J Neurosurg 115:1013–1018, 2011

Hospital costs, incidence, and inhospital mortality rates of traumatic subdural hematoma in the United States

Clinical article

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Object. This study provides the first US national data regarding frequency, cost, and mortality rate of traumatic subdural hematoma (SDH), and identifies demographic factors affecting morbidity and death in patients with traumatic SDH undergoing surgical drainage.

Methods. A retrospective analysis was conducted by querying the Nationwide Inpatient Sample, the largest all-payer database of nonfederal community hospitals. All cases of traumatic SDH were identified using ICD-9 codes. The study consisted of 2 parts: 1) trends data, which were abstracted from the years 1993–2006, and 2) univariate analysis and multivariate logistic regression of demographic variables on inhospital complications and deaths for the years 1993–2002.

Results. Admissions for traumatic SDH increased 154% from 17,328 in 1993 to 43,996 in 2006. Inhospital deaths decreased from 16.4% to 11.6% for traumatic SDH. Average costs increased 67% to $47,315 per admission. For the multivariate regression analysis, between 1993 and 2002, 67,864 patients with traumatic SDH underwent operative treatment. The inhospital mortality rate was 14.9% for traumatic SDH drainage, with an 18% inhospital complication rate. Factors affecting inhospital deaths included presence of coma (OR = 2.45) and more than 2 comorbidities (OR = 1.60). Increased age did not worsen the inhospital mortality rate.

Conclusions. Nationally, frequency and cost of traumatic SDH cases are increasing rapidly.
(DOI: 10.3171/2011.6.JNS101989)

Key Words • **traumatic subdural hematoma** • **incidence** • **cost** • **traumatic brain injury** • **National Inpatient Sample** • **mortality**

Traumatic SDH is most often characterized by the acute onset of traumatic bleeding into the space between the dura and arachnoid membranes, typically within hours and by definition always following head injury. A smaller proportion of traumatic SDH will present in a chronic manner, with the insidious development of SDH after 3 or more days. Available evidence suggests traumatic SDH occurs in 12%–30% of patients with severe head injury.[21] Treatment for traumatic SDH may be either surgical or nonsurgical, and operative decisions are based on multiple presenting factors including GCS score, head CT findings, neurological evaluation, clinical stability, time since injury, comorbidities, and age. The two most important prognostic indicators are age and GCS score, and several studies have correlated the presence of preoperative CT findings with poor outcomes.[7,21] Despite neurosurgical advances and rising health care costs nationally, traumatic SDH remains a cause of significant morbidity and death.

No national studies for the US exist concerning costs, inhospital complication rates, and death for patients with traumatic SDH. This analysis begins to fill this gap with the first nationwide study on traumatic SDH. Current mortality data suggest a rate between 40% and 60% for surgical patients, with 60%–70% for those presenting in a coma.[4,13–15,18,19,21,30] A recent review article in the *New England Journal of Medicine* noted that large multiinstitutional studies (when they exist) are often decades old, and resource utilization, practice patterns, and population demographics have changed significantly since these studies were conducted.[11] More recent studies have provided outcomes using data largely from single-institution series with fairly small patient samples.[1,5,7,9,13–15,19,21–23,25,27–30]

The NIS, the largest all-payer inpatient database, provided the data for this study. This database collects a 20% stratified sample of nonfederal community hospitals, consisting of approximately 8 million annual discharges

Abbreviations used in this paper: GCS = Glasgow Coma Scale; LOS = length of stay; NIS = Nationwide Inpatient Sample; SDH = subdural hematoma.

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from 1004 hospitals in 37 states yearly, with growing participation every year.[10] Nationwide Inpatient Sample data are available starting in 1988, and the number of states participating in the NIS has grown from 8 in the first year to 42 at present. The Agency for Healthcare Research and Quality maintains the database as part of a federal-state-industry partnership to identify and analyze national trends in health care use, quality, and cost.

Whether a traumatic SDH presents as acute or chronic depends on a variety of factors, including age, presence of cortical atrophy, and mechanism of injury. Younger patients tend to acquire traumatic SDH through injuries sustained because of high-speed mechanisms such as automobile accidents, resulting in acute presentations. In contrast, elderly patients often acquire traumatic SDH by falling, resulting in more insidious, chronic injuries.[5] However, an inherent limitation of analysis based on ICD-9 codes is the inability to separate acute versus chronic traumatic SDH due to a lack of coding variables for them in the NIS. Thus, we provide data on all ICD-9 recorded traumatic SDH in the US.

