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Journal
Journal of Pediatric Surgery, 56(6)

ISSN
0022-3468

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Publication Date
2021-06-01

DOI
10.1016/j.jpedsurg.2021.02.044

Peer reviewed

J Pediatr Surg. Author manuscript; available in PMC 2022 June 01.

Increased Mortality in Very Young Children with Traumatic Brain Injury Due to Abuse: A Nationwide Analysis of 10,965 Patients

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Abstract

Background: Traumatic brain injury (TBI) is the leading cause of death and disability in young children; however, the impact of mechanism on outcomes has not been fully evaluated. We hypothesized that children with TBI due to abuse would have a higher mortality than children with accidental TBI due to motor vehicle collisions (MVC).

Methods: We performed a retrospective review of the National Kids' Inpatient (KID) hospitalizations database of children <2 years old with TBI due to abuse or MVC (2000-2016). The primary outcome was mortality. Secondary outcomes were length of stay (LOS) and hospital charges. We investigated predictors of mortality with multivariable regression.

Results: Of 10,965 children with TBI, 65.2% were due to abuse. Overall mortality was 9.8% (n=1074). Abused children had longer LOS (5.7 vs 1.6 days, p<0.0001) and higher hospital charges ($34,314 vs $19,360, p<0.0001) than children with TBI due to MVC. The odds of mortality were 42% higher in children with abusive head trauma (OR 1.42, 95% CI 1.10-1.83, p=0.007) compared to MVCs after adjusting for age, race, sex, neurosurgical intervention, injury severity, and insurance.

Conclusion: Children with abusive traumatic brain injury have increased risk of mortality, longer LOS, and higher hospital charges compared to children with TBI due to motor vehicle collision after adjusting for relevant confounders. Resources must be directed at prevention and early identification of abuse.

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Declarations of Interest: None.

Type of Study: Retrospective comparative prognosis study

Level of Evidence: Level II

Keywords

child abuse; traumatic brain injury; accidental head injury; mortality

Introduction

Traumatic brain injury (TBI) is the leading cause of death in injured children [1] and child abuse is a frequent cause of TBI in children [2]. Previous studies of young children have found a higher incidence of abusive head trauma in younger children, but a higher mortality in older children [3]. Case fatality rates increase with each year of age from 0 to 4 years old [4]. Compared to abusive head trauma, the risk of mortality in children with TBI due to accidental injury does not seem to increase with age [3].

However, there have been no studies examining the relationship between age, mechanism, and mortality in abusive head trauma compared to accidental head trauma in very young children, specifically those less than two years old. Children younger than two years old have an incidence of child abuse of 17 per 100,000 person-years, with the highest incidence in infants less than one year of age, at 29.7 cases per 100,000 person-years compared to 3.8 per 100,000 person-years in children 1-2 years old [2]. This peak in incidence may be partially attributed to the timing of infant crying behaviors [5]. However, this factor alone cannot explain all cases of abusive head trauma and does not explain the higher mortality of abusive head trauma in older children.

We hypothesized that very young children with TBI due to abuse would have worse outcomes, including increased mortality, longer hospital length of stay, and increased hospital charges when compared to children with TBI due to accidental head trauma. For a comparison cohort, we chose motor vehicle collision as the mechanism of accidental head trauma to avoid capturing children with TBI due to other mechanisms that may have sustained abuse but not been identified as such.

1. Methods:

1.1 Database

We utilized the Kids' Inpatient Database (KID), which is an administrative claims database of hospitalizations that is part of the Healthcare Cost and Utilization Project. This dataset is available every three years starting in 1997 and was most recently published in 2016. The database samples 80% of pediatric hospitalizations from 4,200 hospitals around the United States, and captures data from all payors, including uninsured patients. In this study, we included cases captured in 2000, 2003, 2006, 2009, 2012, and 2016. Hospitalizations from 955 unique hospitals in 42 states were included. Institutional Review Board approval was obtained (IRB #1582638).

