Patient Characteristics and Clinical and Intraoperative Variables Affecting Outcome in Pediatric Traumatic Brain Injury

Ankur Dhanda[1] Ashish Bindra[2] Roshni Dhakal[3] Siddharth Chavali[4] Gyaninder P. Singh[5] Pankaj K. Singh[6] Purva Mathur[7]

[1]Department of Neuroanesthesia and Neurocritical Care, Akash Superspeciality Hospital, New Delhi, India
[2]Department of Neuroanaesthesiology and Critical Care, Jai Prakash Narayan Apex Trauma Centre, All India Institute of Medical Sciences, New Delhi, Delhi, India
[3]Jai Prakash Narayan Apex Trauma Centre, All India Institute of Medical Sciences, New Delhi, India
[4]Consultant, Neuroanaesthesia and Neurocritical Care, AIG Hospitals, Hyderabad, Telangana, India
[5]Department of Neuroanaesthesiology and Critical Care, Jai Prakash Narayan Apex Trauma Centre, All India Institute of Medical Sciences, New Delhi, Delhi, India
[6]Department of Neurosurgery, All India Institute of Medical Sciences, New Delhi, India
[7]Lab Medicine, Jai Prakash Naraian Apex Trauma Centre, All India Institute of Medical Sciences, New Delhi, India

Address for correspondence Ashish Bindra, DM, Department of Neuroanaesthesiology and Critical Care, Room No. 118, Jai Prakash Narayan Apex Trauma Centre, All India Institute of Medical Sciences, Ansari Nagar, New Delhi110029, India (e-mail: dr_ashi2208@yahoo.com).

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Abstract

Background Pediatric traumatic brain injury (TBI) has distinctive pathophysiology and characteristics that differ from adults. These can be attributed to age-related anatomical and physiological differences and distinct patterns of injuries seen in children. Our aim was to identify the patient characteristics, clinical variables during intensive care and intraoperative management associated with poor functional outcome in a cohort of pediatric TBI patients.

Methods Retrospective chart review of pediatric TBI patients admitted to neurotrauma intensive care unit (NICU) over a period of 1 year.

Results A total of 105 children (< 12 years) with head injury were admitted in the NICU during the study period. The most common mechanism of injury was fall in 78% cases. Fifty-four patients (51.4%) presented with a severe head injury (Glasgow coma scale [GCS] ≤ 8), while 31 (29.5%) and 20 (19.1%) had a mild and moderate head injury. The most common finding was skull fractures (59%), contusions (36.2%), and subdural hematoma (SDH) (30.4%). Forty nine patients (46.7%) required surgical management. The median duration of anesthesia was 205 (interquartile range [IQR] 65, 375) minutes, and median blood loss during the surgery was 16.7 mL/kg body weight with 41% requiring intraoperative blood transfusions. Median duration of ICU and

Keywords
- Glasgow outcome score
- intensive care unit
- pediatric
- traumatic brain injury

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hospital stay was 5 (IQR 1, 47) and 8 (IQR 1, 123) days, respectively. GOS at discharge ≤ 3 representing poor outcome was present in 35 patients (33.3%). Mortality was seen in 15 (14.3%) patients. Multivariate analysis identified postresuscitation GCS ≤ 8 on admission as independent predictor of mortality, and postresuscitation GCS ≤ 8 on admission and NICU stay of > 7 days as independent predictor of poor outcome.

Conclusion Despite advances in neurointensive care, mortality and morbidity remains high in pediatric head trauma and is mainly dependent on postresuscitation GCS and NICU stay of more than 7 days. Multidimensional approach is required for its prevention and management.

