Published in final edited form as:

World Neurosurg. 2020 September ; 141: e105–e111. doi:10.1016/j.wneu.2020.04.216.

Risk Factors for the Development of Post-Traumatic Hydrocephalus in Children

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Abstract

OBJECTIVE: The aim of this study was to investigate the national impact of demographic, hospital, and inpatient risk factors on posttraumatic hydrocephalus (PTH) development in pediatric patients who presented to the emergency department after a traumatic brain injury (TBI).

METHODS: The Nationwide Emergency Department Sample database 2010–2014 was queried. Patients (<21 years old) with a primary diagnosis of TBI and subsequent secondary diagnosis of PTH were identified using the *International Classification of Diseases, Ninth Revision, Clinical Modification* coding system.

RESULTS: We identified 1,244,087 patients who sustained TBI, of whom 930 (0.07%) developed PTH. The rates of subdural hemorrhage and subarachnoid hemorrhage were both significantly higher for the PTH cohort. On multivariate regression, age 6–10 years (odds ratio [OR], 0.6; 95% confidence interval [CI], 0.38–0.93; $P = 0.022$), 11–15 years (OR, 0.32; 95% CI, 0.21–0.48; $P < 0.0001$), and 16–20 years (OR, 0.24; 95% CI, 0.15–0.37; $P < 0.0001$) were independently associated with decreased risk of developing hydrocephalus, compared with ages 0–5 years. Extended loss of consciousness with baseline return and extended loss of consciousness without baseline return were independently associated with increased risk of developing hydrocephalus. Respiratory complication (OR, 28.35; 95% CI, 15.75–51.05; $P < 0.0001$), hemorrhage (OR, 37.12; 95% CI, 4.79–287.58; $P = 0.0001$), thromboembolic (OR, 8.57; 95% CI, 1.31–56.19; $P = 0.025$), and neurologic complication (OR, 64.64; 95% CI, 1.39–3010.2; $P = 0.033$) were all independently associated with increased risk of developing hydrocephalus.

CONCLUSIONS: Our study using the Nationwide Emergency Department Sample database shows that various demographic, hospital, and clinical risk factors are associated with the development of hydrocephalus after traumatic brain injury.

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Conflict of interest statement: The authors declare that the article content was composed in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Keywords

Pediatrics; Posttraumatic hydrocephalus; Traumatic brain injury

INTRODUCTION

Traumatic brain injury (TBI) is a major cause of morbidity and mortality in the United States.[1–6] In 2014 alone, nearly 2.87 million nationwide TBI-related emergency department (ED) visits, hospitalizations and deaths occurred, representing a 53% increase in ED-associated events over the past decade.[7] Furthermore, approximately 837,000 of these events were pediatric.[7] TBI in the pediatric population represents a unique risk, because younger patients can have potentially lifelong complications, including seizures, dementia, cranial nerve injuries, and psychiatric complications.[8] As a result, both policy-makers and hospitals alike have begun to prioritize public initiatives targeting the surveillance and management of pediatric TBI-related care.[9–13]

One significant complication of TBI is posttraumatic hydrocephalus (PTH), caused by the disruption of cerebrospinal fluid passage through the ventricular system after injury.[8] PTH has been associated with longer lengths of hospitalization and increased costs.[14,15] Accordingly, previous studies have attempted to examine the risk factors associated with PTH development after TBI.[16] For example, in a retrospective cohort study of 124,444 pediatric inpatient admissions for TBI, Rumalla et al.[16] reported that patients aged 0–5 years old, Medicaid insurance status, electrolyte disorder, and weight loss were all independently associated with higher rates of PTH. The investigators also showed that care of PTH incurred an additional $69,805 in total cost.[16] However, although previous studies have examined the risk factors for admitted patients, there remains an urgent, unmet need to better understand the nuanced variability in risk factors for patients managed in the ED setting.

Therefore, the aim of this study was to investigate the national impact of demographic, hospital, and inpatient risk factors on PTH development in pediatric patients who presented to the ED after a TBI.

