Comorbidities and Complications of Spinal Fusion for Scoliosis

Jay G. Berry, MD, MPH,* Michael Glotzbecker, MD,‡ Jonathan Rodean, MPP,* Izabela Leahy, RN, BSN, MS,* Matt Hall, PhD,* Lynne Ferrari, MD§

abstract

BACKGROUND AND OBJECTIVES: General pediatricians and hospitalists are increasingly summoned to optimize the comorbid conditions of children with medical complexity (CMC) undergoing major surgery. We assessed the relationship between specific chronic conditions of CMC and hospital resource use with spinal fusion for scoliosis, an operation with high cost and morbidity.

METHODS: Retrospective analysis of 7252 children age ≥ 5 years with an underlying complex chronic condition undergoing spinal fusion between January 1, 2010 through December 31, 2014 in 41 children's hospitals. Hospital length of stay (LOS), cost, and 30-day readmission rate were compared across comorbid conditions by using linear and logistic regression accounting for demographic characteristics and clustering of patients by hospital.

RESULTS: Fifty-nine percent of children had ≥ 4 comorbid conditions. As the number of chronic conditions increased from 1–3 to ≥ 10, median LOS increased 60% (5 [interquartile range (IQR), 4–7] to 8 [IQR, 5–13] days); median hospital cost increased 53% ($52,319 [IQR, $37,937–71,513] to $80,429 [IQR, $58,602–$111,965]); and readmission rates increased 293% (5.4% to 15.8%) (P < .001 for all). In multivariable analysis, conditions strongly associated with LOS and cost were chronic respiratory insufficiency (LOS: +2.1 days; cost: +$12,070; and bladder dysfunction (LOS: +0.8 days; cost: +$4014) (P < .001 for all). Readmission likelihood was highest with bladder dysfunction (odds ratio, 1.5; 95% confidence interval, 1.1–2.0) and epilepsy (odds ratio, 1.2; 95% confidence interval, 1.0–1.5).

CONCLUSIONS: Chronic respiratory insufficiency, bladder dysfunction, and epilepsy had significant associations with hospital resource use for CMC undergoing spinal fusion. Pediatricians, patients, and families may find it useful to consider these conditions when striving to benefit the children's perioperative health and outcomes.

*Complex Care Service, Division of General Pediatrics, Department of Medicine, ‡Division of Orthopedic Surgery, Department of Surgery, and §Department of Anesthesiology, Perioperative, and Pain Medicine, Boston Children’s Hospital, Harvard Medical School, Boston, Massachusetts; and Children’s Hospital Association, Overland Park, Kansas

Drs Berry, Glotzbecker, Leahy, and Ferrari conceptualized and designed the study and drafted the initial manuscript; Dr Hall and Mr Rodean carried out the initial analyses and reviewed and revised the manuscript; and all authors approved the final manuscript as submitted.

DOI: 10.1542/peds.2016-2574

Accepted for publication Dec 2, 2016

Address correspondence to Jay G. Berry, MD MPH, Division of General Pediatrics, Boston Children’s Hospital, Harvard Medical School, 21 Autumn St, Room 2122, Boston, MA 02115. E-mail: jay.berry@childrens.harvard.edu

PEDIATRICS (ISSN Numbers: Print, 0031-4005; Online, 1088-4275).

Copyright © 2017 by the American Academy of Pediatrics

WHAT’S KNOWN ON THIS SUBJECT: General pediatricians and hospitalists are increasingly summoned to help optimize control of comorbid conditions and contain hospital resource use in children with medical complexity undergoing major surgery, such as spinal fusion for scoliosis.

WHAT THIS STUDY ADDS: Spinal fusion hospital resource use increases with the number of comorbid conditions; chronic respiratory insufficiency, bladder dysfunction, and epilepsy had the strongest associations. Pediatricians assisting with perioperative care may find it useful to consider these conditions.


WHAT'S KNOWN ON THIS SUBJECT: General pediatricians and hospitalists are increasingly summoned to help optimize control of comorbid conditions and contain hospital resource use in children with medical complexity undergoing major surgery, such as spinal fusion for scoliosis.

