

Hospital Burdens of Patients With Cerebral Palsy Undergoing Posterior Spinal Fusion for Scoliosis

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Abstract

Study Design: Retrospective cohort study.

Objectives: Many patients undergoing posterior spinal fusion (PSF) for scoliosis have concurrent cerebral palsy (CP), which is associated with many medical comorbidities and inherent operative risk. We aimed to quantify the contribution of CP to increased cost, length of stay (LOS), and complication rates in patients with scoliosis undergoing PSF.

Methods: Using the National Inpatient Sample database, we collected data regarding patient demographics, hospital characteristics, comorbidities, in-hospital complications, and mortality. Primary outcomes included complications, hospital LOS, and total hospital costs. Multivariate regression models assessed the contribution of CP to in-hospital complications, discharge status, and mortality. Linear regression identified the contribution of a diagnosis of CP on hospital LOS and inflation-adjusted cost.

Results: Cerebral palsy was an independent predictor of several complications. The most striking differences were seen for mortality (odds ratio [OR]: 3.40, $P < .001$), a postoperative requirement for total parenteral nutrition (OR: 3.16, $P < .001$), urinary tract infection (OR: 2.75, $P < .001$), surgical site infection (OR: 2.67, $P < .001$), and pneumonia (2.21, $P < .001$). Patients with CP ultimately cost an additional \$13 482 ($P < .001$) with a 2.07-day greater LOS ($P < .001$) than patients without CP.

Conclusion: Most complications were seen in higher rates in the CP cohort, with higher cost and LOS in patients with CP versus those with idiopathic scoliosis (IS). Our findings represent important areas of emphasis during preoperative consultations with patients with CP and their families. Extra care in patient selection and multifaceted treatment protocols should continue to be implemented with further investigation on how to mitigate common complications.

Keywords

cerebral palsy, cost, spinal fusion, pediatric, complication, scoliosis, burden

Introduction

Scoliosis is a common pathology of the spine. Progressive or severe deformities are often corrected by posterior spinal fusion (PSF), effectively reducing potential for future morbidity.^{1–5} These procedures are extremely costly, hospital length of stay (LOS) after PSF is significant, and complications can be substantial.^{6,7} Idiopathic scoliosis (IS) arises in patients without concomitant disease related to the spinal deformity, while neuromuscular scoliosis (NMS) occurs in patients who have one of several varying neurological conditions.⁸ Cerebral palsy (CP) is neurological disorder that is a leading cause of disability in children. Many patients undergoing PSF for scoliosis have concurrent CP^{9,10}. By the age of 20 years, roughly 75% of patients

with CP have a Cobb angle $\geq 40^\circ$.¹¹ Additionally, CP is associated with a host of medical comorbidities.^{12–14} Decision to operate on such patients, therefore, lies in careful assessment of curve progression and morbidity associated with this deformity weighed against concomitant comorbidities and inherent

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operative risk of these complex patients. This ultimately requires understanding of the degree of risk of complications in patients undergoing PSF for NMS with CP.

We aimed to quantify the contribution of CP to increased cost, LOS, and complication rates in patients with scoliosis undergoing PSF. While large national database studies certainly exist characterizing the increased complication rates seen after PSF in patients with NMS versus those with IS,¹⁰ to date a database study that focuses specifically on the relative risk of patients with CP undergoing this procedure has not been produced. It is commonly understood that patients with CP will experience higher rates of complications, higher costs, and longer LOS after PSF versus those without this condition.¹⁵⁻²⁰ Still, it is valuable to place numeric odds ratios on risk of in-hospital complications and to generate actual cost and LOS values of patients with CP undergoing PSF as compared to the IS cohort. Thus, the purpose of this study is to provide exact odds ratios for development of complications after PSF as well as specific numbers for increase in cost and LOS seen with patients with CP using a weighted national database. We hypothesize that a diagnosis of CP will lead to significant increases in complication rate, cost, and LOS after corrective surgery for scoliosis.

Methods

Data Source

The National Inpatient Sample (NIS) is well known to be not only the largest but one of the most valid and reliable all-payer inpatient databases for epidemiological studies.²¹ The NIS provides annual admission and discharge data from a 20% stratified sample of all hospitals, being sure to conceal patient identity and prevent identification to maintain Health Insurance Portability and Accountability Act (HIPAA) compliance.

