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ORIGINAL ARTICLE

Traumatic brain injury in children and adolescents: An institutional observational study

Lesión cerebral traumática en niños y adolescentes: Estudio observacional institucional

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Abstract

Introduction. Traumatic brain injury is a complex neurological condition resulting from an external force that inflicts physical damage to the brain, disrupting the intricate network of neurons and brain structures, leading to a spectrum of impairments. The injury may be caused by a direct impact to the head, penetrating head injury, or violent shaking of the head and body. Consequences are multifaceted and potentially affect cognitive functions, physical abilities, emotional regulation, and quality of life

Methods. An observational from March 2023 to May 2024 among individual under 18 years of age who presented with traumatic brain injury warranting admission to the Department of Neurosurgery. Patients were recruited according to the inclusion criteria and followed up 3 and 6 months after discharge. A structured platform was used to note all the information required for the study. The data collected for the study were systematically updated on an Excel spreadsheet. The outcomes at three and six months post injury were evaluated and was used to assess disability at three and six months postinjury.

Results. Statistical analysis revealed no significant associations between outcomes and factors such as age, sex, mechanism of injury, or CT findings; however, both the severity of TBI and the management approach were identified as statistically significant predictors of functional outcome.

Conclusion. This study revealed that pediatric traumatic brain injury accounts for 10.2% of all TBI cases. It also emphasizes the clinic-radiological inconsistency between the Glasgow Coma Scale score, clinical presentation, and CT findings.

Keywords: craniocerebral trauma; traumatic brain injuries; accidents; accidental falls; child; disability evaluation.

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Resumen

Introducción. La lesión cerebral traumática (LCT) es una condición neurológica compleja que resulta de una fuerza externa que inflige daño físico al cerebro, interrumpiendo la intrincada red de neuronas y estructuras cerebrales, lo que lleva a un espectro de deterioros. La lesión puede ser causada por un impacto directo craneano, una lesión penetrante o un sacudimiento violento de la cabeza y el cuerpo. Las consecuencias son multifacéticas y pueden afectar las funciones cognitivas, las capacidades físicas, la regulación emocional y la calidad de vida.

Métodos. Se realizó un estudio observacional de marzo de 2023 a mayo de 2024 entre menores de 18 años que presentaron lesión cerebral traumática que justificó su ingreso al Departamento de Neurocirugía. Los pacientes fueron reclutados según los criterios de inclusión y se les realizó un seguimiento a los 3 y 6 meses después del alta. Se utilizó una plataforma estructurada para registrar toda la información requerida para el estudio. Los datos recopilados para el estudio se actualizaron sistemáticamente en una hoja de cálculo de Excel. Los resultados a los tres y seis meses después de la lesión fueron evaluados y utilizados para determinar la discapacidad posterior a la lesión.

Resultados. El análisis estadístico no reveló asociaciones significativas entre los resultados y factores como la edad, el sexo, el mecanismo de la lesión o los hallazgos de la tomografía computarizada (TC); sin embargo, tanto la gravedad de la LCT como el enfoque de manejo fueron identificados como predictores estadísticamente significativos del resultado funcional.

Conclusión. Este estudio reveló que la lesión cerebral traumática pediátrica representa el 10,2 % de todos los casos de LCT. También enfatiza la inconsistencia clínico-radiológica entre la puntuación de la Escala de Coma de Glasgow, la presentación clínica y los hallazgos de la TC.

Palabras clave: traumatismos craneocerebrales; lesiones traumáticas del encéfalo; accidentes; accidentes por caídas; niño; evaluación de la discapacidad.

Introduction

Traumatic brain injury (TBI) is a complex neurological condition caused by external forces damaging the brain, leading to cognitive, physical, and emotional impairments. In children, TBI poses unique challenges due to the brain's developmental vulnerability, which significantly contributes to morbidity and mortality. Lifelong disability often results from pediatric TBI, placing a substantial burden on affected individuals, families, and society [1]. Globally, the incidence of pediatric TBI ranges from 47 to 280 cases per 100,000 children, with TBI accounting for more than half of all childhood deaths [2]. Boys are more frequently affected by greater participation in risky activities, such as sports and motor vehicle crashes [3].