Introduction

Traumatic brain injury (TBI) is defined as an alteration in brain function, or other evidence of brain pathology, caused by an external force.[1] It is a major health concern worldwide across socioeconomic and demographic barriers. It is multifarious in etiology and mechanism with varying outcomes. Head injury in children can cause long-term sequelae, ranging from physical disability to hampering emotional and mental growth and cognitive impairment. In developing nations having medical and financial resources limitations, it causes a big burden on the individual as well as nation. In 2013, a total of approximately 2.8 million TBI-related emergency department (ED) visits, hospitalizations, and deaths (TBI-EDHDs) occurred in the United States. The highest rates of TBI-EDHDs were among the oldest or youngest age groups. The most common principal mechanisms of injury for TBI-EDHDs were falls, being struck by or against an object, and road traffic accidents (RTA). Approximately half of all fall-related TBI-EDHDs occurred among those aged 0 to 4 years and ≥ 75 years.[2] Pediatric TBI has distinctive pathophysiology and characteristics that differ from adults. These can be attributed to age-related anatomical and physiological differences and distinct patterns of injuries seen in children.

The aim of the present study was to collect demographic, admission, neurocritical care and intraoperative variables and its impact on the care of the children with head injury. Prognostic factors associated with poor functional outcome and mortality in a cohort of pediatric TBI patients were identified.

Methods

After approval of the Institute Ethics Committee, this retrospective study was conducted in the neurotrauma intensive care unit (NICU) at Jai Prakash Narayan Apex Trauma Center (JPNATC), All India Institute of Medical Sciences (AIIMS), New Delhi, India. Medical records over a period of 1 year (May 2016–April 2017) were reviewed and included children with head injury under 12 years of age admitted to the NICU. The following data was collected: age, sex, height, weight, time from injury to admission in NICU, mechanism of injury, NICU admission vitals including pulse rate, respiratory rate, blood pressure and oxygen saturation, postresuscitation Glasgow coma scale (GCS), associated injuries, radiological findings, cranial/extracranial surgery, amount of intraoperative blood loss and blood transfusion, duration of anesthesia, ICU stay and hospital stay, and Glasgow outcome scale (GOS) at discharge. GOS ≤ 3 was taken as a poor outcome.

Compiled data was collated and analyzed using Stata Statistical Software: Release 13 College Station, TX: StataCorp LP. Descriptive values were expressed as frequencies for dichotomous variables and as mean ± standard deviation (SD) or median (minimum-maximum value) for continuous variables. Univariate analysis was done using Chi-square test or Fisher exact test to identify variables associated with mortality and poor outcome. Then, multivariate logistic regression was utilized to identify factors associated with mortality and poor outcome independently, and odds ratio was also calculated. *p* value less than 0.05 was considered significant.

Results

A total of 105 children with head injury were admitted in the NICU during the period from May 2016 to April 2017. Basic demographic data are given in ►**Table 1**. Mechanisms of injury are described in ►**Table 2**, with the most common mechanism being fall in 78% and RTA in 15.4% of the patients, with pedestrians being involved in 8.6% cases. Fifty-four patients (51.4%) presented with a severe head injury (GCS ≤ 8)

Table 1 Basic demographic data

Variable	Mean (SD)/median (range)/ratio
Age	4 years (14 days to 12 years)
Male to female ratio	1.33
Age group 0–4 years (male/female ratio)	0.94
Age group 4–12 years (male/female ratio)	2.4
Height (cm)	98.6 (22.2)
Weight (kg)	15.5 (7.2)
Time from injury to admission in ICU	3.75 hours (0.5 to 55 hours)

Abbreviation: SD, standard deviation.

Table 2 Mechanism of injury

Mechanism of injury	0–4 years	4–12 years	Frequency	%
RTA pedestrian	3	6	9	8.6
RTA cyclist	1	0	1	1.0
RTA motorcyclist	2	1	3	2.9
RTA other vehicle occupant	0	3	3	2.9
Fall	54	28	82	78
Others[a]	2	5	7	6.6
Total	62 (59%)	43 (41%)	105	100

Abbreviation: RTA, road traffic accident.
[a]Others—assault blunt instrument, fall of object on head, other violence, and unknown cause.

