Epidemiology of Neurotrauma in Pediatric Intensive Care Unit: A Single-center Experience of 10 Years

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Abstract

Background: Traumatic brain injury (TBI) in children can lead to grave consequences. The mechanism, mode, and management of pediatric neurotrauma are different from adult neurotrauma, and there is a growing demand to study the clinicoepidemiology of pediatric TBI.

Objective: To explore the clinicoepidemiological profile and outcome of pediatric neurotrauma.

Methods: This single-center retrospective study was conducted at a tertiary referral hospital in the PICU involving children (1 month to 18 years) sustaining TBI (2012–2022). Demographic, clinical, and laboratory details at the onset of admission were collected. Predictors of mortality were compared between survivors and non-survivors.

Results: Demographic, clinical, and laboratory data of 316 children with traumatic brain injuries at admission were collected and analyzed. The median (IQR) age was 72 months (36–132 months), with 68% of the cohort being male. The majority of the study population (49.1%) was under the age of 5 years. Injury from a fall was the most frequent mechanism of injury (53.5%), followed by road traffic accidents (5%). More than half of the study population suffered mild-TBI (55%). The overall mortality was 8.9% (28/316), and it was highest in the severe TBI group (31.6%) and under-5 years population (42.9%). Lower pediatric trauma score (PTS) (AOR: 0.52; 95% CI: 0.34–0.82) and polytrauma were significantly associated with mortality (AOR: 4.61; 95% CI: 1.02–20.86).

Conclusion: Traumatic brain injury is a significant concern in the pediatric population, particularly those under the age of 5 years. Lower PTS and polytrauma predicted poor outcome.

Keywords: Epidemiology, Pediatric traumatic brain injury, Outcome.

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Highlights

- Falls from height and road traffic accidents were the leading causes of traumatic brain injury (TBI) in children.
- Lower pediatric trauma score (PTS) and polytrauma in children suffering head injury increase the risk of death.
- Pediatric trauma score <5 predicted mortality with sensitivity and specificity of 82.14 and 89.93%, respectively.

Introduction

Traumatic brain injury is a major cause of acquired brain injury leading to mortality and morbidity in children and adolescents. Pediatric neurotrauma presents distinct challenges compared to adult neurotrauma due to differences in physiology and anatomy in developmental stages. Children are more prone to suffer grave consequences due to their anatomical features, such as weak neck musculature and large heads.[1]

Falls from height, followed by road traffic accidents (RTAs), are the leading causes of TBI in infants and children, unlike adults, who are likely to suffer neurotrauma due to high-impact RTAs.[2,3] There have been increased incidences of RTAs in the pediatric population, particularly in the adolescent age-group.[2] The Indian Ministry of Road Transport and Highways, in its yearly publication, "Road Accidents in India 2022," notified that the total number of males and females killed in accidents was 1,45,177 (86.2%) and 23,314 (13.8%), respectively, and children (<18 years) accounted for 6% (9,528) of the total deaths. The outcome depends on the severity, extent, and distribution of the injury and the age at which the injury has occurred. Data on pediatric TBI from the Indian subcontinent are limited. Understanding the clinicoepidemiology of pediatric TBI is crucial for developing preventive and treatment protocols. Hence, we undertook this study to explore the clinicoepidemiological profile and determine the prognostic factors in children with TBI.

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Methods

This single-center retrospective study was conducted at an urban tertiary referral hospital with a 12-bed PICU over a period of 10 years (2012–2022). The institutional review board approved this study (IEC number: 79/2020) with a waiver of informed consent. We included and extracted data of children (1 month to

18 years) with TBI from medical sections and electronic records. Demography, clinical details at admission, mode of injury, and severity of TBI were recorded. In addition, PTS, neuroimaging details, treatment, length of PICU and hospital stay, and outcome were captured.

