



## National Trends in the Surgical Management of Adolescent Idiopathic Scoliosis: Analysis of a National Estimate of 60,108 Children From the National Inpatient Sample Over a 13-Year Time Period in the United States

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Received 30 October 2015; revised 23 August 2016; accepted 4 September 2016

### Abstract

**Study Design:** Analysis of Nationwide Inpatient Sample (NIS).

**Objective:** Evaluate evolution of operative treatment of adolescent idiopathic scoliosis (AIS).

**Summary of Background Data:** Spinal surgery is one of the most rapidly evolving branches of surgery. Changes in AIS operations are incompletely defined.

**Methods:** Children (10–18 years) with ICD-9 diagnosis of idiopathic scoliosis who underwent thoracic and/or lumbar spinal fusion identified in the NIS (1998–2011) were analyzed. Population-based utilization rates were calculated from US Census data. Patient demographics, surgical approach, operative techniques, complications during hospitalization, hospital stay length, and charges were analyzed.

**Results:** 60,108 children (46,256 girls, 13,776 boys, 76 gender not specified; average age 14.1 years) were identified. Thoracic fusions were the majority. Number of operations increased over time. For thoracic fusions, posterior operations significantly increased, whereas anterior and anterior/posterior operations decreased significantly. Although anterior operations for lumbar fusions declined, this was not as steep as thoracic. Use of autogenous bone graft (including iliac crest) significantly increased, which mirrored significant decreases in alternative fusion agents. Thoracoplasty significantly decreased, whereas osteotomy significantly increased. The average complication rate was 3.7%. Rates of blood transfusions, infection, and neural injury did not differ significantly from 1998 to 2011. Device-related complications increased significantly over time. Average lengths of hospital stay decreased significantly, whereas average total hospital charges increased significantly.

**Conclusions:** In a representative sample of the US population from 1998 to 2011, operative approaches and techniques for AIS significantly changed. Anterior procedure is rarely performed for thoracic curves; lumbar curves continue to be treated with anterior and posterior approaches. Osteotomy and autogenous bone graft increased, while thoracoplasty decreased. Overall complication rates remain stable, whereas hospital lengths of stays decreased and charges increased.

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**Keywords:** Adolescent idiopathic scoliosis; National inpatient sample (NIS); Surgical approaches; Complications; Charges

### Introduction

Posterior spine fusion was conceived by Russell Hibbs in 1914 [1]. Instrumentation of the spine was introduced in the 1950s to decrease pseudarthrosis and improve correction [1,2]. Instrumentation systems [3–8], fusion agents [9–13] and surgical techniques (approach, thoracoplasty, osteotomy) [14–21] continue to evolve and to stir debate. The purpose of this study is to evaluate trends in

Author disclosures: AAT (none); DCS (none); FC (none); MD (other from Fixes 4 Kids, outside the submitted work).

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surgical treatment for AIS in children between 1998 and 2011 using the Nationwide Inpatient Sample (NIS).

## Materials and Methods

### Study design

We queried the NIS database for hospitalization discharges between 1998 and 2011. The NIS is part of a family of databases and software tools developed for the Healthcare Cost and Utilization Project (HCUP) and is the largest publicly available all-payer inpatient health care database in the United States. The NIS survey is stratified by region and various hospital factors, including census region, ownership, location, teaching status, and bed size. Regions include the following: *South*—Virginia, West Virginia, North Carolina, South Carolina, Georgia, Florida, Kentucky, Tennessee, Mississippi, Alabama, Oklahoma, Texas, Arkansas, Louisiana, Delaware, Maryland, and District of Columbia; *Midwest*—Wisconsin, Michigan, Illinois, Indiana, Ohio, Missouri, North Dakota, South Dakota, Nebraska, Kansas, Minnesota, and Iowa; *West*—Idaho, Montana, Wyoming, Nevada, Utah, Colorado, Arizona, New Mexico, Alaska, Washington, Oregon, California, and Hawaii; *Northeast*—Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, Pennsylvania, New Jersey.

