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Clinical Study

Surgical treatment of early-onset idiopathic scoliosis in the United States: a trend analysis of 15 years (1997–2012)

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Abstract

BACKGROUND CONTEXT: Early-onset scoliosis is a challenging problem that is defined as a curvature of the spine of more than 10 degrees identified in a child less than 10 years. Early-onset idiopathic scoliosis (EOIS) can cause substantial morbidity and may require surgical intervention.

PURPOSE: The aim of the present study was to identify the trends of EOIS type of surgeries, length of hospital stay, in-hospital complications, and total inpatient admission charges over a 15-year study period in the United States from 1997 to 2012.

STUDY DESIGN/SETTING: This retrospective study used the ICD-9-CM (International Classification of Diseases, Ninth Revision, Clinical Modification) codes from the Healthcare Cost and Utilization Project (HCUP) Kids Inpatient's Database (KID) for a 15-year period (1997–2012).

PATIENT SAMPLE: We identified a total of 897 patients with EOIS over the 15-year study period.

OUTCOME MEASURES: The present study determines the current trends for EOIS surgeries.

METHODS: The present study had no funding sources or any potential conflicts of interest associated biases. Idiopathic scoliosis patients with ages between 0 and <10 years were identified from the Kids' Inpatient Database with ICD-9-CM code 737.30. Posterior, anterior, and combined spinal surgeries were identified in EOIS through the procedure codes. Patients' gender, discharge diagnosis (comorbidities), hospital length of stay (LOS), mortality rates, hospital charges, and in-hospital complication rate data were collected between 1997 and 2012. The primary grouping variable of the study was the type of surgery (posterior, anterior, and combined). The trends of each variable (female gender, mortality rates, in-hospital complications rates, discharge diagnosis, LOS, and total hospital charges) were assessed for each surgical group separately. Cost inflation of hospital charges was adjusted for the year 2012. An analysis of variance test was used to analyze continuous variables and a chi-square test was used for categorical variables. A linear regression test was used to assess the trend of changes. $p \leq .05$ was considered statistically significant.

RESULTS: The study identified 897 patients, with 546 (61%) of them requiring surgery. Spine deformity surgery rates significantly decreased in patients with EOIS over time from 75% in 1997 to 47% in 2012, p=.019. In the surgery cohort, the male to female distribution was 37% and 63%, respectively. The overall mortality rate was 0.1%. The average length of hospital stay was 8 days and

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the average number of discharge diagnosis was 5.3. Aggregated complications were seen in 6% of the patients. The total mean hospital charge (per 2012 US dollars) was $119,613, which increased significantly for all types of surgeries. Over the 15-year study period, 62% (n=342) of the patients had posterior surgeries, 13% (n=71) of the patients had anterior surgeries, and 24% (n=133) of the patients had combined (anterior and posterior) surgeries. Posterior surgeries increased significantly from 33% in 1997 to 91% in 2012 (p<.004). Combined surgeries saw a significant decline from 50% to 4.3% (0<0.001). Anterior surgeries also decreased from 17% to 4.3% (p<.126), but this did not reach statistical significance.

CONCLUSIONS: From 1997 to 2012 (15 years) study period of patients with EOIS, posterior-based surgeries significantly increased. The overall surgery rate has significantly decreased for these patients. A significant increase in hospital charges were noticed in posterior, anterior, and combined surgeries.

Keywords: Early-onset idiopathic scoliosis; Hospital charges; In-hospital complications; Length of hospital stay; Posterior-based surgery, anterior-based surgery, combined surgery; Trend analysis

Introduction

Early-onset scoliosis (EOS) is a challenging problem and has been evolving over time. Early-onset scoliosis is defined as a curvature of the spine of more than 10 degrees identified in a child below the age of 10 years [1]. It encompasses all etiologies including congenital, syndromic, neuromuscular, and idiopathic. Like adolescent idiopathic scoliosis (AIS), there is no clear etiology for the development of early-onset idiopathic scoliosis (EOIS). Early-onset idiopathic scoliosis is further categorized based on the age of onset into infantile idiopathic scoliosis (diagnosed before age 4) and juvenile idiopathic scoliosis (diagnosed between ages 4 and 10).

Ninety percent of infantile idiopathic curves can be resolved without any treatment. However, in high-risk progressive curves, bracing and surgery are indicated. Ten to 15% of idiopathic curves in children are juvenile idiopathic curves. The treatment options are similar to AIS which may be observation, bracing, and surgery. The management of EOIS can be difficult as it involves an intricate and fine balance between the growths of the thorax, height, and maturity of the lungs. The true incidence of EOIS remains unknown, but a few studies have found a prevalence of <1% [2]. There is a wide spectrum in managing EOIS ranging from careful observation, growth-preserving surgeries, and definite fusion.

