Variation in 60-day Readmission for Surgical-site Infections (SSIs) and Reoperation Following Spinal Fusion Operations for Neuromuscular Scoliosis

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Background: Readmission for surgical-site infection (SSIs) following spinal fusion for NMS impacts costs, patient risk, and family burden; however, it may be preventable. The purpose of this study was to examine variation in hospital performance based on risk-standardized 60-day readmission rates for SSI and reoperation across 39 US Children's Hospitals.

Methods: Retrospective cohort study using the Pediatric Health Information Systems (PHIS) database involving children aged 10 to 18 years with ICD9 codes indicating spinal fusion, scoliosis, and neuromuscular disease discharged from 39 US children's hospitals between January 1, 2007 and September 1, 2012. Readmissions within 60 days for SSI were identified based on the presence of ICD9 codes for (1) infectious complication of device or procedure, or (2) sepsis or specific bacterial infection with an accompanying reoperation. Logistic regression models accounting for patient-level risk factors for SSI were used to estimate expected (patient-level risk across all hospitals) and predicted (weighted average of hospital-specific and all-hospital estimates) outcomes. Relative performance was determined using the hospital-specific predicted versus expected (pe) ratios.

Results: Average volume across hospitals ranged from 2 to 23 fusions/quarter and was not associated with readmissions. Of the 7560 children in the cohort, 534 (7%) were readmitted for reoperation and 451 (6%) were readmitted for SSI within 60 days of discharge. Reoperations were associated with an SSI in 70% of cases. Across hospitals, SSI and reoperation rates ranged from 1% to 11% and 1% to 12%, respectively. After adjusting for age, sex, insurance, presence of a gastric tube, ventriculoperitoneal shunt, tracheostomy, prior admissions, number of chronic conditions, procedure type (anterior/posterior), and level (> 9 or < 9 vertebrae), *pe* ratios indicating hospital performance varied by 2-fold for each outcome.

Conclusions: After standardizing outcomes using patient-level factors and relative case mix, several hospitals in this cohort were more successful at preventing readmissions for SSIs and reoperations. Closer examination of the organization and implementation of strategies for SSI prevention at high-performing centers may offer valuable clues for improving care at lower performing institutions.

Level of Evidence: Level III.

Key Words: spinal fusion, neuromuscular scoliosis, outcomes, surgical site infection, safety and quality, reoperation

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Surgical-site infections (SSI) result in over 8000 deaths in US hospitals each year, costing the health care system 3.5 to 10 billion US dollars annually.[1,2] For children who have undergone spinal fusion procedures, SSIs are particularly devastating and costly. Treatment of these infections often requires multiple readmissions, additional procedures for wound debridement or device removal, and prolonged antibiotic therapy, in some cases resulting in up to 2 weeks in additional hospital days, and a 2- to 3-fold increase in total cost per operation.[3–6]

It is well known that children with scoliosis secondary to neuromuscular disease have the highest risk of infection, and according to some studies SSI rates can range from 3% to as high as 40% in this population.[7–9] Accompanying factors such as the length of surgery and technology dependence [eg, gastric tubes (GT) or ventriculoperitoneal shunts (VPS)] convey an even higher risk. However, the exact causal pathway of this heightened risk remains unclear,[10] making the development of evidence-based standards of care for SSI prevention challenging.

As a result, SSI prevention measures continue to vary broadly across hospitals,[11–14] particularly for children who fall into the high-risk NMS category. This variation remains significant even after adjustment for patient and surgical factors and likely plays some part in differences across hospitals in rates of SSI-related outcomes. Whereas researchers have quantified the extent

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and variation of infectious complications occurring during the surgical admission,[15] little has been published about the prevalence and variation in SSIs and reoperations that occur after discharge and require rehospitalization.

The primary purpose of this study was to utilize data from the Pediatric Health Information Systems (PHIS) database to estimate national risk-standardized rates of readmission for SSI following spinal fusion for neuromuscular scoliosis. We secondarily aimed to quantify the degree of variation in these rates, accounting for hospital and patient factors. The overarching objective was to identify hospitals that appear to be high performers for SSI prevention so that hospital-level drivers of high performance can be more closely examined.