WHAT THIS STUDY ADDS: Spinal fusion hospital resource use increases with the number of comorbid conditions; chronic respiratory insufficiency, bladder dysfunction, and epilepsy had the strongest associations. Pediatricians assisting with perioperative care may find it useful to consider these conditions.
Children with medical complexity (CMC) are a rapidly growing pediatric population with a substantial impact on the health care system. These children have lifelong, life-limiting chronic conditions and multiple comorbidities related to the impairment of multiple organ systems, which make coordinating their care and optimizing their health a challenge. They experience frequent, costly hospitalizations that are often lengthy and include major surgical interventions required to improve their daily functioning. Due to their associated medical complexity and fragility, surgery in these children may be complicated and have a high likelihood of perioperative adverse events and other suboptimal outcomes.

General pediatricians and hospitalists are increasingly summoned to optimize the health of CMC undergoing major surgery. To help achieve the triple aim of increased patient satisfaction, improved quality of care, and decreased cost, pediatricians are integrating with surgeons, anesthesiologists, specialists, and other providers to help assess and manage the specialists, and other providers with surgeons, anesthesiologists, patient satisfaction, improved quality to achieve the triple aim of increased systems, which make coordinating their care and optimizing their health a challenge. They experience frequent, costly hospitalizations that are often lengthy and include major surgical interventions required to improve their daily functioning. Due to their associated medical complexity and fragility, surgery in these children may be complicated and have a high likelihood of perioperative adverse events and other suboptimal outcomes.

General pediatricians and hospitalists are increasingly summoned to optimize the health of CMC undergoing major surgery. To help achieve the triple aim of increased patient satisfaction, improved quality of care, and decreased cost, pediatricians are integrating with surgeons, anesthesiologists, specialists, and other providers to help assess and manage the children's comorbidity conditions before, during, and after surgery.

Despite the promise of involving pediatricians in the perioperative management of comorbid conditions for CMC, little is known about which comorbidities have the strongest associations with health outcomes and use of expensive hospital resources after major surgical interventions. Identifying the conditions with these associations may help inform the development and implementation of specific perioperative clinical pathways designed to best manage the conditions.

Therefore, the goal of the current study is to assess the comorbid conditions on a recent cohort of CMC undergoing spinal fusion for scoliosis across multiple children's hospitals. Spinal fusion was selected as a representative procedure because it has a high cost and high complication rate and it is associated with prolonged recovery, which can be physiologically stressful for the children. After spinal fusion, CMC are known to have an increased risk of postoperative complications and hospital readmissions. Although national efforts to optimize the health for CMC undergoing spinal fusion are underway, no standardized guidelines for perioperative care exist. Therefore, the objectives of this study were to (1) assess the relationship between specific chronic conditions and other clinical characteristics on hospital resource use for children with complex neuromuscular or genetic conditions undergoing spinal fusion; and (2) distinguish which characteristics are associated with the highest resource use.

**METHODS**

**Study Design and Setting**

This study is a multicenter, retrospective cohort analysis of the Pediatric Health Information System (PHIS). PHIS is an administrative database of 41 not-for-profit, tertiary-care children's hospitals, located in all US geographic regions, who are affiliated with the Children's Hospital Association (Overland Park, KS) that submitted data to PHIS consistently between January 1, 2010 and December 31, 2014; an additional 3 PHIS hospitals not submitting data consistently in this period were not included for analysis. PHIS data quality and reliability are assured through Children's Hospital Association and participating hospitals. In accordance with the policies of Boston Children's Hospital Institutional Review Board, this study of deidentified data was not considered human subjects research.

**Study Population**

The study population was children age \( \geq 5 \) years with an underlying neuromuscular or genetic complex chronic condition (CCC) undergoing spinal fusion for the first time during the study period in any of the PHIS hospitals. We withheld instituting an age ceiling for the cohort because, even for older patients (eg, age \( \geq 21 \) years), there was likely a clinical reason that led to the decision for pediatric surgeons to operate and care for them in a freestanding children's hospital. Children with 1 of these CCCs were identified from International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) diagnosis codes contained in Feudtner's set of CCCs (version 2). Hospitalizations for spinal fusion were identified with a primary ICD-9-CM procedure code for primary spinal fusion (810.0X).