There is paucity of data available which examine the surgical details of this subgroup of patients. The aim of the present study was to identify the trends of EOIS type of surgeries, length of hospital stay, in-hospital complications, and total inpatient admission charges over a 15-year study period in the United States from 1997 to 2012.

Methods

The present study had no funding sources or any potential conflicts of interest associated biases. This was a retrospective study that reviewed data to determine surgical treatment trends in EOIS surgeries in the United States. The data available were provided through the Healthcare Cost and Utilization Project (HCUP) Kids Inpatient's Database (KID) for a 15-year period (1997–2012). The database is updated every 3 years and consists of inpatient details of cases of patients<21 years of age. The database consists of up to 7 million patients annually from more than 4,000 US hospitals in more than 44 states.

Idiopathic scoliosis cases were identified by ICD-9-CM code (International Classification of Diseases, Ninth Revision, Clinical Modification)=737.30 from the KID database (1997–2012). Next, patients who were diagnosed with idiopathic scoliosis between the ages of 0 and 10 years were filtered from the idiopathic scoliosis cases. Further, patients with EOIS who had posterior and anterior spinal surgeries were identified through ICD-9 CM procedure codes and placed in two separate groups (Table 1). Patients with EOIS who had both anterior and posterior ICD-9 CM procedure codes were also identified and placed in a third group (combined surgeries).

Other data collected were patients' gender, discharge diagnosis (comorbidities), hospital length of stay (LOS), mortality rates, and hospital charges. In-hospital complications related to surgery were noted and are summarized in Table 1.

Table 1
List of variables and ICD-9 codes

Type of surgery	ICD-9 code
Posterior	81.03, 81.05, 81.07, 81.35, 81.37
Anterior	82.02, 82.4, 81.06, 81.08, 81.32, 81.34, 82.36, 81.38
Type of complication	**ICD-9 code**
Dural injury	749.31
Nerve/Cord injury	997.01, 997.02, 997.09
Wound-related	998.11, 998.12, 998.13, 998.30
Vascular (DVT or PE)	415.11, 415.12, 415.13, 415.19, 453.40, 453.41, 453.42, 453.81, 453.82, 453.83
Infection (wound, pneumonia, urinary)	998.51, 998.59, 486, 599.0
Blood transfusion	
Blood transfusion	99.04

ICD-9, International Classification of Diseases, Ninth Revision; DVT, deep vein thrombosis; PE, pulmonary embolism.

Data analysis

The primary grouping variable of the study was the type of surgery (posterior, anterior, and combined). The trends of each variable (female gender, mortality rates, in-hospital complications rates, discharge diagnosis, LOS, and total hospital charges) were assessed for each surgical group separately. Cost inflation of hospital charges was adjusted for the year 2012. This was completed using the Department of Labor Bureau of Labor Statistics Inflation Calculator (http://www.bls.gov/data/inflation_calculator.htm).

Data were analyzed using IBM SPSS statistics 22 (IBM Corp., Armonk, NY, USA). An analysis of variance test was used to analyze continuous variables and a chi-square test was used for categorical variables. A linear regression test was used to assess the trend of changes. p≤.05 was considered statistically significant.

Results

We identified a total of 897 patients with EOIS over the 15-year study period. A total of 546 patients (61%) out of 897 required surgery. Spine deformity surgery rates significantly decreased in patients with EOIS over time from 75% in 1997 to 47% in 2012, p=.019 (Graph 1).

In the surgery cohort, the male to female distribution was 37% and 63%, respectively. The overall mortality rate was 0.1%. The average length of hospital stay was 8 days and the average number of discharge diagnosis was 5.3. Aggregated complications were seen in 6% of the patients.