1.2 Patient Selection

We included children < 2 years old who were hospitalized and diagnosed with head trauma, identified by International Classification of Diseases-9 and 10-Revision-Clinical

Modification (ICD-9-CM, ICD-10-CM) codes (Supplementary Table 1). To identify the etiology, patients were classified as sustaining abusive head trauma if they had an ICD-9-CM or ICD-10-CM code describing definite or presumptive abusive head trauma as defined by the Centers for Disease Control [6]. We excluded children who sustained trauma due to lack of supervision. ICD-9-CM and ICD-10-CM codes were also used to identify accidental head trauma by identifying patients with a traumatic brain injury following a motor vehicle collision (MVC).

We collected data on patient demographics, injury mechanism, insurance, hospital region, length of stay, in-hospital mortality, and hospital charges. Race was categorized as white, black, Hispanic, or other, defined as Asian, Pacific Islander, Native American, or not specified. Insurance was categorized as Medicaid, private insurance, or other, defined as self-pay, no charge, or not specified.

The KID dataset does not include injury severity score, so injury severity was derived from ICD-9-CM and ICD-10-CM codes and empirically derived survival risk ratios from the National Trauma Data Bank to calculate an ICISS (International Classification Injury Severity Score) measure of injury severity [7–9]. The ICISS measures likelihood of survival following an injury based on prior patients with similar injuries based on ICD codes. When multiple injuries are sustained, the ICISS is calculated by multiplying the survival risk ratio for each injury. ICISS has been validated in pediatric trauma patients [10]. Unlike injury severity score (ISS), in which a higher score indicates higher levels of severity, a high ICISS indicates high survivability of an injury, thus a lower ICISS indicates higher injury severity. ICISS ranges from 0 to 1, with an ICISS of 0 representing no likelihood of surviving the injury.

To further account for severity of brain injury, the KID dataset was queried for patients in each cohort who underwent any neurosurgical intervention during their admission. KID utilized ICD-9-CM procedure codes for patients prior to October 1, 2015 and ICD-10-PCS (Procedure Coding System) for patients from October 1, 2015 and beyond. Patients were categorized as having undergone neurosurgical intervention if they had any of these procedure codes linked to their admission (Supplementary Table 2).

1.3 Statistical Analysis

Descriptive statistics were performed to describe baseline characteristics and outcomes of the study cohort. Continuous data are presented as median and interquartile range (IQR). Bivariate analyses were performed to identify statistically significant associations between predictor variables and outcome variables. Multivariable analysis was performed to identify factors significantly associated with the outcomes of mortality, hospital length of stay, and hospital charges. An adjusted logistic regression model for survey data was implemented to study mortality. Effects of explanatory variables are presented as an odds ratio (OR), 95% confidence interval (95% CI), and p-values. Multivariable linear regression models with log-transformed outcomes were used to investigate the outcomes of length of hospital stay and total charges. A subgroup analysis was performed by stratifying children by age into two cohorts: 0-11 months and 12-23 months and repeating the above analyses. All tests were two-sided and p-values <0.05 were considered statistically significant. Analyses were performed with SAS software, version 9.4 (SAS Institute, Cary, NC, USA).

2. Results:

2.1 Baseline Characteristics

There were 10,965 patients identified with TBI from abuse or accidental trauma, specifically, MVC (Table 1). Two-thirds had TBI due to abuse (65.2%, n = 7152) compared to 34.8% with TBI due to accidental head trauma (n = 3813). The majority of patient were < 1 year old (74.9%, n = 8214). Over half of patients were male (59.9%, n = 6459). Children with TBI from abuse were younger than children with TBI from accidental trauma, with 85.4% of abused children under one year of age compared to 55.2% of children with TBI from accidental trauma ($p < 0.0001$). Abused children were also more likely to be male, at 60.9% compared to 55.3% of children with accidental head trauma ($p < 0.0001$). Race ($p < 0.0001$) and insurance ($p < 0.0001$) were also significantly associated with mechanism, with white children (50.2% of abused children) and children with Medicaid (73.3% of abused children) making up higher proportions of the abusive head trauma group.