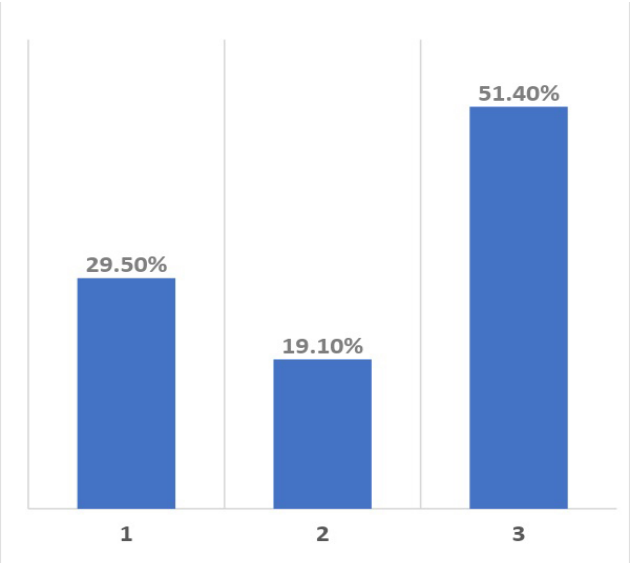

Fig. 1 Postresuscitation Glasgow coma scale (GCS) in the patients. 1: Mild head injury. 2: Moderate head injury. 3: Severe head injury.

while 31 (29.5%) and 20 (19.1%) had a mild and moderate head injury (GCS 13–15 and GCS 9–12), respectively, with a median postresuscitation GCS of 7 (range 3–15) (►**Fig. 1**).

Radiological diagnosis based on CT scan of the head was undertaken in all the patients and is described in ►**Table 3**. The most common finding was skull fractures in 59% of the patients, with contusions being present in 36.2% and subdural hematoma (SDH) in 30.4% of the patients. Only five children had associated extracranial injuries, in which one patient had an odontoid process fracture with no canal compromise, second had a hemopneumothorax, another one had a grade I splenic injury, while two patients had fractures of the shaft of the femur.

Patient's vital parameters (mean ± SD) on presentation in the NICU were found to be a respiratory rate of 20 ± 3 breaths per minute, pulse rate of 114 ± 29 beats per minute, systolic blood pressure of 111 ± 18 mm Hg, diastolic blood pressure of 71 ± 13 mm Hg, and oxygen saturation of 97 ± 3%. In all the patients, crystalloids were used as the fluid for resuscitation. Of the 10 patients requiring vasopressors, noradrenaline was used in six, and dopamine was used in four patients. Mechanical ventilation was instituted in 65.7% of the patients in the NICU with a median duration of respiratory support for 5.5 (Interquartile range [IQR] 1, 50) days, and 23 of those patients were tracheostomized during the hospital stay. None of the patients developed ventilator-associated pneumonia. Maintenance of sedation and analgesia was achieved using a combination of fentanyl and midazolam infusion in the majority of the patients (91.4%). However, dexmedetomidine was also used as a sedative/analgesic therapy in nine patients.

Various neurosurgical interventions were undertaken in the management of these patients. Forty-five patients (42.9%) required craniectomy/craniotomy ± evacuation of clot and four patients underwent surgery for elevation of depressed fracture. Intracranial pressure (ICP) monitoring in the NICU was undertaken in 37 patients (35.2%) and an external ventricular drain was inserted in three patients (2.9%) for both measurement and management of raised ICP. Protocol based on pediatric traumatic head injury guidelines was undertaken in the NICU management of these patients. In patients undergoing surgery, the median duration of anesthesia was 205 (IQR 65, 375) minutes, and median blood loss during the surgery was 16.7 mL/kg body weight with 41% requiring intraoperative blood transfusions. General anesthesia with sevoflurane and air was the preferred choice of anesthesia, and total intravenous anesthesia was used in only five patients.

The patients who had extracranial injuries had undergone intervention/surgeries, which included hip Spica application in one and an external fixator application and fasciotomy in another for fracture shaft of the femur, intercostal drain insertion for hemopneumothorax, and C1-C2 cervical spine fixation was done in patient with fracture of the odontoid process. A 6-month-old child was diagnosed with spinal cord injury without radiological abnormality (SCIWORA) 3 days after the history of fall from bed. The CT scan of head and cervical spine showed no abnormality, but there were no upper and lower limb movements in the child. MRI was done which showed cord edema at C4 level.

