Tethered cord syndrome: nationwide inpatient complications and outcomes

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Object. Previous investigations of health outcome after spinal surgery for tethered cord syndrome (TCS) have been single-institution studies. The aim of this study was to report inpatient complications and outcomes on a nationwide level.

Methods. The Nationwide Inpatient Sample (NIS) was used to identify patients who underwent spinal surgery for TCS in the US between 1993 and 2002. Patients who had a primary diagnosis of TCS (ICD-9 742.59) and also underwent spinal laminectomies were included in this study. Multivariate analysis was performed to analyze the effects of patient and hospital characteristics on variables such as mortality rate, nonfatal complications, LOS, and adverse outcomes in general (defined as death or discharge to an institution rather than home).

Results. The NIS sample included data on 9733 patients with TCS who underwent surgery. The means for mortality rate, complication rate, and LOS, respectively, were 0.0005%, 9.48%, and 5.6 days. Postoperative hemorrhages or hematomas (mean rate 2.3%) were the most common complications reported. Age and complications were the only significant predictors of adverse outcome on multivariate analysis. Patients older than 65 years had a three-fold increase in risk of adverse outcome compared with patients 18 to 44 years of age. On average, one postoperative complication led to a 3-day increase in mean LOS and added more than \$9000 to hospital charges.

Conclusions. This study provides a national perspective on inpatient complications and outcomes after spinal surgery for TCS in the United States. The authors have demonstrated the impact of age, complications, and medical comorbidities on the outcome of surgery for patients with this common disorder.

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KEY WORDS • complication • epidemiology • outcome • tethered cord syndrome

TETHERED CORD SYNDROME is one of the most common spinal disorders encountered by pediatric neurosurgeons. The entity refers to a constellation of signs of motor and sensory neuron dysfunction attributable to abnormally increased tension on the spinal cord. Tethered cord syndrome has been associated with a number of disorders including a wide range of spinal dysraphisms, trauma, infection, and neoplasm.^{12,14} The treatment for TCS is primarily surgical, with success rates varying based on the severity of symptoms and underlying pathophysiological conditions. Previous information about outcomes for TCS have been obtained from single-institution studies.^{2,3,7-9,14,15} No studies to date have been done to provide nationwide estimates of complication rates after spinal surgery for tethered cord.

In the present study, we used the NIS database to provide population estimates of outcomes and complication rates and to characterize types of complications following

surgery for TCS. We evaluated the influence of patient and hospital characteristics on outcomes, complication rates, discharge disposition, and mortality rates after TCS surgery in the US from 1993 through 2002.

Clinical Material and Methods

Data Source

Data were obtained from the NIS, which is the largest all-payer inpatient care database in the US.¹ It is maintained by the AHRQ and is used by policymakers to identify, track, and analyze trends in healthcare use, access, charges, quality, and outcomes. It contains data from approximately 8 million annual discharges from 1004 hospitals in 37 states. It represents a 20% stratified sample of nonfederal community hospitals, representing about 85% of all hospital discharges in the US. The discharge abstract includes the Clinical Classification Codes and ICD-9 diagnostic and procedure codes and is stratified by admission and discharge status, demographic data, charges (regardless of payer), LOS, geographical variations, complications, and deaths.¹

Abbreviations used in this paper: AHRQ = Agency for Healthcare Research and Quality; CI = confidence interval; ICD-9 = International Classification of Diseases, ninth revision; LOS = length of stay; NIS = Nationwide Inpatient Sample; OR = odds ratio; TCS = tethered cord syndrome.

TABLE 1
Patient and hospital characteristics and associated complication rates
following spinal surgery for TCS from 1993 through 2002*

Variable	No. of Cases	Percentage of Patients	Complication Rate (%)	p Value
age in yrs				0.035†
0–17	5830	71.0	7.0	
18–44	1532	18.6	9.8	
45–64	704	8.6	9.0	
≥65	148	1.8	20.3	
sex				0.96
M	4365	44.8	7.9	
F	5368	55.2	7.8	
race				0.58
Caucasian	5671	71.5	7.9	
African-American	471	5.9	8.3	
other	1794	22.6	9.9	
no. of comorbidities				0.0014†
0	8420	86.5	7.0	
1	878	9.0	12.0	
2	292	3	13.7	
≥3	142	1.5	21.6	
hospital vol				0.95
very low	2070	21.3	8.7	
low	1936	19.9	7.4	
medium	2395	24.6	8.4	
high	1746	17.9	7.3	
very high	1585	16.3	6.9	
hospital size				0.38
small	1976	20.3	6.0	
medium	1784	18.3	7.3	
large	5973	61.4	8.6	
yr of treatment				0.84
1993–1997	4117	42.3	7.6	
1998–2002	5616	57.7	8.0	

* Complete data were not available for all categories.