METHODS

Data Source

The Nationwide Emergency Department Sample (NEDS) is a part of the Healthcare Cost and Utilization Project, which is maintained by the Agency for Healthcare Research and Quality. NEDS comprises approximately 25 million to 35 million ED visits each year across more than 950 hospitals in 34 states. This is approximately a 20% stratified sample of U.S. hospital-based EDs. Each ED visit is assigned a discharge weight to obtain a national estimate. The weights assigned to these discharges were based on the ratios of total ED visits to ED visits sampled in NEDS. The diagnoses reported in NEDS were the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM). NEDS was queried from 2010 to 2014 for patients to be used in analysis for patients <21 years old with a primary diagnosis of TBI (ICD9 code of 850.xx–854.xx). The fourth digit of the ICD-9 code was used to identify whether an injury was open or closed, whereas the fifth digit was used to identify the severity of the disease. The database was then queried for any secondary diagnosis of PTH (331.3, 331.4, 331.5). All patients with a secondary diagnosis code of congenital hydrocephalus (742.3) were intended to be excluded but there was no overlap on investigation. In accordance with the Healthcare Cost and Utilization Project Data Use Agreement, no sample size <11 was reported in this study.

Predictor Variables

We identified demographic variables, hospital characteristics, pre-existing medical comorbidities, cause of injuries, and type of injury. Patient age was categorized into 0–5 years, 6–10 years, 11–15 years, and 16–20 years. The cause of the injury was determined using codes from the Certified Coding Specialist (CCS) and ICD-9 coding systems. The causes included motor vehicle accidents (CCS 2607), falls (CCS 2603), blunt trauma by person or object (CCS 2614), firearm (CCS 2605), cycling incident (CCS 2608), and shaken baby syndrome (ICD-9-CM 995.55). The length of loss of consciousness (LOC) (no LOC; brief LOC [<1 hour]; moderate LOC [1–24 hours]; prolonged LOC baseline return [≥24 hours]; prolonged LOC no return [≥24 hours]; and other LOC) was determined by the ICD-9 coding.

Outcome Variables

Patients with PTH were identified as having any listed secondary diagnosis of any listed diagnosis of noncongenital hydrocephalus (331.3–331.5). It was then confirmed that none of those patients had a listed diagnosis of congenital hydrocephalus (742.3). The fourth digit of the ICD-9 code for the primary diagnosis was used to differentiate between open and closed intracranial injuries, whereas the fifth digit of the ICD-9 code was used to characterize the severity of the injury. The complication variables were identified using ICD-9 codes and identified as respiratory (518.4, 518.5, 518.81–518.84), cardiac (997.1 and 410), renal and urinary (584 and 997.5), hematoma or hemorrhage (998.1–998.13), iatrogenic stroke (997.02), unspecified nervous system complication (997.00, 997.01, 997.09), thromboembolic (415, 415.11–415.19, 451.0–451.9), and septicemia (998.51, 998.59, 996.63, 996.67).

Statistical Analysis

Descriptive statistics were conducted for the patients in the defined cohorts to describe demographic and hospital data. Univariate and multivariate logistic regression analyses were performed to identify the factors associated with PTH. Weighted frequencies were used for all analyses generating national estimates. Two-sided hypothesis testing was performed and $P < 0.001$ was used to indicate significance for all comparisons. Nonparametric data were expressed as median and compared via nonweighted, Mann-Whitney U test. Data analysis was performed with Stata version 13.1 (StataCorp LLC, College Station, Texas, USA). If the variables had a P value <0.001, they were included in the multivariate model. Cause of injury was not examined in the multivariable analysis because of strong colinearity with variables that represent the severity of injury, such as LOC.

