



Trends in Treatment of Scheuermann Kyphosis: A Study of 1,070 Cases From 2003 to 2012

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Abstract

Study Design: Retrospective review of KID Inpatient Database (KID) from 2003, 2006, 2009, and 2012.

Objectives: The aim of this study was to evaluate the impact of advances in spinal surgery on patient outcomes in the treatment of Scheuermann kyphosis (SK).

Summary of Background Data: SK is one of the most common causes of back pain in adolescents. Trends in diagnoses and surgical treatment and approach to SK have not been well described.

Methods: SK patients aged 0–20 years in KID were identified by ICD-9 code 732.0. KID-supplied year- and hospital-trend weights were used to establish prevalence. Patient demographics, surgical details, and outcomes were analyzed with analysis of variance.

Results: A total of 1,070 SK patients were identified (33.2% female), with increasing incidence of SK diagnosed from 2003 to 2012 (3.6–7.5 per 100,000, $p < .001$). The average age of operative patients was 16.1 ± 2.0 years and did not change (16.27–16.06 years, $p = .905$). The surgical rate has not changed over time (72.8%–72.8%, $p = .909$). Overall, 96.3% of operative patients underwent fusion, with 82.2% of cases spanning ≥ 4 levels; in addition, 8.6% underwent an anterior-only surgery, 74.6% posterior-only, and 13.6% combined approach. From 2003 to 2012, rates of posterior-only surgeries increased (62.4%–84.4%, $p < .001$) whereas the rate of combined-approach surgeries decreased (37.6%–8.8%, $p < .001$). Overall complication rates for SK surgeries have decreased (2003: 20.9%; 2012: 11.9%, $p = .029$). Concurrently, the rate of ≥ 4 -level fusions has increased (43.5%–89.6%, $p < .001$), as well as the use of Smith-Petersen (7.8%–23.6%, $p < .001$) and three-column osteotomies (0.0%–2.7%, $p = .011$). In subanalysis comparing posterior to combined approaches, complication rates were significantly different (posterior: 9.88%, combined: 19.46%, $p = .005$). Patients undergoing a combined approach have a longer length of stay (LOS) than patients undergoing a posterior-only approach (7.8 vs. 5.6 days, $p < .001$).

Conclusions: Despite unchanged demographics and operative rates in SK, there has been a shift from combined to isolated posterior approaches, with a concurrent increase in levels treated. A combined approach was associated with increased complication rates, LOS, and total charges compared to isolated approaches. Awareness of these inherent differences is important for surgical decision making and patient education.

Levels of Evidence: Level III.

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Keywords: Scheuermann kyphosis; Trends; Complications; Surgical trends; Posterior fusion; Surgical approach

Introduction

Scheuermann kyphosis (SK) is one of the most common causes of back pain in adolescents [1–5]. It is a spinal disorder named after Dr. Holger Wefel Sheuermann, who first

described this rigid thoracic kyphosis in adolescents in 1921 [6]. The classic diagnostic criteria were established by Sorensen in 1964 as being three or more wedged vertebrae in the thoracic spine [7]. There are other pathologic changes, including disc and endplate lesions and irregular endplates

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[8,9]. Drummond proposed that the diagnosis of the disease should be based on two or more adjacent wedged vertebra in 1987 [2]. The etiology of SK is multifaceted and somewhat undefined, but has been shown to have a dominant autosomal genetic component—a study using a Danish cohort of 35,000 twins showed that SK has a heritability of 74% [10].

The incidence of SK has been reported in the literature ranging from 0.04% to 10% of the general population [2,11–13]. SK generally occurs toward the end of the juvenile age, between 8 and 12, and the most rigid form of SK presents in adolescents ages 12–16 years old, with no major differences in sex [13]. SK is often confused for adolescent postural kyphosis; thus, a physical examination and radiographic analysis are necessary to differentiate the two conditions [14]. The main difference between the two on physical examination is the rigidity of the spine, as well as neurologic examination, hamstring tightness, and range of motion of joints [14].