† Statistically significant value.

Inclusion Criteria

All patients treated and discharged between 1993 and 2002 who had a primary diagnosis of tethered cord syndrome (ICD-9 diagnosis code 742.59) and underwent spinal laminectomies (ICD-9 primary procedure codes 0359, 0309, and 034) were included in this study.

Patient Characteristics

Independent variables such as patient age, sex, race, comorbidities, hospital size, and year of treatment were abstracted from the NIS. Age was categorized into the following four groups: 0 through 17 years, 18 through 44 years, 45 through 64 years, 65 years and older. Year of treatment was categorized into two groups: 1993 through 1997 and 1998 through 2002. The frequency of sets of medical comorbidities, as described by Elixhauser et al.,⁶ was calculated using version 3.2 of the AHRQ comorbidity software (available at <http://www.hcup-us.ahrq.gov/toolssoftware/comorbidity/comorbidity.jsp>). A single comorbidity score was then derived and used in the analysis.

Outcome Variables

The primary outcomes were adverse outcome and complication rate. Complications were identified using the following ICD-9 codes: neurologic complications (997.00–997.09); pulmonary complications (518.81–518.85, 997.3);

thromboembolic complications including deep venous thrombosis and pulmonary embolism (415, 387, 415.11–415.19, 4510–4519, 4530–4539); cardiac complications (997.1, 410); urinary and renal complications (584, 997.5); hematoma complicating a procedure (998.1–998.13).

Adverse outcome was defined as death or discharge to an institution rather than home. Adverse outcome, LOS, and hospital charges were also abstracted from the NIS data set. Annual hospital volume was determined using the unique hospital identifier for each institution. Annual hospital volume was then divided into quintiles representing very low, low, medium, high, and very high volumes. The numerical thresholds for volume were 1 through 11 cases per year (very low), 12 through 20 cases per year (low), 21 through 38 cases per year (medium), 39 through 67 (high), and more than 67 cases per year (very high).

Statistical Analysis

Descriptive statistics for demographic variables were conducted. Outcomes were compared using chi-square analysis for categorical variables. A probability value of less than 0.05 was accepted as significant. A multivariate logistic regression model was constructed for the multivariate analysis, and those variables found which were determined to have a significant effect ($p < 0.10$) on the basis of univariate analysis were incorporated into the multivariate

Outcomes and complications of surgery in tethered cord syndrome

TABLE 2

Summary of patient outcomes after surgery for TCS

Parameter	Value
total no. of cases (discharges)	9733
in-hospital mortality rate (%)	0.0005
total complication rate (%)	9.48
mean LOS	5.6 days
mean total charges (\$)	20,363

analysis. The multivariate ORs are reported with the 95% CIs. The multivariate analysis was performed for the following outcome variables: death, nonfatal complications, discharge status, and LOS. Extrapolations to the entire US population were performed using the SAS survey procedure methodology. All the data analyses were performed with SAS version 9.1 (SAS Institute, Inc.) running on Windows XP professional edition.