The causes of TBI in children vary by age group. Infants and toddlers often suffer TBI from falls or shaken baby syndrome [4,5], whereas older children are more likely to experience TBI from sports-related injuries, bicycle accidents, or motor vehicle crashes. Adolescents face greater risk due to vehicle collisions and contact sports such as football, wrestling, and violent altercations [6,7]. Developing brain characteristics, including increased water content and poor myelination, increase susceptibility to injury. For example, infants are more vulnerable to fatal TBI because of their top-heavy body structure, leading to a higher incidence of head injuries [8].

Pediatric TBI is underreported in developing countries such as India, where systematic data collection is lacking [9]. Despite ongoing research on adult trauma, pediatric TBI remains understudied in India, which hampers the development of comprehensive prevention and management strategies. International efforts such as the International Mission for Prognosis and Analysis of Clinical Trials (IMPACT) study aim to improve outcome predictions for pediatric TBI patients,

contributing to better management and rehabilitation strategies worldwide [10].

Through this study, we intended to fill this gap by estimating the burden of pediatric TBI in a tertiary care setting and identifying the key mechanisms leading to TBI in different age groups. This study aimed to analyze the epidemiological characteristics and injury patterns of pediatric TBI patients at a tertiary care center. The key objective was to determine the prognostic indicators of TBI in children and adolescents. This study elucidated the common mechanisms of injury, sex predominance, and age-related patterns, as well as the assessment of injury severity, prevalent radiological findings, and post discharge outcomes.

Methods

An observational study was conducted in a tertiary care center in Manipal, Karnataka (India), from March 2023 to May 2024 among individuals less than 18 years of age who were presented with traumatic brain injury warranting admission to the Department of Neurosurgery. Patients were recruited from March 2023 to November 2023 according to the inclusion criteria and followed up at 3 and 6 months after discharge. The exclusion criteria for this study included individuals aged 18 years and older, patients who were discharged directly from the emergency room due to minor injuries, and those admitted to different departments for more severe chest or abdominal injuries, or fractures associated with minor head injuries. Additionally, patients who died in the emergency room were also excluded from the study.

A structured platform was used to note all the information required for the study. The data collected for the study were systematically updated on an Excel spreadsheet. Patients were included based on the established inclusion criteria, and the gathered data were stratified and organized according to various factors, including age, sex, mechanism of injury, Glasgow Coma Scale (GCS) score, radiological findings, and management strategies. The outcomes at three and six months postinjury were evaluated via the modified Rankin scale (mRS), which was used to assess disability at three and six months postinjury, with scores ranging from 0-2 indicating good functional outcomes, scores ranging from 3-5 indicating poor outcomes, and a score of 6 indicating death. The data collected were analyzed via SPSS software with the help of a statistician to assess the results.

Results

This study included a total of 51 pediatric participants, comprising 36 males and 15 females, reflecting a significant male predominance, with males representing 70.59% of the cohort. The mean age of the subjects was 8.7 ± 5.3 years, with an age range ranging from 6 months to 17 years, resulting in a total age span of 16.5 years.

The participants were stratified into three distinct age categories: the preschool group (children aged ≤ 4 years), which included 16 individuals; the school-age group (children aged 5-12 years), which included 20 individuals; and the teenage group (children aged 13-17 years), which included 15 individuals. Notably, while there was a general male predominance across the entire study population, the preschool group presented a slight female predominance, with nine females constituting 56.25% of that subgroup. In contrast, male predominance was markedly pronounced in the other age groups, with males accounting for 80% of the school-age group and 86.67% of the teenage group.