Treatment for SK is debated in the literature and is controversial. Bracing is in some circumstances indicated for skeletally immature patients with the aim being to improve the kyphosis [8,15]. Surgical intervention is indicated in SK patients for a large kyphotic curve, pain following conservative treatment, neurologic or cardiopulmonary impairments [11,15]. Differences in outcomes for posterior-only procedures versus anterior-posterior surgeries have been described in the literature. A study from 1956 demonstrated that posterior-only surgeries were associated with some failed treatment for SK, possibly because of inadequate correction or lack of support from the anterior portion of the spine [16]. Thus, anterior-posterior combined-approach surgeries for SK were proposed, though with initial increased morbidity rates for patients undergoing combined-approach procedures [11]. Temponi et al. in 2011 compared posterior-only surgeries (with Smith-Peterson osteotomies) with combined-approach procedures and found that combined-approach surgeries achieved more correction of the curve but were associated with increased complication rates [11]. Advances in materials and implants used in spine surgery and technology available then led to a shift toward posterior-only approach surgeries for SK to avoid the high morbidity rates with combined-approach procedures. These posterior-only surgeries with associated pedicle screws and Smith-Peterson osteotomies have been reported as achieving and maintaining better correction and had fewer complications than combined-approach procedures in the treatment of SK [17–19]. These improvements demonstrate that in select cases, the need for combined-approach surgeries for

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SK can be obviated and posterior-only surgeries can be performed instead, with better reported outcomes.

To date, few studies have investigated Scheuermann kyphosis on a national scale. Jain et al. studied the trends in all SK surgical patients using the Nationwide Inpatient Sample database [20]. Their study looked at only surgical SK patients with a mean age of 24.9 years, with 53% of patients older than 18 years, who underwent surgical treatment for SK. Jain and colleagues studied surgical trends and changes in surgical approach in this cohort, but lacked the study of overall trends in diagnoses and treatment for all SK patients, both operative and nonoperative. Limited literature exists looking at SK in a solely pediatric and adolescent population for overall trends as well as surgical treatment trends and complications related to surgical approach.

Therefore, the aim of this study was to analyze national trends in the diagnosis and surgical treatment of Scheuermann kyphosis in adolescents using the pediatric-specific Kid Inpatient Database and to compare the surgical approach chosen for the surgery.

Methods

Data source

The Kid Inpatient Database (KID) is the largest publicly-available all-payer pediatric (age <21 at admission) inpatient health care database in the United States. The Agency for Healthcare Research and Quality's Healthcare Cost and Utilization Project (HCUP) created this KID database. KID sampling includes complicated and uncomplicated births, as well as other pediatric inpatient procedures from community, non-rehabilitation hospitals. The KID database contains 107 data elements, using *International Classification of Disease, Ninth Revision, Clinical Modification* (ICD-9-CM) format to code all of the diagnoses and procedures. With more than 3 million hospital stays per three-year database, it is designed to allow accurate calculation of medical condition incidences using HCUP-provided trend weights [21,22]. A detailed overview of the KID design is available at <https://www.hcup-us.ahrq.gov/kidoverview.jsp>.

Patient sample

The sample included patients in the KID database with a diagnosis of Scheuermann kyphosis using the ICD-9 code 732.0. A subanalysis looked at SK patients undergoing any

spinal surgery and compared patients undergoing a posterior-only approach surgery to patients with a combined (anterior and posterior) approach surgery. Comorbidities and concurrent conditions and syndromes were assessed using ICD-9 codes and included conditions such as Marfan syndrome, Prader-Willis syndrome, and Ehlers-Danlos syndrome. Complications assessed included the following: dysphagia, nervous system complications, cardiac, peripheral vascular disease, respiratory, digestive, urinary, device, postoperative shock, hematoma/seroma, nerve puncture, wound dehiscence, infection, posthemorrhagic anemia, acute respiratory distress syndrome, pulmonary embolism, deep vein thrombosis, dural tear and were determined based on ICD-9 codes.