Results

A total of 9733 patients underwent spinal surgery for TCS. Patient and hospital characteristics and their association with morbidity rates are presented in Table 1. Approximately 90% of patients were 44 years of age or younger—71.0% were 17 years of age or younger and 18.6% were between 18 and 44 years of age. The 1.8% of patients who were 65 years of age or older experienced a nearly threefold increase in complication rate (20.3%) compared with those who were 17 years of age or younger (7.0%). Slightly more female patients (55%) were treated than male patients. Seventy-one percent of patients were Caucasian and 86.5% exhibited no comorbidities. Comorbidities had a significant impact on the complication rate, with the presence of one comorbidity increasing the risk of complication from 7.0 to 12.0% and the presence of three comorbidities raising the complication rate to 21.6%. Complication rates calculated on the basis of numbers of surgical procedures performed for the treatment of TCS ranged from 6.9 to 8.7% and did not differ significantly between centers in which fewer TCS procedures were performed (lower volume centers) and those in which more were performed (higher volume centers). The great majority of cases were done in medium- to large-sized hospitals (18.3 and 61.4%, respectively). The number of cases performed was slightly higher in the more recent years: 5616 cases were recorded for the period from

TABLE 3

Complications following surgery for TCS stratified by category*

Complication	Frequency	Percentage of Surgeries
postop hemorrhage/hematoma	224	2.3
renal	216	2.2
pulmonary	184	1.9
neurological	156	1.6
infectious	104	1.1
thromboembolic (DVT, PE)	30	0.003
cardiac	9	0.0001
all complications	923	9.5

*DVT = deep venous thrombosis; PE = pulmonary embolism.

TABLE 4

Effect of complications on LOS and hospital charges in cases of surgically treated TCS

No. of Complications	Mean LOS	Mean Total Charges (\$)
0	5.23	19,238
1	8.63	28,726
2	19.87	59,721
3	14.30	29,787

1998 to 2002 compared with 4117 cases from 1993 to 1997 (Table 1). The highest-volume centers had a greater likelihood of prolonged LOS (OR 2.4; see Table 5).

The overall in-hospital complication rate was 9.48%, the mean LOS was 5.6 days, and the in-hospital mortality rate for the entire cohort was virtually zero (0.0005%). The mean value for total charges per case was \$20,363 (Table 2).

Postoperative hematoma (2.3%) and renal complications (2.2%) were the most commonly reported complications with neurological (1.6%) and infectious (1.1%) complications affecting slightly fewer patients (Table 3).

The effect of number of complications on LOS and hospital charges is quantified and summarized in Table 4. The presence of one postoperative complication increased the mean LOS from 5.23 to 8.63 days and increased hospital charges by more than \$9000.

Age, comorbidities, race, and complications were sig-

TABLE 5

Multivariate analysis of LOS after spinal surgery for TCS

Variable	OR	95% CI
age in yrs		
0–17	0.54	0.34–0.87
18–44*	NA	NA
45–64	0.66	0.35–1.23
≥65	2.49†	1.11–5.60
comorbidities		
0*	NA	NA
1	1.78†	1.03–3.08
2	1.23	0.45–3.34
≥3	1.40	0.39–5.02
complications		
0*	NA	NA
1	5.14†	3.11–8.50
2	14.03†	4.40–44.76
≥3	>999†	>999
race		
Caucasian*	NA	NA
African-American	1.77†	1.03–3.07
other	0.93	0.53–1.63
year group		
1993–1997*	NA	NA
1998–2002	0.40	0.25–0.65
hospital vol		
very low*	NA	NA
low	1.83	0.90–3.75
medium	0.66	0.36–1.23
high	1.51	0.54–4.21
very high	2.37†	1.56–3.60

* Reference group for comparison.

† Statistically significant value.

nificant predictors of LOS on multivariate analysis (Table 5). Patients who were 65 years old or older had a higher risk of complications after surgery (OR 2.49) and therefore a longer LOS, as might be expected. Patients with one comorbidity had a significantly higher risk of having a complication and correspondingly increased LOS. The number of complications directly correlated with the LOS (OR 5.14, 14.03, and ≥ 999 for one, two, and three complications, respectively).

Multivariate analysis demonstrated that age and complications were the only clear predictors of outcome (Table 6). Patients who had two complications experienced a nearly eightfold increase in adverse outcome compared with those who had no complications. Patients 65 years old or older also had a threefold higher risk of death or discharge to a location other than home (OR 3.15). There was no significant effect of hospital volume, race, sex, or comorbidity on outcome.

Discussion

Our study presents nationwide estimates of outcomes and complication rates following surgery for TCS in the US from 1993 through 2002. This analysis included a total of 9733 cases involving patients who underwent spinal surgery for TCS and demonstrated an overall complication rate of 9.5% and a mean LOS of 5.6 days (Tables 1 and 2).