**Main Outcome Measures**

The main outcome measures were hospital length of stay (LOS), 30-day, unplanned, all-cause hospital readmission, and hospital cost. LOS was measured in days. Hospital readmissions, for any unplanned reason, were measured within 30 days of discharge from the spinal fusion admission by using criteria endorsed by the National Quality Forum. National Quality Forum criteria define planned readmissions as those that are usually scheduled in advance of the readmission for a planned procedure; when one of them was coded as the primary procedure, the readmission was classified as a planned readmission. Reasons for readmission were described by using All Patient Refined Diagnosis Related Groups (3M Health Systems). Hospital cost included patient room, medications, equipment, therapies, treatment, procedures, etc. Hospital cost did not include professional (eg, physician) services because this information is not available in PHIS.
Demographic and Clinical Characteristics

We also assessed patient demographic characteristics that might correlate with outcomes after spinal fusion for children in the cohort. Demographic characteristics included sex, age at admission in years, payer (eg, Medicaid, private insurer, and other), and race/ethnicity (Hispanic, non-Hispanic black, non-Hispanic white, and other).

We assessed the type and number of comorbid conditions, of any complexity, experienced by the children using the Agency for Healthcare Research and Quality (AHRQ) Chronic Condition Indicator (CCI) system, which categorizes >14,000 ICD-9-CM diagnosis codes into chronic versus nonchronic conditions. The CCI system was used for this method over the CCC system described above because the CCCs, by design, do not include all of the comorbid conditions known to affect children, including asthma, bladder dysfunction, dysphagia, gastroesophageal reflux, etc. The CCI system includes these conditions. The number and the exact CCIs were used for all statistical analyses of comorbid conditions. For exact CCIs, the 10 most prevalent (Fig 1) comorbid conditions were selected for analysis. In addition to the children’s chronic conditions (identified by using the AHRQ CCI system), we assessed the number and type (eg, antibiotic, cardiac, etc) of medications administered during their hospitalization using Truven Analytics’ (Ann Arbor, MI) Clinical Transaction Classification pharmacy codes.

We also assessed acute illnesses (eg, acute renal failure, pneumonia, sepsis, seizure, etc) that occurred during the spinal fusion hospitalization that might also be associated with hospital resource use. The acute illnesses, informed by previous studies of spinal fusion as well as our own clinical experiences, were identified with ICD-9-CM diagnosis codes used in previous studies. The acute illnesses were not recognized as chronic conditions in the AHRQ CCI system. However, some of the illnesses could have been associated with an acute exacerbation of a chronic health condition (eg, a child with chronic respiratory insufficiency [categorized as a chronic condition] experienced respiratory arrest [categorized as an acute illness] during the hospitalization) (Supplemental Information).

RESULTS

Study Population

There were 7252 patients with a complex neuromuscular or congenital/genetic CCC who underwent spinal fusion between 2010 and 2014 in the study cohort. The most common complex conditions in the cohort were cerebral palsy (33.4%), brain malformation (15.8%), and chromosomal syndrome (12.2%) (Table 1). The median age in years at admission was 13 (interquartile range [IQR], 11–15). Most patients were non-Hispanic white (62.5%), female (53.4%), and were covered under Medicaid (50.2%). Most patients (68.9%) had ≥9 vertebrae fused during the spinal fusion (Table 1).

Multiple chronic conditions were prevalent among the cohort; 95.6% of patients had ≥2 chronic conditions in addition to the orthopedic abnormality (eg, scoliosis) that led to the indication for spinal fusion (Table 1). The majority (58.9%) of patients had ≥4 chronic conditions. Epilepsy (26.5%), gastroesophageal reflux disease (20.3%), asthma (20.3%), and dysphagia (8.4%) were among the most common chronic conditions...
### TABLE 1
Demographic, Clinical, and Hospitalization Characteristics of Children With A Complex Neuromuscular or Genetic Condition Undergoing Complex Spinal Fusion Across US Freestanding Children’s Hospitals