Statistical analysis

IBM SPSS Statistics version 23.0 (IBM Corp., Armonk, NY) was used to perform all descriptive and comparative statistics. We estimated the prevalence of SK cases in the United States using HCUP sampling weights. KID year- and hospital-weights define sampling weights by the ratio of discharges in the American Hospital Association contributing hospitals to discharges in the sample. Trends in demographic variables, hospital charges, surgical details, and outcomes were assessed using analysis of variance. Differences between posterior-only surgeries and combined-approach surgeries were studied using Chi-squared tests to assess differences in demographics, surgical variables, and complications between these two groups of surgical SK patients.

Results

SK patient demographics

1070 SK patients were identified in the KID database from 2003 to 2012. The prevalence of SK has increased from 2003 to 2012, from 3.6 to 7.5 per 100,000 (p < .001). The top primary and secondary diagnoses of these patients are listed in Table 1: 627 patients had a primary diagnosis of SK and 128 patients had a secondary diagnosis of SK. In

Table 1
Top 4 primary and secondary diagnoses for patients with a SK diagnosis.

	Diagnosis	Frequency, n (%)
Primary diagnoses		
1	Scheuermann kyphosis	627 (58.6)
2	Scoliosis acquired - kyphosis (postural)	53 (5.0)
3	Scoliosis other - kyphosis (acquired)	32 (3.0)
4	Scoliosis	32 (3.0)
Secondary diagnoses		
1	Scheuermann kyphosis	128 (13.5)
2	Posthemorrhagic Anemia	61 (5.7)
3	Spine curvature	36 (3.4)
4	Kyphosis (acquired)	21 (2.0)

SK, Scheuermann kyphosis.

Table 2
Demographics of all SK patients.

	All SK patients (N = 1,070)
Age, mean ± SD	16.21 ± 2.13
Infantile	1 (0.1)
Juvenile	6 (0.6)
Adolescent	1,058 (99.3)
Gender (% female)	353 (33.2)
Race	
White	695 (65.0)
Black	17 (1.6)
Hispanic	91 (8.5)
Asian	6 (0.6)
Native American	5 (0.5)
Other	50 (4.7)
Charlson comorbidity index, mean ± SD	0.391 ± 0.797
Length of stay, mean ± SD	5.42 ± 4.08
Weekend admission	79 (7.4)
Average total charges, mean ± SD	\$128,306.04 ± \$107,509.39
Died during hospitalization	1 (0.1)
Depression	59 (5.5)
Anxiety	48 (4.5)

SK, Scheuermann kyphosis.

Values are n (%) unless otherwise noted.

addition, 33.2% of patients were female, and the average age of these SK patients was 16.1 ± 2.0 years (Table 2). Nineteen (1.8%) SK patients have a codiagnosed syndrome or congenital anomaly, the most common of which were Marfan syndrome and Prader-Willis syndrome (Table 3). The average age of patients presenting to hospitals across the United States has not changed in the last decade (16.27 years in 2003 and 16.06 years in 2012, p = .905). Fifty-nine (5.5%) of SK patients have depression and 48 (4.5%) have anxiety.

Table 3
Associated syndromes and congenital anomalies with SK patients.

Syndrome	Frequency
Marfan syndrome	4
Prader-Willis syndrome	3
Ehlers-Danlos syndrome	1
Situs inversus	1
Chromosome anomaly (not sex chromosome)	1
Neurofibromatosis type 1	1
Other congenital anomaly	1
Syndrome total	12
Anomaly	
Bone	5
Neck	1
Nervous	1
Genitourinary	0
Gastrointestinal	0
Eye	0
Ear	0
Lung	0
Face	0
Endocrine	0
Anomaly total	7

SK, Scheuermann kyphosis.

Table 4
Surgical trends for operative SK patients.