METHODS

A retrospective cohort study was performed using data from the Pediatric Health Information System (PHIS). PHIS contains detailed hospital administrative and billing data from 43 noncompeting children's hospitals affiliated with the Children's Hospital Association (CHA). Contributing hospitals are located in 17 of the 20 major metropolitan areas in the United States and represent a significant proportion of centers that perform high volumes of spinal surgery on children. PHIS data include: patient demographics; admission and discharge date; preoperative and postoperative lengths of stay; insurance type; primary and secondary diagnoses and procedures; and all itemized charges. Each patient is assigned a unique identifier, which allows them to be tracked longitudinally. Data are quality checked by CHA before being published for use.

Patient Selection

We selected records from the database with an International Disease Classification Clinical Modification (ICD9-CM) procedure code for spinal fusion procedure and diagnostic code indicating nontraumatic spinal deformity (n = 22,218). All children aged 10 to 18 years were discharged between January 1, 2007 and September 1, 2012 were considered eligible. If spinal fusion was not listed as a secondary procedure, we confirmed that primary procedures were related to spinal fusion operations (eg, bone graft, chest wall incision, or vertebral resection). We excluded admissions with concurrent procedures, such as shunt revisions or dental procedures (n = 500).

The NMS cohort was defined by selecting any child with a diagnosis of neuromuscular disease (eg, Duschenne muscular dystrophy or spinal muscular atrophy), neurologic impairment, spina bifida, or cerebral palsy. Children with <60 days of available data before admissions or following their discharge date were excluded from the study. Hospitals that performed <2 spinal fusions for NMS per quarter were also excluded, leaving 39 hospitals in the final analysis

Comorbidities including the presence of gastrointestinal ostomies (colostomies and gastrostomy tubes), tracheostomies, and ventricular drainage devices (shunts) were defined by ICD9-CM diagnosis and procedure codes as in previous studies.[11] These were identified using only ICD9-CM codes recorded for the index admissions and admissions before the index hospitalization. Other measured covariates included sex, age (continuous), number of admissions in the 60 days before the index admission (<1 vs. ≥ 1), fusion level (>9 vs. <9 vertebra), insurance (government vs. private), and year of surgery.

Outcomes

Readmissions for SSI and reoperation at 60 days were the primary and secondary outcomes. Sixty, as opposed to 30 day, readmissions were used based on a study by Mackenzie et al[16] reporting that only 67% of SSIs were identified within the 30-day window. Reoperation was defined as any readmission associated with a procedure code indicating a refusion, incision and debridement, or operation to soft tissue, bone, or thoracic area. SSIs were defined as any readmission with an ICD9 code indicating (1) infectious complication of device or procedure, or (2) sepsis or specific bacterial infection with an accompanying reoperation. In a sample of patients at our own institution, this algorithm accurately predicted SSI with a sensitivity of 0.85 and specificity of 0.99.

Statistical Analysis

Characteristics of the full cohort as well as the population of children readmitted for SSI and/or reoperation were described using means and percents.

Univariable and Multivariable Analyses

To account for the clustering of patients within hospitals, we used multilevel logistic regression for both univariable and multivariable analyses. We estimated the independent associations between SSI readmission and patient/surgery characteristics using the above defined categories. Discharge year, sex, government insurance, and age were included in all models a priori. Other covariates were retained in the models if: (1) the association with the outcome was statistically significant ($P < 0.05$), (2) inclusion altered the estimated effects of other covariates by $>10\%$, or (3) inclusion improved model fit based on likelihood ratio testing.

Estimating Predicted Versus Expected (pe) Ratios

We used predicted versus expected readmission rates because this approach better accounts for clustering of patients within hospitals of varying case volumes than an observed versus expected approach.[17,18] For each outcome, we first estimated expected SSI rates using multivariable logistic regression with patient factors as fixed effects.[19] We then estimated predicted SSI rates—the weighted average of hospital-specific and all-hospital estimates—using hierarchical multivariable logistic regression with readmission as the dependent variable, hospital as a random effect, and patient-level characteristics as fixed effects. Hospital-specific *pe* ratios were multiplied by the average observed rates of SSI and re-

operation across all hospitals to determine risk-standardized outcomes rates for each hospital. Observed, expected, and predicted readmission rates were depicted graphically to illustrate each hospital's deviation from what is expected given their relative case mix.

All data management and analyses were conducted using SAS version 9.2 statistical software (SAS Institute Inc.) and STAT version 12.0 (StataCorp, LP).