On bivariate analysis, the mortality rate did not differ by mechanism, with 10.4% of children with abusive head trauma dying compared to 8.8% of children with accidental head trauma ($p = 0.071$). However, children with abusive head trauma had significantly longer hospitalizations (median 5.7 days vs. 1.6 days, $p < 0.0001$) and higher hospital charges (median $34,314 vs. $19,360, $p < 0.0001$). Children who suffered abusive head trauma were significantly more likely to undergo neurosurgical intervention (24.9% vs. 10.9%, $p < 0.0001$). Of children who died, the median survival from injury to death was 1.8 days (IQR 0.7 – 3.9 days) for children with abusive head trauma and 0.7 days (IQR 0-1.9 days) for children with accidental head trauma ($p < 0.0001$).

2.2 Factors associated with mortality, length of stay, and hospital charges

On multivariable analysis, children with TBI due to child abuse had a 42% increased odds of mortality compared to children with TBI from accidental head trauma (OR 1.42, 95% CI 1.10-1.83, $p = 0.007$), after adjusting for age, mechanism, ICISS, neurosurgical intervention, race, insurance, and hospital region (Table 3). Children who underwent neurosurgical intervention had a two-fold increased odds of mortality (OR 1.94, 95% CI 1.48-2.54, $p < 0.0001$). A higher ICISS score, indicating less severe injury, was associated with significantly decreased odds of mortality (OR 0.005, 95% CI 0.003-0.008, $p < 0.0001$). Additionally, children with abusive head trauma had a 97% longer LOS than children with accidental head trauma ($p < 0.0001$) and an average of $15,137 higher hospital charges per patient ($p < 0.0001$, Table 4).

2.3 Subgroup analysis by age

We then performed a sub-group analysis of children stratified by age. The younger cohort was defined as 0-11 months old, and the older cohort was defined as 12-23 months old (Table 5). On bivariate analysis, there was no difference in the mortality rate of the younger cohort (9.8%) and the older cohort (9.9%, $p = 0.86$). Multivariable regression was performed in each age cohort (Table 6), and there was no difference in mortality rates by mechanism in the younger age group (OR 0.99, 95% CI 0.74-1.32, p =0.93). However, in the older group, abusive head trauma was associated with a nearly four-fold higher odds of mortality, at 16.1% compared to 6.1% in the accidental head trauma group, after adjusting for mechanism, race, injury severity, insurance, and hospital region (OR 3.44, 95% CI 2.04-5.82, p < 0.0001). Patients undergoing neurosurgical intervention had an increased odds of mortality in both 0-11 month old patients (OR 1.74, 95% CI 1.28-2.37, p < 0.0001) and 12-23 month old patients (OR 2.45, 95% CI 1.47-4.10, p < 0.0001). The relationship between age, mechanism, and mortality is displayed in Figure 1, with increasing probability of mortality by age in children with abusive head trauma and decreasing probability of mortality by age in children with accidental head trauma.

3. Discussion:

In this nationwide study of 10,965 children younger than two years old with traumatic brain injury, we found that children with abusive head trauma had an overall significantly higher mortality, hospital length of stay, and hospital charges than children with accidental head trauma, after adjusting for age, mechanism, injury severity, neurosurgical intervention, race, insurance, and hospital region. In order to further investigate the effect of age on outcomes in this cohort, we performed a subgroup analysis by age < 12 months old compared to age 12-23 months. Although abusive head trauma was more common in the younger cohort of children aged 0-11 months, mortality was significantly higher in the older cohort of children aged 12-23 months who sustained abusive head trauma compared to accidental head trauma after adjusting for the same factors as above. This finding did not hold true in younger children aged 0-11 months, who had similar mortality rates regardless of mechanism.

Young children, and particularly infants, are the most frequent victims of child abuse. In a study of 19,149 children who sustained abusive injuries in the National Trauma Data Bank, 95% were under 5 years of age, and 71% were younger than one year old, with an overall mortality of 9% [11]. The most common injury was traumatic brain injury and children with TBI had an increased risk of mortality. Despite the higher incidence in younger children, case fatality rates from abusive head injury rise with age [4]. Interestingly, we found that mortality rates in the youngest cohort of abused children did not differ between abusive or accidental head trauma, but that the older cohort had a significantly higher mortality rate, after adjusting for injury severity.