The Glasgow Coma Scale was used to classify the severity of TBI (≤8 being severe, 9–12 as moderate, and ≥13 as mild).[4] Cranial CT was performed in children with any one of the features: severe TBI, GCS<13, loss of consciousness, vomiting, seizure, or focal neurological deficits. Raised intracranial pressure was managed as per standard guidelines.[5] Functional outcome of children with TBI at discharge was recorded using the Glasgow outcome scale (GOS).[6] (GOS-5 = good recovery, GOS-4 = moderate disability, GOS-3 = severe disability, GOS-2 = persistent vegetative state, and GOS-1 = death).

Statistical Methods

Data were analyzed using STATA software StataCorp. 2019. Stata Statistical Software: Release 16. College Station, TX: StataCorp LLC. All categorical data were presented using frequency and percentages; all continuous data were described using mean and standard deviation or median (IQR). A chi-square test or Fisher's exact test was applied for the categorical observations based on the expected frequency; a one-way ANOVA or Kruskal–Wallis test was applied based on the distribution. An independent sample *t*-test or Mann–Whitney *U* test was applied for continuous measurements after checking the normality assumption. Penalized Logistic regression analysis was carried out to assess the factors associated with mortality. A Kaplan–Meier estimate of the cumulative probability of survival to day 30 was performed. A log-rank test was conducted to evaluate the difference in average survival time across different severities of TBI. *p*-value was considered significant at the 5% level of significance for all comparisons.

Results

During the study period (2012–2022), a total of 380 children sustaining trauma were admitted to PICU. Out of 380 children, data of 316 children with TBI were analyzed (Fig. 1). The median (IQR) age of the study population was 72 months (36–132), with predominantly male participants (68%). Nearly half of the population was less than 5 years of age. The most common mode of injury observed in the study was injury by falls (53.5%), followed by RTAs (44%) and others (2.5%). The most common mechanism of injury in the under-5 years age-group was trauma due to fall (73.5%), whereas in the adolescent group, RTA was common (65.5%) (Fig. 1). Only 14.9% (47/316) of children were presented within 6 hours of trauma. Demographics, clinical characteristics, and outcomes are shown in Table 1.

More than half of the study population suffered mild TBI (55%), followed by severe TBI (25%) and moderate TBI (20%). In the cohort, 27.8% (88/316) of the children were found to be hypotensive at admission, and the prevalence of hypotension was higher in the severe TBI group, 50% (44/88) ($p < 0.001$). Trauma-induced coagulopathy was noticed in 11% of the population, and it was more common in the severe TBI group, 27.8% (22/79) ($p < 0.001$). Similarly, intracranial bleed was more common in the severe TBI group ($p < 0.001$). Post-traumatic seizures PTS were observed in 18% of the children and significantly higher in the severe group.

Traumatic spinal injury was observed in three patients. The most common type of intracranial bleed observed on CT imaging

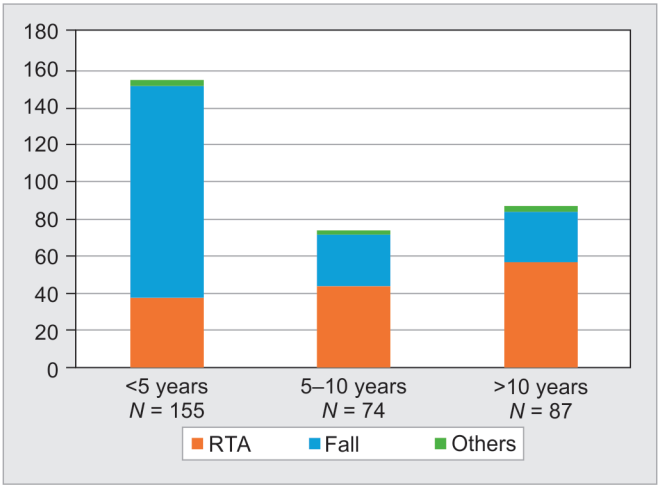

Fig.1: Mechanism of injury in different age-groups

Table 1: Comparison of demography, clinical characteristics, and outcome in children with TBI based on severity