Various mechanisms of injury, including road traffic accidents (RTA), fall from a height, and falls while playing were identified in the study. A total of 27 patients reported a history of RTA, 20 patients experienced falls from height, three patients reported falls during play, and one patient sustained an injury from a falling jackfruit. No cases of battered baby syndrome were identified in this study. RTA were identified as the most common cause of injury, affecting 52.94% of the cohort, followed by falls from height, which accounted for 39.22% of the cases.

Among patients involved in RTA, three cases of underage driving were reported. A breakdown of vehicle involvement revealed that 13 patients were associated with two-wheelers (ten as pillion

riders and three as drivers), whereas six patients were associated with four-wheelers (one front passenger and five rear passengers). The additional injury mechanisms included two bicycle riders, two bus accident victims, and two pedestrians (Figure 1).

In the preschool age group, falls from a height were the predominant mechanism of injury, affecting 62.5% of the patients. Conversely, among teenagers, RTA were the leading cause, affecting 86.67% of individuals. The school-age group demonstrated an equal distribution; with eight patients each presenting with histories of RTA and falls from height.

Clinical assessments revealed a variety of symptoms among the cohort, including loss of consciousness in 19 patients, vomiting in 24 patients, headache in 18 patients, ear bleeding in 11 patients, nasal bleeding in seven patients, oral cavity bleeding in two patients, seizures in one patient, rhinorrhea in one patient, and a lucid interval in one patient.

Using GCS, TBI were classified as mild, moderate, or severe. Among the 51 patients, 35 (68.63%) presented with mild TBI, seven (13.73%) with moderate TBI, and nine (17.65%) with severe TBI.

Among the patients assessed, nine had normal CT brain findings. The most prevalent finding was skull bone fractures, which were observed in 26 patients (50.98%). Other notable CT findings included epidural hematoma (EDH) in nine patients, subdural hematoma (SDH) in 14 patients, subarachnoid hemorrhage (SAH) in five patients, intraventricular hemorrhage (IVH) in one patient, and contusion in 20 patients (Figure 2). Additionally, six patients exhibited midline shifts, seven had traumatic pneumocephalus, and cerebral edema was noted in 14 patients. All patients with normal CT scans were classified as having mild TBI; however, 17 patients with mild TBI also presented with intracranial hemorrhage, and four exhibited midline shifts (Figure 3), indicating a discrepancy between the clinical presentation and radiological findings.

The management strategies used varied, with 40 patients (78.43%) receiving conservative treatment and 11 patients (21.57%) receiving surgical intervention. Among the 35 patients with mild TBI, 29 were managed conservatively, and six received surgical care.

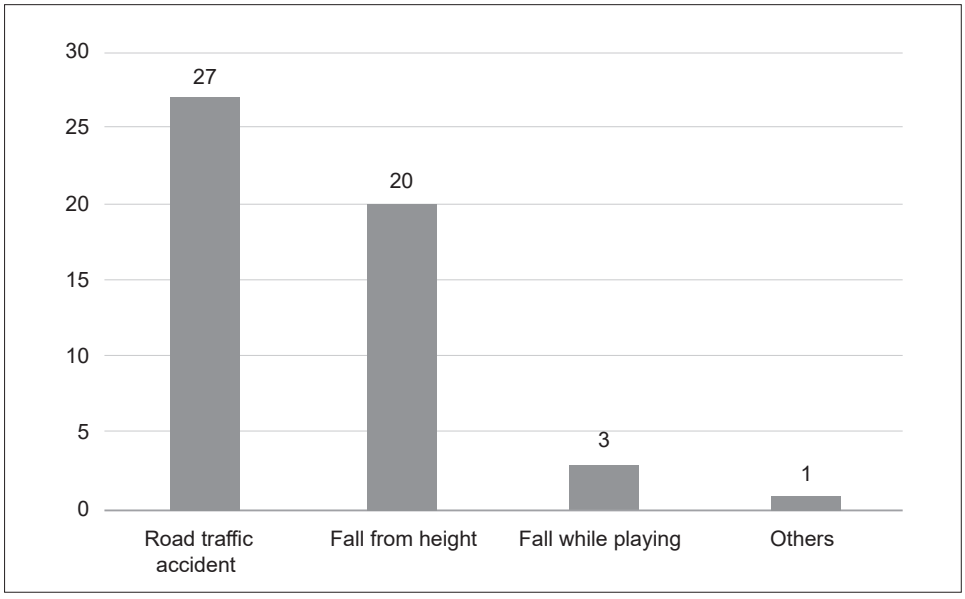


Figure 1. Mechanism of injury.

