Disparities in clinical and economic outcomes in children and adolescents following surgery for tethered cord syndrome in the United States

Faris Shweikeh, MD,¹ Lutfi Al-Khouja, BS,¹ Miriam Nuño, PhD,¹ J. Patrick Johnson, MD,^{1,2} Daniel Drazin, MD,¹ and Matthew A. Adamo, MD³

¹Department of Neurosurgery, Cedars-Sinai Medical Center, Los Angeles; ²Department of Neurosurgery, University of California Davis Medical Center, Sacramento, California; and ³Department of Neurosurgery, Albany Medical Center, Albany, New York

OBJECT Tethered cord syndrome (TCS) is a common spinal abnormality. In this study, the authors analyzed demographics, complications, and outcomes in children and adolescents who underwent surgery for TCS.

METHODS Using the national Kids' Inpatient Database (KID), the authors retrospectively identified patients with a primary diagnosis of TCS who were treated with spinal laminectomy and discharged in 2000, 2003, 2006, and 2009. Descriptive analysis was provided for patient- and hospital-level characteristics. Mortality, complications, non-routine discharges, in-hospital length of stay (LOS), and total charges were documented for the entire cohort and age-specific cohorts (0–5, 6–10, 11–15, and 16–20 years). Comparisons by complications and age groups were conducted.

RESULTS A total of 7397 children and adolescents met the criteria in the 4 studied years. The mean age was 5.7 years; 55.3% of patients were younger than 5 years, 21.5% were 6–10 years, and 16.2% were 11–15 years. Most surgeries were performed in patients who were female (55.0%) and white (64.4%) and were performed at large (49.8%), teaching (94.2%), and urban (99.1%) children's (89.3%) hospitals. The trend showed an increase in prevalence from 2000 (19.9%) to 2009 (29.6%). Common comorbidities included anomalies in spinal curvature (16.7%), urinary or bladder dysfunction (14.3%), and spinal stenosis/spondylosis (1.4%). Non-routine discharges (3.3%) were significantly higher with advancing age, increasing from 2.2% in those younger than 5 years to 9.0% in those older than 15 years ($p < 0.0001$). There was a similar increasing trend for complications (6.8% to 13.9%, respectively, $p < 0.0001$) and average LOS (3.5 to 5.1 days, respectively, $p < 0.0001$). Hospital charges increased with age from an average of \$28,521 in those younger than 5 years to \$36,855 in those older than 15 years ($p < 0.0001$).

CONCLUSIONS There was a steady trend of increasing operative treatment for TCS over the more recent years. The nationwide analysis was also indicative of an existing disparity, based on age, in complications, outcomes, and charges following TCS surgical correction. Older children tended to have more complications, longer LOS, more non-routine discharges, and higher hospital costs. The results are highly supportive of surgery at a younger age for this condition. Future research should investigate this correlation, especially considering the efforts to control and reduce health care costs.

<http://thejns.org/doi/abs/10.3171/2014.9.PEDS14241>

KEY WORDS tethered cord syndrome; pediatric; adolescents; spine; filum terminale; national study; epidemiology

ONE of the occult spinal dysraphisms, tethered cord syndrome (TCS), is a condition associated with neurological, orthopedic, and urological sequelae.^{1,2} The basic associated pathophysiology is traction of the lower spinal cord by a tightened filum terminale.^{1,2} Although it was described more than 150 years ago, the term “tethered spinal cord” was introduced in 1976 by Hoffman and colleagues.^{2,4,5,7} Although the term has been extended

to include multiple causes, the tethering in TCS is most commonly caused by a constricted, thickened, and/or excessively fatty filum as first described by these authors.^{2,4,5,7} There has been a steady increase in the incidence of TCS and other occult spinal dysraphisms, likely secondary to increased recognition of the syndrome and increased use of imaging modalities.^{2,4} There is evidence to indicate a relation between TCS and neural tube defects and other

ABBREVIATIONS KID = Kids' Inpatient Database; LOS = length of stay; TCS = tethered cord syndrome; VATER = vertebral anomalies, imperforate anus, tracheoesophageal fistula, and renal-radial anomalies.