In this study we analyzed 2 sets of data obtained from the NIS. In the first part of the study (Part 1), we analyzed trends in costs and frequency of traumatic SDH from 1993 to 2006. In the second part of the study (Part 2), we used a multivariate logistic regression model to analyze cost, morbidity, and mortality rate, and identify factors that may affect mortality rate following surgery over a 10-year period. Inclusion criteria and statistical methods are discussed separately for each analysis.

Methods

Inclusion Criteria

Part 1 of the study was designed to investigate trends in admissions, cost, LOS, and inhospital deaths. All patients from 1993 to 2006 who had a primary diagnosis of traumatic SDH (ICD-9 codes 852.20–852.39, SDH following injury with and without mention of open intracranial wound) were included in Part 1 of the study, tracking cost and incidence data. This category excludes traumatic SDH occurring with skull fracture because all skull fractures are categorized by ICD-9 code without clarity regarding concomitant traumatic SDH. The 5th digit of the code for traumatic SDH specifies no loss of consciousness, brief (< 1 hour) loss of consciousness, moderate (1–24 hours) loss of consciousness, prolonged (> 24 hours) with a return to baseline level of consciousness, or prolonged (> 24 hours) without a return to baseline level of consciousness (including death).

The second part of the study (Part 2) was a logistic regression analysis of surgical treatment and inhospital deaths from all patients from 1993 to 2002 who had a primary diagnosis of traumatic SDH, as defined in Part 1, and who underwent ICD-9 procedure code 01.31, incision of cerebral meninges for drainage. There was no operative data available for 2003–2006. The ICD-9 code 01.31 was the procedure code most frequently associated with these diagnoses (data not shown).

Patient and Hospital Characteristics

In Part 2 of the study, independent variables including age, sex, race, comorbidities, year of treatment, and hospital size were abstracted from the NIS. If race was unspecified for a patient, the default was considered white. Patient ages were grouped into 5 categories: 0–17 years, 18–44 years, 45–64 years, 65–84 years, or older. Race was analyzed as 3 categories: white, black, and other. A single comorbidity score was derived for each patient using the Agency for Healthcare Research and Quality software and the Elixhauser-Coffey method.[8,10] In Part 2 of the study, treatment year was divided into 2 groups, from 1993 to 1997, and from 1998 to 2002. The NIS categorizes hospital size as small, medium, or large, depending on location and teaching status. Small size is 1–49 beds for rural hospitals, 1–99 beds for urban nonteaching hospitals, and 1–199 beds for urban teaching hospitals. Medium size is defined as 50–99 beds for rural, 100–199 beds for urban nonteaching, and 200–499 beds for urban teaching hospitals; and large size is defined as more than 100 beds for rural, more than 200 beds for urban nonteaching, and more than 500 for urban teaching hospitals.

Outcome Variables

In Part 2 of the study, death was the primary outcome measure. Mortality data were directly abstracted from the NIS. In addition, complication rates were calculated. Complications were defined using the following ICD-9 codes: hemorrhage and hematoma complicating a procedure (998.1–998.13); neurological complications (997.00–997.09); thromboembolic complications, including deep venous thrombosis and pulmonary embolus (387, 415, 415.11–415.19, 4510–4519, 4530–4539); pulmonary complications not including pulmonary embolus (518.81–518.85, 997.3); cardiac complications (997.1, 410); and urinary and renal complications (584, 997.5). Additionally, LOS and hospital charges were obtained directly from the NIS.

Statistical Analysis

Bivariate analyses were performed in Part 2 of the study to evaluate associations between independent risk factors and disposition. Both chi-square analysis and the Fisher exact test were used for categorical variables when appropriate. The Student t-test was used for continuous variables. A probability value < 0.05 was considered significant. A multivariate logistic regression model was constructed and backward stepwise regression was performed with the final model including variables significant at $p < 0.05$. Odds ratios and 95% CIs for multivariate analysis are reported.