Source: Created by the authors using data from the study.

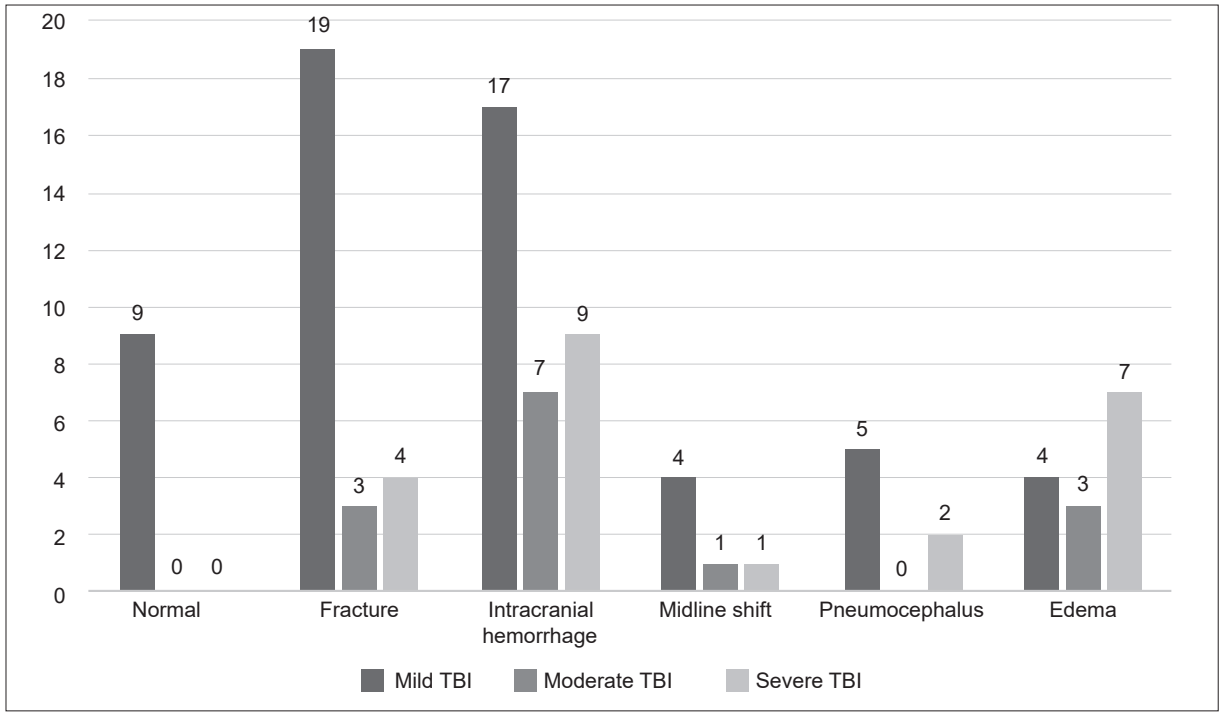


Figure 2. Computed tomography findings according to severity.
* TBI: traumatic brain injury.

Source: Created by the authors using the data collected during the study.