SUBMITTED May 13, 2014. **ACCEPTED** September 4, 2014.

INCLUDE WHEN CITING Published online January 9, 2015; DOI: 10.3171/2014.9.PEDS14241.

DISCLOSURE The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

congenital abnormalities.^{2,4} Other syndromes associated with TCS include caudal agenesis, anorectal atresia, and VATER syndrome (vertebral anomalies, imperforate anus, tracheoesophageal fistula, and renal-radial anomalies).

Surgical sectioning of the filum has been reported to be safe and associated with a low rate of complications. When complications do occur, they include CSF leak, infection, or nerve root or spinal cord injuries leading to motor weakness, radiculopathy, or bladder dysfunction. Surgery frequently improves symptoms and may prevent future neurological sequelae. The operation involves release of the tension within the filum and is usually low risk. However, surgical management remains slightly controversial and should be offered on a case-by-case scenario. In this study, we used a national database to analyze demographics, complications, and outcomes in children and adolescents who underwent surgical correction of their TCS.

Methods

Data Source and Cohort Selection

Children diagnosed with TCS during 2000, 2003, 2006, and 2009 were identified using the Healthcare Cost and Utilization Project's Kids' Inpatient Database (KID). KID, compiled by the Agency for Healthcare Research and Quality, is a nationally representative database that samples 80% of pediatric hospital discharges and 10% of uncomplicated births to increase the statistical power to detect and evaluate rare conditions among hospitalized children. Hospital discharges are weighted based on the sampling scheme to permit inferences for a nationally representative population. In 2009, the most recent year for which the KID is available at this time, the KID contained de-identified information for 7.4 million weighted discharges from 4121 hospitals in 44 states. Using ICD-9-CM codes, patients with a primary diagnosis of TCS (ICD-9-CM Code 742.59) and treated with a spinal laminectomy (ICD-9-CM Code 03.59, 03.09, or 03.4) in 2000, 2003, 2006, and 2009 were identified.

Patient and Hospital Characteristics

Patient age, sex, and race; primary payer; type of admission (emergency/urgent, elective, or other); discharge disposition (routine, transfer, died, or other); and median household income were documented. Hospital level characteristics included bedsize, teaching status, region (Northeast, Midwest, South, or West), location (urban or rural), and children's hospital status. Children's hospitals included children's general hospitals, children's specialty hospitals, and children's units in general hospitals. Year of diagnosis for these patients was also documented in this study.

Outcomes of Interest

Mortality rate, non-routine discharge, complication rate (%), average length of stay (LOS), and total hospital charges were the main outcomes of interest. A non-routine discharge was denoted when a death, transfer, or other non-routine event was documented as the reason for discharge. The complications assessed in this study are listed in Table 1.

Statistical Analysis

A descriptive analysis for the entire cohort (n = 7397) was provided for patient- and hospital-level characteristics. Univariate comparisons according to patient demographics, hospital characteristics, and outcomes were assessed using chi-square and Student t-tests. Multivariate analysis was performed for complications, length of stay, and non-routine discharge. A p value ≤ 0.05 was considered to be statistically significant. All analyses used SAS for Windows (version 9.1, SAS Institute Inc.).

Results

Demographics

According to the KID database, a total of 7397 patients with TCS underwent a spinal laminectomy in 2000, 2003, 2006, or 2009 in hospitals across the nation. Patient demographics are summarized in Tables 2 and 3. The mean patient age was 5.7 years; 55.3% of patients were younger than 5 years, 21.5% were between 6 and 10 years, 16.2% were between 11 and 15 years, and 6.9% were between 16 and 20 years (Table 2). More females were represented in this cohort (55.0%). Whites (64.4%) followed by Hispanics (18.9%) and blacks (6.6%) were the leading race categorizations among these patients; note that no race data were not reported for 25.3% of the patients. In this cohort, 87.9% of patients underwent an elective spinal laminectomy, while 12.0% underwent emergency/urgent treatment. Common comorbidities included anomalies in spinal curvature (16.7%), urinary or bladder dysfunction (14.3%), epilepsy (3.3%), and spinal stenosis and spondylosis (1.4%) (Table 4).