	2003	2006	2009	2012	p
Surgical rate	115 (72.8)	183 (74.1)	230 (74.4)	259 (72.8)	.909
Age, mean \pm SD	16.27 \pm 2.05	16.03 \pm 1.91	16.15 \pm 1.91	16.06 \pm 1.98	.915
Combined approach	38 (37.6)	35 (20.3)	19 (8.7)	20 (8.8)	<.001*
Posterior-only	63 (62.4)	137 (79.7)	200 (91.3)	607 (84.4)	<.001*
2–3 levels fused	1 (0.9)	16 (8.7)	11 (4.8)	14 (5.4)	.524
\geq 4 levels fused	50 (43.5)	158 (86.3)	207 (90.0)	232 (89.6)	<.001*
Interbody	23(20.0)	29 (15.8)	47 (20.4)	47 (18.1)	.961
BMP	3 (2.6)	19 (10.4)	43 (18.7)	20 (7.7)	.961
SPO	9 (7.8)	22 (12.0)	44 (19.1)	61 (23.6)	<.001*
3CO	0	0	6 (2.6)	7 (2.7)	.011*
Posterior decompression	39 (33.9)	34 (18.6)	26 (11.3)	18 (6.9)	<.001*

BMP, bone morphogenic protein; SK, Scheuermann kyphosis; SPO, Smith-Peterson osteotomy; 3CO, 3-column osteotomy. Values are n (%) unless otherwise noted. Bolded cells with ‘*’ represent statistical significance ($p < .05$).

As a reference, the entire KID database contains 12,718,381 patients with an average age of 6.88 years (range 0–20) and is 53.8% female. The most common diagnoses overall in the KID database are pneumonia, bronchiolitis due to respiratory syncytial virus, asthma, and appendicitis. In addition, 1.7% of patients in the KID database have a diagnosis of depression and 0.8% have a diagnosis of anxiety.

Surgical SK patients

Overall, there were 787 (73.6%) SK patients who underwent spinal surgery during their hospital stay. The rate of SK patients undergoing surgery has not changed from 2003 to 2012 (72.8%–72.8%, $p = .909$; Table 4). In addition, 96.3% of operative patients underwent fusion, with 82.2% of cases spanning \geq 4 levels. Moreover, 8.6%

underwent an anterior-only surgery, 74.6% posterior-only, and 13.6% a combined approach. The rate of anterior-only surgeries has not changed from 2003 to 2012 ($p = .820$). Overall complication rates for SK surgeries have decreased (2003: 20.9%, 2012: 11.9%, $p = .029$). Concurrently, the rate of \geq 4-level fusions has increased (43.5%–89.6%, $p < .001$), as well as the use of Smith Peterson (7.8%–23.6%, $p < .001$) and three-column osteotomies (0.0%–2.7%, $p = .011$). Total hospital charges increased from 2003 (\$98,707 \pm \$45,738) to 2012 (\$192,394 \pm \$102,655) ($p < .001$).

Surgical SK patients—Surgical approach subanalysis

From 2003 to 2012, the rate of posterior-only surgeries increased (62.4%–84.4%, $p < .001$), whereas the rate of combined-approach surgeries decreased over time (37.6%

Table 5
Demographic differences between posterior-only surgeries and combined approach surgeries for SK patients.

	Posterior (n = 607)	Combined (n = 112)	p
Age	16.03 \pm 1.93	16.26 \pm 2.02	.256
Infantile	0	0	—
Juvenile	2	0	.713
Adolescent	602	111	.713
Gender (% female)	192	32	.508
Race			
White	403	71	.588
Black	6	0	.597
Hispanic	58	6	.205
Asian	3	2	.175
Native American	4	0	.507
Other	36	4	.378
Charlson comorbidity index	0.437 \pm 0.875	0.389 \pm 0.740	.533
Length of stay	5.59 \pm 2.34	7.75 \pm 3.66	<.001*
Weekend admission	10	2	.581
Average total charges	\$168,130.79 \pm 100,494.54	\$172,808.70 \pm 101,407.30	.658
Died during hospitalization	0	0	—
Depression	26	4	.487
Anxiety	22	8	.117

SK, Scheuermann kyphosis.

Bolded cells with ‘*’ represent statistical significance ($p < .05$).

–8.8%, $p < .001$; Table 5). A total of 607 patients underwent a posterior-only surgery, and 112 had a combined-approach procedure. Patients undergoing a combined approach had longer length of stay (LOS) than patients undergoing a posterior-only approach (7.8 vs. 5.6 days, $p < .001$). Age, race, gender, and CCI were all similar between posterior and combined-approach surgical patients (all $p > .05$).