Hospitals are randomly selected to achieve a representative sample of approximately 20% in each hospital stratum (ie, region [Northeast/Midwest/South/West], location/teaching [nonteaching rural/teaching urban/nonteaching urban], ownership [government/nongovernment], bedsize [stratified by tertiles] [22], and all discharge records are collected from the randomly selected hospitals each year. Data for each hospitalization include diagnoses and procedures, patient demographics, hospital characteristics, lengths of stay, outcomes, expected payment sources, and charges [22]. These data are in the NIS file, as well as sampling weights and other variables to allow calculation of national estimates [23]. In its unweighted form, the NIS contains data from more than 7 million hospital stays per annum; weighted, it estimates more than 36 million hospitalizations nationally (ie, HCUP) [22].

United States Census Bureau data were used to estimate the total US population 18 years and younger in 1998–2011. Regional population sizes were obtained for 2000–2011. US population estimates were used to calculate incidence of procedures.

### Patient population

International Classification of Diseases—9th Revision (ICD-9) diagnoses and procedure codes were used to identify our patient cohort. Inclusion criteria were age 10–18 years, a diagnosis of idiopathic scoliosis (ICD-9 737.30), and spinal fusion (ICD-9 81.02–81.08; thoracic: 81.04–81.05, lumbar: 81.06–81.08). Codes for

instrumentation were not evaluated in this study because instrumentation and fusion for idiopathic scoliosis in children typically is performed through the same approach. For example, the addition of opposite side instrumentation such as interbody cages is exceedingly rare in children, in contrast with adults undergoing operative treatment of scoliosis. We excluded patients <10 years old, cervical spine fusions (81.02–81.03), curvature of the spine associated with other conditions (Charcot-Marie-Tooth disease, mucopolysaccharidosis, osteitis deformans, fibrosa cystica, osteoporosis, poliomyelitis, late effect of rickets, Pott, tuberculosis: ICD-9 737.4, 737.41, 737.43), recognized scoliotic conditions of spina bifida/myelomeningocele (ICD-9 741.00–741.03, 741.90–741.93), neurofibromatosis (ICD-9 237.7–237.79), cerebral palsy (ICD-9 330.0–330.9, 333.7, 333.71, 343.0–343.4, 343.8, 343.9), Prader-Willi syndrome (ICD-9 759.81), Marfan syndrome (ICD-9 759.82), and congenital musculoskeletal disease (ICD-9 759.89, 754.2).

### Outcome measures

Operative characteristics included surgical approach (anterior, posterior, combined anterior-posterior), fusion agent (iliac crest bone graft [ICBG], ICD-9 77.79; bone morphogenetic protein [BMP], ICD-9 84.52), thoracoplasty (ICD-9 33.34), and posterior osteotomy (ICD-9 77.20, 77.29, 77.39). Cases that involved another type of bone graft (ie, allograft) were those not associated with an ICD-9 code for BMP and/or ICBG. Postoperative complication data included infection (ICD-9 998.5, 998.51, 998.59, 996.67, 996.63), dural tear (998.2, 349.3, 349.31, 349.39), neural injury (ICD-9 349.89, 349.1, 996.75, 952.00–952.09, 952.2, 952.3, 952.4, 952.8, 952.9, 997.0, 997.01, 997.09), device complication (996.2, 996.49, 996.59, 996.75, 996.78), and other/non-specified (998.8, 998.81, 998.89, 998.9, 999.9). We also evaluated the use of blood transfusions (ICD-9 99.04), length of hospital stay, and total hospital charge, which was defined as the dollar amount for the entire hospital stay [24]. Charges were adjusted for inflation to 2011 dollars and do not include professional fees or the amount that was reimbursed for each procedure [24].

### Statistical analysis

Pearson chi-squared tests were used to determine statistical significance in trends. A p-value <.05 was considered statistically significant. All statistical analysis was performed using R, version 3.0.2 (R Foundation).

## Results

Overall, 60,108 children (46,256 girls, 13,776 boys, 76 gender not specified) underwent operation for AIS between 1998 and 2011. Thoracic curves were most commonly treated (n = 53,780; 89.4%); lumbar fusions accounted for

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