The overall complication rate of 9.5% is within the range of what has been previously reported for tethered cord surgeries (0–12%).^{2,3,7,8} Our analyses included only complications that have been shown to be generally reliably captured by the NIS database, summarized in Table 3.^{10,13} The primary complications noted were postoperative hematoma (2.3%) and renal complications (2.2%), with neurological and infectious complications being less common (1.6 and 1.1%, respectively). Authors of prior studies have quoted the infection rate associated with tethered cord release surgery to be approximately 9% and have attributed this rate in part to the development of cerebrospinal fluid leaks.² Unfortunately, lumbar cerebrospinal fluid leak is not one of the complications reliably coded for in the NIS database, and its incidence is therefore difficult to analyze accurately. In our study, age and complications were the only significant predictors of adverse outcome (defined as death or discharge to an institution rather than home) on multivariate analysis. Patients 65 years old or older had a threefold increased risk of adverse outcome compared with patients 18 to 44 years of age (Table 6). Adult patients with tethered cord often have preoperative deficits secondary to tethering, such as bladder dysfunction, that may be worsened postoperatively.¹¹ Other authors have reported a similar adverse association between age and lumbar spine surgery.^{4,5}

In addition, the presence of medical complications had a strong effect on outcome. The presence of one complication increased the LOS by 3 days and the hospital charges by more than \$9000 (Table 4). Similarly, patients with two complications had a much greater risk of an adverse outcome than those with none (OR 7.9). Decreasing the number of in-hospital complications is thus critical to the prevention of adverse outcomes after tethered cord

TABLE 6
Multivariate analysis of adverse outcome
after spinal surgery for TCS

Variable	OR	95% CI
age in yrs		
0–17	0.19	0.09–0.41
18–44*	NA	NA
45–64	1.29	0.67–2.45
≥ 65	3.15†	1.08–9.15
sex		
F	1.3	0.77–2.20
M	NA	NA
comorbidities		
0*	NA	NA
1	1.6	0.86–2.98
2	0.91	0.31–2.72
≥ 3	1.3	0.31–5.51
complications		
0*	NA	NA
1	1.19	0.51–2.75
2	7.91†	2.27–27.54
≥ 3	2.54	0.11–57.54
hospital vol		
very low*	NA	NA
low	1.66	0.87–3.19
medium	1.26	0.49–3.27
high	0.76	0.30–1.95
very high	0.57	0.18–1.86

* Reference group for comparison.

† Statistically significant value.

surgery. Higher-volume centers had nearly a 2.4-fold greater LOS; the exact reasons for this difference cannot be determined, but it may be due to a higher proportion of more challenging and complex cases resulting in longer postoperative courses.

Study Limitations

While providing many broad interpretations based on a nationwide sample, the research approach used in this study has several limitations. Differentiation of patients in the database requires accurate definition and entry of ICD-9 codes into the database. In our study, the code commonly used for tethered cord syndrome (ICD-9 742.59) also includes some disorders that are uncommon or generally do not require surgical intervention (amyelia, atelomyelia, congenital anomaly of spinal meninges, defective development of cauda equina, hypoplasia of spinal cord, myelomelia, and myelodysplasia). The majority of these other disorders do not come to clinical attention, and therefore the great majority of those cases analyzed represent TCS. By cross-referencing with the ICD-9 procedure codes for spinal laminectomies (0359, 0309, and 034), we extracted only those cases in which patients were treated surgically for their initially diagnosed condition, essentially narrowing the study group to the patients with surgically treated TCS.

Although the NIS database may not report all in-hospital complications, previous studies using the database have demonstrated a significant negative correlation between complications and outcome, suggesting that the

database does capture important complications that adversely affect outcome.

Other limitations of the database include the fact that it does not provide a way to study the relationship between case complexity and outcome. For example, a case of a large multilevel lipomyelomeningocele in which spinal cord reconstruction is performed may be coded the same as a case of a simple, terminal filum lipoma. The coding is at the discretion of the individual surgeon performing the procedure. Anomalies such as lipo/myelomeningocele (741.9) and diastematomyelia (742.51), which can occur with TCS, have their own individual diagnosis codes and therefore should be coded separately and will be the subject of a future analysis.