RESULTS

Patient Demographics and Hospital Characteristics

Between 2010 and 2014 there were 1,244,087 pediatric patients (<21 years old) who sustained TBI, of whom 930 (0.07%) developed PTH (Table 1). Of the patients who had hydrocephalus, the youngest cohort aged 0–5 years had the greatest proportion of hydrocephalus development (0–5 years, 326 [0.17%] vs. 6–10 years, 162 [0.09%] vs. 11–15 years, 207 [0.05%] vs. 16–20 years, 235 [0.05%]; $P < 0.0001$), but gender was not found to have a statistically significant role (male, 627 [0.08%] vs. female, 302 [0.07%]; $P = 0.2739$) (Table 1). Furthermore, more had Medicaid insurance compared with other insurance providers (Medicaid, 437 [0.12%] vs. private, 369 [0.05%] vs. self-pay, 54 [0.06%] vs. other, 66 [0.09%]; $P < 0.0001$) and lower-middle income status ($1–$41,999, 191 [0.07%] vs. $42,000–$51,999, 343 [0.11%] vs. $52,000–$67,999, 216 [0.07%] vs. ≥$68,000, 169 [0.05%]; $P = 0.0006$) (Table 1). Among those patients with TBI who developed hydrocephalus, more were treated in urban hospitals (rural, 23 [0.01%] patients vs. urban, 907 [0.09%]; $P < 0.0001$), in teaching hospitals (nonteaching, 178 patients [0.03%] vs. teaching, 752 [0.14%]; $P < 0.0001$), and in hospitals with a trauma center (not trauma center, 180 [0.03%] vs. trauma center, 698 [0.1%]; $P < 0.0001$) (Table 1).

Clinical Presentation

Compared with patients with TBI with no LOC or brief to moderate LOC, patients with extended LOC had the largest proportion of hydrocephalus (no LOC, 380 [0.06%] vs. brief LOC, 107 [0.06%] vs. moderate LOC, <11 vs. prolonged LOC, baseline return, 23 [3.42%] vs. prolonged LOC, no baseline return, 81 [2.23%] vs. other, 334 [0.09%]; $P < 0.0001$) (Table 2). Patients with TBI who presented with a concussion had the smallest proportion of hydrocephalus development compared with patients with other types of TBI (concussion, 325 [0.03%] vs. laceration/contusion, 55 [0.31%] vs. subarachnoid hemorrhage, 121 [1.02%] vs. subdural hemorrhage, 279 [1.59%] vs. extradural hemorrhage, 28 [0.83%] vs. other, 123 [0.34%]; $P < 0.0001$) (Table 2). Of patients with TBI with open injuries, a greater proportion develop hydrocephalus compared with those presenting with closed injury (open, 34 [1.54%] vs. closed, 896 [0.07%]; $P < 0.0001$) (Table 2). On comparison of the cause of injury, shaken baby syndrome had the greatest proportion of patients develop hydrocephalus compared with the other mechanism cohorts (motor vehicle accident, 156 [0.12%] vs. fall, 253 [0.07%] vs. blunt trauma, 121 [0.03%] vs. firearm, 23 [2.28%] vs. cycling incident, 17 [0.05%] vs. shaken baby syndrome, 14 [10.94%]; $P < 0.0001$) (Table 2).

In-Hospital Complications and Discharge Disposition

On univariate analysis of the effect of in-hospital complications on the rate of hydrocephalus, respiratory (184 [3.45%]; $P < 0.0001$), cardiac (<11; $P < 0.0001$), renal and urinary (15 [3.62%]; $P < 0.0001$), hematoma (<11; $P < 0.0001$), thromboembolic (<11; $P < 0.0001$), septicemia (13 [26.17%]; $P < 0.0001$), and other neurologic (20 [49.19%]; $P < 0.0001$) complications were all associated with hydrocephalus development (Table 3). Among patients developing hydrocephalus after TBI, significantly more were admitted to inpatient services compared with other dispositions from ED (routine, 251 [0.02%] vs. transfer to short-term hospital, 52 [0.16%] vs. transfer to skilled nursing facility/intermediate care facility, 8 [0.18%] vs. home health care, <11 vs. against medical advice, <11 vs. admitted as inpatient, 619 [0.88%] vs. died in ED, <11; $P < 0.0001$) (Table 3). Furthermore, patients admitted with hydrocephalus encountered the largest proportion of transfers to home health care compared with other dispositions (routine, 354 [0.59%] vs. transfer to short-term hospital, <11 vs. transfer to skilled nursing facility/intermediate care facility, 164 (3.33%] vs. home health care, 33 (3.89%] vs. against medical advice, <11 vs. died in hospital, 57 [2.28%]; $P < 0.0001$) (Table 3).