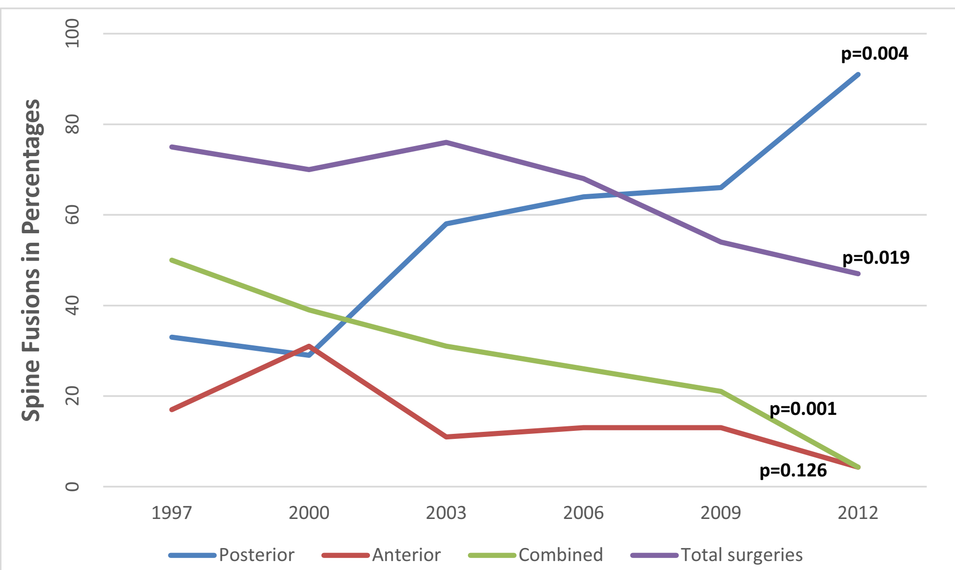
The total mean hospital charge (per 2012 US dollars) was $119,613 (Table 2). Hospital charges increased significantly for all types of surgery when adjusted to 2012 US dollars (Graph 2). For posterior-type procedures, the average cost was $45,947 in 1997 compared with $176,791 in 2012 (p<.001). For anterior surgeries, the cost increased by 2.8 times (p<.002), and for combined surgeries, the cost increased by 1.98 times (p<.004).

Over the 15-year study period, 62% (n=342) of the patients had posterior surgeries, 13% (n=71) of the patients had anterior surgeries, and 24% (n=133) of the patients had combined (anterior and posterior) surgeries. Posterior surgeries increased significantly from 33% in 1997 to 91% in 2012 (p<.004). Combined surgeries saw a significant decline from 50% to 4.3% (0<0.001). Anterior surgeries also decreased from 17% to 4.3% (p<.126), but this did not reach statistical significance.

The complication and mortality rates remained comparable throughout the study period. No mortalities were seen in the anterior or combined surgical groups; and only one mortality (1.7%) was reported in 2003 in the posterior surgery group. The mean in-hospital complication rate was approximately 6% for the surgery cohort. Within the groups, the mean in-hospital complication for posterior surgeries was 5%, anterior 3%, and combined 6.5%. The change in complication rate was not significant. In both the anterior and the combined surgical groups, there was a decline, although nonsignificant, in the complication rates from 12.5% and 13%, respectively, to 0%.

The average blood transfusion rate for the surgery cohort was 22%. In posterior surgeries, the average blood transfusion rate was 21%, anterior surgeries 17%, and combined surgeries 21%. No significant trend changes were noticed in average transfusion rates over the study period for all three groups.

The average number of discharge diagnosis (comorbidities) for the surgical cohort was 5.3. The average number of comorbidities was higher in combined surgeries with a mean=6.7 compared with posterior surgeries with a mean=5



Graph 1. Fifteen-year US trends of types of early-onset scoliosis (EOS) surgeries.

Table 2
Trend analysis of various parameters (1997–2012)

Surgery type	Year	Gender (F %)	Mortality rates (%)	LOS (d) mean	Comorbidities (mean)	Complication rates (%)	Blood transfusion rates (%)	Hospital charges (2012 USD)
Posterior	1997	47	0.00	7	5	0	13	45,947
	2000	60	0.00	7	5	7	20	60,734
	2003	63	1.70	8	4	3	28	92,039
	2006	31	0.00	7	4	3	17	119,103
	2009	74	0.00	7	5	6	24	150,915
	2012	67	0.00	9	7	6	26	176,791
p-Value		.46		.29	.22	.22	.19	<.001
Anterior	1997	50	0	8	4	12.5	13	51,884
	2000	75	0	7	5	6.3	25	51,416
	2003	50	0	6	3	0	18	87,189
	2006	75	0	6	3	0	0	124,454
	2009	57	0	5	4	0	6	134,862
	2012	80	0	5	9.4	0	40	145,882
p-Value		.344		.008	.27	.04	.66	.002
Combined	1997	57	0.00	11	6	13	17	102,787
	2000	70	0.00	8	6	5	35	97,747
	2003	71	0.00	12	6	0	35	140,559
	2006	45	0.00	7	7	6.9	20	138,023
	2009	48	0.00	10	8	8	20	193,265
	2012	40	0.00	6.2	5.4	0	17	204,083
p-Value		.105		.27	.66	.28	.21	.004