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>N (%)</th>
<th>Median (Interquartile Range) Hospital Cost</th>
<th>US Dollars</th>
<th>30-d Readmission Rate, %</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Overall cohort</strong></td>
<td>7252</td>
<td>6 (4–8)</td>
<td>61225 (43626–86420)</td>
<td>8.7</td>
</tr>
<tr>
<td><strong>Demographic Characteristics</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>3378 (46.6)</td>
<td>6 (4–9)</td>
<td>63391 (44774–90734)</td>
<td>8.8</td>
</tr>
<tr>
<td>Male</td>
<td>3874 (53.4)</td>
<td>5 (4–8)</td>
<td>59145 (42752–81976)</td>
<td>8.6</td>
</tr>
<tr>
<td>Race/ethnicity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-Hispanic white</td>
<td>4529 (62.5)</td>
<td>6 (4–8)</td>
<td>60254 (41655–85208)</td>
<td>8.3</td>
</tr>
<tr>
<td>Non-Hispanic black</td>
<td>832 (11.5)</td>
<td>6 (4–8)</td>
<td>63735 (46376–91003)</td>
<td>8.8</td>
</tr>
<tr>
<td>Hispanic</td>
<td>1130 (15.6)</td>
<td>6 (5–8)</td>
<td>62370 (48319–85737)</td>
<td>11.0</td>
</tr>
<tr>
<td>Other</td>
<td>761 (10.5)</td>
<td>6 (4–8)</td>
<td>61217 (44206–87513)</td>
<td>7.5</td>
</tr>
<tr>
<td>Age at admission, y</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5–10</td>
<td>1381 (19.0)</td>
<td>6 (4–8)</td>
<td>58087 (38683–81070)</td>
<td>8.7</td>
</tr>
<tr>
<td>11–15</td>
<td>4236 (58.4)</td>
<td>6 (4–8)</td>
<td>62303 (45557–85664)</td>
<td>8.5</td>
</tr>
<tr>
<td>16–20</td>
<td>1519 (20.9)</td>
<td>6 (4–8)</td>
<td>62745 (43945–91031)</td>
<td>8.8</td>
</tr>
<tr>
<td>≥21&lt;sup&gt;b&lt;/sup&gt;</td>
<td>116 (1.6)</td>
<td>7 (5–12)</td>
<td>61244 (40308–93920)</td>
<td>17.2</td>
</tr>
<tr>
<td>Payor</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Public insurance</td>
<td>3628 (50.2)</td>
<td>6 (4–8)</td>
<td>63540 (4152–85241)</td>
<td>10.1</td>
</tr>
<tr>
<td>Private insurance</td>
<td>3355 (46.1)</td>
<td>5 (4–8)</td>
<td>59761 (42173–84576)</td>
<td>7.5</td>
</tr>
<tr>
<td>Other</td>
<td>268 (3.7)</td>
<td>6 (4–8)</td>
<td>48573 (32849–67356)</td>
<td>5.2</td>
</tr>
<tr>
<td>Underlying CCC</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cerebral palsy</td>
<td>2420 (33.4)</td>
<td>7 (5–10)</td>
<td>71569 (53476–98083)</td>
<td>11.7</td>
</tr>
<tr>
<td>Brain malformation</td>
<td>1144 (15.8)</td>
<td>7 (5–11)</td>
<td>71439 (52831–101776)</td>
<td>11.2</td>
</tr>
<tr>
<td>Chromosomal syndrome&lt;sup&gt;c&lt;/sup&gt;</td>
<td>887 (12.2)</td>
<td>5 (4–8)</td>
<td>58234 (44231–77226)</td>
<td>7.0</td>
</tr>
<tr>
<td>Central nervous system degeneration</td>
<td>656 (8.8)</td>
<td>7 (5–10)</td>
<td>70823 (52157–101681)</td>
<td>11.7</td>
</tr>
<tr>
<td>Other genetic syndrome&lt;sup&gt;d&lt;/sup&gt;</td>
<td>606 (8.4)</td>
<td>6 (5–8)</td>
<td>62857 (46431–90904)</td>
<td>9.4</td>
</tr>
<tr>
<td>Muscular dystrophy</td>
<td>487 (6.7)</td>
<td>7 (5–8)</td>
<td>70174 (53655–101608)</td>
<td>10.7</td>
</tr>
<tr>
<td>Spina bifida</td>
<td>485 (6.7)</td>
<td>6 (5–8)</td>
<td>64980 (48432–90724)</td>
<td>14.8</td>
</tr>
<tr>
<td>Hydrocephalus&lt;sup&gt;e&lt;/sup&gt;</td>
<td>415 (5.7)</td>
<td>6 (5–8)</td>
<td>70418 (52092–102008)</td>
<td>10.6</td>
</tr>
<tr>
<td>No. of chronic conditions</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>317 (4.4)</td>
<td>4 (3–5)</td>
<td>34632 (25014–51116)</td>
<td>2.2</td>
</tr>
<tr>
<td>1–3</td>
<td>2668 (36.8)</td>
<td>5 (4–7)</td>
<td>52319 (37937–71513)</td>
<td>5.4</td>
</tr>
<tr>
<td>4–6</td>
<td>1836 (26.7)</td>
<td>6 (5–8)</td>
<td>62824 (48497–85206)</td>
<td>8.9</td>
</tr>
<tr>
<td>7–9</td>
<td>1072 (14.8)</td>
<td>7 (5–11)</td>
<td>71197 (53324–100563)</td>
<td>10.2</td>
</tr>
<tr>
<td>≥10</td>
<td>1259 (17.4)</td>
<td>8 (5–13)</td>
<td>80429 (53802–111985)</td>
<td>15.8</td>
</tr>
<tr>
<td>Technology assistance</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Any</td>
<td>3068 (42.3)</td>
<td>7 (5–11)</td>
<td>72275 (53255–101835)</td>
<td>12.3</td>
</tr>
<tr>
<td>Digestive</td>
<td>1320 (18.2)</td>
<td>7 (5–12)</td>
<td>75785 (53505–105570)</td>
<td>13.6</td>
</tr>
<tr>
<td>Respiratory</td>
<td>408 (5.6)</td>
<td>9 (6–17)</td>
<td>82695 (58012–125784)</td>
<td>15.4</td>
</tr>
<tr>
<td>Nervous</td>
<td>575 (7.9)</td>
<td>7 (5–10)</td>
<td>73330 (53655–101968)</td>
<td>15.1</td>
</tr>
<tr>
<td>Renal</td>
<td>141 (1.9)</td>
<td>7 (5–13)</td>
<td>72449 (55019–101826)</td>
<td>9.9</td>
</tr>
<tr>
<td>Cardiovascular&lt;sup&gt;f&lt;/sup&gt;</td>
<td>109 (1.5)</td>
<td>7 (5–12)</td>
<td>68799 (52485–100966)</td>
<td>11.0</td>
</tr>
<tr>
<td>Other</td>
<td>423 (5.8)</td>
<td>7 (5–11)</td>
<td>68233 (46207–100616)</td>
<td>10.4</td>
</tr>
<tr>
<td>Medication classes prescribed during admission</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1–3</td>
<td>27 (0.4)</td>
<td>5 (3–7)</td>
<td>36016 (21929–44910)</td>
<td>7.4</td>
</tr>
<tr>
<td>4–5</td>
<td>1202 (17.5)</td>
<td>5 (4–6)</td>
<td>47813 (34145–64834)</td>
<td>7.2</td>
</tr>
<tr>
<td>6–7</td>
<td>3912 (56.8)</td>
<td>5 (4–7)</td>
<td>58869 (43345–78787)</td>
<td>7.9</td>
</tr>
<tr>
<td>≥8</td>
<td>1742 (25.3)</td>
<td>8 (5–14)</td>
<td>80724 (59258–112084)</td>
<td>11.0</td>
</tr>
</tbody>
</table>