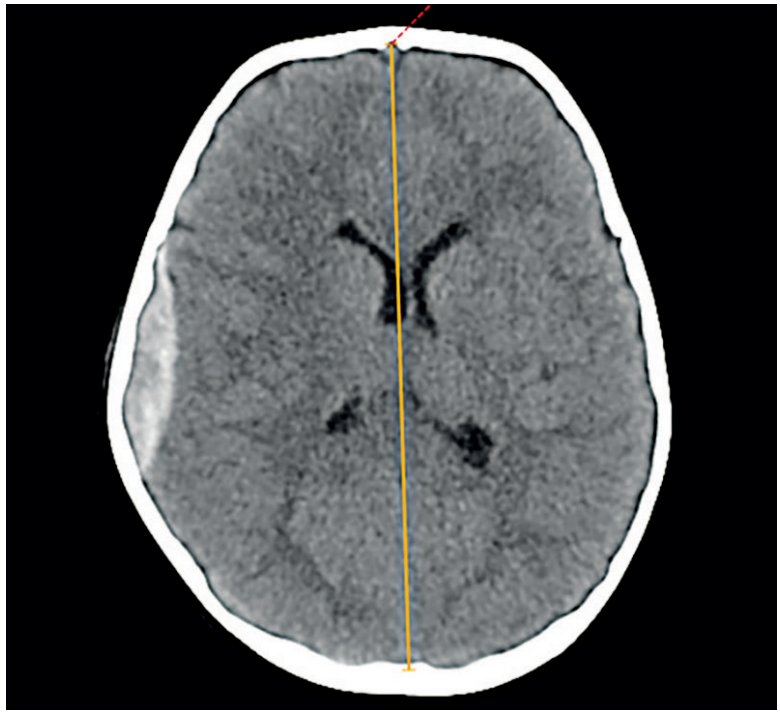


Figure 3. Plain head computed tomography of a 4-year-old boy following traumatic brain injury with Glasgow Coma Scale (GCS) score of 15 at presentation showing midline shift and right epidural hematoma.

Source: CT image of the actual study subject obtained from the institute's archives, after obtaining consent from the authorities and the patient.

Among the seven patients in the moderate TBI group, six received conservative management, and one underwent surgery. Among the nine patients with severe TBI, five were treated conservatively, while four required surgical intervention. Across all groups, conservative management was more prevalent than surgical options were, with no statistically significant association observed between TBI severity and management approach (p=0.181).

The average duration of hospitalization was 6.27 ± 8.5 days (range: 1- 43). The mean duration of ICU admission was 2.69 ± 6.6 days (range: 1-43), indicating that some patients did not necessitate ICU care. No statistically significant association was found between hospital stay duration and TBI severity at presentation (p=0.11), although a significant correlation was identified between ICU stay duration and TBI severity (p=0.02). Three patients died during the study.

Follow-up assessments were conducted at 3- and 6-month post-discharge and the modified Rankin scale was for outcome evaluation (Tables 1 and 2). The participants were classified into two groups: those with good functional outcomes and those with poor functional outcomes. Patients who died during the study were assigned a score of 6. At the 3-month mark, 43 patients had good functional outcomes, whereas five had poor outcomes. By 6 months, 45 patients had good outcomes, and three had poor outcomes.

Statistical analysis did not reveal significant associations between functional outcomes and factors such as age, sex, mechanism of injury, or computed tomography (CT) findings. However, both TBI severity and management approach were found to be significant predictors of functional outcomes.

Discussion

TBI in children and adolescents demands prompt intervention because of its significant association with childhood mortality and the potential for

Table 1. Outcome prognosticators at the 3-month follow-up.

MRS at 3 months	Good functional outcome	Poor functional outcome	Death	Total	p-value
Age					
Preschool	15	1	0	16	
School going	18	0	2	20	0.64
Teenagers	10	4	1	15	
Gender					
Male	28	5	3	36	0.46
Female	15	0	0	15	
Mechanism of injury					
Road traffic accident	21	5	1	27	
Fall from height	18	0	2	20	0.445
Fall while playing	3	0	0	3	
Other	1	0	0	1	
CT findings					
Normal	9	0	0	9	
Fractures	22	3	1	26	
ICH	25	5	3	33	0.33
Midline shift	4	1	1	6	
Pneumocephalus	6	0	1	7	
Edema	7	4	3	14	
Severity					
Mild TBI	35	0	0	35	
Moderate TBI	6	1	0	7	<0.001
Severe TBI	2	4	3	9	
Management					
Conservative	37	3	0	40	0.001
Surgical	6	2	3	11	

CT: computed tomography; ICH: intracranial hemorrhage; TBI: traumatic brain injury.