Multivariate Regression of Risk Factors for Hydrocephalus Development

On multivariate regression analysis, age 6–10 years (odds ratio [OR], 0.60; 95% confidence interval [CI], 0.38–0.93; $P = 0.022$], 11–15 years (OR, 0.32; 95% CI, 0.21–0.48; $P < 0.001$), and 16–20 years (OR, 0.24; 95% CI, 0.15–0.37; $P < 0.001$) were all independently associated with decreased risk of developing hydrocephalus compared with ages 0–5 years (Table 4). Prolonged LOC with baseline return (OR, 8.54; 95% CI, 2.74–26.63; $P < 0.001$), prolonged LOC with no baseline return (OR, 3.81; 95% CI, 1.52–9.55; $P = 0.004$), and other LOC (OR, 1.38; 95% CI, 1.02–1.88; $P = 0.038$) were all independently associated with increased risk of developing hydrocephalus compared with no LOC, whereas brief LOC (<1 hour) ($P = 0.348$) and moderate LOC (1–24 hours) ($P = 0.727$) were not found to have a statistically significant role (Table 4). Furthermore, respiratory (OR, 28.35; 95% CI, 15.75–51.05; $P < 0.001$), hematoma or hemorrhage (OR, 37.12; 95% CI, 4.79–287.58; $P = 0.001$), thromboembolic (OR, 8.57; 95% CI, 1.31–56.19; $P = 0.025$), and other neurologic (OR, 64.64; 95% CI, 1.39–3010.2; $P = 0.033$) complications were all independently associated with increased risk of developing hydrocephalus compared with nonpresence of the complication, whereas cardiac ($P = 0.321$), renal and urinary ($P = 0.779$), and septicemia ($P = 0.151$) were not found to have a statistically significant role (Table 4). Open wound (OR, 3.47; 95% CI, 1.23–9.81; $P = 0.019$) was independently associated with increased risk of developing hydrocephalus compared with closed wound (Table 4).

Length of Hospital Stay, ED, and Inpatient Charges

The median length of stay for patients with TBI without PTH was 1 day, whereas the median length of stay for patients with TBI with PTH was 9.5 days (no PTH, 1[1–3] days vs. PTH, 9.5 [2–29.5] days; $P < 0.0001$) (Table 5). The median total ED charge for patients with TBI without PTH was $2209, and the median total ED charge for patients with TBI with PTH was $2356 (no PTH, $2209 [$915–$3812] vs. PTH, $2356.5 [$1372–$4111.75]; $P = 0.0296$) (Table 5). The median total inpatient charge for patients with TBI without PTH was $23,663, and the median total inpatient charge for patients with TBI with PTH was $123,357 (no PTH, $23,663 [$12,289–$48,777.5] vs. PTH, $123,357.5 [$31,132–$354,476]; $P < 0.0001$) (Table 5).

DISCUSSION

In this retrospective administrative database study investigating factors associated with PTH in pediatric patients presenting to the ED after a TBI, we show that income status, insurance status, hospital characteristics, age, clinical presentation, presence of complications, and discharge disposition were associated with higher rates of PTH. Furthermore, on multivariate regression, open wound, respiratory complication, neurologic complication, thromboembolic complication, hematoma, extended LOC, and younger age were independently associated with higher PTH incidence.

There have been a few studies in the literature that have attempted to characterize the incidence of PTH in the inpatient pediatric population. In a retrospective study of 124,444 inpatient pediatric patients with TBI, Rumalla et al.[16] found that 1.0% of patients developed PTH. Similarly, in a retrospective cohort study of 91,583 pediatric patients with TBI, Bonow et al.[17] found that 0.9% of the cohort developed PTH. Furthermore, in another retrospective cohort study of 51 children who underwent decompressive craniectomy for severe TBI, Kan et al.[18] found the rate of PTH to be 40.0%, postulating that hydrocephalus occurs at higher rates in cases of severe TBI. Consistent with these findings, we identified a 0.07% national rate of pediatric patients with TBI developing PTH in the ED setting, reflecting a potentially milder distribution of head injury in the ED population.