<sup>a</sup> Hospital resource use (LOS, cost, and readmission rate) varied significantly (P < .001) across the categories for each characteristic.

<sup>b</sup> Most patients age ≥21 years were age 21 to 25 years.

<sup>c</sup> Chromosomal syndromes included, but were not limited to, velocardiofacial syndrome, Down syndrome, and Edward syndrome.

<sup>d</sup> Other genetic syndromes included, but were not limited to, Marfan syndrome and multiple congenital anomalies.

<sup>e</sup> The hydrocephalus category does not include patients with spina bifida.
experienced by the patients. Forty-two percent of patients were assisted with medical technology (Fig 1). Among the most common technologies were those related to the digestive system (27.9%) (eg, gastrostomy), nervous system (7.9%) (eg, cerebrospinal fluid ventricular shunts), and respiratory system (5.6%) (eg, tracheostomy) (Fig 1, Table 1).

**LOS, Hospital Cost, and 30-day Readmissions**

Median hospital LOS and cost for spinal fusion was 6 days (IQR, 4–8 days) and $61,275 (IQR, $43,626–$86,240), respectively. The 30-day, all-cause readmission rate was 8.7%. Musculoskeletal health issues (eg, spinal hardware complication and infection) were the most common reason for readmission (45.6% [n = 288]), followed by skin (eg, wound dehiscence, seroma, or hematoma) (16.5% [n = 104]), and respiratory (eg, pneumonia) (9.5% [n = 60]) issues (Fig 1). An array of 10 health problems accounted for an additional 19.8% of readmissions; constipation/gastrointestinal dysmotility (3.2% [n = 20]), pyelonephritis/urinary tract infection (3.0% [n = 19]), and seizure (2.7% [n = 17]) were the most common (Fig 2).

