Variation in Adolescent Idiopathic Scoliosis Surgery: Implications for Improving Healthcare Value

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Objectives To investigate the variation in care and cost of spinal fusion for adolescent idiopathic scoliosis (AIS), and to identify opportunities for improving healthcare value.

Study design Retrospective cohort study from the Pediatric Health Information Systems database, including children 11-18 years of age with AIS who underwent spinal fusion surgery between 2004 and 2015. Multivariable regression was used to evaluate the relationships between hospital cost, patient outcomes, and resource use.

Results There were 16 992 cases of AIS surgery identified. There was marked variation across hospitals in rates of intensive care unit admission (0.5%-99.2%), blood transfusions (0%-100%), surgical complications (1.8%-32.3%), and total hospital costs ($31 278-$90 379). Hospital cost was 32% higher at hospitals that most frequently admitted patients to the intensive care unit ($P = .009$), and 8% higher for each additional 25 operative cases per hospital ($P = .003$). Hospital duration of stay was shorter for patients admitted to hospitals with highest intensive care unit admission rates and higher surgical volumes. There was no association between cost and duration of stay, 30-day readmission, or surgical complications. The largest contribution to hospital charges was supplies (55%). Review of a single hospital's detailed cost accounting system also found supplies to be the greatest single contributor to cost, the majority of which were for spinal implants, accounting for 39% of total hospital costs.

Conclusions The greatest contribution to AIS surgery cost was supplies, the majority of which is likely attributed to spinal implant costs. Opportunities for improving healthcare value should focus on controlling costs of spinal instrumentation, and improving quality of care with standardized treatment protocols. *(J Pediatr 2018;195:213-9).*

Adolescent idiopathic scoliosis (AIS) is a curvature of the spine of at least 10° in children ages 10-18 years of age for whom there is no underlying condition that might cause the curve.[1] AIS is the most common spinal abnormality of childhood and has a marked predilection for girls compared with boys.[2,3] The natural history of AIS is curve progression during growth, which may be accompanied by marked deformity, psychosocial stress, and decreased self-esteem.[4] In the most severe cases, pain, physical disability, and cardiorespiratory compromise can occur.[5] Several treatment modalities have evolved to address the progressive nature of AIS and its complications, including "watch and wait" conservative management, bracing, and surgery. Surgical intervention with spinal fusion is considered for patients with curves of 50° or greater at skeletal maturity.[4] Spinal fusion is performed by either a posterior or, less frequently, an anterior approach, and rods are attached to the spine by a variety of implants, including pedicle screws, hooks, and sublaminar wires or tapes. Implant selection varies by surgeon. Pedicle screws are most frequently used because of their ability to provide greater curve correction.[6,7]

Surgical management of AIS is a common and costly reason for pediatric hospital admission in the US, ranking it as the 5th most expensive and 48th most common indication for hospitalization.[8] Not only is the cost of AIS surgery among the highest for pediatric conditions, but also the cost is increasing out of proportion compared with other inpatient conditions.[9] Average charges for AIS surgery have more than tripled from $55 495 in 1997 to more than $177 000 in 2012, totaling more than $1 billion in health care expenditures annually (adjusted for 2012 dollars).[10] During this same time period, charges for all pediatric inpatient admissions only doubled.[10]

Although AIS is common, no expert consensus or evidence-based treatment guidelines exist to standardize care in the US. Not surprisingly, both AIS surgical care and costs vary markedly variable across the US. Complication and infection rates, hospital duration of stay, and average total charges vary by region and often

AIS	Adolescent idiopathic scoliosis
e^{β}	Exponentiated coefficients
ICD-9	*International Classification of Diseases, 9th edition*
ICU	Intensive care unit
PCH	Primary Children's Hospital
PHIS	Pediatric Health Information Systems

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by individual hospital.[11,12] Additionally, there is large variation in AIS surgical costs across US children's hospitals, 37% of which is attributable solely to the hospital where care was received.[8] It remains unclear what specific aspects of care are responsible for this variation and if the variation is associated with patient outcomes.

The purpose of this study is to investigate the variation in cost of spinal fusion surgery for AIS, identify the drivers of cost, and determine if there is a consistent relationship between cost and outcomes. Through this investigation we aim to identify opportunities to improve healthcare value (defined as quality/cost) for the surgical management of AIS.