There are several possible explanations for this finding. Older children may be at higher risk for mortality due to the injury patterns sustained and these patterns may differ from those seen in abused infants [3]. Due to a heightened awareness of the increased incidence of child abuse in infants [12], slightly older children may be at risk for misdiagnosis or late diagnosis of abuse, which is associated with worse outcomes [13]. As children in the 12-23 month age group are becoming ambulatory, they may be more likely to have their injuries attributed to accidental mechanisms such as falls, rather than abuse. As many as 30% of abusive injuries are misdiagnosed [14], with a mean of 2.8 visits to a physician required before diagnosis, although some children require as many as 9 visits [14]. Abuse is often serial [15], and older children have more time to sustain multiple abusive injuries. Lastly, preventative interventions are often directed at infants, aimed at educating caregivers on crying behaviors and the dangers of shaken baby syndrome [17], which are likely different mechanisms than those of children older than 12 months presenting with abusive head trauma.

In addition to the severe consequences of abuse on children, increased levels of resources are often needed to care for these children, including trauma team activation [16], use of child protection teams [18], higher intensive care unit utilization, and longer hospital length of stay, resulting in a higher hospital costs compared to victims of accidental trauma [19]. Our findings support these, with abused children having longer hospitalizations and higher hospital costs when compared to children with accidental head trauma. Once medically clear, discharge may be delayed due to need for a safe disposition plan, which is associated with a mean delay of 4.4 days and $13,648 of additional hospital charges during that time [20].

Our study is limited due to its retrospective nature and the utilization of a claims database; therefore, not all clinically relevant information is available for analysis. In addition, the KID database includes only inpatient hospitalizations and does not capture children discharged from the emergency department, thus potentially missing some patients with minor TBIs. Additionally, data on intensive care unit admission rates or lengths of stay is lacking. To address this, we have used neurosurgical intervention as an indicator of neurologic injury severity. However, there are likely some children who did not undergo neurosurgical intervention due to non-survivable brain injuries, who would be missed by this classification. Our study is strengthened by its large size, analyzing over 10,000 hospitalizations for abusive or accidental brain injury in patients younger than two years of age. In addition, it is a nationwide sample that should be representative of trends around the country. More detailed geographic analyses remain an area of future research, as we noted significantly differing rates of abusive head trauma by region. However, as the KID database categorizes region into four large areas (Northeast, Midwest, South, and West), the data provided lack the granularity needed to understand the reasons behind these findings.

4. Conclusion:

Children younger than two years old who sustain abusive head trauma have a significantly higher mortality, longer hospital length of stay, and higher hospital charges than children with accidental head trauma after adjusting for significant covariates. Although abusive head trauma was more common in children younger than 12 months, mortality rates did not differ by mechanism on multivariable analysis. However, for older children, aged 12-23 months, mortality was significantly higher among children who suffered abusive head trauma compared to children with accidental head trauma on multivariable analysis. These children represent an extremely vulnerable population with little to no ability to advocate for themselves, and providers must remain vigilant in the early identification of child abuse and prevention of repeat violence in very young children.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

Funding Information:

The project described was supported by the National Center for Advancing Translational Sciences, National Institutes of Health, through grant number UL1 TR001860 for authors C.M.T. and E.G.B. The content is solely the responsibility of the authors and does not necessarily represent the official views of the NIH.