Univariate Analysis

A majority of the patients undergoing spinal laminectomy for TCS had private insurance (58.5%), while 33.7% had Medicaid (Table 2). Hospital-level characteristics for all and cohort-specific patients are documented in Table 3. Most surgeries were performed at large (49.8%) teaching (94.2%) hospitals located in an urban area (99.1%). A large fraction of patients were treated at a children's hospital (89.3%).

Outcomes

Of the 7397 patients included in this study, 9 (0.12%) died prior to discharge and 243 (3.3%) had non-routine discharges. Non-routine discharges were significantly higher with increased age, increasing from 2.2% in those younger than 5 years to 9.0% in those older than 15 years ($p < 0.0001$). The average complication rate among all cohorts was 7.2%, and a positive trend can be seen with increasing age (Table 5); age groups 0–5 and 6–10 years showed a complication rate of 6.8% and 5.5%, respectively, while age groups 11–15 and 16–20 years showed a rate of 8.1% and 13.9%, respectively ($p < 0.0001$). Figure 1 outlines specific complication rates stratified by age and indicates a higher rate with increasing age among various complications including pseudomeningocele, urinary tract infection, pulmonary, procedure-related, and gastrointestinal. The older age groups also had longer in-hospital

TABLE 1. ICD-9-CM diagnosis codes for complications

Complication	ICD-9-CM Diagnosis Codes
Neurological	99700, 99701, 99709, 7843
Pulmonary	5070, 5184, 51881, 51882, 51883, 51884, 51889, 9973, 99731, 99739
Respiratory	5184, 5185, 51881, 51882, 51883, 51884, 9973
Thromboembolic	387, 4510, 4511, 45111, 45119, 4512, 4518, 45181, 45182, 45183, 45184, 45189, 4519, 453, 4530, 4531, 4532, 4533, 4534, 45340, 45341, 45342, 4535, 45350, 45351, 45352, 4536, 4537, 45371, 45372, 45373, 45374, 45375, 45376, 45377, 45379, 4538, 45381, 45382, 45383, 45384, 45385, 45386, 45387, 45389, 4539, 4151
Cardiac	9971, 410, 4100, 41001, 4101, 41010, 41011, 4102, 41020, 41021, 4103, 41030, 41031, 4104, 41040, 41041, 4105, 41050, 41051, 4106, 41060, 41061, 4107, 41070, 41071, 4108, 41080, 41081, 4109, 41090, 41011
Procedure-related	998, 9980, 9981, 99811, 99812, 99813, 9982, 9983, 99830, 99831, 99832, 99833, 9984, 9985, 99851, 99859, 9986, 9987, 9988, 99881, 99882, 99883, 99889, 9989, 9981, 99811, 99812, 99813
Urinary tract infection	584, 9975
Infection, other	510, 5100, 5109, 038, 0380, 0381, 03810, 03811, 0381, 03819, 0382, 0383, 0384, 03840, 03841, 03842, 03843, 03844, 03849, 0388, 0389, 320, 3200, 3201, 3202, 3203, 3207, 3208, 32081, 32082, 32089, 53110, 53111, 5192, 5901, 59010, 59011, 59080, 683
Pseudomeningocele	349.2
Hydrocephalus	3313, 3314
Vascular	9977, 99771, 99772, 99779, 9972
Postop fluid & electrolyte abnormalities	2760, 2761, 2762, 2763, 2764, 2765, 276, 2767, 2768, 2769
Stroke/hemorrhage	2535, 99811, 99702, 430, 431, 4320, 4321, 4329
Gastrointestinal	5780, 5781, 5789, 5350, 570, 5750, 5770, 9974
Tracheostomy/gastrostomy	311, 3121, 3129, 312
Mechanical ventilation	9670, 9671, 9672
Seizure	7803, 78031, 78039
Hemiplegia/hemiparesis	3420, 3421, 3428, 3429
Wound-related	99811, 99812, 99813, 99831, 99832, 99859