Inclusion Criteria

This study was exempt from institutional review board clearance given the nonidentified data in the NIS. The NIS was queried from 2003 to 2015 for all patients up to age 25 undergoing PSF for IS and NMS. Fusion level was defined by ICD-9-CM (International Classification of Disease, 9th Revision, Clinical Modification) procedure codes 81.63 (fusion or refusion of 4-8 vertebrae) and 81.64 (fusion or refusion of 9 or more vertebrae). We removed outliers of patients undergoing PSF of less than 4 fusion levels as these procedures were thought to be considerably less intensive than larger spinal fusions, and therefore likely to confound data relating to surgical and medical complications. From this final population, a subset of patients with a concurrent diagnosis of CP was identified through ICD-9 codes. Data was taken from before the ICD-10 era to avoid coding errors.

Parameters of Interest

Data regarding patient demographics, hospital characteristics, comorbidities, in-hospital complications, and mortality was

retrieved. Patient comorbidities were stratified using the Elixhauser comorbidity index.^{22,23} The categorical age variable was defined using age group 0 to 11, 11 to 14, and 15 to 17. Primary insurance was defined as Medicaid, Medicare, private, or other. Hospital characteristics were also determined since PSF is often undertaken in larger, tertiary referral hospital centers. Therefore, an effort to control for the size and location of the hospital was made. These characteristics included hospital capacities by bed size (small, medium, and large), location/teaching status (rural vs urban teaching vs urban nonteaching), and hospital region (Northeast vs Midwest vs South vs West).

Outcome Variables

The primary outcomes included complication, hospital LOS, and total hospital costs. Complications were defined using ICD-9-CM codes as follows: neurologic injury, wound dehiscence, transfusion, hemorrhage, device complications, septicemia, respiratory distress, abdominal complications, pneumonia, surgical site infection (SSI), urinary tract infection (UTI), total parenteral nutrition, mortality, and non-home discharge. Conversion of NIS provided total hospital "charges" to total "costs" was conducted by the HCUP cost-to-charge ratio files.²⁴

Statistical Analysis

Separate multivariate regression models were run to assess the contribution of CP to in-hospital complications, discharge status, and mortality, while controlling for patient demographics, comorbidities, and hospital-level confounders. Through coarsened-exact matching, patients were matched on demographics and comorbidities to create a comparable cohorts of patients.²⁵ Linear regression was then performed to identify the contribution of a diagnosis of CP on hospital LOS and inflation-adjusted cost.

Results

Out of 70 564 patients undergoing PSF for IS or NMS secondary to CP, 4618 (6.6%) had a diagnosis of CP. Demographic variables, seen in Table 1, were generally evenly distributed. Of note, patients with private insurance outnumbered with a frequency of 66.9%, urban-teaching hospitals with a frequency of 90.3%, large hospitals with a frequency of 54.5%, patient age 11 to 17 with a frequency of 77.2%, fusion level of 9 or more vertebra with a frequency of 23.3%, and female sex with a frequency of 75.5%.

For all patients, the most common complications were postoperative hemorrhage (15.4%), abdominal complications (4.5%), and respiratory distress (4.0%). In-hospital mortality was seen in 47 patients (0.07%). CP was an independent predictor of several complications including mortality (odds ratio [OR]: 3.40, $P < .001$), a postoperative requirement for total parenteral nutrition (OR: 3.16, $P < .001$), UTI (OR: 2.75, $P < .001$), SSI (OR: 2.67, $P < .001$), and pneumonia (2.21, $P < .001$). Patients with CP also had an increased risk of non-

Table 1. Demographics and Analysis of Trends in Spinal Fusion Surgery for Pediatric and Adolescent NMS.

Variable	Frequency (%)
Payer	
Medicare	177 (0.3%)
Medicaid	16 127 (26.3%)
Private	41 020 (66.9%)
Other	4003 (6.5%)
Median household income national quartile for patient ZIP code	
\$1 to \$47 999	13 481 (22.0%)
\$48 000 to \$60 999	14 366 (23.4%)
\$61 000 to \$81 999	15 837 (25.8%)
\$82 000+	17 643 (28.8%)
Location/teaching status of hospital (Strata)	
Rural	578 (0.9%)
Urban—nonteaching	5341 (8.7%)
Urban—teaching	55 409 (90.3%)
Hospital region	
Northeast	10 231 (16.7%)
Midwest	13 513 (22.0%)
South	24 997 (40.8%)
West	12 586 (20.5%)
Bed size of hospital (Strata)	
Small	11 724 (19.1%)
Medium	16 152 (26.3%)
Large	33 452 (54.5%)
Patient age (years)	
0-10	2287 (3.7%)
11-16	47 374 (77.2%)
17-25	11 666 (19.0%)
Fusion level	
Fusion of 4-8 vertebrae	47 019 (76.7%)
Fusion of 9 or more vertebrae	14 309 (23.3%)
Condition	
AIS	65 946 (93.4%)
CP	4618 (6.6%)
Sex	
Female	46 272 (75.5%)
Male	15 055 (24.5%)
Total	70 564 (100%)

Abbreviations: AIS, adolescent idiopathic scoliosis; CP, cerebral palsy.

home discharge (OR: 3.71, $P < .001$). All significant complications, their frequencies, and associated odds ratios are listed in Table 2. A visual representation is also shown in Figure 1. With regard to total cost to hospital LOS, a patient with CP ultimately cost an additional \$13 482 ($P < .001$) and had a 2.06-day greater LOS ($P < .001$) than a patient without CP, shown in Table 3.