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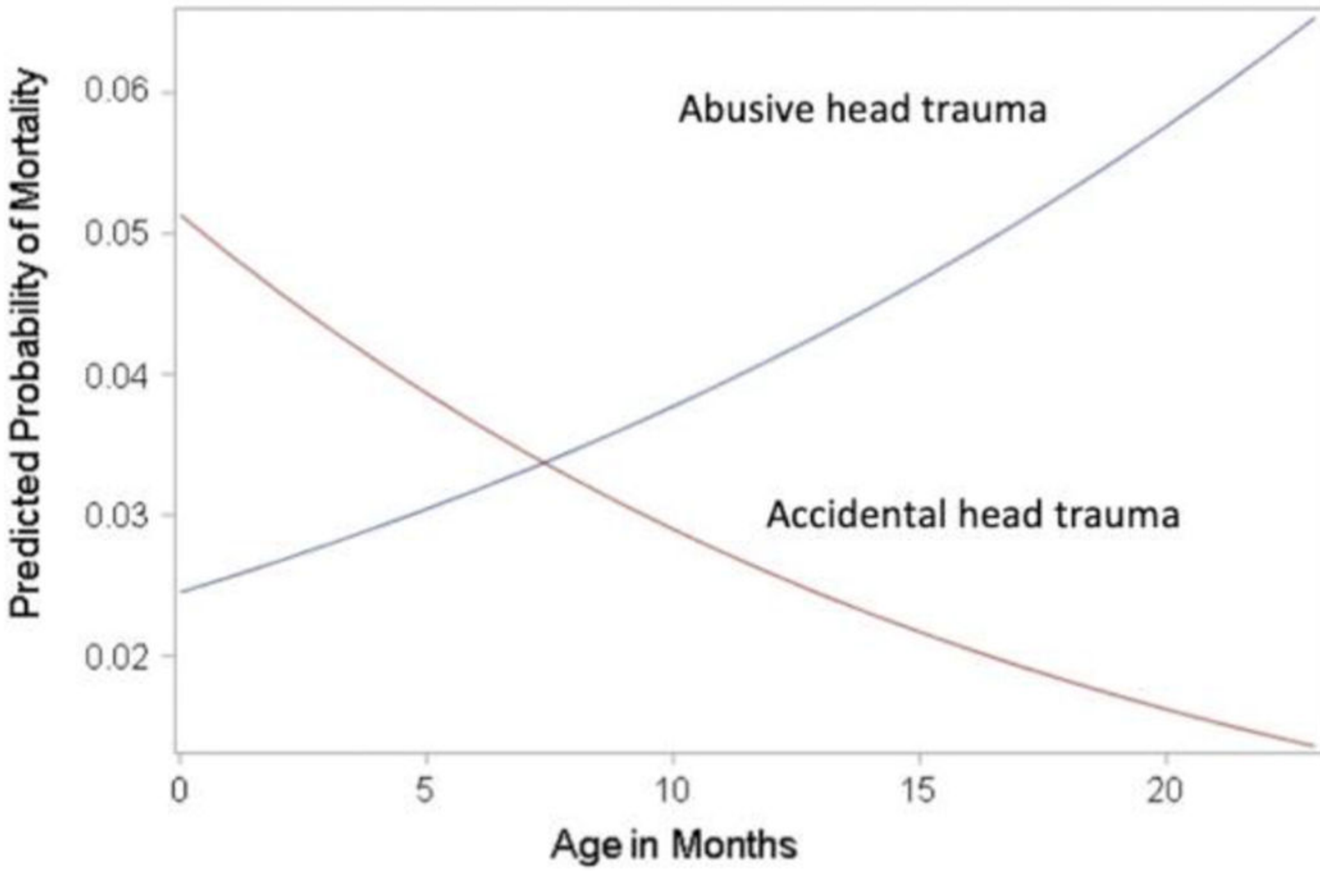

Figure 1:
Association of age, mechanism of injury, and mortality.