stays after surgery compared with the average of 3.8 days (range 0–87 days). The LOS averaged 3.5 days for patients 0–5 years, 3.7 days for those 6–10 years, 4.5 days for those 11–15 years, and 5.1 days for those 16–20 years ($p < 0.0001$). Mean total charges for the TCS patients undergoing spinal laminectomy were calculated to be \$28,683 (SD \$1196) and increased with age from an average of \$28,521 in those younger than 5 years to \$36,855 in those older than 15 years ($p < 0.0001$). There was a trend toward an increase in prevalence from 2000 (19.9%) to 2009 (29.6%).

Multivariate Analysis

Table 6 presents results of multivariate analysis for complications, non-routine discharge, and LOS. The ICD-9-CM diagnosis codes for assessed complications are presented in Table 1. Age and preexisting conditions were strongly associated with the odds of a complication. Older patients (16–20 years) had a 2.2 odds of experiencing a complication (OR 2.2 [95% CI 1.3–2.8]) compared with patients 6–10 years of age. Similarly, patients with a preexisting condition were twice as likely to experience a complication compared with patients without preexisting conditions. Age, type of admission, and type of insurance were all associated with the LOS. Younger patients (age 0–5 years: estimate -0.37), nonelective admissions (estimate -2.43), and nonprivate insurance patients (estimate -0.29) had significantly shorter hospital stays. Older age

(OR 2.4 [95% CI 1.0–5.7]) was only mildly associated with the odds of a non-routine discharge.

Discussion

Fatty infiltration or excessive tightening of the filum terminale undermines its normal function in stabilizing the spinal cord. The subsequent adhesion and tugging on the cord results in the symptoms associated with TCS. Such symptoms include neurogenic bladder, weakness, numbness, spasticity, spinal deformities, deformities in feet, and skin lesions.^{1,4,9} Surgical release is an option that is widely practiced by pediatric neurosurgeons. From this descriptive analysis, we have identified patient age and the presence of comorbidities to be factors affecting surgical outcomes in children and adolescents undergoing surgical intervention for TCS. Although surgical intervention has been shown to be an effective treatment for patients with TCS, proper assessment of patients prior to surgery and risk stratification by age and comorbidities will help us better determine the risk of those with poor outcomes.

In this analysis of more than 7000 children with a diagnosis of TCS who underwent spinal laminectomy in 2000, 2003, 2006, or 2009, we examined multiple factors including demographics, complications, and outcomes. We compared the association between complications, age groups, and the number of comorbidities. We find that most pa-

TABLE 2. Characteristics of 7397 patients with TCS who were surgically treated in 2000, 2003, 2006, or 2009*

Variable	Value
Age in yrs	
Mean	5.7
SE	0.2
Median	4.0
IQR	1–10
Age category in yrs	
0–5	4094 (55.3)
6–10	1593 (21.5)
11–15	1201 (16.2)
16–20	509 (6.9)
Female	4021 (55.0)
Race	
White	3562 (64.4)
Black	365 (6.6)
Hispanic	1047 (18.9)
Asian/Pacific Islander	165 (3.0)
Native American	22 (0.40)
Other	365 (6.6)
Primary payer	
Medicare	13 (0.18)
Medicaid	2491 (33.7)
Private insurance	4319 (58.5)
Self-pay	77 (1.0)
Other	481 (6.5)
Admission type	
Emergency/urgent	755 (12.0)
Elective	5514 (87.9)
Other	1 (0.02)
Discharge disposition	
Routine	7151 (96.7)
Transfer	96 (1.3)
Other	137 (1.8)
Died	9 (0.1)
Median household income	
\$1–24,999	1274 (17.5)
\$25,000–34,999	1886 (25.9)
\$35,000–44,999	1920 (26.4)
≥\$45,000	2191 (30.1)

IQR = interquartile range.