Our study was considered to not constitute human subjects research by the Children's Hospital of Philadelphia (CHOP) Institutional Review Board according to 45 CFR 46.101(b4), as the participants in PHIS are not readily identifiable. A data use agreement between the CHA and CHOP addresses HIPAA and participant privacy requirements.

RESULTS

Patient Characteristics

We identified 7560 NMS index operations at 39 hospitals. Patient and surgery characteristics for the NMS and readmission cohorts are described in Table 1. The mean age of patients at the time of surgery was 12 years, and half of the procedures were performed on females. The most common diagnosis was CP (31%) and 20% of all children had >1 comorbidity in addition to neuromuscular disease. Most of the surgeries involved fusion of greater than 9 vertebral levels and 20% involved an anterior approach.

A total of 1207 (16%) children were readmitted for any cause in the 60 day follow-up period. Of these, 451 (6%) were for SSIs and 534 (7%) were associated with a reoperation. Sixty nine percent of reoperation readmissions had a diagnosis of SSI (Table 2).

Readmission rates for SSI and reoperation were 2-fold greater than average for children with spina bifida (12% vs. 6% and 14% vs. 7%). Further, associated with both types of readmissions were the presence of a GT, VPS, >1 CCC, >1 prior admission, anterior approach, and insurance.

Across hospitals, the median observed rate for SSI readmission was 5.7% [interquartile range (IQR), 3.2 to 7.5; range, 1 to 12] and for reoperation readmissions was 6.6% (IQR, 4.0 to 9.2; range, 1 to 15). There was no association between hospital surgical volume or hospital region and either outcome.

Risk-Standardized Hospital Comparisons

In the fully adjusted models, several characteristics were independently associated with SSI and reoperation (Table 2). Most notably, patients with Spina Bifida had an odds ratio (OR) = 2.2 [95% confidence interval (CI), 1.6-3.1] for SSI and OR = 2.3 (95% CI, 1.6-3.2) for reoperation despite controlling for other high-risk characteristics.

There was no correlation between expected and observed rates for either outcome. Risk-standardized (predicted) rates of SSI and reoperation ranged from 3.6% to 8.0% and 4.3% to 8.6%, respectively. For both SSI and reoperation, performance varied by >2-fold, with *pe* ratios for SSI and reoperation readmissions ranging from 0.7 to 1.6 and 0.8 to 1.6, respectively (Figs. 1A, B). In general, hospitals with the highest observed SSI rates tended to be the lowest performers (highest *pe* ratios).

DISCUSSION

Preventing unplanned readmissions for postoperative complications in children is a major priority to healthcare executives, providers, payers, and families.[20] This study of nearly 8000 NMS surgeries across 39 major US children's hospitals demonstrated that readmission rates for SSI and reoperation vary to a high degree and that this variability is not accounted for by patient and surgery factors. This is the first study to date to use a large sample, nationally representative cohort to estimate rates of complications occurring after discharge. Furthermore, although rates of 60-day readmission for SSI were 6% on average and as high as 12% at some hospitals, we were able to differentiate hospitals that appeared to achieve better than expected outcomes for their patients relative

TABLE 1. Characteristics of Study Cohort and Patients Readmitted Within 60 Days for Surgical-site Infection (SSI) or Reoperation

Patient/Procedure Characteristic	Index Admission (n = 7560)	60 d SSI Readmission (n = 451)	60 d Reoperation (n = 534)
SSI [n (%)]	—	451 (6.0)	368 (69)
Reoperation [n (%)]	—	368 (82)	534 (7.1)
Age [mean (SD)]	12 (3.7)	12 (3.9)	12 (3.9)
Female [n (%)]	3,780 (50)	228 (51)	265 (50)
Cerebral palsy [n (%)]	2,362 (31)	143 (32)	166 (31)
Spina bifida [n (%)]	727 (10)	84 (19)*	104 (19)*
Government insurance[n (%)]	4,242 (56)	270 (60)*	316 (60)*
>1 CCC Systems [n (%)]	1,517 (20)	208 (30)*	124 (23)*
VP shunt [n (%)]	920 (12)	92 (20)*	97 (18)*
GI ostomy [n (%)]	1,843 (24)	157 (29)*	157 (29)*
Tracheostomy [n (%)]	557 (7)	45 (10)*	42 (8)
≥1 admit in prior 60 d [n (%)]	1,636 (22)	114 (25)*	138 (26)*
>9 vertebrae Fused [n (%)]	5,028 (67)	315 (70)	349 (65)
Anterior approach [n (%)]	1,556 (21)	113 (25)*	151 (28)*

*$P < 0.001$.