**Univariable Analysis of Chronic Conditions and Hospital Resource Use**

In univariable analyses, as the number of chronic conditions increased, LOS, hospital cost, and readmission rates increased significantly (P < .001). For example, as the number of chronic conditions increased from 1–3 to ≥10, median LOS increased by 60% from 5 days (IQR, 4–7 days) to 8 days (IQR, 5–13 days); median hospital cost increased by 53% from $52,319 (IQR, $37,937–$71,513) to $80,429 (IQR, $58,602–$111,965); and 30-day readmission rates increased nearly 3 times from 5.4% to 15.8% (P < .001 for all) (Table 1). Of all forms of technology assistance, respiratory was associated with the longest median LOS (9 days [IQR, 6–17 days]), highest median hospital cost ($82,695 [IQR, $58,012–$125,784]), and highest 30-day readmission rate (15.4%).

**Chronic Conditions**

There was significant variation in the individual contributions of specific chronic conditions, accounting for the presence of each other as well as demographic characteristics and acute illnesses, on hospital resource use (Fig 3). The chronic conditions with the strongest associations with LOS and cost were chronic respiratory insufficiency (LOS: +2.1 days; cost: +$12,070); and bladder dysfunction (LOS: +0.8 days; cost: +$4014) (P < .001 for all). The additive effect of multiple chronic conditions on hospital resource use was substantial. For example, asthma, enterostomy, epilepsy, esophageal reflux, intellectual disability, dysphagia, respiratory insufficiency, and bladder dysfunction, collectively, added $25,720 and 4.6 hospital days. Readmission likelihood was highest with bladder dysfunction (odds ratio [OR], 1.5; 95% confidence interval [CI], 1.1–2.0) and epilepsy (OR, 1.2; 95% CI, 1.0–1.5) (Fig 3). Bladder dysfunction was the only chronic condition assessed that was significantly associated (P < .001) with higher hospital cost, longer LOS, and a greater likelihood of hospital readmission (Fig 3).

**Acute Illnesses**

Similarly, there was significant variation in the individual contributions of specific acute illnesses, accounting for the presence of each other as well as demographic characteristics and chronic conditions, on hospital resource use (Fig 4). For example, urinary tract infection added $14,272 (95% CI, $11,809–$16,735) and 3.5 days (95% CI, 3.1–3.9) to hospitalization cost and LOS, respectively, after controlling for chronic bladder dysfunction and spina bifida. Acute respiratory arrest added $16,328 (95% CI, $13,763–$18,893) and 2.6 days (95% CI, 2.2–3.0) after controlling for asthma, chronic respiratory insufficiency, and
BERRY et al

Three of the acute illnesses assessed, decubitus ulcer, hypertension, and respiratory arrest, were significantly \( (P < .001) \) associated with all 3 measures of hospital resource use: higher hospital cost, longer LOS, and a greater likelihood of hospital readmission (Fig 4).

DISCUSSION

The findings from the current study highlight the importance of chronic conditions and acute illnesses in children with a complex neuromuscular or genetic condition undergoing spinal fusion, a high-risk, expensive surgery. The array of organ systems affected by children's chronic conditions, including digestive, emotional, neurologic, respiratory, and urinary, reflect the children's high degree of medical complexity. As the patients' number of chronic conditions increased, the LOS, hospital charges, and likelihood of hospital readmission increased substantially. Of all the chronic conditions assessed, chronic respiratory insufficiency, bladder dysfunction, and epilepsy had significant associations with increased LOS, cost, and readmission. Three acute illnesses that occurred during the hospitalization, decubitus ulcer, hypertension, and respiratory arrest, were also associated with increased hospital LOS, cost, and readmission, resulting in the use of additional hospital resources.

![Figure 3](https://example.com/figure3.png)

**FIGURE 3**
Associations of comorbid conditions and hospital resource use for children with a complex neuromuscular or genetic condition spinal fusion. All point estimates and variance were derived from multivariable analysis of generalized linear regression (for LOS and hospital cost) and generalized estimating equations (for hospital readmission). All models included the comorbid conditions displayed, which were the 10 most prevalent conditions in the cohort, as well as age, sex, race/ethnicity, and acute illnesses. Data were clustered by hospital in each model.