* Values are presented as the number of patients (%) unless indicated otherwise. Missing values: race (25.3%), admission type (15.2%), primary payer (0.02%), discharge disposition (0.05%), income (1.7%).

tients were treated at large teaching hospitals in urban areas. Additionally, the overwhelming majority (89%) were managed at children's hospitals. The patient distribution over the years listed increased from 2000 (19.9% of our study population) to 2009 (29.6% of our study population), showing an increasing trend of surgical management of TCS in the pediatric population (Table 3). The increase could be speculated to be due to both surgeon and patient

TABLE 3. Hospital characteristics of 7397 TCS patients who were surgically treated in 2000, 2003, 2006, or 2009

Variable	No. of Patients (%)
Hospital bedsize	
Small	1416 (20.4)
Medium	2073 (29.8)
Large	3457 (49.8)
Missing	450 (6.1)
Teaching hospital	
Yes	6543 (94.2)
No	403 (5.8)
Missing	450 (6.1)
Hospital region	
Northeast	1136 (15.4)
Midwest	1554 (21.0)
South	2667 (36.1)
West	2039 (27.6)
Hospital location	
Urban	6884 (99.1)
Rural	62 (0.9)
Missing	450 (6.1)
Children's hospital	
Yes	6136 (83.0)
No	732 (9.9)
Missing	52 (7.159)
Year of diagnosis	
2000	1406 (19.0)
2003	1657 (22.4)
2006	2145 (29.0)
2009	2187 (29.6)
Missing	2 (0.03)

preferences, as well as to enhanced and ubiquitous use of imaging modalities.

This pediatric population averaged 5.7 years of age, similar to what has been reported in a recent study,⁹ with most patients (55.3%) younger than 5 years. We categorized the patients based on 4 different age groups for comparison (ages 0–5, 6–10, 11–15, and 16–20 years). There was a slight female preponderance in this study group, consistent with findings of Kanev et al. and Lad et al.^{6,7} However, more studies are needed to confirm this in the pediatric population as some studies indicate some variability in sex prevalence.^{1,9} Additionally, multiple studies (including this analysis) have shown much greater prevalence in Caucasians/whites compared with other races and ethnicities (64.4%, Table 2).⁷

Of the patients analyzed, 7.2% had complications following initial spinal laminectomy. This complication rate is similar to what others have found and reported.^{7,9} Our data suggest a positive correlation between increasing age and risk for complications. On average, the 0- to 5-year-old group had a complication risk of 6.8%, while the 16- to 20-year-old group had a 13.9% risk ($p < 0.0001$). The risk increased in a stepwise fashion from one age group to the

TABLE 4. Preexisting conditions in 7397 patients with TCS who were surgically treated in 2000, 2003, 2006, or 2009

Variable	Total	Age Category in Yrs*				p Value
		0–5	6–10	11–15	16–20	
No. of patients	7397	4094 (55.3)	1593 (12.5)	1201 (16.2)	509 (6.9)	
Urinary/bladder dysfunction	1055 (14.3)	321 (7.8)	349 (21.9)	276 (22.9)	110 (21.5)	<0.0001
Spondylosis/spinal stenosis	103 (1.4)	33 (0.80)	27 (1.7)	31 (2.6)	12 (2.3)	0.001
Spinal curvature anomalies	1232 (16.7)	522 (12.7)	277 (17.4)	332 (27.7)	100 (19.7)	<0.0001
Seizure/epilepsy	2443 (3.3)	89 (2.2)	78 (4.9)	61 (5.0)	15 (2.9)	<0.0001
Hydrocephalus	63 (0.9)	23 (0.6)	23 (1.4)	13 (1.1)	15 (2.9)	0.10

* Values are number of patients (%).

next older age group, although the 0- to 5-year age group had a slightly higher percentage than the 6- to 10-year age group. Our review of the KID database shows that complications following spinal laminectomy for TCS do not vary in relation to race, income, sex, insurance type, or institution type where the surgery was performed (Tables 5 and 6). This helps eliminate some potential confounders and provides more evidence toward the correlation between patient age and complications/outcomes. Kanev et al.⁶ found a similar trend and concluded that surgery performed at an earlier age resulted in better outcomes, though at long-term follow-up, particularly in bladder function. Besides age, there was a significant correlation between comorbid conditions and the development of complications (Table 6). However, there was not a clear trend of increased comorbidities with increasing age. For instance, while the prevalence of urinary symptoms increased with age, the increase in prevalence of other comorbidities was inconsistent among the age groups.