Although the factors associated with PTH in pediatric patients with TBI in an emergency setting have yet to be explored, previous studies have noted demographic features associated with the development of PTH. In their study, Rumalla et al.[16] showed that age 0–5 years, female gender, Medicaid insurance status, and nonwhite race were associated with higher rates of PTH after TBI, whereas household income status had no effect on PTH rates. Moreover, the investigators noted that hospital bed size had no impact on PTH rate, whereas rural hospitals and teaching hospitals had higher PTH rates.[16] Similarly, in their study, Bonow et al.[17] found younger age, government insurance status, and nonwhite race to be associated with higher rates of PTH after TBI. However, male gender had no influence on PTH rates.[17] In a retrospective study of 526 all-age patients after TBI, Chen et al.[19] found that increased age was associated with increased rates of PTH, whereas male gender had no statistically significant impact. Similarly, in their study, Kaammersgaard et al.[20] found increased age to be associated with higher rates of PTH. In another retrospective cohort study of 301 patients with traumatic subarachnoid hemorrhage with ages ranging from 4 to 82 years, Tian et al.[21] found that increasing age was a risk factor for PTH. On the other hand, in a retrospective study of 194 all-age patients undergoing decompressive craniectomy after TBI, Honeybul et al.[22] found that neither age nor male gender had a significant impact on PTH rates. Similar to those studies, we found Medicaid insurance, low income status, and young age to be associated with higher rates of PTH, whereas gender did not have a statistically significant impact. Hospitals that were urban, teaching, or contained trauma centers also had higher rates of hydrocephalus after TBI. These findings warrant further studies to identify patient-specific and institution-specific factors associated with hydrocephalus in the pediatric population after TBI.

The impact of clinical presentation of patients experiencing TBI on rate of PTH has been explored previously. In their study, Rumalla et al.[16] showed that prolonged LOC, subdural hematoma, subarachnoid hemorrhage, open injury, shaken baby syndrome, and firearm injury all led to increased rates of hydrocephalus after TBI. In addition, the investigators found that brief LOC, concussion, motor vehicle accident, blunt trauma, and cycling accidents were associated with decreased PTH rates.[16] In their study, Bonow et al.[17] showed that subdural hematoma, subarachnoid hemorrhage, skull fracture with hemorrhage, and child abuse injuries were all associated with higher rates of PTH. Moreover, concussion and skull fracture without hemorrhage were found to be associated with lower rates of PTH after TBI.[17] In the study by Chen et al.,[19] lower Glasgow Coma Scale score, shorter duration of LOC, intra-axial hemorrhage/brain contusion, and higher Fisher grade were associated with higher rates of PTH. The investigators also showed that open injury, mechanism of injury, and location of lesion played no role in the development of hydrocephalus.[19] In their study, Honeybul et al. showed low Glasgow Coma Scale score and bilateral subdural hygroma to be associated with higher incidence of PTH, whereas subarachnoid hemorrhage had no statistically significant impact. Our results build on these findings, showing that duration of LOC, type of TBI, nature of injury, and cause of injury were all significantly associated with presence of PTH. Specifically, shaken baby syndrome, open injury, subdural hemorrhage, subarachnoid hemorrhage, and prolonged LOC were all associated with higher rates of hydrocephalus after injury. Early identification of these symptoms in the ED setting may help risk-stratify those patients at increased risk for developing PTH.

The implications of PTH development may be seen in terms of patient morbidities and health care cost. In their study, Rumalla et al.[16] showed that any complication, with the most prevalent being neurologic, pulmonary, urinary, and septicemia, was significantly associated with increased hydrocephalus rates. Furthermore, in a retrospective study of 417 patients with severe TBI, Linnemann et al.[23] found that patients with PTH had longer rehabilitation stays compared with patients without PTH. Similarly, in their study, Honeybul et al.[22] reported longer rehabilitation stays for patients with PTH than for patients without PTH after TBI. Our study corroborates these trends, because we found that respiratory, neurologic, and septicemic complications as well as nonroutine discharge were associated with higher rates of PTH. Furthermore, development of PTH after TBI is costly. In their study, Rumalla et al.[16] showed that development of PTH was associated with approximately 5-fold increased hospital costs ($86,596 vs. $16,791), partly because of the increased rate of complications and hospital stays in this cohort. Although we showed a similar 5-fold increase in charges made during the inpatient management of pediatric patients with TBI, the median charge of patients with PTH treated in the ED remained only slightly greater than that of patients without PTH ($2357 vs. $2209). Therefore, further investigation of the specific risk factors that drive admission in the ED setting for pediatric patients with TBI may be essential for improving the quality of patient care and reducing the soaring health care costs.