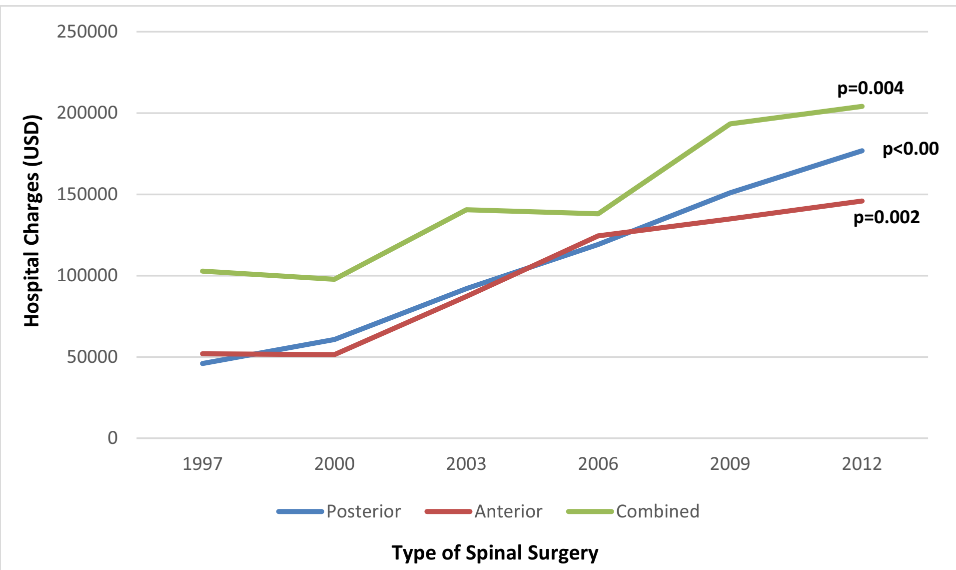
LOS, length of stay.

and anterior surgeries with a mean =4.7. There were no significant changes in trend noticed over the study period in all three surgical groups.

The average hospital LOS for the surgical cohort was 8 days. The mean LOS for posterior surgery was 7 days, anterior surgery was 6 days, and combined surgery was 9 days. The LOS was constant for posterior surgeries over time. The LOS data showed a significant decline in anterior surgeries from 8 days in 1997 to 5 days in 2012 (p>.008). In the combined surgical group, the trend of LOS followed an alternate pattern of high and lows, but the overall difference was not significant (p=.27) (Table 2).

Discussion

In the present study, we examined the surgical trends of EOIS in the United States over a 15-year period (1997–2012). The definition of EOS has been evolving over time. Dickson [3] first described EOS as a spine deformity noticed in children less than 5 years of age. The age increment was



Graph 2. Fifteen-year trend of hospital charges by type of surgery.

revised in 2014 to include all cases of spinal deformity noted in children less than 10 years of age by the Growing Spine Study Group and Scoliosis Research Society [4]. Early-onset scoliosis has been subdivided based on etiology and includes congenital, neuromuscular, syndromic, and idiopathic [5]. The main rationale to identify and define EOS was to differentiate it from infantile and juvenile scoliosis considering its impact on respiratory consequences in severe curves [6]. We reviewed the idiopathic type of EOS and used the current working definition to include all cases of scoliosis in children less than 10 years of age.

The surgery rate in patients with EOIS decreased in the present study over time. Serial casting and bracing are the first-line conservative treatments in EOIS. Over time, improvements have been noticed in casting and bracing techniques, and have led to better correction of spinal curvature and delays in the progression of the curve until puberty to undergo definitive spinal fusion [7,8]. There has been an increased trend toward conservative treatments versus surgical treatment due to complications. Therefore, surgery rates have declined in early-onset idiopathic patients.

Hospital charges increased over the 15-year period after adjusting for the 2012 US dollars. The overall increase in cost for EOIS was 2.4 times and was greatest for posterior approach-based surgery (3.8 times) compared with anterior (2.8 times) and combined (2 times) surgeries. High average hospital charges were reported in combined surgeries and followed by posterior and anterior surgeries in the present study.