Discussion

This work represents the utilization of the largest sample size to date evaluating the impact of CP on complications, cost, and LOS after PSF for NMS. In multivariate analysis, virtually all complications were seen in higher rates in the CP cohort, and cost and LOS were substantially higher in patients with CP versus those with IS. These findings merit further discussion,

Table 2. Multivariate Analysis of Complications and Their Associations With Cerebral Palsy.

Complications	Frequency (%)	CP (OR)	95% CI	P
Neurologic injury	298 (0.5%)	1.46	1.01, 2.11	.046
Wound dehiscence	419 (0.6%)	1.65	1.27, 2.13	<.001
Transfusion	15 964 (24.2%)	1.74	1.63, 1.87	<.001
Hemorrhage	10 158 (15.4%)	1.77	1.44, 2.18	<.001
Device complications	1032 (1.6%)	1.79	1.49, 2.16	<.001
Septicemia	155 (0.2%)	1.90	1.30, 2.76	<.001
Respiratory distress	2715 (4.0%)	2.00	1.80, 2.24	<.001
Abdominal complications	2987 (4.5%)	2.03	1.80, 2.28	<.001
Pneumonia	715 (1.1%)	2.21	1.82, 2.67	<.001
Surgical site infection	303 (0.5%)	2.67	2.00, 3.57	<.001
Urinary tract infection	797 (1.2%)	2.75	2.27, 3.32	<.001
Total parenteral nutrition	656 (1.0%)	3.16	2.62, 3.82	<.001
Mortality	47 (0.07%)	3.40	1.71, 6.77	<.001
Non-home discharge ^a	1118 (1.8%)	3.71	3.18, 4.34	<.001

Abbreviations: CP, cerebral palsy; OR, odds ratio; CI, confidence interval.

^aData for discharge destination only available after 2005.

as they represent important areas of emphasis during preoperative consultations with patients and family.

Analysis of Complications

Complication rates in patients with CP undergoing PSF for NMS can be high, necessitating utmost care in surgical decision making. A recent meta-analysis compiling 15 years of available literature in pediatric populations treated surgically reported complication rates that are very high: pulmonary complications (22.71%), implant complications (12.71%), and infections (10.91%) were among the highest reported rates.²⁶ A total of 28.2% of these patients experienced postoperative respiratory complications of some kind.²⁶ Our complications were not pooled into general categories, but instead were reported as specific diagnoses, making comparisons with this data difficult. Still, 2 categories of complications emerge as significant contributors to the burden of disease for patients with NMS undergoing PSF: (1) respiratory complications and (2) infectious complications. These 2 categories warrant further discussion.

Respiratory Complications

Respiratory distress, seen in 4.0% of our sample population at an odds ratio of 2.00× for the CP cohort, was the most common respiratory complication seen in our study. Of note, our study population only underwent PSF with no anterior surgical inventions such as thoracotomy or VATS procedures. This finding may not come as a surprise to those familiar with the management of complex scoliosis patients: the deformity very commonly impairs respiratory mechanics.⁸ In addition to higher likelihood of respiratory distress, CP patients