Results

Part 1

In Part 1 of the study, previous studies on operative and nonoperative traumatic SDH mortality rate were analyzed and organized into a table (Table 1). In our study, we were able to observe significantly more cases. From 1993 to 2006, the number of hospitalizations and cost per

TABLE 1: Summary of recent studies on traumatic SDH

Authors & Year	No. of Patients	Ages Included (yrs)	Study Design	Treatment	Mortality Rate (%)	GCS Scores Included
Abe et al., 2003	80	all	case series	surgical & nonsurgical	32.5	all
Cagetti et al., 1992	26	80–100	retrospective cohort	surgical	88.5	all
Cruz et al., 2001	178	all	randomized control trial	surgical	14.3 for high-dose, 25 for low-dose mannitol	all
Dent et al., 1995	211	all	retrospective cohort	surgical & nonsurgical	27.5	all
Hatashita et al., 1993	60	all	retrospective cohort	surgical	63 (<4 hrs), 35 (>4 hrs)	all
Koç et al., 1997	113	all	case series	surgical	60	all
Kotwica et al., 1993	200	18–65	retrospective cohort	surgical	58.0	all
Massaro et al., 1996	127	all	retrospective cohort	surgical & nonsurgical	57.6	all
Sakas et al., 1995	22	all	prospective cohort	surgical	64.0	<9
Servadei et al., 1998	65	all	prospective cohort	surgical & nonsurgical	47.7	<9
Woertgen et al., 2006	180	all	retrospective cohort	surgical	53 (craniectomy), 32.3 (craniotomy)	all
Yanaka et al., 1993	170	all	retrospective cohort	surgical	36.5	all
Zumkeller et al., 1996	174	all	retrospective cohort	surgical	52.0	all

admission increased substantially (Fig. 1). Admissions for traumatic SDH increased 154% from 17,328 in 1993 to 43,996 in 2006. Average treatment costs increased 67% to $47,315 in 2006 from $28,347 in 1993. In contrast to the increase in cost, the average LOS in the hospital decreased from 11.5 to 7.1 days during this period. Inhospital deaths decreased from 16.4% to 11.6%. The 2006 aggregate charges (the "national bill") for traumatic SDH was $1,901,337,744; in 1997, the earliest year for which these data were available, it was $587,292,459. This represents a 224% increase over 9 years.

An estimated 392,834 ICD-9–coded admissions for traumatic SDH occurred between 1993 and 2006 (Table 2). The mean charges per admission during this period were $36,662. The mean LOS was 8.2 days, with an average mortality rate of 14.0%.

Part 2

Between 1993 and 2002, 67,864 procedures to drain traumatic SDH were performed (Table 2). The mortality rate was 14.9% for traumatic SDH drainage, with an 18% complication rate as defined above. The mortality rate did not differ significantly for admissions with operative treatment compared with all hospitalizations for traumatic SDH.

Risk factors for death were analyzed (Tables 3 and 4). Multivariate analysis found no effect of race, sex, or year of operation. Factors affecting the mortality rate included presence of coma (OR = 2.45) and more than 2 comorbidities (OR = 1.60). Different age groups had significantly different mortality rates, with lower mortality in age groups 45–64 and 65–84 compared with ages 18–44. Mean patient age was 46.7 years old. Data on operative admissions were available only from 1993 to 2002. During this period a total of 236,375 admissions occurred, of whom 67,864 underwent operative drainage (Table 2), a rate of 28.7%. The cost and LOS for those undergoing surgical treatment were higher than for those who did not receive surgical treatment.

Discussion

Traumatic SDH is a common neurosurgical problem. Our analysis demonstrates that traumatic SDH admissions increased annually from 1993 to 2006. When corrected for population growth, the incidence of traumatic SDH in 1993 was 6.67/100,000, which increased in 2006 to 14.7/100,000. In a separate study based on ICD-9 codes that investigated the incidence of epidural hematoma over the same time period, the increased number of admissions was exactly as predicted by population growth.[12] In the present analysis, we therefore believe that the increase in incidence of traumatic SDH corrected for population growth reflects an actual increase. Patients older than 80 years accounted for one-third of the patients with traumatic SDH from 1993 to 2006. This may reflect the increasing size of the elderly proportion of the population, who may be more susceptible to developing traumatic SDH for a variety of reasons, increased likelihood of falling, increased extraaxial spaces secondary to atrophy, and increased use of anticoagulation and antiplatelet agents.