Finally, the database does not provide information on severity of presenting symptoms or preoperative deficits. Data on 30-day perioperative outcomes and long-term efficacy/outcomes of these procedures in terms of pain reduction and restoration of neurological or bladder function are also not available.

Despite these limitations, the NIS data provide a valuable opportunity for examining trends in the frequency of procedures, population characteristics, and health outcomes on a national basis and provide insights into how to improve national health resource utilization.

Conclusions

We have provided a nationwide perspective on inpatient complications and outcomes after spinal surgery for TCS in the US. We have quantified the impact of age, complications, and medical comorbidities on LOS, hospital charges, and outcomes. This study is, to our knowledge, the first such analysis for spinal surgery for TCS on a nationwide level. The negative impact of age, comorbidities, and complications and its effect on health resource utilization have been demonstrated.

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References

1. Agency for Health Care Research and Quality: **Nationwide Inpatient Sample (NIS), Healthcare Cost and Utilization Project (HCUP)**. Rockville, MD: Agency for Healthcare Research and Quality, 2004. (<http://www.hcup-us.ahrq.gov/nisoverview.jsp>) [Accessed 6 July 2007]
2. Albright AL, Pollack IF, Adelson PD, Solot JJ: Outcome data

- and analysis in pediatric neurosurgery. **Neurosurgery** **45**: 101–106, 1999
3. Bowman RM, McLone DG, Grant JA, Tomita T, Ito JA: Spina bifida outcome: a 25-year prospective. **Pediatr Neurosurg** **34**: 114–120, 2001
4. Carreon LY, Puno RM, Dimar JR, Glassman SD, Johnson JR: Perioperative complications of posterior lumbar decompression and arthrodesis in older adults. **J Bone Joint Surg Am** **85**: 2089–2092, 2003
5. Deyo RA, Cherkin DC, Loeser JD, Bigos SJ, Ciol MA: Morbidity and mortality in association with operations on the lumbar spine. The influence of age, diagnosis, and procedure. **J Bone Joint Surg Am** **74**:536–543, 1992
6. Elixhauser A, Steiner C, Harris DR, Coffey RM: Comorbidity measures for use with administrative data. **Med Care** **36**:8–27, 1998
7. Herman JM, McLone DG, Storrs BB, Dauser RC: Analysis of 153 patients with myelomeningocele or spinal lipoma reoperated upon for a tethered cord. Presentation, management and outcome. **Pediatr Neurosurg** **19**:243–249, 1993
8. Hüttmann S, Krauss J, Collmann H, Sörensen N, Roosen K: Surgical management of tethered spinal cord in adults: report of 54 cases. **J Neurosurg** **95** (2 Suppl):173–178, 2001
9. La Marca F, Grant JA, Tomita T, McLone DG: Spinal lipomas in children: outcome of 270 procedures. **Pediatr Neurosurg** **26**:8–16, 1997
10. Lawthers AG, McCarthy EP, Davis RB, Peterson LE, Palmer RH, Iezzoni LI: Identification of in-hospital complications from claims data. Is it valid? **Med Care** **38**:785–795, 2000
11. Lee GY, Paradiso G, Tator CH, Gentili F, Massicotte EM, Fehlings MG: Surgical management of tethered cord syndrome in adults: indications, techniques, and long-term outcomes in 60 patients. **J Neurosurg Spine** **4**:123–131, 2006
12. Lew SM, Kothbauer KF: Tethered cord syndrome: an updated review. **Pediatr Neurosurg** **43**:236–248, 2007
13. McCarthy EP, Iezzoni LI, Davis RB, Palmer RH, Cahalane M, Hamel MB, et al: Does clinical evidence support ICD-9-CM diagnosis coding of complications? **Med Care** **38**:868–876, 2000
14. Steinbok P, Garton HJ, Gupta N: Occult tethered cord syndrome: a survey of practice patterns. **J Neurosurg** **104** (5 Suppl):309–313, 2006
15. van Leeuwen R, Notermans NC, Vandertop WP: Surgery in adults with tethered cord syndrome: outcome study with independent clinical review. **J Neurosurg** **94** (2 Suppl):205–209, 2001

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