Median duration of ICU and hospital stay was 5 (IQR 1, 47) and 8 (IQR 1, 123) days, respectively. Fifteen patients died prior to discharge in NICU (14.3%). Patients who expired had a median age of 2 years, with 60% of them being females, and their postresuscitation median GCS was 5 with 93.3% having severe head injury. Skull fractures followed by SDH were the two most common radiological findings present in 60% and 53.3% of these patients, respectively. Median hospital stay was 5 (IQR 1, 22) days.

Table 3 Radiological findings on CT scan

CT scan finding	Frequency	%
No abnormality	5	4.8
Skull fracture	62	59.0
Contusion	38	36.2
Subarachnoid / Intraventricular hemorrhage	10	9.5
Intracerebral hemorrhage	10	9.5
Extradural hematoma	20	19.0
Subdural hematoma	32	30.4
Diffuse axonal injury	2	1.9
Pneumocephalus	7	6.7
Hypoxic damage/infarct	8	7.6
Midline shift/mass effect	15	14.3
Diffuse edema	7	6.7

Variables associated with mortality on univariate analysis are shown in ►**Table 4** and variables associated with poor outcome on univariate analysis are shown in ►**Table 5**. Multivariate analysis identified postresuscitation GCS ≤ 8 on admission as independent predictors of mortality with a *p* value < 0.05 (►**Table 6**). GOS at discharge ≤ 3 representing poor outcome was present in 35 patients (33.3%) and a favorable outcome was present in 55 patients (52.4%). Multivariate analysis identified postresuscitation GCS ≤ 8 on admission and NICU stay of > 7 days as independent factors predicting poor outcome with a *p* value < 0.05 (►**Table 6**).

Discussion

TBI is among the common causes of mortality and disability in the pediatric age group worldwide. It is a rising major health problem across boundaries and socioeconomic status. Mechanisms of TBI often have age-dependent association, with falls being common in the pediatric age group.

The median age in our study was found to be 4 years, with 59% of the children with TBI falling under 4 years of age with a female predominance. Above that age, there was a male predominance. In the US, highest rates of TBI-EDHD were observed among those aged ≥ 75 years, followed by 0 to 4 years, with an overall male to female to ratio of 1.18.[2] However, increased number of girls injured under the age of 4 years in our study may be related to reduced care and supervision given to female child.

Median time from injury to admission was 3.75 hours in our hospital, with seven patients (6.7%) reaching after 24 hours from time to injury. Variable time to admission ranging from 1 hour to 24 hours has been reported, depending upon prehospital services, transportation system and referral system present.[3,4] Reduction in prehospital time is important for improving outcomes. However, we did not find a correlation between time to admission and outcome in our study.

Fall was the most common mechanism of injury in 78.1% of the patients, followed by pedestrians involved in RTA. Developing nations experienced lower rates of RTA-related TBI, and injured children were more commonly pedestrians.[5] More than 50% of TBI in children was accounted for by falls in studies from developed as well as developing countries.[2,6,7,8,9,10]

Improved parental supervision, and road and home safety measures can decrease the incidence of this trauma.

Severe TBI accounted for 51.4% of the children in our study. However, majority of the studies show more than 80% children have mild TBI in severity, except few studies which show > 40% patients presented with severe TBI.[11-16]We included only the patients admitted in the ICU, excluding those who might have been shifted to the wards or discharged from ED, which could be the reason for higher number of patients with severe TBI in this study.

There were multiple intracranial pathologies per child. The most common radiological finding was skull fracture in 59% of the patients, followed by contusions and SDH as 36.2% and 30.4%, respectively. Only 4.8% had a normal scan in our study out of the 31 children with mild TBI as compared with (58%– 92%) in studies that included mostly mild TBI.[17,18,19] Studies have reported that patients with abnormal CT scan most commonly had skull fractures (19%–45%) and contusions (15% to 61%).[3,8,15,17,19] Skull bones of the children are thin and pliable, making them prone to be fractured by less blunt forces as compared with adults.