The average charge per traumatic SDH admission has increased substantially. The growth in hospital charges varies from year to year, but the net result has been a 67% increase in charges per admission from 1993 to 2006. If inflation alone were responsible for charge increases, the increase should only be 39%.[24] Thus, the additional 28% increase in charges, or approximately $7,767 per admission, should be attributable to other factors. The reason for the additional charges cannot be determined from our data, although it may reflect changes in intensity of care, hospital billing practices, and other factors. A separate study of epidural hematoma based on ICD-9 codes over the same time period demonstrated a similar increase in charges (67% vs 69%, respectively), suggesting the increases in charges are not specific to traumatic SDH.[12] However, the increase in charge per admission and overall number of admissions has resulted in enormous cost increases. Our results indicate that the annual national

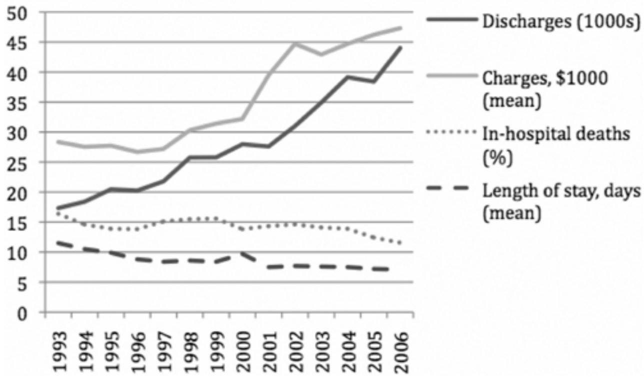

Fig. 1. Traumatic SDH trends in hospital discharges, charges, inhospital deaths, and LOS from 1993 to 2006. These data were obtained from the NIS database using the ICD-9 code for the principle diagnosis of traumatic SDH.

bill for traumatic SDH in 2006 approached $2 billion, compared with roughly $600 million a decade earlier.

Inpatient mortality rates declined slightly during the past 14 years, likely because of a number of factors. There may be increased availability and use of resources, which would correspond with increased costs. More rapid disposition, as evidenced by decreasing LOS, may result in decreases in inpatient deaths without changes in long-term mortality rates.

Overall, our reported mortality rates were lower than most reported in the literature. Some prior studies used to establish mortality rates are decades old, and we found that most traumatic SDH studies only analyze patients who were treated surgically. Additionally, the NIS includes a larger and broader sample size, including community hospitals, as opposed to studies based on large centers that may receive more complex trauma cases. Consistent with this hypothesis, large hospitals in our study had 40% higher mortality rates. Our sample included only those hospitalizations in which traumatic SDH was recorded as the primary diagnosis, limiting confounding data based on death from associated injuries. Further, the NIS data set excludes patients with skull fractures, which may exclude some traumatic SDH due to high-energy mechanisms such as high speed collisions, which therefore may limit deaths secondary to other brain trauma (such as diffuse axonal injury). Finally, our data only include inhospital deaths, which excludes deaths occurring after discharge, thus providing a lower mortality rate than studies with longer follow-up.

In the time period studied, 28.7% of admissions for traumatic SDH underwent surgical drainage. The average age of those patients undergoing subdural drainage was 46.7 years old. The major risk factors for increased risk of death following surgical drainage were comorbidities and presence of coma. Three or more comorbidities increased the mortality rate by 60%. The presence of coma was the strongest predictor of increased risk of death. Following operative drainage, the presence of any loss of consciousness was associated with a 145% increased risk of inhospital death.

TABLE 2: Summary of traumatic SDH cases and patient outcomes

Variable	Operative (1993–2002)	Total (1993–2002)	Total (1993–2006)
total no. of hospitalizations	67,864	236,375	392,834
inhospital mortality (%)	14.9	14.7	14.0
mean LOS (days)	10.2	8.9	8.2
mean total charges ($)	38,612	30,902	36,662

TABLE 3: Analysis of mortality according to age following SDH drainage (1993–2002)

Age Range (yrs)	No. of Patients	Mortality Rate (%)	OR (95% CI)
0–17	1,443	21.6	1.17 (0.86–1.62)
18–44	10,427	19.0	referent group
45–64	14,785	12.5	0.60* (0.52–0.70)
65–84	19,350	12.6	0.61* (0.53–0.71)
>80	21,932	16.6	0.87 (0.76–1.00)

* Statistically significant.