An average LOS of 3.8 days was reported in our data (range of 3.5–5.1, Table 5). The 0- to 5-year age group averaged an LOS of 3.5 days, while the 16- to 20-year age

group had a higher average of 5.1 days ($p < 0.0001$, Table 5). Again, LOS increased in a stepwise fashion from one age group to the next older age group. A similar trend in non-routine discharges was noted, with a continuous increase in its likelihood with age, from 2.2% in the 0- to 5-year age group and up to 9.0% in the 16- to 20-year age group. Additionally, older pediatric patients had higher total charges. Patients 16–20 years old were faced with an average total charge of \$36,855 compared with the total average of \$28,683 and \$28,521 in those 0–5 years ($p < 0.0001$, Table 5). From these findings, we see more evidence supporting the theory that older patients with TCS who undergo spinal laminectomy are at an increased risk for complications, causing a longer LOS and more frequent non-routine discharges leading to greater total charges.⁷

Previously Lad et al.⁷ performed a similar study through the Nationwide Inpatient Sample. While our analysis focused on the pediatric population, a more commonly afflicted group, their study covered both the adult and pediatric populations. Their evaluation was focused on surgically managed patients with TCS treated between 1993 and 2002. They found a total of 9733 cases, with

TABLE 5. Outcomes of 7397 tethered cord syndrome patients treated with spinal laminectomy in 2000, 2003, 2006, or 2009*

Variable	Total	Age Category in Yrs†				p Value
		0–5	6–10	11–15	16–20	
No. of patients	7397	4094 (55.3%)	1593 (21.5%)	1201 (16.2%)	509 (6.9%)	
Mortality	9 (0.12)	1 (0.03)	8 (0.49)	0 (0)	0 (0)	NE
Non-routine discharge	243 (3.3)	90 (2.2)	52 (3.3)	55 (4.6)	46 (9.0)	<0.0001
Complications	536 (7.2)	280 (6.8)	87 (5.5)	98 (8.1)	71 (13.9)	<0.0001
LOS in days						
Mean	3.8	3.5	3.7	4.5	5.1	<0.0001
SD	3.2	3.2	2.3	3.3	4.3	
Median	3	3	3	4	4	
IQR	2–4	2–4	2–5	3–5	3–6	
Range	0–7	0–87	1–35	1–41	1–57	
Total charges in \$						
Mean	28,683	28,521	27,107	32,431	36,855	<0.0001
SD	1196	24,639	17,674	23,844	30,007	
Median	23,892	23,352	22,896	26,499	29,104	
IQR	16,100–35,904	15,780–34,381	15,369–34,102	17,594–39,044	18,970–46,441	

NE = not estimable.

* Differences in outcomes according to race, income, insurance, and children's hospital were found to be nonsignificant.

† Values are number of patients (%) unless indicated otherwise.

FIG. 1. Complication rates of tethered cord syndrome patients stratified by age categories. UTI = urinary tract infection. Figure is available in color online only.

5830 patients between the ages of 0 and 17 years, a number smaller than ours. Notably, patients who were 65 years or older had a higher risk of complications after surgery and longer LOS. They also had a higher likelihood of non-routine discharge and risk of death on discharge. However, the elderly population is widely known to more likely be in poorer health with more comorbidities and other associations that can bring about such differences. On the other hand, a similar causality cannot explain the dissimilarities seen in our study between the different age groups; all the patients were in their youth without any expected variances in their overall health. The reasons for this occurrence could only be speculated. It can be hypothesized that older children may have more coexisting medical conditions than younger children. Another possibility is that the de-

lay in diagnosis and treatment of TCS may result in more severe consequences and symptoms, worsening outcomes after surgery in older children. Along the same lines, TCS in older children and adolescents could represent a different disease entity from that in young children or a condition along the spectrum of TCS.