Majority of pediatric TBI are managed nonoperatively as they are commonly mild TBI. Our study had a high-operative rate due to the increased number of patients with severe TBI, which required NICU admission and intervention. Similarly, reports which had higher severe head injury had an increased rate of surgeries (21%–63%).[15,20] Among interventions, craniotomy/craniectomy, with or without evacuation of clot was undertaken in 45 patients, (42.9%) and ICP monitoring, in 37 patients (35.2%), were the most common, followed by placement of external ventricular drain (EVD) and elevation of depressed fracture in 2.9% and 3.8%, respectively. Previous studies found the most common interventions to be craniotomy/craniectomy for hematoma evacuation (37%–48%), placement of EVD (19%–47%), followed by fracture elevation (13%–23%).[11,17,20]

The overall mortality in our study was found to be 14.3%. It is on the higher end of the spectrum, with many studies reporting only up to 1%–7%.[8,21,22,23] However, mortality more than 10% was reported in populations of Sweden, Spain, UK, and South Africa.[12,16,24,25] It would depend on multiple factors, including the severity of the injury, time to emergency response and level of care and infrastructure available. Mortality is higher in our study, because severe head injury at admission constituted maximum number of cases.

From our study, factors independently associated with mortality on multivariate analysis were postresuscitation GCS ≤ 8, whereas post resuscitation GCS ≤ 8 on admission and NICU stay of >7 days were independent factors predicting poor outcome. Various studies have identified low GCS as a risk factor for death and poor outcome.[4,26,27,28,29,30] Monitoring closely and early interventions may be justified in children with head injury with low GCS scores. Young age and diffuse

Table 4 Characteristics and univariate analysis of variables associated with mortality

Variable		Expired *n* = 15 (14.3%)	Alive *n* = 90 (85.7%)	*p*-Value
Age	< 4 years	13 (12.4%)	49 (46.6%)	0.02
	4–12 years	2 (2.0%)	41 (39.0%)	
Sex	Male	6 (5.7%)	54 (51.4%)	0.15
	Female	9 (8.6%)	36 (34.3%)	
Time to admission [a](*n* = 98)	0–4 hours	10 (9.5%)	44 (42.0%)	0.6
	4–12 hours	4 (3.8%)	29 (27.6%)	
	> 12 hours	1 (0.9%)	10 (9.5%)	
Postresuscitation GCS on admission	< 8	14 (13.3%)	40 (38.0%)	< 0.001
	9–15	1 (0.9%)	50 (47.6%)	
CT scan findings	Skull fracture	9 (8.6%)	53 (50.5%)	0.93
	Contusion	5 (4.7%)	33 (31.4%)	0.80
	SAH/IVH	2 (2.0%)	8 (7.6%)	0.63
	ICH	1 (0.9%)	9 (8.6%)	1
	EDH	2 (2.0%)	18 (17.1%)	0.73
	SDH	8 (7.6%)	24 (23.0%)	0.04
	Pneumocephalus	1 (0.9%)	6 (5.7%)	1
	Hypoxic damage/infarct	2(2.0%)	6 (5.7%)	0.32
	Diffuse edema	4 (3.8%)	3 (2.8%)	0.008
	Midline shift/mass effect	3 (2.8%)	12 (11.4%)	0.44
ICP monitoring		5 (4.7%)	32 (30.4%)	0.86
Surgery: a. Craniotomy/craniectomy +/- hematoma evacuation b. Elevation of depressed fracture		7 (6.6%) 1 (1.0%)	38 (36.1%) 03 (2.8%)	0.74
Duration of anesthesia	< 180 minute	6 (5.7%)	27 (25.7%)	1.0
	> 180 minute	2 (2.0%)	14 (13.3%)	
Blood loss	< 15ml/kg	3 (2.8%)	21 (20.0%)	0.14
	15–30 ml/kg	3 (2.8%)	18 (17.1%)	
	> 30 mL/kg	2 (2.0%)	2 (2.0%)	
Blood transfusion	Yes	8 (7.6%)	35 (33.3%)	0.29
	No	7 (6.6%)	55 (52.3%)	
Duration of NICU stay	< 7 days	12 (11.4%)	52 (49.5%)	0.15
	> 7 days	3 (2.8%)	38 (36.1%)	

Abbreviations: EDH, extradural hematoma; GCS, Glasgow coma scale; ICH, intracerebral hemorrhage; ICP, intracranial pressure; IVH, intraventricular hemorrhage; NICU, neurotrauma intensive care unit; SAH, subarachnoid hemorrhage; SDH, subdural hematoma.
[a]Date available for 98 patients.

edema on CT in our study were identified as other factors in multivariate analysis but were not found to be statistically significant. Age and mortality have a controversial effect. Some studies reported age and outcome to be related, whereas some studies found survival was independent of age.[26,27,30-32] Diffuse brain edema is also a common factor associated with mortality and poor outcome.[26,28,29] Prolonged NICU stay may be attributed to the severity of injury and patients requiring neurosurgical interventions.