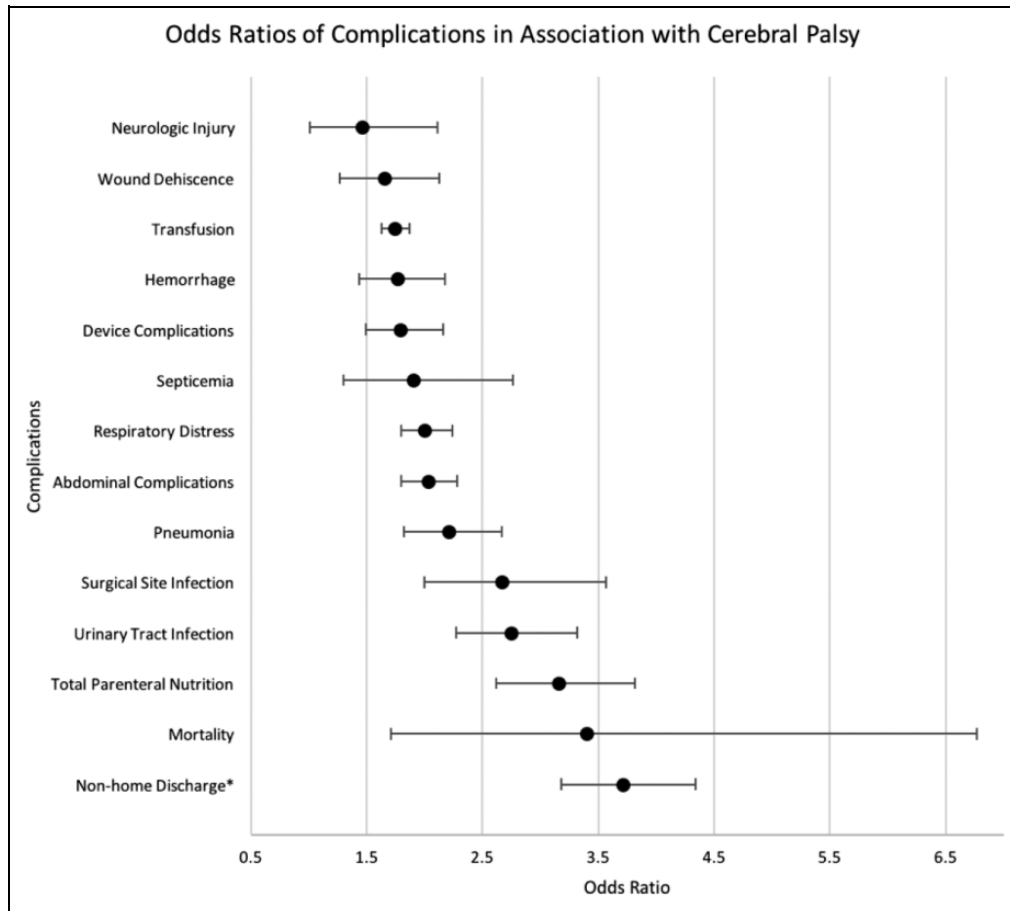


Figure 1. Odds ratios of complications associated with cerebral palsy.

Table 3. Multivariate Analysis of Cost and LOS and Their Association With Cerebral Palsy.

Factors	AIS	CP	Difference	P
Cost	\$61 218	\$74 700	\$13 482	<.001
Length of stay	6.39 days	8.45 days	+2.06	<.001

Abbreviations: LOS, length of stay; AIS, adolescent idiopathic scoliosis; CP, cerebral palsy.

experienced a 2.21 × odds ratio for development of pneumonia after PSF. As a potential solution to reduce the rate of respiratory complications seen after these procedures, the literature proposes the use of noninvasive positive pressure ventilation (NPPV). In a recent series, complete prevention of respiratory complications was achieved in a cohort of patients undergoing scoliosis correction procedures by the use of postoperative NPPV in addition to preoperative respiratory training.²⁵

Despite the described high risk of respiratory complications, poor preoperative respiratory function should not necessarily be considered grounds for contraindication to PSF. Patients can actually recover a tremendous degree of respiratory capacity after this procedure, greatly enhancing quality of life and reducing burden of disease.²⁷ Careful risk-benefit assessment

of the CP patient with poor respiratory function and NMS who is a candidate for PSF is imperative, in consultation with pulmonary specialists, and we urge providers to utilize the odds ratios reported in this study in their decision making regarding proceeding with operative management.

Infectious Complications

Our analysis demonstrated high rates of infectious complications in patients with CP undergoing PSF. Odds ratios for development of postoperative UTI and SSI were 2.67 × and 2.75 ×, respectively. A recent series of 466 patients showed a strong correlation between UTI and SSI after instrumented spinal procedures.²⁸ SSI causes significant morbidity and cost-contribution across surgical disciplines. It has been the focus of much investigation.²⁹⁻³⁵ A recent systemic review indicated the following risk factors as significantly associated with development of postoperative SSI after pediatric scoliosis surgery: inappropriate antibiotic use, NMS, instrumentation, increased hospital stay days, and residual postoperative curve as risk factors for SSI after pediatric scoliosis surgery.³⁶ These issues constitute areas of potential focus for intervention in SSI reduction strategies, and the documented risk factor of NMS for SSI is consistent with the results of our analysis.