Source: Created by the authors using data collected during the study.

Table 2. Outcome prognosticators at the 6-month follow-up.

MRS at 6 months	Good functional outcome	Poor functional outcome	Death	Total	p-value
Age					
Preschool	16	0	0	16	
School going	18	0	2	20	0.52
Teenagers	11	3	1	15	
Gender					
Male	30	3	3	36	0.725
Female	15	0	0	15	
Mechanism of injury					
Road traffic accident	23	3	1	27	
Fall from height	18	0	2	20	0.704
Fall while playing	3	0	0	3	
Other	1	0	0	1	
CT findings					
Normal	9	0	0	9	
Fractures	24	1	1	26	
ICH	27	3	3	33	0.31
Midline shift	4	1	1	6	
Pneumocephalus	6	0	1	7	
Edema	8	3	3	14	
Severity					
Mild TBI	35	0	0	35	
Moderate TBI	6	1	0	7	<0.001
Severe TBI	4	2	3	9	
Management					
Conservative	38	2	0	40	0.002
Surgical	7	1	3	11	

CT: computed tomography; ICH: intracranial hemorrhage; TBI: traumatic brain injury.

Source: Created by the authors using the data collected during the study.

lasting disabilities. The clinical evaluation of pediatric TBI is multifaceted and involves the use of the Pediatric Glasgow Coma Scale (PGCS) and detailed clinical and neurological examinations. Imaging techniques such as CT and magnetic resonance imaging (MRI) are crucial for diagnosing structural brain injuries. GCS is traditionally used to assess TBI severity in adults, but pediatric adjustments are made for children under 5 years of age [9]. For children under 2 years of age, verbal response scoring is based on behaviors such as babbling or crying, whereas children aged 2-5 years, verbal responses range from appropriate words to moaning or grunting. Frequent GCS assessments allow tracking changes in neurological status, and lower scores indicate more severe injuries requiring urgent intervention. The management of pediatric TBI is affected by injury severity and CT scan findings. Mild TBI patients, where the child is alert and has a normal CT scan, can often be discharged with follow-up care. Moderate to severe cases, however, necessitate intensive care, including monitoring in the intensive care unit (ICU) and management of increased ICP. Medical interventions include the use of mannitol to reduce the ICP, and sedatives such as morphine and midazolam help manage pain, anxiety, and the ICP. The use of steroids in managing cerebral edema remains controversial because studies have shown no significant benefits or a risk of complications. Seizures are common within the first 24 hours of TBI, and prophylactic anticonvulsants such as phenytoin are used to prevent post traumatic seizures. Surgical management is crucial for expanding hematomas that cause cerebral shifts, and early ventriculostomy may be performed to manage ICP in severe cases [8]. Approximately 90% of pediatric TBI patients

are discharged from the emergency department without significant complications, although mortality rates for severe TBI range from 20% to 39%, with non-accidental causes such as abusive head trauma being the leading contributors. Long-term complications vary based on injury severity, ranging from mild cognitive impairments to severe disabilities. Secondary complications such as pneumonia, deep vein thrombosis, and pulmonary embolism may arise in immobilized patients, whereas severe cases often require long-term support through tracheostomies or gastrostomy tubes [9].