In general, there has been an overall health-care cost inflation that has resulted in these increased surgical costs. Martin et al. [9] reported an increase in the surgical cost of AIS of 11.3% annually in a 10-year study period (2001–2011). Over the years, there has been an increase in posterior approach-based surgeries that involve the use of pedicle-based instrumentation [9–17]. Posterior surgeries include longer levels of fixation and are not level preserving which results in an increase in the overall cost of surgeries [18]. Surgeons are also using more pedicle screws to achieve a greater degree of correction [9,10]. Higher implant density, along with use of newer technology or metals, also results in these higher costs. Although most early-onset constructs involve growth guidance and may have a limited number of implants or involve serial surgeries, the database did not allow for following serial treatment of a single patient. Pedicle screws have been found to be more expensive per fused level than hook-based constructs [19].

In their study of 125 consecutive cases of adolescent scoliosis surgeries, Kamerlink et al. [10] found that the majority of overall costs can be attributed to implants (29%) followed by intensive and ICU care (22%) costs. In a 10-year study, Martin et al. [9] reported implants contributed to 53% of the total cost in 2013 compared with 28% in 2003. Pedicle screw-based correction of deformities has been found to be superior to using hooks (hybrid constructs), not only in terms of better correction of the deformity but also improvement in pulmonary function in severe cases [20]. Surgeons currently treat much larger curves with pedicle screw constructs, which have been found to increase the use of health-care resources, the levels being fused, and the duration of hospital stay [9,21].

The comparative cost of other spine and non-spinal procedures has also increased; however, the cost of scoliosis treatment has been found to be extremely high. Daniels et al. [22] found that the cost of surgically treating a C2 fracture rose by 1.9 times over an 11-year period. Martin et al. [9] reported an increase in mean hospital charges for non-spine conditions (supracondylar humerus fracture treated with closed reduction and percutaneous pinning and pediatric medical admission for pneumonia) to be 4.5%–6% annually compared with 11% for scoliosis. Use of surgical advances, such as image navigation and fusion products, also plays a role in increase in cost [12–15,23]. In an AIS study, the authors discovered that fusion products contribute 6% of the cost of surgeries [10]. In addition, costs have increased with the increased use of minimum access and video-assisted surgery that involve an infrastructure and operational cost. Discussed above are reasons for the increases in hospital charges in the present study period.

The surgical approach to idiopathic EOS saw a sharp and consistent increase in posterior-based surgeries from 33 % in 1997 to 91 % in 2012. Correspondingly, anterior and combined surgeries saw a decline. Better training, a shorter learning curve in posterior-based surgery including the availability of superior implants, and the ability to correct severe deformities through posterior-based complex osteotomies may have led to this dramatic increase in posterior-based surgeries. A similar trend has also been seen in AIS surgeries [9]. Pedicle screw-based surgical strategies, such as direct vertebral rotation, have been found to provide cosmetic correction of severe deformities and are now frequently used by surgeons [24,25]. Apart from degenerative spinal conditions, posterior approach-based surgeries saw an upward trend for other spinal etiologies, such as infections [26]. Other studies have also suggested a belief of fewer complications and the length of hospital stay with posterior approach-based surgery has led to an increase in popularity for this approach [27,28].

Complication rates associated with EOIS surgeries have not been reported well in the literature. In patients with EOS, the complication rates range from 0% to 89% [29]. The reason for such a wide discrepancy is the lack of standardization and definition of what constitutes a complication. Additionally, inclusion of a heterogeneous population adds to this large disparity. In the present study, the in-hospital complication rate was approximately 6% for EOIS surgical patients. No change in complication rates were noticed in posterior and combined surgeries; however, anterior surgery complication rates decreased over time. A study by Weiss and Goodall [27] reported a hospital complication rate range between 6.3% and 17.8%. The antero-posterior group in their study had a higher complication rate presumably because this group had more severe curves and complex medical issues raising the complication rates. In our study, the average in-hospital complication rate was higher in combined surgeries (6.5%) compared with anterior (3%) and posterior (5%) surgeries. Additionally, the complication rates for anterior and combined surgery declined to 0%. This was probably due to an overall decrease in the number of these surgical procedures and improved overall intraoperative and perioperative quality.

There are certain limitations to the present study. The KID database is derived by reviewing the billing data by the ICD-9-CM codes. It is not possible to delve into the medical or surgical complexities and patient comorbidity factors that can independently influence the results. Additionally, the database does not provide an insight of the outpatient data for these patients and may influence the complications noted. Despite these limitations, the results of the present study form a platform for further studies related to the treatment of EOS, specially related to cost reduction strategies.

Conclusions

From 1997 to 2012 (15 years) study period of patients with EOIS, posterior-based surgeries significantly increased. The overall surgery rate has significantly decreased for these patients. A significant increase in hospital charges were noticed in posterior, anterior, and combined surgeries.

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