The baseline age group, 18–44, had a mortality rate of 19%; the youngest age group, 0–17, had the highest mortality rate (22%). Surprisingly, older populations up to age 80 had significantly lower mortality rates following drainage, of approximately 12%. For those patients older than age 80, mortality rates (16.6%) were similar to baseline. Thus, age does not appear to be an independent risk factor for inhospital death in this data set.

Our age data conflicts with some prior studies of traumatic SDH, which have found worse outcomes in older patients.[3,16] That older populations may be more likely to develop "incidental" traumatic SDH cannot explain the lower mortality rate in our data, as all patients had pathology severe enough that surgical drainage was deemed appropriate. There are likely differing mechanisms involved in traumatic SDH in different age groups, with younger age groups more likely to suffer from high-energy mechanisms, such as motor vehicle accidents, and older populations more likely to suffer from lower energy mechanisms, such as falls, which may impact mortality rates. However, prior studies were not always able to separate age and comorbidity. For example, the Trauma Coma Data Bank noted increased comorbidities among its older populations, and thus it is possible that it may overestimate the impact of age alone.[3] Furthermore, studies that found age to be a predictor of worse outcome often included only patients with poor GCS scores (GCS score < 10).[5,19,20,22] However, of studies reviewed that included all GCS scores, as does this study, 6 of 8 did not identify increased age as an independent risk factor for worse outcome, including 3 with multivariate analysis.[25–27,29,30] The limitations of the NIS preclude any definite conclusions, but these data suggest further investigation of age may be warranted.

As a large administrative database, the NIS does not assess many critical clinical factors. The NIS cannot take into account factors that may substantially impact

TABLE 4: Analysis of mortality rate according to comorbidities, hospital size, and presence of coma following SDH drainage (1993–2002)

Variable	OR (95% CI)
no. of comorbidities	
0	referent group
1	0.97 (0.85–1.10)
2	1.06 (0.91–1.24)
3+	1.60* (1.37–1.86)
hospital size	
small	referent group
medium	1.31 (0.98–1.75)
large	1.39* (1.05–1.83)
coma	
absent	referent group
present	2.45* (2.13–2.82)

* Statistically significant.

mortality rates (severity of SDH on CT, time until treatment, mechanism of injury, and others). While the size and breadth of our sample allow for reliable national estimates, our data are only as precise as ICD-9 codes. The ICD-9 codes do separate traumatic SDH from nontraumatic SDH, but do not specify acute or chronic SDH. A limitation of this study is the inability to examine these factors and whether the traumatic SDH is acute or chronic as variables due to lack of coding information. Also, we are unable to account for variation in local coding practices, but studies examining ICD-9 code accuracy have found them to be reasonably specific.[2,17] It is possible that acute-on-chronic SDH may have been coded as traumatic SDH, resulting in lower mortality rates in elderly populations. The ICD-9 code 01.31, incision of cerebral meninges, does not clearly specify bur hole drainage in contrast to craniotomy with drainage. However, traumatic SDH is most likely to be acute. In addition, our outcome measures do not include long-term functional or neurological components, which may be as critical to surgical decision-making as risk of death. This was not a randomized study and cannot control for decisions made by individual surgeons and individual patients or families.

Conclusions

This study provides valuable demographic and cost information concerning traumatic SDH. To our knowledge, this study provides the first national analysis of traumatic SDH for the US. Our data established a national baseline rate for inhospital mortality of 14%. We identified indicators of increased mortality rate following surgical drainage, including 3 or more comorbidities and the presence of coma. Finally, our data documented large increases in both charges (67%) and incidence (> 100%) of traumatic SDH, with an overall increase of 224% in total charges over 9 years. These trends suggest that the relevance of traumatic SDH, and those who treat it, remains high for the US system.

Disclosure

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

Author contributions to the study and manuscript preparation include the following. Conception and design: Kalanithi. Acquisition of data: Boakye, Kalanithi. Analysis and interpretation of data: Kalanithi, Schubert, Lad. Drafting the article: Kalanithi, Schubert. Critically revising the article: Kalanithi, Schubert, Harris. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Kalanithi. Statistical analysis: Boakye. Administrative/technical/material support: Boakye, Kalanithi, Schubert. Study supervision: Kalanithi, Boakye.

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Manuscript submitted November 26, 2010.
Accepted June 20, 2011.
Please include this information when citing this paper: published online August 5, 2011; DOI: 10.3171/2011.6.JNS101989.
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