2%)	48 (14.5%)	**< 0.001**
Hematologic disorders	247 (1.9%)	6 (1.8%)	0.912
Intropic use prior to surgery	269 (2.1%)	5 (1.5%)	0.482
ASA Grade			**< 0.001**
I-II	2424 (18.6%)	13 (3.9%)	
> II	10642 (81.4%)	319 (96.1%)	
Operative Data			
Type			**< 0.001**
Idiopathic	10265 (78.6%)	181 (54.5%)	
Neuromuscular	970 (7.4%)	25 (7.5%)	
Congenital	572 (4.4%)	32 (9.6%)	
Other/Non-Idiopathic	1259 (9.6%)	94 (28.3%)	
Fusion Length			**< 0.001**
Up to 6 segments	1481 (11.3%)	137 (41.3%)	
7-12 segments	7219 (55.3%)	91 (27.4%)	
> 12 segments	4366 (33.4%)	104 (31.3%)	
Osteotomy	3925 (30.0%)	93 (28.0%)	0.426
Fixation to pelvis	1062 (8.1%)	30 (9.0%)	0.550
Use of intervertebral biomechanical device	55 (0.4%)	4 (1.2%)	**0.033**
Operative time (mins)			0.653
0-240	5036 (38.5%)	132 (39.8%)	
> 240	8030 (61.5%)	200 (60.2%)	

up period, aims to understand whether there is a difference in 30-day outcomes between patients undergoing a primary vs. revision posterior spinal fusion for pediatric deformity.

2. Materials and methods

2.1. Database and patient inclusion/exclusion criteria

This was a retrospective cohort study performed using data from the American College of Surgeons – National Surgical Quality Improvement Program (ACS-NSQIP) Pediatric database [13]. The ACS-NSQIP Pediatric database is a comprehensive and well-audited surgical registry containing records of pediatric patients undergoing various surgical procedures from more than 100 hospitals across the United States. The data is recorded by trained surgical clinical reviewers (SCRs), using a thorough review guideline/protocol – the details of which can be found on the ACS-NSQIP website [13]. Due to the regular auditing cycles of the database, the data have been shown to have excellent validity with inter-reviewer disagreement rates to be below 2%. *Current Procedural Terminology* codes 22800, 22802 and 22804 were used to query the database for pediatric deformity patients undergoing posterior spinal fusions. Revision procedures were identified by the presence of *Current Procedural Terminology* codes for re-insertion of spinal fixation device (22830), exploration of spinal fusion (22849), removal of posterior non-

Table 2
Unadjusted 30-day outcomes between primary vs. revision posterior spinal fusions.

Outcome	Primary	Revision	P-value
Length of stay > 4 days	6229 (52.3%)	191 (57.5%)	0.061
Any complication	630 (4.8%)	25 (7.5%)	**0.024**
Superficial SSI	104 (0.8%)	3 (0.9%)	0.828
Deep SSI	101 (0.8%)	7 (2.1%)	**0.007**
Organ/Space SSI	20 (0.2%)	3 (0.9%)	**0.001**
Wound dehiscence	67 (0.5%)	1 (0.3%)	0.592
Pneumonia	145 (1.1%)	3 (0.9%)	0.723
Unplanned intubation	110 (0.9%)	7 (2.1%)	**0.014**
Pulmonary embolism	3 (< 0.1%)	1 (0.3%)	**0.004**
Renal insufficiency	11 (0.1%)	0 (0%)	0.597
Acute renal failure	5 (< 0.1%)	1 (0.3%)	**0.025**
Urinary tract infection	99 (0.8%)	5 (1.5%)	0.125
Coma	2 (< 0.1%)	0 (0%)	0.822
Stroke	5 (< 0.1%)	0 (0%)	0.721
Seizure	5 (< 0.1%)	0 (0%)	0.721
Peripheral nerve injury	45 (0.3%)	1 (0.3%)	0.894
Cardiac arrest	18 (0.1%)	1 (0.3%)	0.434
Graft failure	4 (< 0.1%)	0 (0%)	0.750
Venous thromboembolism	12 (0.1%)	1 (0.3%)	0.226
Sepsis	85 (0.7%)	3 (0.9%)	0.573
Central line infection	5 (< 0.1%)	0 (0%)	0.721
Bleeding requiring transfusion	8493 (65.0%)	184 (55.4%)	< **0.001**
Mortality	12 (0.1%)	0 (0%)	0.581
30-day readmission	473 (3.6%)	19 (5.7%)	**0.044**
30-day re-operations	372 (2.8%)	22 (6.6%)	< **0.001**

segmental instrumentation (22850), removal of posterior segmental instrumentation (22852) occurring in conjunction with codes for fusion (22800, 22802 and 22804). Patients undergoing anterior-only fusions and concurrent anterior-posterior/combined fusions were removed from the database to ensure that a homogenous set of patients undergoing posterior-only fusions were compared. Additionally, patients with missing data with regard to demographics and surgical complications were also removed from the database to prevent introduction of any bias in the results.