All of the combined-approach surgeries were ≥ 4 -level fusions, whereas the rate of ≥ 4 -level surgeries for posterior-only approach surgeries was 84.5% (100% vs. 84.5%, $p < .001$; Table 6). Three-column osteotomy, Smith-Peterson osteotomy rates, and BMP use were all similar between the two groups (both $p > .6$). Discectomy rates for combined-approach surgeries was 55% and interbody use was 27.7%. For posterior-only surgeries, discectomy rates were 2.8% and interbody use was 16.9% (Table 5). Patients undergoing combined-approach surgeries had higher complication rates than patients who had posterior-only surgeries (19.46% vs. 9.88%, $p = .005$) as well as higher rates of respiratory complications not including pneumonia (6.25% vs. 0.99%, $p = .01$). All other

individual complication rates did not differ between combined-approach and posterior-only surgeries (all $p > .05$; Table 5).

Discussion

Trends and treatment of Scheuermann kyphosis remains controversial and understudied. Treatment for adult deformity has expanded in recent years and the understanding of sagittal alignment has increased, which possibly has a direct or indirect role in the ways in which pediatric spine surgeons approach Scheuermann kyphosis, a purely sagittal deformity. This study found that the prevalence of SK in the United States has increased in the last decade, from 3.6 to 7.5 per 100,000 from 2003 to 2012. Similarly, the prevalence of adolescent idiopathic scoliosis has been reported to increase over time, with one study reporting an increase from 1.66% to 6.17% from 2000 to 2008 in a Korean population of over 1 million schoolchildren [23].

In the present study, we reported the national trends over the last decade in diagnosis, demographics, and surgical treatment of SK. There has been a significant increase in

Table 6
Surgical details and complications for posterior-only surgeries and combined approach surgeries for SK patients.

Procedures	Posterior, n (%)	Combined, n (%)	p
Levels fused			
Simple (2–3)	30 (4.94)	0	.009*
Complex (≥ 4)	513 (84.5)	112 (100)	<.001*
Revision	18 (2.96)	2 (1.79)	.754
3CO	9 (1.48)	2 (1.79)	.684
SPO	109 (17.95)	18 (16.07)	.688
Laminectomy	20 (3.29)	5 (4.46)	.572
Discectomy	17 (2.80)	61 (54.46)	<.001*
Corpectomy	9 (1.48)	2 (1.79)	.684
Interbody	103 (16.97)	31 (27.68)	.012*
Posterior decompression	34 (5.60)	63 (56.25)	<.001*
BMP	72 (11.86)	8 (7.14)	.190
Complication			
Dysphagia	0	0	—
Nervous system	4 (0.66)	3 (2.68)	.080
Cardiac	6 (0.99)	1 (0.89)	.701
Peripheral vascular disease	0	0	—
Respiratory	6 (0.99)	7 (6.25)	.001*
Digestive	6 (0.99)	0	.597
Urinary	7 (1.15)	3 (2.68)	.194
Device	15 (2.47)	2 (1.79)	.661
Postoperative shock	0	0	—
Hematoma/seroma	8 (1.32)	2 (1.79)	.660
Puncture nerve	5 (0.82)	1 (0.89)	.639
Wound dehiscence	2 (0.39)	2 (1.79)	.177
Infection	3 (0.49)	3 (2.68)	.052
Posthemorrhagic anemia	66 (10.87)	16 (14.29)	.331
ARDS	8 (1.32)	2 (1.79)	.660
Pulmonary embolism	0	0	—
Deep vein thrombosis	1 (0.16)	0	.844
Dural tear	2 (0.39)	1 (0.89)	.399
At least 1 complication	60 (9.88)	22 (19.64)	.005*

ARDS, acute respiratory distress syndrome; BMP, bone morphogenic protein; SK, Scheuermann kyphosis; SPO, Smith-Peterson osteotomy; 3CO, 3-column osteotomy.