TABLE 2. Adjusted Odds of Readmission for Surgical-site Infection (SSI) and Reoperation for Patient and Surgery Characteristics

Patient/Procedure Characteristics	60 d SSI OR	60 d Reoperation OR
Age [mean (SD)]	0.96	1.0
Female	0.96	0.94
Cerebral palsy	1.1	1.2
Spina bifida	2.2*	2.2*
Government insurance	1.2	1.1
> 1 CCC systems	1.2	1.2
VP shunt	1.3	1.0
GI ostomy	1.3*	1.3
Tracheostomy	1.1	0.98
≥ 1 admit in prior 60 d	1.0	1.2
> 9 vertebrae fused	1.4*	1.1
Anterior approach	1.1	1.4*

*$P < 0.05$.
OR indicates odds ratio.

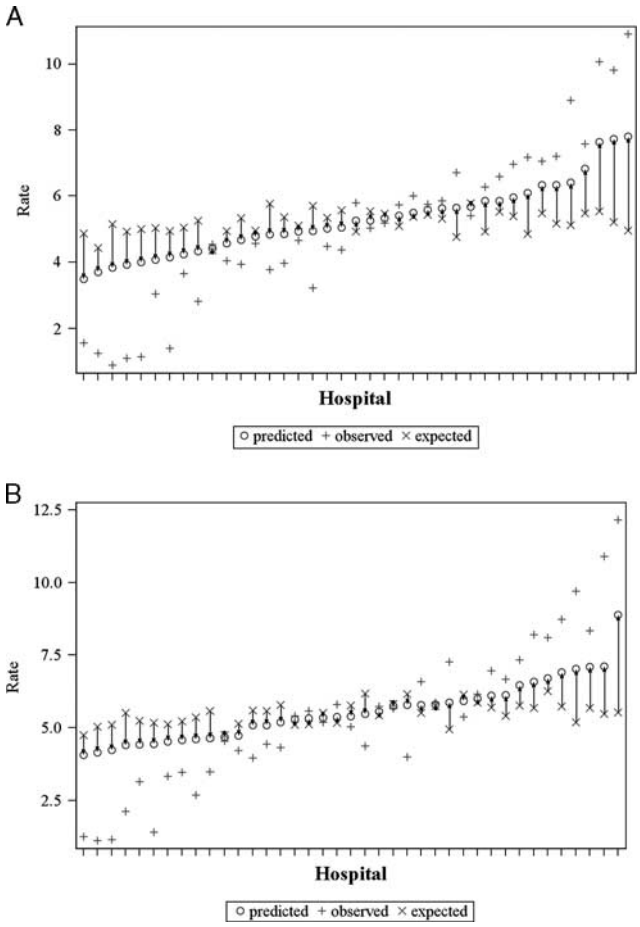

FIGURE 1. Observed, expected, and predicted 60-day readmission rates for (A) surgical-site infection (SSIs) and (B) reoperation following spinal fusion for NMS across 39 children's hospitals from 2007 to 2012. Red plus signs represented unadjusted/observed rates, blue circles represent the predicted (adjusted) rates, and green *x*'s represent the expected rates. Arrows show the deviation of each hospital's rates from what would be expected from their given case mix. Each tick on the *x*-axis represents an individual hospital.

to other hospitals with similar populations. These data make an important contribution to the existing literature on variation in outcomes for children undergoing spinal fusion, as well as provide comparative benchmarks for postoperative complication rates for the purposes of quality and safety improvement.

The prevalence of SSIs and other complications for the NMS spinal fusion population have been approximated from a variety of multicenter data sources. In a recent retrospective chart review study examining all NMS surgeries performed at 3 centers between 2006 and 2008, 26 of 198 (13.1%) operations were complicated by SSI within 365 days of primary spinal fusion.[16] Data from the Scoliosis Research Society registry found that of 1974 NMS surgeries submitted to the registry over 3 years, 5.5% were complicated by SSI within 30 days of discharge.[21] These numbers, however, did not specifically examine readmission or reoperation and were limited by surgeon self-report. Utilizing 2012 data from the National Surgical Quality Improvement Program (NSQIP) clinical registry, Pugely and colleagues identified 30-day wound 203 complications and reoperation rates of 4.67% and 5.5%, respectively.[22,23] These rates were 204 determined from 514 randomly selected cases performed across 50 hospitals and did not 205 specifically examine readmissions.