Limitations of our study are that it is a single-center retrospective study with a small sample size. GOS at discharge was noted and patients were not followed-up at after the discharge due to the retrospective nature of the study. Neurobehavioral and psychosomatic changes and symptoms which might occur during the course could have identified at long-term follow-up. We did not study the postresuscitation pupil size and reactivity, which could have been more informative.

Table 5 Characteristics and univariate analysis of variables associated with poor outcome (GOS ≤ 3)

Variable		GOS ≤ 3 *n* = 35 (33.3%)	GOS 4–5 *n* = 55 (52.4%)	*p*-Value
Age	< 4 years	16 (15.2%)	33 (31.4%)	0.18
	4–12 years	19 (18.1%)	22 (21.0%)	
Sex	Male	19 (18.1%)	35 (33.3%)	0.38
	Female	16 (15.2%)	20 (19.0%)	
Mechanism of injury	Fall	22 (21.0%)	48 (45.7%)	0.02
	RTA	8 (7.6%)	5 (4.8%)	
	Others	5 (4.8%)	2 (1.9%)	
Time to admission[a]	0–4 hours	4 (3.8%)	8 (7.6%)	0.86
	4–12 hours	20 (19.0%)	31 (29.5%)	
	> 12 hours	9 (8.6%)	12 (11.4%)	
Post resuscitation GCS on admission	< 8	28 (26.6%)	18 (17.1%)	<0.001
	9–15	7 (6.7%)	37 (35.2%)	
CT scan findings	Skull fracture	20 (19.0%)	33 (31.4%)	0.79
	Contusion	15 (14.3%)	18 (17.1%)	0.33
	SAH/IVH	4 (3.8%)	4 (3.8%)	0.70
	ICH	6 (5.7%)	3 (2.9%)	0.08
	EDH	3 (2.9%)	15 (14.3%)	0.03
	SDH	7 (6.7%)	17 (16.2%)	0.25
	Pneumocephalus	1 (1.0%)	5 (4.8%)	0.39
	Hypoxic damage/ infarct	3 (3.0%)	3 (3.0%)	0.67
	Diffuse edema	2 (2.0%)	1(0.9%)	0.55
	Midline shift/ mass effect	7 (7.0%)	5(4.7%)	0.14
ICP monitoring		19 (18.0%)	13 (12.4%)	0.003
Surgery: a. Craniotomy/craniectomy +/- hematoma evacuation b. Elevation of depressed fracture		15 (14.0%) 0 (0.0%)	23 (21.9%) 03 (2.9%)	0.92
Duration of anesthesia	< 180 minute	3 (3.0%)	11 (10.5%)	
	> 180 minute	12(11.0%)	15 (14.3%)	0.18
Blood transfusion	Yes	13 (12.0%)	22 (21.0%)	0.78
	No	22(21.0%)	33 (31.4%)	
Duration of NICU stay	< 7 days	8 (8.2%)	44 (41.9%)	< 0.001
	> 7 days	27 (26.2%)	11 (10.5%)	
Duration of hospital stay	< 30 days	31 (30%)	54 (51.4%)	0.07
	> 30 days	4 (4%)	1 (0.9%)	

Abbreviations: EDH, extradural hematoma; GCS, Glasgow coma scale; GOS, Glasgow outcome scale; ICH, intracerebral hemorrhage; ICP, intracranial pressure; IVH, intraventricular hemorrhage; NICU, neurotrauma intensive care unit; RTA, road traffic accident; SAH, subarachnoid hemorrhage; SDH, subdural hematoma.
[a]Date available for 84 patients.