Although the current study highlights several associations of conditions with increased hospital resource use for spinal fusion, it is not positioned to determine the true clinical mechanisms responsible for those associations. For example, chronic respiratory insufficiency could have led to delayed or failed extubation and decreased ventilatory reserve with exposure to pain medications, respiratory arrest, or other respiratory challenges that impeded health recovery and prolonged LOS. Alternatively, chronic respiratory insufficiency could have been a proxy indicator of severe neurologic impairment, which could have been the main factor that necessitated longer hospitalization. Assessment of these potential mechanisms in subsequent studies might help reveal opportunities that may exist to precipitate health recovery after spinal fusion.
Additional investigation is needed to assess how well controlled, ahead of surgery, were the myriad chronic conditions associated with increased hospital resource use in CMC undergoing spinal fusion. A detailed assessment of the preoperative severity as well as intra- and postoperative exacerbations of the conditions may improve understanding of how to best manage them in the perioperative period. There is substantial variation across institutions and clinics in the conditions included in preoperative spinal fusion health evaluations. Although assessments of respiratory insufficiency and cardiac dysfunction are commonly included, additional conditions, such as bladder dysfunction and epilepsy, may be worthwhile to consider. Systematic screening, severity profiling, and care management for these conditions, and others, preoperatively could potentially preclude the likelihood that they adversely affect the health of the child during and after spinal fusion. Central to this discussion, additional attention to perioperative management of chronic bladder dysfunction and acute urinary tract infection, in particular, may be warranted; they were both independently associated with increased hospital resource use. Certainly, children with complex chronic neuromuscular conditions (eg, cerebral palsy) are at risk for impaired innervation of bladder musculature that often subsists silently, going undetected while steadily increasing in severity. The severity could potentially worsen with perioperative exposures (eg, shifts in fluid volume, pain medications, etc) and result in subsequent pain from overfilling as well as constipation and infection. In a systematic review, bladder dysfunction has been highlighted as major risk factor for surgical site infection after spinal fusion. Perhaps subsequent investigations may wish to identify the true reasons why bladder dysfunction is associated with increased hospital resource use in CMC undergoing spinal fusion, which may inform how to best diagnose, manage, and control the dysfunction ahead of surgery. In the current study, nearly one-third of hospital readmissions after spinal fusion in CMC were for reasons beyond musculoskeletal and skin issues related directly to the operation. Future studies should assess the capability of contingency planning in spinal fusion discharge care to potentially avoid some of the readmissions. For example, it might be effective to plot and implement instructions and action plans to avoid entirely or mitigate the severity of a variety of acute illnesses that resulted in hospital readmission in the current study, including respiratory infections, gastrointestinal dysmotility, kidney/urinary tract infections, and seizures. Additional attention to the involvement and ability of postdischarge clinicians, including primary, rehabilitation, and home care providers, to assist the children with their recovery and health optimization after acute-care discharge may be warranted. Future efforts to standardize this planning into discharge care might have an effect on reducing unnecessary hospital readmissions after spinal fusion in CMC. This study has several limitations. The identification of the assessed comorbid and acute conditions were dependent on their coding in each hospital’s administrative billing record by discharge. Given the suspected variation in coding practices across hospitals, relying on ICD-9-CM codes may have led to underdetection and undercounting of the conditions. Other methods, such as chart review or prospective data collection, may reveal a higher prevalence of chronic conditions. The PHIS administrative data from the current study are not

FIGURE 4
Associations of acute illnesses and hospital resource use for children with a complex neuromuscular or genetic condition undergoing spinal fusion. All point estimates and variance were derived from multivariable analysis of generalized linear regression (for LOS and hospital cost) and generalized estimating equations (for hospital readmission). All models included the acute illnesses displayed, chosen by previous studies and our clinical experiences, as well as age, sex, race/ethnicity, and comorbid conditions. Data were clustered by hospital in each model.
positioned to distinguish the degree to which the chronic conditions were appropriately recognized and managed before spinal fusion. In addition, the PHIS data cannot reveal when during the hospitalization particular events (eg, hypertension or respiratory arrest) occurred. Important clinical information about the spinal fusion operation itself, including the duration of procedure and blood loss, is not available in PHIS. Younger children (eg, those age <10 years) included in the study may have had a different clinical trajectory and surgical approach to their spine pathology than older children; all multivariable analyses in the current study controlled for younger children. Although we measured hospital readmissions, other important postdischarge outcomes, including missed school days, improvements in functional status, etc, were not available for measurement in PHIS. The study findings may be best generalized to CMC undergoing spinal fusion in children’s hospitals because non–children’s hospitals were not included in the study.43