Few studies have reported risk-adjusted comparisons in complication readmissions across hospitals. One systematic review of 10 single-center case series found SSI rates in NMS ranging from 2.5% to 56.8%.[24] Another study using PHIS data found that complication rates ranged from 05 to 89% (median 10%) following spinal fusion for NMS.[15] These numbers, however, were for in-hospital outcomes only and still did not capture the resource intensity and family burden that was associated with readmissions for these complications.

The driving factors for variation in SSIs following spinal fusion are poorly understood and are likely multifactorial. This study again confirms that patient factors play an important role. The presence of GTs, VPS, spina bifida diagnosis, and insurance are consistently associated with SSI risk; yet, adjusting for these characteristics did not eliminate variation in outcomes across hospitals.[8–10]

Variation in processes for preventing SSIs and other complications may also influence differences in outcomes. In an effort to reduce this variation, leaders in spine surgery have focused on developing best practice guidelines for the few interventions that are supported by evidence.[25] However, many of these evidence-based practices, including use of prophylactic antibiotics and blood conservation protocols, continue to vary widely *across* and even within centers.[11,12] Furthermore, as demonstrated in the adult surgical world with the introduction of the SCIP measures,[26,27] adherence to best practice for SSI care may not fully explain or fix variation in SSI-related outcomes.

Although volume was not associated with outcomes in this or prior studies,[15] other characteristics inherent to particular hospitals have been shown to impact the effectiveness of interventions to improve patient outcomes. In studies examining variation in mortality rates in adult MI, factors such as having platforms for reviewing adverse events and strong safety culture were more strongly associated with high performance than use of protocols and clinical guidelines.[28–30] Organized participation in national consortia has also been shown to contribute to hospitals' successes with reducing rates of adverse events.[31] Further studies are needed to identify which organizational factors may be contributing to better outcomes for children who have spine surgery at high performing centers.

The use of administrative data limits this study in a few notable ways. First, there is the possibility of misclassification of outcomes and patient classification due to coding practices. We attempted to minimize this by using internal chart review to validate SSI coding algorithms. The majority of SSIs that were missed by the algorithm were superficial infections that were treated as an outpatient. It is possible that some hospitals admit a greater proportion of patients with superficial infections than others and, therefore, may appear to have higher rates of SSI. However, most of the SSIs identified in the study also returned to the OR, indicating that readmissions were primarily for more serious and not superficial infections. We also compared the characteristics of patients in our cohort with those of spinal fusion cohorts in other studies and found them to have good face validity.

Second, we were limited in the risk factors that we could reliably measure. For example, although we could accurately assess which patients had VP shunts, we could not measure other patient factors such as preoperative Cobb angle. In many cases with medically complex patients, comorbidities such as neurologic impairment and Cobb angles have a collinear association with outcomes. However, the importance of having clinical variables in conjunction with administrative data for risk-adjusted outcomes measurement cannot be understated; future studies will greatly benefit from the merger of clinical registries with administrative datasets such as the recent merger of PHIS and NSQIP data.[32]

A major strength of our analysis is the large sample size and complete capture of all index surgeries across all years of data. In addition, the use of predicted/expected ratios as opposed to observed/expected ratios provided a more valid risk-standardized estimate of hospital readmission rates and is becoming the standard methodology for comparative outcomes analysis.[19] A final strength is that although these data were collected in cross-section, the analysis can be reproduced over different time periods, allowing researchers to efficiently track changes in risk-standardized SSI and reoperation readmission rates longitudinally. This use of administrative data can enable researchers and safety leaders to track temporal trends, measure the effectiveness of a newly implemented SSI prevention program, or utilize the administrative data to calculate resource utilization and financial impact.

CONCLUSIONS

Among 39 children's hospitals performing spinal fusions for NMS, readmission rates for SSI and reoperation varied by 2-fold, independent of patient factors and hospital size. These readmissions are costly and subject to growing scrutiny from health care executives and payers. Closer examination of high and low performers in SSI prevention may uncover effective organizational strategies for improving these rates across all hospitals.

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