Conclusion

TBI was commonly seen in children less than 4 years of age with female dominance. Males suffered more than females at an older age. Majority of the pediatric TBI were due to falls, with RTA slowly growing. A factor independently associated with mortality was postresuscitation GCS ≤ 8. Poor outcome (GOS ≤ 3) was independently associated with postresuscitation GCS ≤ 8 and NICU stay > 7 days. Despite advances in neurointensive care, mortality and morbidity remains high in pediatric head trauma patients who present with lower GCS.

Table 6 Independent and significant factors predicting mortality and poor outcome in multivariate analysis

	OR	95% CI	*p*-Value
Predictive factors for mortality (*n* = 15)			
Age[a]	5.03	1.3 - 31.9	0.072
Postresuscitation GCS[b]	24.9	2.41 – 257.32	0.007
Diffuse edema on CT	6.46	0.82 – 50.72	0.076
Predictive factors for poor outcome GOS ≤ 3 (*n* = 35)			
Post resuscitation GCS[b]	3.51	1.06 – 11.52	0.038
Duration of NICU stay[c]	8.83	2.82 – 27.58	< 0.001

Abbreviations: CI, confidence interval; GCS, Glasgow coma scale; GOS, Glasgow outcome scale; NICU, neurotrauma intensive care unit; OR, odds ratio.
[a]Age < 4 years vs. 4–12 years.
[b]Postresuscitation GCS ≤8 vs. 9–15.
[c]Duration of stay NICU stay < 7 days vs. > 7 days.

Pediatric TBI needs to be recognized as global health issue, warranting shifts in research and clinical practice to improve care for TBI patients.

Conflict of Interest
None declared.