This study has several limitations inherent to the nature of retrospective studies that use national databases. First, this is a retrospective analysis that uses ICD-9-CM coding, which may have reporting and coding biases. Second, the data may not have been accurately classified or completely reported because some EDs may not be staffed by board-certified emergency medicine–trained physicians. Third, NEDS has information only on the visit level and patient outcome may not be tracked over time. Furthermore, we are unable to comment on whether the PTH may be previously undiagnosed ventriculomegaly of any (not necessarily traumatic) cause. However, NEDS still serves as a useful database to perform a study to identify risk factors associated with PTH in pediatric patients with TBI in an ED setting.

CONCLUSIONS

Our study using the NEDS database shows that various demographic, hospital, and clinical risk factors are associated with the development of hydrocephalus after TBI. Enhancing awareness of these drivers may help provide greater awareness of patients likely to develop PTH such that this complication can be decreased in incidence to improve quality of care and decrease health care costs.

Abbreviations and Acronyms

CCS	Certified Coding Specialist
CI	Confidence interval
ED	Emergency department
ICD-9-CM	International Classification of Diseases, Ninth Revision, Clinical Modification
LOC	Loss of consciousness
NEDS	Nationwide Emergency Department Sample database
OR	Odds ratio
PTH	Posttraumatic hydrocephalus
TBI	Traumatic brain injury

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Table 1.

Univariate Effect of Patient Demographic and Hospital Characteristics on the Rate of Posttraumatic Hydrocephalus

Characteristic	N	Hydrocephalus, n (%)	*P* Value
Total (N)	1,244,087	930 (0.07)	
Age group			<0.0001
0–5 years	193,444	326 (0.17)	
6–10 years	181,401	162 (0.09)	
11–15 years	418,784	207 (0.05)	
16–20 years	450,459	235 (0.05)	
Gender			0.2739
Male	790,163	627 (0.08)	
Female	453,708	302 (0.07)	
Payer			<0.0001
Medicaid	364,119	437 (0.12)	
Private	711,005	369 (0.05)	
Self-pay	93,755	54 (0.06)	
Other	70,925	66 (0.09)	
Income			0.0006
$1–$41,999	272,316	191 (0.07)	
$42,000–$51,999	302,535	343 (0.11)	
$52,000–$67,999	304,768	216 (0.07)	
≥$68,000	343,226	169 (0.05)	
Hospital location			<0.0001
Rural	233,092	23 (0.01)	
Urban	1,010,996	907 (0.09)	
Hospital teaching status			<0.0001
Nonteaching	696,669	178 (0.03)	
Teaching	547,419	752 (0.14)	
Hospital trauma status			<0.0001
Not trauma center	553,780	180 (0.03)	
Trauma center	669,026	698 (0.1)	

Table 2.

Univariate Effect of Clinical Presentation of Traumatic Brain Injury on the Rate of Hydrocephalus