Despite these limitations, the findings from the current study underscore the importance of both chronic conditions and acute illnesses in children with a complex neuromuscular or genetic condition undergoing spinal fusion. General pediatricians, hospitalists, anesthesiologists, intensivists, surgeons, and others may find it useful to review these conditions and illnesses as they continue to assess how to best optimize the children’s health recovery. In particular, it may be important for subsequent initiatives to understand the clinical mechanisms predominately responsible for the relationships between the conditions and hospital resource use. It may also be important to investigate how careful assessment and planning, especially ahead of the operation and at hospital discharge, may help manage the conditions in the perioperative period. Hopefully, these efforts and others will help ensure that CMC achieve the maximum benefit, experience, and outcomes from their spinal fusion operation as well as other types of operations that they may need.

REFERENCES

11. Dadure C, Sola C, Capdevila X. Preoperative nutrition through a prehabilitation program: A key

ABBREVIATIONS

AHRQ: Agency for Healthcare Research and Quality
CCC: complex chronic condition
CCI: Chronic Condition Indicator
CI: confidence interval
CMC: children with medical complexity
ICD-9-CM: International Classification of Diseases, Ninth Revision, Clinical Modification
IQR: interquartile range
LOS: length of stay
OR: odds ratio
PHIS: Pediatric Health Information System

FINANCIAL DISCLOSURE: Dr Glotzbecker has received payment for lectures (including service on speakers bureaus) from Depuy Synthes. The other authors have indicated they have no financial relationships relevant to this article to disclose.

FUNDING: Dr Berry was supported by the Agency for Healthcare Research and Quality (1P30HS024453-01). Funded by the National Institutes of Health (NIH).

POTENTIAL CONFLICT OF INTEREST: The authors have indicated they have no potential conflicts of interest to disclose.

Downloaded from www.aappublications.org/news by guest on July 6, 2021


Comorbidities and Complications of Spinal Fusion for Scoliosis
Jay G. Berry, Michael Glotzbecker, Jonathan Rodean, Izabela Leahy, Matt Hall and Lynne Ferrari
Pediatrics 2017;139;
DOI: 10.1542/peds.2016-2574 originally published online February 2, 2017;

<table>
<thead>
<tr>
<th>Updated Information &amp; Services</th>
<th>including high resolution figures, can be found at: <a href="http://pediatrics.aappublications.org/content/139/3/e20162574">Link</a></th>
</tr>
</thead>
<tbody>
<tr>
<td>References</td>
<td>This article cites 39 articles, 9 of which you can access for free at: <a href="http://pediatrics.aappublications.org/content/139/3/e20162574#BIBL">Link</a></td>
</tr>
<tr>
<td>Subspecialty Collections</td>
<td>This article, along with others on similar topics, appears in the following collection(s):</td>
</tr>
<tr>
<td></td>
<td>Hospital Medicine <a href="http://www.aappublications.org/cgi/collection/hospital_medicine_sub">Link</a></td>
</tr>
<tr>
<td></td>
<td>Surgery <a href="http://www.aappublications.org/cgi/collection/surgery_sub">Link</a></td>
</tr>
<tr>
<td>Permissions &amp; Licensing</td>
<td>Information about reproducing this article in parts (figures, tables) or in its entirety can be found online at: <a href="http://www.aappublications.org/site/misc/Permissions.xhtml">Link</a></td>
</tr>
<tr>
<td>Reprints</td>
<td>Information about ordering reprints can be found online: <a href="http://www.aappublications.org/site/misc/reprints.xhtml">Link</a></td>
</tr>
</tbody>
</table>
Comorbidities and Complications of Spinal Fusion for Scoliosis
Jay G. Berry, Michael Glotzbecker, Jonathan Rodean, Izabela Leahy, Matt Hall and Lynne Ferrari
*Pediatrics* 2017;139;
DOI: 10.1542/peds.2016-2574 originally published online February 2, 2017;

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://pediatrics.aappublications.org/content/139/3/e20162574

Data Supplement at:
http://pediatrics.aappublications.org/content/suppl/2017/01/31/peds.2016-2574.DCSupplemental