References

1 Menon DK, Schwab K, Wright DW, Maas AI; Demographics and Clinical Assessment Working Group of the International and Interagency Initiative toward Common Data Elements for Research on Traumatic Brain Injury and Psychological Health. Position statement: definition of traumatic brain injury. Arch Phys Med Rehabil 2010;91(11):1637–1640
2 Taylor CA, Bell JM, Breiding MJ, Xu L. Traumatic brain injury-related emergency department visits, hospitalizations, and deaths - United States, 2007 and 2013. MMWR Surveill Summ 2017;66(9):1–16
3 Hill CS, McLean AL, Wilson MH. Epidemiology of pediatric traumatic brain injury in a dense urban area served by a helicopter trauma service. Pediatr Emerg Care 2018;34(6):426–430
4 Shekhar C, Gupta LN, Premsagar IC, Sinha M, Kishore J. An epidemiological study of traumatic brain injury cases in a trauma centre of New Delhi (India. J Emerg Trauma Shock 2015;8(3):131–139
5 Dewan MC, Mummareddy N, Wellons JC, III, Bonfield CM. Epidemiology of Global Pediatric Traumatic Brain Injury: Qualitative Review. World Neurosurg 2016;91:497–509
6 Shao J, Zhu H, Yao H, et al. Characteristics and trends of pediatric traumatic brain injuries treated at a large pediatric medical center in China, 2002-2011. PLoS One 2012;7(12):e51634
7 Tabish A, Lone NA, Afzal WM, Salam A. The incidence and severity of injury in children hospitalised for traumatic brain injury in Kashmir. Injury 2006;37(5):410–415
8 Agrawal A, Agrawal CS, Kumar A, et al. Epidemiology and management of paediatric head injury in eastern Nepal. Afr J Paediatr Surg 2008;5(1):15–18
9 Işık HS, Gökyar A, Yıldız O, Bostancı U, Ozdemir C. [Pediatric head injuries, retrospective analysis of 851 patients: an epidemiological study]. Ulus Travma Acil Cerrahi Derg 2011;17(2):166–172
10 Barton BK, Schwebel DC. The roles of age, gender, inhibitory control, and parental supervision in children's pedestrian safety. J Pediatr Psychol 2007;32(5):517–526
11 Amaranath JE, Ramanan M, Reagh J, et al. Epidemiology of traumatic head injury from a major paediatric trauma centre in New South Wales, Australia. ANZ J Surg 2014;84(6):424–428
12 Ferreros I, Peiro S, Chirivella-Garrido J, et al. [Incidence of hospitalization for traumatic brain injury in children and adolescents (Valencia Community, Spain, 2002-2009)]. Rev Neurol 2012;54(12):719–728
13 Trefan L, Houston R, Pearson G, et al. Epidemiology of children with head injury: a national overview. Arch Dis Child 2016;101(6):527–532
14 Kim HB, Kim DK, Kwak YH, et al. Epidemiology of traumatic head injury in Korean children. J Korean Med Sci 2012;27(4):437–442
15 Udoh DO, Adeyemo AA. Traumatic brain injuries in children: a hospital-based study in Nigeria. Afr J Paediatr Surg 2013;10(2):154–159
16 Emanuelson I, v Wendt L. Epidemiology of traumatic brain injury in children and adolescents in south-western Sweden. Acta Paediatr 1997;86(7):730–735
17 Crowe L, Babl F, Anderson V, Catroppa C. The epidemiology of paediatric head injuries: data from a referral centre in Victoria, Australia. J Paediatr Child Health 2009;45(6):346–350
18 Chan HC, Aasim WA, Abdullah NM, et al. Characteristics and clinical predictors of minor head injury in children presenting to two Malaysian accident and emergency departments. Singapore Med J 2005;46(5):219–223
19 Zhu H, Gao Q, Xia X, Xiang J, Yao H, Shao J. Clinically-important brain injury and CT findings in pediatric mild traumatic brain injuries: a prospective study in a Chinese reference hospital. Int J Environ Res Public Health 2014;11(4):3493–3506
20 Mitra B, Cameron PA, Butt W, Rosenfeld JV. Children or young adults? A population-based study on adolescent head injury. ANZ J Surg 2006;76(5):343–350
21 Robertson BD, McConnel CE, Green S. Charges associated with pediatric head injuries: a five year retrospective review of 41 pediatric hospitals in the US. J Inj Violence Res 2013;5(1):51–60
22 Greene NH, Kernic MA, Vavilala MS, Rivara FP. Variation in pediatric traumatic brain injury outcomes in the United States. Arch Phys Med Rehabil 2014;95(6):1148–1155
23 Tsai W-C, Chiu W-T, Chiou H-Y, Choy C-S, Hung C-C, Tsai S-H. Pediatric traumatic brain injuries in Taiwan: an 8-year study. J Clin Neurosci 2004;11(2):126–129
24 Bayreuther J, Wagener S, Woodford M, et al. Paediatric trauma: injury pattern and mortality in the UK. Arch Dis Child Educ Pract Ed 2009;94(2):37–41
25 Schrieff LE, Thomas KGF, Dollman AK, Rohlwink UK, Figaji AA. Demographic profile of severe traumatic brain injury admissions to Red Cross War Memorial Children's Hospital, 2006 - 2011. S Afr Med J 2013;103(9):616–620

26 Feickert HJ, Drommer S, Heyer R. Severe head injury in children: impact of risk factors on outcome. J Trauma 1999;47(1):33–38
27 Ducrocq SC, Meyer PG, Orliaguet GA, et al. Epidemiology and early predictive factors of mortality and outcome in children with traumatic severe brain injury: experience of a French pediatric trauma center. Pediatr Crit Care Med 2006;7(5):461–467
28 Chung CY, Chen CL, Cheng PT, See LC, Tang SF, Wong AM. Critical score of Glasgow Coma Scale for pediatric traumatic brain injury. Pediatr Neurol 2006;34(5):379–387
29 White, JR, Farukhi, Z, Bull, C, et al. Predictors of outcome in severely head-injured children. Crit Care Med 2001;29:534–540
30 Shein, SL, Bell, MJ, Kochanek, PM, et al. Risk factors for mortality in children with abusive head trauma. J Pediatr 2012;161:716, –7 –22
31 Slovis JC, Gupta N, Li NY, Kernie SG, Miles DK. Assessment of Recovery Following Pediatric Traumatic Brain Injury. Pediatr Crit Care Med 2018;19(4):353–360
32 Nakayama DK, Copes WS, Sacco WJ. The effect of patient age upon survival in pediatric trauma. J Trauma 1991;31(11):1521–1526