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Table 1:

Patient characteristics overall and by mechanism

Variable	Abusive head trauma n = 7152	Accidental head trauma n = 3813	p-value
Age, n (%)			<0.0001
0-11 months	6110 (85.4)	2104 (55.2)	
12-23 months	1042 (14.6)	1709 (44.8)	
Male, n (%)	4352 (60.9)	2107 (55.3)	<0.0001
Race, n (%)			<0.0001
White	2876 (50.2)	1300 (41.3)	
Black	1191 (20.8)	731 (23.2)	
Hispanic	1116 (19.5)	788 (25.1)	
Other	548 (9.6)	326 (10.4)	
Insurance, n (%)			<0.0001
Medicaid	5236 (73.3)	1732 (45.7)	
Private	1403 (19.7)	1590 (41.9)	
Other	501 (7.0)	471 (12.4)	
Hospital region, n (%)			<0.0001
Northeast	878 (12.3)	384 (10.1)	
Midwest	1967 (27.5)	651 (17.1)	
South	2529 (35.4)	1636 (42.9)	
West	1778 (24.9)	1141 (29.9)	

Other race includes Asian, Pacific Islander, Native American, or not specified. Other insurance includes self-pay, no charges, or not specified.

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Table 2:

Outcomes of children with abusive head trauma compared to accidental head trauma

Variable	Abusive head trauma n = 7152	Accidental head trauma n = 3813	p-value
Mortality, n (%)	740 (10.4)	334 (8.8)	0.07
Time to death, days: median (IQR)	1.8 (0.7-3.9)	0.7 (0-1.9)	<0.0001
ICISS: median (IQR)	0.93 (0.80-0.99)	0.93 (0.77-0.97)	<0.0001
Neurosurgical intervention, n (%)	1777 (24.9)	416 (10.9)	<0.0001
Length of stay, days: median (IQR)	5.7 (2.5-12.1)	1.6 (0.6-4.3)	<0.0001
Hospital charges: median (IQR)	$34,314 (15,787-83,178)	$19,360 (9,452-41,567)	<0.0001

ICISS: International Classification Injury Severity Score; IQR: Interquartile Range

Table 3:

Predictors of Mortality

Variable	Mortality	
	OR (95% CI)	p-value
Age		
0-11 months	Reference	
12-23 months	0.95 (0.72-1.26)	0.72
Mechanism		
Accidental	Reference	
Abuse	1.42 (1.10-1.83)	0.007
ICISS	0.005 (0.003-0.008)	<0.0001
Neurosurgical intervention	1.94 (1.48-2.54)	<0.0001
Sex		
Female	Reference	
Male	1.05 (0.83-1.32)	0.70
Race		
White	Reference	
Black	1.21 (0.90-1.63)	0.20
Hispanic	0.99 (0.73-1.35)	0.97
Other	2.07 (1.47-2.94)	<0.0001
Insurance		
Private	Reference	
Medicaid	1.72 (1.13-2.61)	0.01
Other	0.93 (0.70-1.23)	0.60
Hospital region		
Northeast	Reference	
Midwest	1.30 (0.77-2.19)	0.32
South	1.49 (0.95-2.33)	0.09
West	1.31 (0.81-2.13)	0.27

OR: Odds Ratio; CI: Confidence Interval. ICISS: International Classification Injury Severity Score. Other race includes Asian, Pacific Islander, Native American, or not specified. Other insurance includes self-pay, no charges, or not specified.

Table 4:

Predictors Hospital Length of Stay and Hospital Charges

Variable	Length of Stay		Hospital Charges	
	Estimate	p-value	Estimate	p-value
Age				
0-11 months	Reference		Reference	
12-23 months	0.94	0.07	$3405	<0.0001
Mechanism				
Accidental	Reference		Reference	
Abuse	1.97	<0.0001	$15137	<0.0001
ICISS	1.04	0.03	−$74659	<0.0001
Neurosurgical intervention	2.41	<0.0001	$76628	<0.0001
Sex				
Female	Reference		Reference	
Male	0.97	0.06	−$1623	0.37
Race				
White	Reference		Reference	
Black	1.09	10	$10834	0.07
Hispanic	1.03	0.78	$7775	0.002
Other	1.08	0.22	$5264	0.03
Insurance				
Private	Reference		Reference	
Medicaid	1.12	<0.0001	$5475	0.04
Other	1.05	0.13	−$6247	0.02
Hospital region				
Northeast	Reference		Reference	
Midwest	1.04	<0.001	−$24946	<0.0001
South	0.91	0.28	−$20412	<0.0001
West	0.93	0.06	−$1379	0.70

ICISS: International Classification Injury Severity Score. Other race includes Asian, Pacific Islander, Native American, or not specified. Other insurance includes self-pay, no charges, or not specified.