Variables	*Total (316)*	*Mild TBI (n = 174)*	*Moderate TBI (n = 63)*	*Severe TBI (n = 79)*	*p-value*
Age (in months) median IQR	72.0 (36.0–132.0)	72.0 (24.0–132.0)	72.0 (36.0–132.0)	48.0 (36.0–108.0)	0.44
<5 years	155 (49.1%)	82 (47.1%)	28 (44.4%)	45 (57.0%)	0.51
5–10 years	74 (23.4%)	40 (23.0%)	17 (27.0%)	17 (21.5%)	
>10 years	87 (27.5%)	52 (29.9%)	18 (28.6%)	17 (21.5%)	
Gender					
Male	216 (68.4%)	125 (71.8%)	43 (68.3%)	48 (60.8%)	0.21
Mode of injury					
RTA	139 (44.0%)	72 (41.4%)	35 (55.6%)	32 (40.5%)	0.32
Fall	169 (53.5%)	97 (55.7%)	26 (41.3%)	46 (58.2%)	
Miscellaneous	8 (2.5%)	5 (2.8%)	2 (3.2%)	1 (1.3%)	
Pediatric trauma score at admission (mean ± SD)	8.2 ± 2.7	9.4 ± 2.0	8.4 ± 1.8	5.3 ± 2.5	<0.001

(Contd...)

Table 1: *(Contd...)*

Variables	*Total (316)*	*Mild TBI (n = 174)*	*Moderate TBI (n = 63)*	*Severe TBI (n = 79)*	*p-value*
Hypotension at admission, *n* (%)	88 (27.8%)	33 (19.0%)	11 (17.5%)	44 (55.7%)	<0.001
Intracranial bleed, *n* (%)					
SAH	76 (24.1%)	26 (14.9%)	14 (22.2%)	36 (45.6%)	<0.001
SDH	82 (25.9%)	35 (20.1%)	13 (20.6%)	34 (43.0%)	<0.001
EDH	69 (21.8%)	22 (12.6%)	19 (30.2%)	28 (35.4%)	<0.001
Polytrauma	48 (15.2%)	26 (14.9%)	6 (9.5%)	16 (20.3%)	0.21
Trauma-induced coagulopathy, *n* (%)	36 (11.4%)	11 (6.3%)	3 (4.8%)	22 (27.8%)	<0.001
Post-traumatic seizures	57 (18.0%)	20 (11.5%)	15 (23.8%)	22 (27.8%)	0.003
Neurosurgical intervention					
Craniotomy/decompressive craniectomy, *n* (%)	18 (5.7%)	3 (1.7%)	3 (4.8%)	12 (15.2%)	<0.001
Duration of PICU stay, median IQR	3.0 (2.0–4.0)	3.0 (2.0–3.0)	3.0 (3.0–3.0)	4.0 (3.0–6.0)	<0.001
Duration of hospital stay, median IQR	5.0 (4.0–8.5)	4.0 (3.0–6.0)	6.0 (5.0–8.0)	8.0 (5.0–12.0)	<0.001
Mortality, *n* (%)	28 (8.9%)	1 (0.6%)	2 (3.2%)	25 (31.6%)	<0.001

EDH, extradural hemorrhage; RTA, road traffic accident; SAH, subarachnoid hemorrhage; SDH, subdural hemorrhage. *p*-value < 0.05 is significant

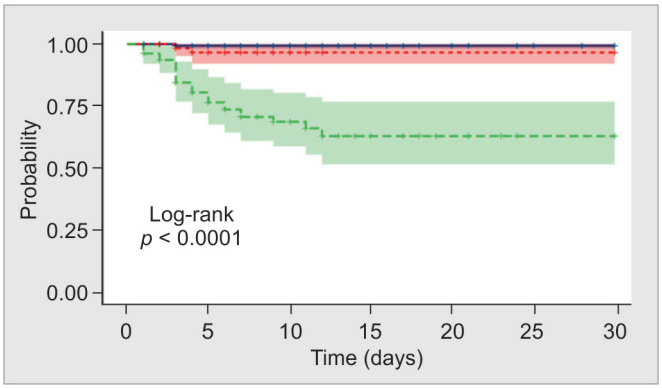

Fig. 2: Kaplan–Meier's estimate of survival according to severity of traumatic brain injury stratified as mild, moderate, and severe TBI