Bolded cells with “*” represent statistical significance ($p < .05$).

the prevalence of SK, though the operative rates for SK have remained the same over time. This increased prevalence could be due to many factors, including increased screening, diagnosis, and better understanding of the condition. Few studies have looked at prevalence rates of SK diagnoses over time, though studies for adolescent idiopathic scoliosis have reported increased prevalence partially because of better screening and counseling [23–25].

The SK patients in the present study using the KID database have higher rates of depression and anxiety than in the overall pediatric and adolescent sampling in the database. This is consistent with reports of increased anxiety/depression in SK patients, likely in part because of the cosmetic effects of SK and decreased body image associated with the large thoracic curve and/or from bracing [26–28]. In addition, we found that a few SK patients also have Marfan syndrome, Prader-Willis syndrome, or Ehlers-Danlos syndrome and eight patients total with a congenital anomaly (seven bone, one neck, one nervous, one unspecified). These syndromes have been previously reported to present in SK patients and there have been reports of congenital anomalies associated with SK and kyphosis [29–32].

We showed that the use of combined-approach procedures to treat SK have declined in recent years, with posterior-only surgeries becoming increasingly more common. These findings are consistent with previous literature that has shown that with the recent advances in surgical techniques and instrumentation, the outcomes following posterior-only surgeries have increased dramatically, and a study by Johnson et al. showed that combined-approach surgeries for SK do not add any additional benefit to SK patients in terms of radiographic outcomes [18,33]. Additionally, recent trends have focused on reducing the occurrence of proximal junctional kyphosis (PJK) by avoiding overcorrection of thoracic hyperkyphosis [34]. This overcorrection, although most likely to occur in flexible SK cases, should be avoided as it can result in loss of correction and implant loosening and is an important consideration for surgeons when operating on an SK patient [35,36].

We found that complication rates significantly differed for SK surgical patients undergoing either posterior-only or combined-approach procedures. The overall complication rate specifically for combined-approach surgeries was 19.64%, and posterior-only procedures had a 9.88% complication rate in our study. These findings are consistent with those recently published by Jain et al., who studied the surgical cohort of SK patients in the Nationwide Inpatient Sample and found an overall complication rate of 17.8% for combined-approach and 8.5% for posterior-only surgeries [20]. In addition, Lonner et al. found that 24% of SK patients who underwent combined-approach surgeries had a major complication, whereas the complication rate was 6% in the posterior-only fusion SK group [36]. In looking at

individual complications, we found that SK patients who had a combined-approach surgery had higher rates of respiratory complications than posterior-only surgical patients, which is consistent with previous findings [20]. Similarly, we found that SK patients undergoing posterior-only fusions had a shorter length of stay than patients who had combined-approach procedures.

We appreciate several limitations in our study. First, the KID only includes in-hospital data and thus we cannot track patients' outcomes once they leave the hospital. This potentially limits our analysis of postoperative complications that could have occurred after a patient was discharged, and it also does not provide any information about the patient before hospital admission. In addition, the KID database does not include any radiographic information, limiting our knowledge of the severity of the deformity preoperatively. KID also does not have the granularity to parse out the exact number of levels fused or the specific instrumentation used, which could potentially impact our findings. The KID database also does not have clinical or radiographic outcomes data, which are important considerations for treatment and technique decision making by physicians. Specifically, we lack details regarding an individual's pain levels both before and after surgery. This analysis also did not determine complication severity, in part because of the lack of granularity regarding complication occurrence in a nationwide database. In spite of these limitations, this is the largest study to date looking at adolescent SK patients and the overall trends in prevalence and treatment in the United States over the last decade.

Conclusions

The prevalence of SK has increased in the last decade, with recent surgical advances changing the evolution of surgical treatment. Despite no differences in trends in patient demographics or operative rates in the last decade, there has been a shift from combined to isolated posterior approach surgical treatment for SK. Combined-approach surgeries were associated with increased complication rates and longer length of stay than SK surgeries that were isolated posterior procedures. Future studies should more closely examine the causes of increasing SK prevalence to determine whether this is a true increase in prevalence or an increase in screening and diagnosis. In light of complications and treatment trends in the perioperative setting, further studies with mid- and long-term follow-up will help determine the appropriateness of these changes.

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