Pattern and Predictors of Pediatric Head Injuries Presenting to an Emergency Department in Southeast Iran: A Cross-Sectional Study

Maryam Ziaie, Mehdi Galavi, Armaghan Hosseinsarbazi, Alireza Bahmani*

Department of Emergency Medicine, Faculty of Medicine, Zahedan University of Medical Sciences, Zahedan, Iran

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Abstract

Background: Traumatic brain injury (TBI) is one of the leading causes of emergency department admissions and neurological morbidity among children worldwide. Identifying epidemiological trends, mechanisms of injury, and outcome predictors is essential for guiding preventive strategies and improving clinical management. This study aimed to evaluate the epidemiological characteristics, mechanisms, and outcomes of pediatric head trauma cases presenting to the emergency department of Khatam-Al-Anbia Hospital in Zahedan, Southeast Iran, during 2022–2023.

Methods: This descriptive, retrospective, cross-sectional study included 112 children under 16 years of age with documented head trauma. Data were extracted from hospital records using a standardized checklist covering demographic variables, mechanism of injury, trauma severity (based on the Glasgow Coma Scale; GCS), and neurological outcome (discharge or death). Consecutive non-probability sampling was applied. Statistical analysis was performed using SPSS version 26.0, employing descriptive statistics and the Chi-square test to explore associations between clinical variables and outcomes.

Results: Of the 112 cases, males comprised 76.8%, and the 6–12-year age group accounted for the largest proportion (48.2%). Road traffic accidents were the predominant cause of trauma (54.5%), followed by falls. Regarding injury severity, 50.0% had mild, 26.8% moderate, and 23.2% severe injuries. The overall mortality rate was 4.5%. Although no significant association was found between age or gender and neurological outcomes, injury severity demonstrated a borderline significant relationship with mortality ($p = 0.076$).

Conclusions: Pediatric head trauma remains a major cause of morbidity and mortality in Southeast Iran, predominantly affecting school-aged boys and primarily resulting from road traffic accidents. Injury severity is a key determinant of outcome. These findings highlight the urgent need for enhanced parental education, implementation of school-based safety programs, and strengthening of prehospital and in-hospital trauma care systems to reduce preventable deaths and improve outcomes.

Keywords: Pediatric Head Injury; Traumatic Brain Injury; Epidemiology; Road Traffic Accident; Glasgow Coma Scale

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Introduction

Traumatic brain injury (TBI) remains one of the leading causes of mortality and long-term disability among children worldwide, posing a major challenge for public health systems and clinical practitioners. It is estimated that more than ten million children sustain head injuries annually, accounting for a substantial proportion of pediatric emergency admissions in both developed and developing countries [1]. The global burden of pediatric TBI is particularly high in low- and middle-income nations, where preventive measures, trauma systems, and rehabilitation infrastructures are often insufficient. In Iran, as in many developing regions, motor vehicle collisions are the predominant mechanism of pediatric head trauma, especially among school-aged boys [2,3]. Other important etiologies include falls, domestic accidents, and child

*** Corresponding author**: Alireza Bahmani
Department of Emergency Medicine, Khatam-Al-Anbia Hospital, Zahedan University of Medical Sciences, Zahedan, Iran.
Email: drbahmani@yahoo.com

abuse, which occur more frequently in toddlers and infants [4].

Pediatric head injuries are unique in both their pathophysiology and clinical implications. Unlike adults, the pediatric brain demonstrates distinct anatomical, physiological, and biomechanical characteristics, including higher water content, thinner cranial bones, and incomplete myelination. These differences make children more susceptible to diffuse brain injury, cerebral edema, and secondary pathophysiological cascades, even after seemingly minor trauma [5]. The outcome of TBI depends not only on the initial mechanical insult but also on a complex interplay of secondary mechanisms such as ischemia, excitotoxicity, inflammation, and electrolyte disturbances [6]. If not recognized and managed promptly, these secondary injuries may result in significant neurological impairment or death.