was subdural hemorrhage (26%), followed by subarachnoid hemorrhage (24%) and extradural hemorrhage (22%). Diffuse axonal injury was observed in 7.9% (25/316) of the cases. Forty-eight (15%) children with TBI suffered concomitant abdominal trauma. Mechanical ventilation was required in 25% of the total population. Neurosurgical intervention in the form of either craniotomy or decompressive craniectomy was performed in 18 patients (6%). The overall mortality rate in the study was 8.9% (28/316), and the highest mortality was observed in the severe TBI group (31.6%). A higher proportion of deaths was observed in the under-5 years group (42.9%). Overall, the mean survival of all patients was 26.4 days. A log-rank test was conducted to evaluate the difference in average survival time across different severities of TBI (Fig. 2). The severe TBI group had significantly fewer average survival days compared to the mild and moderate group ($p < 0.0001$). Among survivors, good recovery (GOS-5) was seen in 61.7% of children, predominantly in the mild-to-moderate TBI group.

Table 2: Comparison of demography, hemodynamic, and laboratory and other various characteristics between survivors and non-survivors

Variables	*Survivors (n = 288)*	*Non-survivors (n = 28)*	*p-value*
Age			0.77
<5 years	143 (49.7%)	12 (42.9%)	
5–10 years	67 (23.3%)	7 (25.0%)	
>10 years	78 (27.1%)	9 (32.1%)	
Gender			
Male	202 (70.1%)	14 (50.0%)	0.03
Female	86 (29.9%)	14 (50.0%)	
Mode of injury			
RTA	123 (42.7%)	16 (57.1%)	0.39
Fall	158 (54.9%)	11 (39.3%)	
Miscellaneous	7 (1.4%)	1 (3.6%)	
Pediatric trauma score (mean ± SD)	8.6 ± 2.3	3.6 ± 2.3	<0.001
Hypotension at admission, *n* (%)	65 (22.6%)	23 (82.1%)	<0.001
Intracranial bleed, *n* (%)			
SAH	63 (21.9%)	13 (46.4%)	0.004
SDH	68 (23.6%)	14 (50.0%)	0.002
EDH	58 (20.1%)	11 (39.3%)	0.02
Polytrauma	37 (12.8%)	11 (39.3%)	<0.001
Trauma-induced coagulopathy	21 (7.3%)	15 (53.6%)	<0.001

EDH, extradural hemorrhage; RTA, road traffic accident; SAH, subarachnoid hemorrhage; SD, standard deviation; SDH, subdural hemorrhage. *p*-value < 0.05 is significant

Predictors of Mortality

A comparison of demography, hemodynamic, laboratory, and other various characteristics between survivors and non-survivors is depicted in Table 2. Non-survivors had lower mean PTSs compared to survivors (3.6 ± 2.3 vs 8.6 ± 2.3), ($p < 0.001$). We observed higher

Table 3: Univariate and multivariate analysis to predict mortality

Variable	*Univariate analysis odds ratio (95% CI)*	*p-value*	*Multivariate analysis odds ratio (95% CI)*	*p-value*
Hypotension at admission	15.78 (5.77–43.14)	0.000	1.49 (0.3–7.5)	0.63
Trauma-induced coagulopathy	14.67 (6.17–34.85)	0.000	2.63 (0.61–11.17)	0.19
Polytrauma	4.38 (1.90–10.09)	0.001	4.61 (1.02–20.86)	0.04*
Pediatric trauma score	0.44 (0.34–0.57)	0.000	0.52 (0.34–0.82)	0.004*
SDH	3.23 (1.46–7.12)	0.004	1.15 (0.3–4.4)	0.84

SDH, subdural hemorrhage, *p*-value < 0.05 is significant

proportion of hypotension (82.1 vs 22.6%, $p < 0.001$), polytrauma (39.3 vs 12.8%, $p < 0.001$), trauma-induced coagulopathy (53.6 vs 7.3%, $p < 0.001$), subdural hemorrhage ($p < 0.05$) in the non-survivor group compared to the survivor group.