2.2. Data/variables collected

Data that was collected from the database was grouped into the following categories for ease of referral – 1) Demographics (age, gender, BMI, race), co-morbidities, operative data (type of scoliosis – idiopathic, neuromuscular, congenital and other/non-idiopathic, fusion length (< 7 segments, 7–12 segments and > 12 segments), use of osteotomy, fixation to pelvis, use of intervertebral biomechanical device and total operative time (< 240 min., > 240 min.). Outcomes data included length of stay (dichotomized into ≤4 days and > 4 days), superficial surgical site infections (SSIs), deep SSIs, organ/space SSIs, wound dehiscence, pneumonia, unplanned intubations, pulmonary embolism, renal insufficiency, acute renal failure, urinary tract infection, coma, stroke, seizure, peripheral nerve injury, cardiac arrest, graft failure, venous thromboembolism, sepsis, central line infection and bleeding requiring transfusion within 30-days of the procedure. An additional variable defined as “Any complication” recorded the presence of any of the above-mentioned complications, with the exception of bleeding requiring transfusion. Additionally, 30-day mortality, 30-day readmissions and 30-day re-operations were also assessed as part of the study.

2.3. Statistical analysis

Univariate analysis, using Pearson Chi-square tests, were used to assess for significant baseline differences in demographic, co-morbidities and operative data between the two groups. Univariate analysis was also used to assess for the presence of significant associations between 30-day outcomes and type of surgery (primary vs. revision). Any 30-day outcome variable with a p-value < 0.05 was then entered into a multivariate logistic regression model to assess the independent impact of type of surgery (primary vs. revision) on the post-operative outcome, while accounting for all baseline differences in demographics, co-morbidities and operative variables using a backward-elimination approach, with entry at p = 0.05 and removal at p = 0.1. Results from multivariate regression models have been reported as adjusted odds ratio (OR) with 95% confidence intervals (CI). For all statistical purposes, a p-value of less than 0.05 was considered significant.

3. Results

3.1. Baseline clinical characteristics

Following application of inclusion/exclusion criteria, a total of 13,398 patients were included in the study. Out of 13,398 patients, 332 (2.5%) underwent a revision spinal fusion procedure. Based off results from univariate analyses, patients undergoing a revision surgery were more likely to be younger (< 12 years), male gender, have lower BMIs and have multiple co-morbidities. A complete description of baseline clinical characteristics can be seen in Table 1. All variables from Table 1 were considered as co-variates and were adjusted for in subsequent regression models.

3.2. 30-day outcomes

Unadjusted analysis showed that patients undergoing a revision vs. a primary fusion were significantly likely to experience the occurrence of any complication (7.5% vs. 4.8%; p = 0.024), deep SSI (2.1% vs. 0.8%; p = 0.007), organ/space SSI (0.9% vs. 0.2%; p = 0.001), unplanned intubation (2.1% vs. 0.9%; p = 0.014), pulmonary embolism (0.3% vs. ˜0%; p = 0.004), acute renal failure (0.3% vs. ˜0%; p = 0.025), 30-day readmissions (5.7% vs. 3.6%; p = 0.044), 30-day re-operations (6.6% vs. 2.8%; p < 0.001) (Table 2).

Following adjustment for all demographic, co-morbidities and operative variables using a backward elimination based regression model, a revision vs. a primary posterior spinal fusion was independently associated with significantly higher odds of deep SSI (OR 2.43 [95% CI 1.10–5.35; p = 0.028), organ/space SSI (OR 4.09 [95% CI 1.19–14.04]; p = 0.025) and 30-day re-operations (OR 1.87 [95% CI 1.17–3.00]; p = 0.009) (Table 3). Following adjustment, revision surgeries were not associated with higher odds of 30-day readmissions (p = 0.396), bleeding requiring transfusion (p = 0.107), acute renal failure (p = 0.171), pulmonary embolism (p = 0.999), unplanned intubation (p = 0.285) and the occurrence of any complication (p = 0.618).

Table 3
Multivariate analysis assessing impact of revision surgery on 30-day outcomes following pediatric spine fusions. Adjusted for age, gender, BMI, race, all co-morbidities, ASA grade, type of scoliosis, fusion length, use of osteotomy, use of intervertebral biomechanical device and total operative time. Reference: Primary.

Outcome	Adjusted OR [95% CI]	P-value
Any complication	1.12 [0.72-1.73]	0.618
Deep SSI	2.43 [1.10-5.35]	**0.028**
Organ/Space SSI	4.09 [1.19-14.04]	**0.025**
Unplanned intubation	1.58 [0.68-3.64]	0.285
Pulmonary embolism	–	0.999
Acute renal failure	9.39 [0.38-231.30]	0.171
Bleeding requiring transfusion	0.82 [0.64-1.05]	0.107
30-day readmissions	1.24 [0.76-2.03]	0.396
30-day re-operations	1.87 [1.17-3.00]	**0.009**

4. Discussion

While revision spinal fusions in pediatric deformities are relatively uncommon, as evidenced by an incidence of 2.5% in our study, these surgeries are associated with significant morbidity as compared to primary spinal fusions. By analyzing a national surgical database with an adequate follow-up period of 30-days post-procedure, the current study's results show that revision posterior spinal fusions are associated with higher risks of serious wound complications (deep and organ/space SSIs) and subsequent 30-day re-operations.