In addition to age, the number of compounding comorbidities present increases the risk for postoperative complications, consistent with the multivariate analysis conducted by Lad et al. Bui et al.² summarized the common comorbidities in patients with TCS, which can include cutaneous manifestations, orthopedic abnormalities (i.e., leg-length discrepancy, foot asymmetry, foot deformity, and progressive scoliosis), and urological problems (i.e., neurogenic bladder, incontinence, and frequent urinary

TABLE 6. Multivariate analysis of factors associated with the outcomes of complications, non-routine discharge, and LOS

Variables	Outcomes					
	Complications		Non-Routine Discharge		LOS	
	OR (95% CI)	p Value	OR (95% CI)	p Value	Estimate (SE)	p Value
Age group in yrs (ref: 6–10)						
0–5	1.9 (1.2–3.2)	0.01	0.6 (0.3–1.3)	0.23	–0.37 (0.13)	0.005
11–15	1.8 (1.04–3.3)	0.04	1.2 (0.6–2.5)	0.63	0.64 (0.22)	0.005
16–20	2.2 (1.3–2.8)	0.005	2.4 (1.0–5.7)	0.05	0.84 (0.23)	0.0003
Race (ref: white)						
Non-white	0.8 (0.5–1.3)	0.40	1.0 (0.6–1.6)	0.56	0.12 (0.21)	0.59
Sex (ref: female)						
Male	1.1 (0.8–1.5)	0.49	0.6 (0.3–1.1)	0.12	0.03 (0.13)	0.79
Type of admission (ref: elective)						
Non-elective	2.0 (1.0–4.1)	0.06	1.7 (0.8–3.5)	0.14	–2.43 (0.67)	0.0004
Insurance (ref: private)		0.86				
Non-private	1.0 (0.7–1.4)		1.2 (0.7–2.0)	0.61	–0.29 (0.13)	0.03
Preexisting condition (ref: no)*						
Yes	2.1 (1.4–3.0)	0.0002	0.9 (0.5–1.5)	0.56	0.27 (0.15)	0.07

Ref = reference.

* Conditions considered: urinary/bladder dysfunction, spondylosis, degeneration of disc disease, spinal curve anomalies, seizure/epilepsy, or hydrocephalus.

tract infections). In their experience, Bui et al. have found cutaneous manifestations in 59% of TCS patients, a neurogenic bladder in 18%, and leg or foot length discrepancy in 6%.² Other common comorbidities include degenerative disc disease, spinal stenosis and spondylosis, anorectal abnormalities, split cord malformation, OEIS syndrome (omphalocele, extrophy of the cloaca, imperforate anus, and spinal malformations with TCS), VATER associations, and the Currarino triad (anorectal malformation, presacral mass, and sacral bone abnormalities).^{1,3,8,9,10} To date, no large-scale study has been conducted to determine the prevalence of these comorbid conditions with TCS.

Looking forward, this study shows the need for future research to focus on this correlation between age, comorbidities, complications, LOS, non-routine discharges, and higher hospital costs in children undergoing surgery for TCS. Our findings are highly suggestive that surgery should be performed, preferably at a younger age. Additionally, further follow-up is needed in regard to patients who undergo repeat operations for retethering and its possible association with the factors discussed above. It is more likely that older patients have a higher predisposition to developing complications, rather than having a different disease entity. However, it could also be likely that older children have a more advanced or undetected form of the condition with a different pathophysiology—an area that could be further investigated in future research. Aspects such as lesion type, lesion size, histopathology, and mechanisms of disease would be of interest for further evaluation. This and future research will hopefully result in reducing the rate of complications and hospital costs by helping physicians and surgeons better identify the risk a patient may have with surgery and determine if treatment is cost-effective.

Limitations

There are multiple limitations to studies based on national databases such as KID. Although it covers a large patient population, it is retrospective in nature and only a limited amount of information can be obtained. For instance, clinical data on preoperative symptoms, radiological findings, and certain comorbidities are unattainable. These would help determine the methodology of treatment selection and identify patients who may require a certain treatment over another. Additionally, it is not possible to determine long-term outcomes such as relief of symptoms and clinical improvement at follow-up. Other limitations include missing data, possible coding errors of procedures and diagnoses, and possible overrepresentation of patients discharged repeatedly.