On univariate analysis, hypotension at admission, polytrauma, PTS, trauma-induced coagulopathy, and subdural hemorrhage were associated with mortality, but on multivariate analysis, polytrauma (OR: 4.61; 95% CI: 1.02–20.86) and low PTS (OR: 0.52; 95% CI: 0.34–0.82) were found to be independent risk factors for mortality (Table 3). On receiver operator curve analysis, PTS <5 predicted mortality with sensitivity and specificity of 82.14 and 89.93%, respectively, with an area under the curve of 0.9 (Youden's index-0.72) (Fig. 2) (Appendices I and II).

Discussion

Traumatic brain injuries are the main cause of morbidity and mortality in children and adolescents in developing countries. Accidental injuries are on the rise and have become an important social problem. The present study explored the clinicoepidemiologic profile of TBI in children over a period of 10 years. Children younger than 5 years had a higher predisposition to TBI, and falling from height was the commonest mechanism of injury. Additionally, polytrauma and low PTS (<5) are associated with poor outcomes.

In the present study, median age (IQR) was 72 months (36–132 months), and the incidence of trauma was highest in the under 5-year age-group. Similar observations were noted in an epidemiological study by Bhargava P et al. (59%).[7] In a study by Sharma et al.,[8] school-going children (6–12 years) were more prone to head injury due to trauma (43%). A prospective study from India observed increased incidence of trauma in school-going children aged 6–12 years.[9] Boys were more predisposed to TBI compared to girls, and our results concur with previous studies.[1,2,10] Large head circumference and increased muscular and physical activities in boys as compared to girls may be the reasons for the higher incidence in boys.[11] The most common mode causing head injury in the study cohort was injury by fall from height, and the finding agrees with previous studies.[2,4,12] However, in a study by Barcenas et al.,[13] RTAs accounted for most TBIs (64.4%). We observed that mild TBI was the most common type of TBI in the current study, and the results align with results of previous studies.[2] Radiological abnormalities on CT scan play a significant role in determining the seriousness of the trauma. According to our study, subdural hemorrhage (26%) was the commonest intracranial bleed, followed by subarachnoid hemorrhage (24%) and extradural hemorrhage (22%), as evidenced in CT scans, and the results are similar to previous pediatric studies.[14,15]

Pediatric trauma score can lead to morbidity following head injury, and its incidence ranges between 10 and 20%.[13–18] Furthermore, we observed PTS in 18% of children suffering TBI, and the number of children developing PTS was higher in the severe group, 28% (22/79) ($p = 0.003$). A retrospective study by Park JT et al.[14–17] identified PTS in 15% of children with TBI, and the severe TBI group had a higher incidence of PTS. A study by Ratan SK et al.[16–19] revealed children suffering severe TBI had a higher likelihood of developing PTS.

In the present cohort, 28 (8.9%) children died. A higher proportion of deaths was observed in the under-5 years group (42.9%), and factors such as hypotension at admission, lower PTS, polytrauma, and SDH predicted poor outcomes. Higher mortality was encountered in the severe TBI category (31.6%). Mortality ranged between 3 and 6% in the previous studies.[1,13,17–20] Barcenas LK et al.[13] observed higher mortality in the severe TBI (26.4%) group. A retrospective study by White et al.[21] witnessed 24% mortality in severe TBI and observed higher odds of survival (19-fold increase) with maximum systolic blood pressure ≥135 mm Hg. Equivalent results were noted by author Michaud LJ et al.[19–22] with mortality of 33% in children suffering severe TBI. The severity of the brain injury and the presence of chest injuries were associated with increased mortality. A prospective observational study in the adult population suffering TBI suggested the presence of hypotension, AKI, coagulopathy, and GCS <6 were the independent risk factors for mortality.[20–23]

We analyzed 10-year data on pediatric TBI with the intention to decrease the lacunae in the existing pool of limited literature. The study is affected by several limitations, the major one being the retrospective nature of the study. We were unable to study long-term outcome of the discharged children. Detail radiological abnormalities such as contusions, diffuse axonal injury, and craniofacial fractures were not described. Though it was a retrospective study, we were able to define factors affecting mortality, and our results were in good agreement with previous pediatric studies.