While the indications for a revision surgery following a primary spinal fusion in pediatric deformities remain diverse, it is important to understand that the revision procedure is a technically challenging surgery, which can be associated with a significant financial burden on the health-care system and causes significant emotional distress to patients and care-givers/parents alike. The overall complication rate noted in our study was 7.5%, with wound complications amounting to 3.9%. This finding is similar to a past Scoliosis Research Society (SRS) database study analyzing more than 23,918 pediatric spinal deformity cases and showing a wound-complication rate of 4% in revision procedures [14].

In another single-center institutional review of 50 pediatric deformity patients, Yagi et al found that an overall complication rate of 14% [15]. With the current study showing an overall complication rate of 7.5% it is probable that the smaller sample size in the study by Yagi et al may yield an inherent bias in the results. Perhaps, the most recent broad-based and nationally representative study is that involving the NIS database by De La Garza Ramos et al. The authors reported an overall complication rate of 16.7% by analyzing more than 72,000 pediatric spinal fusion surgeries [12]. The differences in the overall complication rates between the NIS study and ours can be explained by a multitude of reasons. Firstly, the NIS is an inpatient-only administrative database which relies on the use of codes to analyze complications. The inherent risk of mis-coding with administrative data may yield an inherent bias to the results. Secondly, the authors studied all types of spinal fusions (anterior, posterior and combined) which have been shown to be associated with different rates of outcomes in adult spinal literature [16,17]. Finally, the NIS database captures only inpatient data in contrast to our study which looks at overall 30-day outcomes. It is important to also mention that the NSQIP database only records a set number of outcomes, based on chart-review, and therefore while the data is reported to be accurate, it potentially lacks the recording of other spine-related adverse events such as respiratory failure, dural tears, implant-related complications and iatrogenic nerve/vessel damage during surgery. The lack of data with regard to the latter complications may be another reason for the differences in reported outcomes between our study and past reported literature. It is also interesting to mention that in contrast to our findings reported no differences in hospital stay between primary vs. revision spinal fusions, the study by De La Garza Ramos et al reported a significantly longer length of stay for revision procedures. The NSQIP database contains data largely from academic medical centers where there is an increased focus towards adoption of health policies aimed at reducing the costs associated with a prolonged length of stay. This hypothesis is further supported by the data from our study reporting a mean length of stay for primary vs. revision posterior spinal fusions to be 5.3 vs. 5.8 days in contrast to the former study by De La Garza Ramos et al reporting an average length of stay of 7.9 days for revision and 6.6 for primary spinal fusions, in pediatric deformities, using the NIS dataset, which is a 20% stratified sample from community hospitals all across the United States.

Similar differences between primary and revision adult spinal deformity surgeries have been reported. Diebo et al analyzed more than 9000 cases of patients undergoing spinal deformity surgery using the Nationwide Inpatient Sample (NIS) database and found revision surgeries to be associated with higher odds of procedure-related complications, such as hematoma/seroma formation, post-operative wound infections and dehiscence, as compared to primary surgeries [11].

When translating the findings to clinical practice, providers should consider disseminating pictorial guides regarding wound-care to care-givers/parents following posterior spinal fusions in pediatric deformities [18]. Another alternative would be to consider risk-stratifying patients to identify those who may be at a higher risk of wound complications and subsequently discharging these patients to post-acute care facilities for continued care, under surveillance. This may be particularly helpful in catching a potential growing surgical site infection early-on, and allow providers to launch appropriate optimization strategies to prevent an untoward re-admission associated with re-operation.

While the study expands on the findings of past literature with a longer follow-up period, it is not without limitations. Firstly, the NSQIP database only records data up to 30 days following the procedure. This is particularly important given that recent literature has shown that surgical site infections are known to occur well beyond the 30-day period [19,20]. Future research power-houses should focus on construction of databases with a longer follow-up period to ensure that most complications are accurately captured to allow appropriate analysis to take place. The NSQIP database also does not contain information with regard to whether patients received intra-operative antibiotics which may influence the rate of infections in the post-operative period. The database also lacks granular clinical data with regards to severity of curve progression as well as indications for why the revision surgery took place.

Despite the limitations, the current study's findings build upon evidence from past literature by analyzing outcomes over a longer follow-up period to identify higher rates of wound-complications and re-operations in pediatric deformity patients undergoing a revision vs. a primary posterior spinal fusion surgery. Pediatric deformity patients undergoing revision spinal fusions would benefit from enhanced risk-stratification and subsequent increased awareness regarding adverse outcomes among caregivers.

Disclosures

The American College of Surgeons National Surgical Quality Improvement Program and the hospitals participating in the ACS NSQIP are the source of the data used herein; they have not verified and are not responsible for the statistical validity of the data analysis or the conclusions derived by the authors.

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