Table 5:

Patient characteristics and outcomes by age

Variable	Age 0-11 months n = 8214	Age 12-23 months n = 2751	p-value
Mechanism, n (%)			<0.0001
Accidental	2104 (25.6)	1709 (62.1)	
Abuse	6110 (74.4)	1042 (37.9)	
Male, n (%)	4896 (59.7)	1562 (56.8)	0.04
Race, n (%)			0.01
White	3163 (47.7)	1014 (45.2)	
Black	1359 (20.5)	563 (25.1)	
Hispanic	1459 (22.0)	445 (19.8)	
Other*	650 (9.8)	223 (10.0)	
Insurance, n (%)			<0.0001
Medicaid	5480 (66.9)	1489 (54.40)	
Private	2065 (25.2)	928 (33.9)	
Other*	652 (8.0)	321 (11.7)	
Hospital region, n (%)			0.012
Northeast	956 (11.6)	306 (11.1)	
Midwest	2037 (24.8)	581 (21.1)	
South	3157 (38.4)	1007 (36.6)	
West	2063 (25.1)	856 (31.1)	
Mortality, n (%)	802 (9.8)	272 (9.9)	0.86
ICISS: median (IQR)	0.93 (0.80-0.99)	0.91 (0.73-0.97)	<0.0001
Neurosurgical intervention, n (%)	1730 (21.1)	463 (16.9)	0.0003
Length of stay, days: median, (IQR)	4.5 (1.7-10.4)	2.5 (0.9-6.8)	<0.0001
Hospital charges: median (IQR)	$29,467 (13,444-72,089)	$25,183 (11,328-56,466)	<0.0001

ICISS: International Classification Injury Severity Score; IQR: Interquartile Range. Other race includes Asian, Pacific Islander, Native American, or not specified. Other insurance includes self-pay, no charges, or not specified.

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Table 6:

Predictors of Mortality Stratified by Age

Variable	Age 0-11 months		Age 12-23 months	
	OR (95% CI)	p-value	OR (95% CI)	p-value
Mechanism				
Accidental	Reference		Reference	
Abuse	0.99 (0.74-1.32)	0.93	3.44 (2.04-5.82)	<0.0001
ICISS	0.006 (0.003-0.009)	<0.0001	0.003 (0.001-0.008)	<0.0001
Neurosurgical intervention	1.74 (1.28-2.37)	<0.0001	2.45 (1.47-4.10	0.0007
Sex				
Female	Reference		Reference	
Male	1.09 (0.85-1.42)	0.49	1.04 (0.67-1.64)	0.85
Race				
White	Reference		Reference	
Black	0.98 (0.70-1.38)	0.92	2.14 (1.16-3.94)	0.02
Hispanic	0.87 (0.63-1.21)	0.41	1.80 (0.95-3.43)	0.07
Other	1.91 (1.28-2.87)	0.002	2.81 (1.35-5.86)	0.01
Insurance				
Private	Reference		Reference	
Medicaid	1.70 (1.13-2.55)	0.01	1.20 (0.50-2.84)	0.68
Other	0.92 (0.70-1.22)	0.66	0.55 (0.30-1.02)	0.05
Hospital region				
Northeast	Reference		Reference	
Midwest	1.26 (0.72-2.20)	0.41	1.38 (0.58-3.30)	0.47
South	1.50 (0.91-2.47)	0.11	1.41 (0.70-2.82)	0.34
West	1.31 (0.76-2.28)	0.33	1.26 (0.60-2.65)	0.55

OR: Odds Ratio; CI: Confidence Interval. ICISS: International Classification Injury Severity Score. Other race includes Asian, Pacific Islander, Native American, or not specified. Other insurance includes self-pay, no charges, or not specified.