Analysis of Cost and Length of Stay

Our findings reiterate the need for careful cost-benefit analysis when choosing to operate on patients with CP. An additional cost of \$13 482 and LOS of 2.07 days of PSF in patients with CP, especially in addition to documented increased complication rates, mandates careful patient selection. Of note, a study utilizing the NIS (1997-2003) to compare patients undergoing scoliosis surgery with NMS versus other causes of scoliosis found that NMS was associated with increased hospital LOS (10.3 vs 7.7 days) and hospitalization total cost (\$80 251 vs \$62 154).³⁷ A more recent study evaluating the NIS from 2002 to 2011 showed an even greater cost differential between NMS and other forms of scoliosis (\$36 805 vs \$65 244) with an LOS of 9.21 versus 6.70 days between the 2 cohorts.¹⁰ These 2 studies report a cost differential of +\$18 097 and +\$28 439 and an LOS differential of +2.6 days and +2.51 days when comparing NMS to other forms of scoliosis; higher numbers than our reported values of +\$13 482 and +2.07 days. This finding suggests that forms of NMS other than CP might represent higher comorbidity burdens leading to increased LOS and cost, although this is beyond the scope of the present study. Additionally, our more recent sampling (2003-2015) may indicate that perioperative procedure has improved in recent years for complex patients, driving the costs of PSF in patients with NMS (including those with CP) down and narrowing the gap in economic burden between IS and NMS.

Much research has been targeted at reducing costs associated with procedures of the spine. In the adult deformity cohort, the use of cell saver has shown to be cost-efficient above an estimated blood loss of 614 mL.³⁸ Given an odds ratio of 1.74 for need for postoperative transfusion after PSF in the CP cohort found in our analysis, the use of cell saver in such patients may be cost beneficial. Cost-containment protocols have also been shown to drive down the costs of implants and to reduce intersurgeon variability in procedural cost.³⁹ With aggregate cost of all spinal procedures tallying \$33.9 billion, cost-containment protocols are important in the management of NMS across the country.

Strengths and Limitations

While the potential to analyze massive samples is an obvious strength of databases like the NIS, there are many inherent limitations to such studies which must be understood when interpreting results of studies of this kind.^{40,41} First and foremost, the NIS does not contain information regarding longitudinal follow-up, such as outcome scores or subsequent complications after the initial inpatient hospitalization. Additionally, this database does not allow for evaluation of certain patient characteristics (physical exam and several vital sign and laboratory abnormalities) and surgeon characteristics (operative experience of the surgeon, exact instrumentation used). These variables may also contribute to variation between the study cohorts. The NIS also precludes evaluation of many specific factors which affect patients with CP, such as GMFCS

status. However, our study provides baseline data which can be utilized as a starting point for risk-benefit discussion. The data can be considered in light of each patient's individual markers of CP disease severity.

Second, ICD-9-CM coding practices lack standardization across the country, which lead to inaccuracies within the database. For example, many patients with the diagnostic code for "Idiopathic Scoliosis" also had the diagnostic code for "Cerebral Palsy." Indeed, the code "Neuromuscular Scoliosis" would be the correct code for such patients. Regardless, our patient cohorts underwent PSF for correction of scoliosis, either with or without CP, and the exact diagnostic code (IS vs NMS) assigned to whichever form of scoliosis they have should not affect their outcomes. The National Hospital Ambulatory Medical Care Survey and the American Hospital Association Annual Survey Databases are linked to the NIS as a form of accuracy cross-checking.¹⁰ Still, such discrepancies in coding exist, and are important to be aware of.

While national database analyses certainly have limitations, our results have clinical utility and we hope physicians will use our study to provide patients with CP and their families with specific numbers as to how their risk for several common complications may differ from those undergoing PSF for IS. There is significant variation between our results and studies obtaining odds ratios for NMS without the qualifier of having CP. We believe that patients with CP and NMS should not be grouped in with other patients with NMS, but should be considered independently as their results may differ.

Additionally, we provide a recent sampling of the NIS comparing NMS patients to those with IS. Prospective analysis factoring in variables that are not possible to evaluate in the NIS of patients with CP undergoing PSF would be valuable to continue to explore complication rates seen in these patient cohorts.

CP is associated with increased cost, LOS, and complications after PSF versus patients undergoing PSF for IS. Extra care in patient selection and multifaceted treatment protocols should continue to be implemented in the management pathway of CP. Further investigation is needed to identify ways in which to mitigate the most common complications in those with CP.


Declaration of Conflicting Interests

The author(s) declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: John M. Rhee: Walters Kluwer: Royalties; Biomet: Royalties; Stryker: Royalties; Medtronic: Speaking. The other authors have no conflicts of interest to disclose.

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