The female predominance among children under 4 years of age can be attributed to several factors. Differences in supervision levels might influence injury rates. Developmental vulnerabilities specific to young girls could affect their susceptibility to injuries, and there may be a reporting bias where caregivers are more likely to seek medical attention for girls. Additionally, girls might be exposed to different environments with varying risk levels. As children grow older, boys are more likely to engage in higher-risk activities such as contact sports, rough play, and adventurous behaviors, which can lead to a greater incidence of TBIs than girls are. The male predominance observed in our study aligns well with the findings from comparative studies [11,12]. The primary cause of TBI is road traffic accidents, whereas falls from a height are most prevalent among preschoolers, with three cases of underage driving identified. This aligns with comparative studies where road traffic accidents were found to be the most common mechanism of injury. The severity of TBI, as assessed by the GCS upon arrival, was classified as mild in 68.63% of the patients, moderate in 13.73%, and severe in 17.65%. Interestingly, 17.65% of the participants presented with normal CT scans upon admission, whereas skull fractures and intracranial hemorrhages were the most common abnormal findings. This finding corroborates earlier studies, which similarly highlighted skull fractures as the most common finding [11,12]. An interesting finding from our study was that clinical features often do not correlate with radiological results, as 17 patients exhibited intracranial hemorrhage, and four had midline shifts despite being classified as having mild TBI. Conservative management was implemented in 78.43% of the patients, whereas 21.57% required surgical intervention. Statistical analysis revealed no significant association between TBI severity and the chosen management approach (p=0.181). The average duration of hospital stay was 6.27 days, with an average ICU stay of 2.69 days. Although there was no significant correlation between the length of hospital stay and TBI severity (p=0.11), a statistically significant association was noted between the duration of ICU stay and injury severity. The absence of a significant correlation between hospital stays and TBI severity may be influenced by factors such as administrative procedures or differing rehabilitation requirements that do not necessarily align with the severity of the injury. In this study, two patients with severe TBI were erroneously observed to have shorter hospital stays, as both patients unfortunately passed away within two days of admission. Throughout the study, three mortalities were recorded. Statistical analysis revealed no significant associations between outcomes and factors such as age, sex, mechanism of injury, or CT findings; however, both the severity of TBI and the management approach were identified as statistically significant predictors of functional outcome.

This study has several limitations that may affect its findings. The small sample size restricts the ability of the results to be generalized, while a brief study period may not capture long-term outcomes. Additionally, recruiting participants from a single center limits the representativeness of the population, impacting the applicability of the findings.

Conclusion

This study revealed that pediatric TBI accounts for 10.22% of all TBI cases. It also emphasizes the clinic-radiological inconsistency between the GCS score, clinical presentation, and CT findings. Additionally, the study identified road traffic accidents and falls from a height as the most common

causes of pediatric TBI, with variations observed across different age groups. A significant association between the severity of TBI and the duration of ICU stay was observed. Notably, the severity of TBI and management strategy emerged as significant predictors of long-term functional outcomes. These findings can serve as a foundation for developing targeted and effective prevention strategies aimed at improving community safety. The implementation of such programs has the potential to significantly reduce the morbidity and mortality associated with TBI in children and adolescents.

Compliance with ethical standards

Informed consent: The study protocol for this research was conducted in accordance with the Declaration of Helsinki and was formally approved by the ethical committee review at our institution (IEC2:373/2022) and is registered with the Clinical Trials Registry of India: CTRI/2023/03/050206 - dated 01/02/2023. Informed consent was obtained from participants, or their legal guardians, to publish identifiable information, images, or data after explaining to them the study protocol in the best possible way in a language that is best understood.

Conflicts of interest: All the authors declare that they have no conflict of interest on going through the complete manuscript for it further proceedings.

Use of Artificial Intelligence: We declare that this study has been carried out and manuscript has been prepared with no use of Artificial Intelligence.

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Author's contribution:

- Conception and design of the study: Annappa Kudva.
- Acquisition of data: Roshni Stanley.
- Data analysis and interpretation: Roshni Stanley.
- Drafting the manuscript: Jithin Abraham Jacob.
- Critical review and final approval: Roshni Stanley, Annappa Kudva, Girish Menon, Jithin Abraham Jacob.

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