Conclusions

Our results, from a national database of children and adolescents surgically treated for TCS, indicate multiple significant findings. First, the operative management of TCS has increased in frequency over recent years. This could be due to both surgeon and patient preferences, as well as to the enhanced and ubiquitous use of imaging modalities. Second, there are a number of highly significant differences in outcomes between different age groups.

This trend in different outcomes was observed with increasing age. All measures of outcome analyzed—LOS, non-routine discharges, complications, and hospital charges—were all significantly higher as patient age increased. This is highly supportive of surgery at a young age for this condition. It also begs the question of why such a finding exists and, more importantly, brings awareness to its presence to surgeons, specialists, and the health care system in its entirety. Future research should investigate this correlation, especially considering the efforts to control and reduce health care costs.

References

1. Ailawadhi P, Kale SS, Agrawal D, Mahapatra AK, Kumar R: Primary tethered cord syndrome—clinical and urological manifestations, diagnosis and management: a prospective study. *Pediatr Neurosurg* 48:210–215, 2012
2. Bui CJ, Tubbs RS, Oakes WJ: Tethered cord syndrome in children: a review. *Neurosurg Focus* 23(2):E2, 2007
3. Filippidis AS, Kalani MY, Theodore N, Rekate HL: Spinal cord traction, vascular compromise, hypoxia, and metabolic derangements in the pathophysiology of tethered cord syndrome. *Neurosurg Focus* 29(1):E9, 2010
4. Hertzler DA II, DePowell JJ, Stevenson CB, Mangano FT: Tethered cord syndrome: a review of the literature from embryology to adult presentation. *Neurosurg Focus* 29(1):E1, 2010
5. Hoffman HJ, Hendrick EB, Humphreys RP: The tethered spinal cord: its protean manifestations, diagnosis and surgical correction. *Childs Brain* 2:145–155, 1976
6. Kanev PM, Lemire RJ, Loeser JD, Berger MS: Management and long-term follow-up review of children with lipomyelomeningocele, 1952–1987. *J Neurosurg* 73:48–52, 1990
7. Lad SP, Patil CG, Ho C, Edwards MS, Boakye M: Tethered cord syndrome: nationwide inpatient complications and outcomes. *Neurosurg Focus* 23(2):E3, 2007
8. Michelson DJ, Ashwal S: Tethered cord syndrome in childhood: diagnostic features and relationship to congenital anomalies. *Neurol Res* 26:745–753, 2004
9. Ostling LR, Bierbrauer KS, Kuntz C IV: Outcome, reoperation, and complications in 99 consecutive children operated for tight or fatty filum. *World Neurosurg* 77:187–191, 2012
10. Yamada S, Won DJ, Pezeshkpour G, Yamada BS, Yamada SM, Siddiqi J, et al: Pathophysiology of tethered cord syndrome and similar complex disorders. *Neurosurg Focus* 23(2):E6, 2007

Author Contributions

Conception and design: Drazin, Shweikeh. Acquisition of data: Nuño. Analysis and interpretation of data: Shweikeh, Al-Khouja, Nuño. Drafting the article: Shweikeh, Al-Khouja. Critically revising the article: Shweikeh, Adamo. Reviewed submitted version of manuscript: Drazin, Shweikeh, Adamo. Approved the final version of the manuscript on behalf of all authors: Drazin. Statistical analysis: Nuño. Study supervision: Johnson, Adamo.

Supplemental Information

Previous Presentation

The abstract was presented at the 2014 Annual Meeting of the AANS/CNS Section on Disorders of the Spine and Peripheral Nerves in Orlando, Florida, on March 5, 2014.

Correspondence

Doniel Drazin, Cedars Sinai Medical Center, Department of Neurosurgery, 8631 W. Third St., Ste. 800E, Los Angeles, CA 90048. email: doniel.drazin@cshs.org.