Methods

This investigation included 3 components. The first was a retrospective cohort study using the Pediatric Health Information Systems (PHIS) database; the cohort in this study is referred to as the PHIS cohort. The second was a validation of the *International Classification of Diseases, 9th edition* (ICD-9) based AIS definition used to identify the PHIS cohort, based on data from the Primary Children's Hospital (PCH); this study used the PCH validation cohort. PHIS charge data are not granular enough to provide detail on the cost contribution of the different components of hospital care. Thus, the third component of this investigation was a descriptive study of detailed costs at PCH using the PCH cost cohort.

For the PHIS cohort, we used the PHIS database, which is composed of deidentified administrative and billing data. PHIS is maintained by the Children's Hospital Association, a national collaborative of 220 US children's hospitals that focuses on improving quality, cost, and delivery of care. There are 49 freestanding, tertiary care US children's hospitals within the Children's Hospital Association that submit data to the PHIS. The database includes hospital characteristics, patient demographics, ICD coding for diagnoses and procedures, as well as itemized charges for medications, radiologic studies, laboratory tests, and supplies. Data quality and reliability are maintained by both Children's Hospital Association and participating hospitals.[13]

For the PCH validation cohort we used the surgical case list maintained by the University of Utah Orthopedic Clinic at PCH, as well as the Intermountain Enterprise Data Warehouse. Data from these sources were verified by manual chart review. The University of Utah Institutional Review Board approved the study and waived the requirement for informed consent.

The PHIS cohort included all patients discharged from a PHIS hospital between January 2004 and September 2015 who were aged 11-18 on admission and who had an ICD-9 diagnosis code for AIS (737.30 or 737.0) as well as an ICD-9 procedure code for spinal fusion (81.0X, 81.62, 81.63, 81.64). Patients with codes for a complex chronic condition[14,15] were excluded, as were any patients with a code for a condition associated with neurologic impairment[16] that could potentially confound the diagnosis of AIS. We also excluded patients at hospitals with low surgical volume (<30 cases over the entire study period). If a patient underwent multiple surgeries during the study period, data from only the first surgery were included in the analysis.

The PCH validation cohort included all patients in the PHIS database who underwent spinal fusion surgery at PCH for any reason (including those excluded in the PHIS Cohort as above) between January 2007 and September 2015, and who were aged 11-18 years at admission. Patients excluded from the PHIS cohort were used to identify potentially missed AIS cases. The PCH cost cohort included all patients from the PHIS cohort whose surgery was performed at PCH and whose AIS diagnosis was confirmed by cross-referencing the orthopedic surgery case list and medical record review.

Statistical Analyses

We queried the PHIS database to determine the cost of inpatient care and measures of resource use for surgical treatment of AIS across US children's hospitals. Measures of resource use included hospital duration of stay, intensive care unit (ICU) admission, and blood transfusion. We identified receipt of blood transfusion through 3 ICD-9 procedure codes (99.00, 99.02, and 99.04) and 1 Clinical Transaction Code (531515). Surgical outcome measures included 30-day readmission rate and surgical complication rate. A list of surgical complications, as defined by PHIS, is provided in **Table I** (available at www.jpeds.com). Patient characteristics were summarized as count (%) for categorical variables and as mean and standard deviation, or median, IQR, and range for continuous variables. We compared hospital cost and patient outcomes, adjusting for both patient- and hospital-level characteristics using multivariable generalized estimating equation regression. An exchangeable covariance matrix was used to account for potential correlation in outcomes among patients belonging to the same hospital. Cost and duration of stay outcomes were modeled using a gamma distribution (with a log link) and binary outcomes using a binomial distribution. From the gamma outcome models, exponentiated coefficients (e^{β}), their 95% CIs and *P* values were reported. These e^{β} coefficients provide interpretations of multiplicative effects; for example, an $e^{\beta} = 1.14$ for female patients relative to males for duration of stay would indicate that female duration of stay was 14% longer on average than males. ORs, their 95% CIs, and *P* values were reported from logistic regression models.

Hospital costs were estimated based on cost/charge ratios as reported to the Centers for Medicare and Medicaid Services. All cost and charge data were adjusted for geography and inflation and are reported in 2014 dollars. Several variables (ICU admission rate, blood transfusion rate, and total hospital cost) were categorized into quartiles, determined by their summaries and rankings at the hospital level, to enable comparisons across hospitals.

To validate the PHIS definition of AIS, we used the PCH validation cohort and cross-referenced this with the PCH orthopedic surgery case list. Sensitivity and specificity of the PHIS definition were calculated using the PCH case list as the "gold standard."