Conclusion

Traumatic brain injuries are the main cause of morbidity and mortality in children and adolescents in developing countries. Children under 5 years of age were more prone to TBI. The commonest mode of sustaining TBI was a fall from height. Lower PTS and polytrauma predicted poor outcome. Pediatric head injuries can be prevented with parental vigilance, creating a safe environment, and the formulation of preventive strategies. Further multicenter studies from the Indian subcontinent will help in better understanding of the epidemiology, management, and outcome of pediatric TBI.

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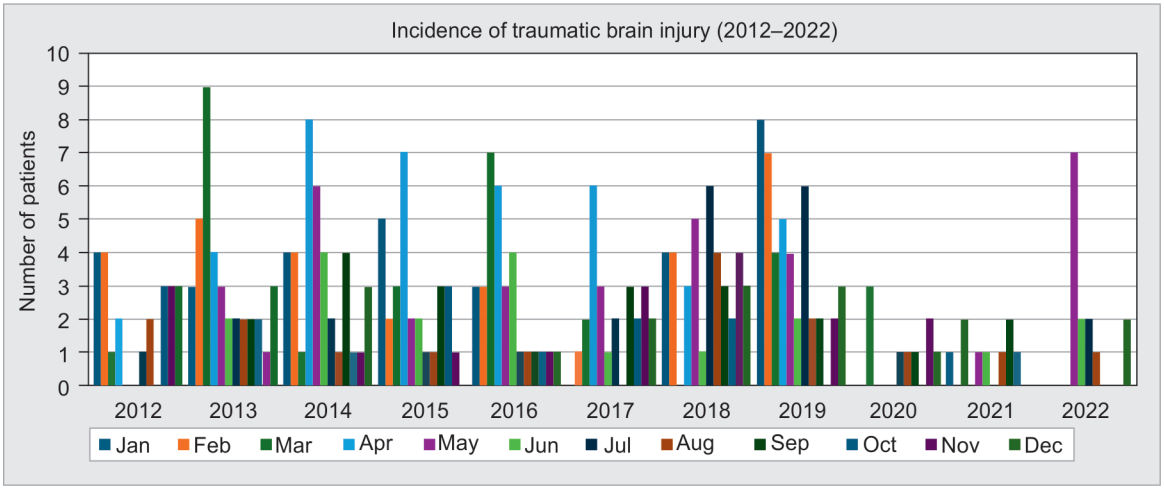
Appendix I



Appendix I: Incidence of trauma (2012–2022)

Appendix II

Appendix II: ROC analysis of PTS

Results table

Cutpoint	*Sensitivity (%)*	*Specificity (%)*	*PPV (%)*	*NPV (%)*	*Youden's index*	*AUC*	*Metric score*
<=0	7.14	100	100	91.72	0.07143	0.931	1.07
<=1	14.29	99.65	80	92.28	0.13938	0.931	1.14
<=2	28.57	98.96	72.73	93.44	0.27530	0.931	1.28
<=3	53.57	97.22	65.22	95.56	0.50794	0.931	1.51
<=4	64.29	95.14	56.25	96.48	0.59425	0.931	1.59
<=5	82.14	89.93	44.23	98.11	0.72073	0.931	1.72
<=6	96.43	79.51	31.4	99.57	0.75942	0.931	1.76
<=7	96.43	70.83	24.32	99.51	0.67262	0.931	1.67
<=8	96.43	56.25	17.65	99.39	0.52679	0.931	1.53
<=9	96.43	45.14	14.59	99.24	0.41567	0.931	1.42
<=10	100	21.88	11.07	100	0.21875	0.931	1.22
<=11	100	5.56	9.33	100	0.05556	0.931	1.06
<=12	100	0.69	8.92	100	0.00694	0.931	1.01
<=13	100	0	8.86	NaN	0.00000	0.931	1.00

Scale: Trauma score