Characteristic	**N**	**Hydrocephalus, n (%)**	***P* Value**
Total (N)	1,244,087	930 (0.07)	
Clinical presentation (loss of consciousness)			<0.0001
None	674,148	380 (0.06)	
Brief (<1 hour)	171,957	107 (0.06)	
Moderate (1–24 hours)	1773	<11	
Prolonged (≥24 hours), baseline return	673	23 (3.42)	
Prolonged (≥24+ hours), no baseline return	3649	81 (2.23)	
Other	391,888	334 (0.09)	
Type of traumatic brain injury			<0.0001
Concussion	1,157,346	325 (0.03)	
Laceration/contusion	17,517	55 (0.31)	
Subarachnoid hemorrhage	11,875	121 (1.02)	
Subdural hemorrhage	17,566	279 (1.59)	
Extradural hemorrhage	3360	28 (0.83)	
Other	36,423	123 (0.34)	
Nature of injury			<0.0001
Open	2222	34 (1.54)	
Closed	1,241,866	896 (0.07)	
Cause of injury			<0.0001
Motor vehicle accident	126,742	156 (0.12)	
Fall	377,556	253 (0.07)	
Blunt trauma by person/object	385,234	121 (0.03)	
Firearm	1022	23 (2.28)	
Cycling incident	32,327	17 (0.05)	
Shaken baby syndrome	128	14 (10.94)	

Table 3.

Univariate Effect of In-Hospital Complications and Discharge Disposition on the Rate of Hydrocephalus

Characteristic	N	Hydrocephalus, n (%)	*P* Value
Total (N)	1,244,087	930 (0.07)	
Complications			
Respiratory	5055	184 (3.45)	<0.0001
Cardiac	19	<11	<0.0001
Renal and urinary	409	15 (3.62)	<0.0001
Hematoma	33	<11	<0.0001
Thromboembolic	76	<11	<0.0001
Septicemia	50	13 (26.17)	<0.0001
Other neurologic	41	20 (49.19)	<0.0001
Disposition from ED			<0.0001
Routine	1,130,809	251 (0.02)	
Transfer to short-term hospital	31,322	52 (0.16)	
Transfer to skilled nursing facility, intermediate care facility	4677	8 (0.18)	
Home health care	719	<11	
Against medical advice	3093	<11	
Admitted as inpatient	70,211	619 (0.88)	
Died in ED	1010	<11	
Disposition from inpatient			<0.0001
Routine	59,849	354 (0.59)	
Transfer to short-term hospital	1440	<11	
Transfer to skilled nursing facility, intermediate care facility	4921	164 (3.33)	
Home health care	864	33 (3.89)	
Against medical advice	520	<11	
Died in hospital	2506	57 (2.28)	

ED, emergency department.

Table 4.

Multivariate Risk Factors for Hydrocephalus

Predictor Variable	Odds Ratio (95% Confidence Interval)	*P* Value
Age		
0–5 years	Reference	
6–10 years	0.6 (0.38–0.93)	0.022
11–15 years	0.32 (0.21–0.48)	<0.001
16–20 years	0.24 (0.15–0.37)	<0.001
Loss of consciousness		
None	Reference	
Brief (<1 hour)	1.25 (0.79–1.97)	0.348
Moderate (1–24 hours)	1.29 (0.31–5.43)	0.727
Prolonged (24+ hours), baseline return	8.54 (2.74–26.63)	<0.001
Prolonged (24+ hours), no baseline return	3.81 (1.52–9.55)	0.004
Other	1.38 (1.02–1.88)	0.038
In-hospital complications		
Nonpresence of the complication	Reference	
Respiratory	28.35 (15.75–51.05)	<0.001
Cardiac	6.88 (0.15–310.41)	0.321
Renal and urinary	1.44 (0.11–17.98)	0.779
Hematoma or hemorrhage	37.12 (4.79–287.58)	0.001
Thromboembolic	8.57 (1.31–56.19)	0.025
Septicemia	15.63 (0.37–664.54)	0.151
Other neurologic	64.64 (1.39–3010.2)	0.033
Open		
Closed	Reference	
Open	3.47 (1.23–9.81)	0.019

Table 5.

Length of Stay, Emergency Department, and Inpatient Charges

Outcome	No PTH, Median (IQR)	PTH, Median (IQR)	*P* Value
Length of stay (days)	1 (1–3)	9.5 (2–29.5)	<0.0001
Emergency department charge ($)	2209 (915–3812)	2356.5 (1372–41,11.75)	0.0296
Inpatient charge ($)	23,663 (12,289–48,777.5)	123,357.5 (31,132–354,476)	<0.0001

PTH, posttraumatic hydrocephalus.