Electrolyte imbalances—particularly abnormalities in serum sodium, potassium, and plasma osmolality—play a critical role in determining neurological outcomes following TBI. Dysnatremia (hyponatremia or hypernatremia) can exacerbate cerebral edema, increase seizure risk, and contribute to poor neurological recovery. Potassium disturbances, on the other hand, have been linked to increased brain lactate production, elevated intracranial pressure, and heightened neuronal excitability [7–9]. Although the precise mechanisms connecting electrolyte changes to neurological outcomes are not fully understood, several studies have emphasized the importance of continuous monitoring and targeted correction of sodium and potassium levels as part of early neuroprotective strategies [10,11].

Despite advances in neuroimaging technologies, many pediatric patients with mild or moderate TBI show no abnormal findings on CT or MRI scans, complicating both diagnostic and prognostic evaluations [12]. In such cases, clinical scoring systems such as the Glasgow Coma Scale (GCS) and biochemical markers are essential for assessing injury severity and predicting outcomes. Moreover, inadequate prehospital care, delayed transport, and insufficient early resuscitation remain major contributors to poor prognosis in many developing regions, where access to specialized pediatric trauma units is limited [13,14].

Several studies have characterized the epidemiology of pediatric TBI across different countries; however, regional data from Southeast Iran remain scarce. Understanding local epidemiological patterns, mechanisms of injury, demographic variations, and outcome predictors is essential for helping clinicians and policymakers design effective preventive and interventional strategies tailored to regional needs [15–17]. Regional differences in cultural practices, traffic safety enforcement, and emergency response capabilities further highlight the necessity of local research to address these contextual factors.

Given the high burden of pediatric head trauma and the scarcity of regional evidence, the present study aimed to investigate the epidemiological characteristics, clinical patterns, and predictors of pediatric head injuries presenting to the emergency department of Khatam-Al-Anbia Hospital in Zahedan, Southeast Iran, during 2022–2023. By delineating the demographic profile, mechanisms and severity of injuries, associated biochemical changes, and immediate outcomes, this study seeks to improve understanding of pediatric TBI in this region and to support the development of evidence-based strategies for prevention, early recognition, and optimized management of affected patients.

Methods

Study Design and Setting

This descriptive, retrospective, cross-sectional study was conducted in the Emergency Department of Khatam-Al-Anbia Hospital, Zahedan, Southeast Iran. The study period spanned two consecutive years, from 2022 to 2023 (corresponding to 1401–1402 in the Iranian calendar). Khatam-Al-Anbia Hospital is a tertiary referral center that serves a large pediatric population across Sistan and Baluchestan Province.

Study Population and Eligibility Criteria

The study population consisted of pediatric patients under 16 years of age who presented to the emergency department with any form of head trauma during the study period. Inclusion criteria encompassed all children younger than 16 years diagnosed with traumatic head injury, as confirmed by clinical evaluation and/or imaging. Exclusion criteria included patients (or guardians) unwilling to participate, as well as those with a known history of cardiovascular, pulmonary, metabolic, diabetic, or renal disorders, since such comorbidities could confound biochemical and neurological outcomes.

Sample Size and Sampling Method

The minimum required sample size was calculated using the standard formula for prevalence studies. Assuming a prevalence (p) of 8%, a 95% confidence level (Z = 1.96), and a precision (d) of 0.05, the estimated sample size was 112 participants. A convenience sampling method was employed, and eligible patients who met the inclusion and exclusion

criteria were consecutively enrolled.

Data Collection Procedures

Data were collected retrospectively from hospital medical records and laboratory reports using a structured checklist developed by the researchers and approved by the study supervisor. The checklist captured demographic variables (age, sex), mechanism of injury, severity of head trauma, Glasgow Coma Scale (GCS) score on admission, laboratory parameters (serum sodium, potassium, and osmolality), and short-term neurological outcomes.

The severity of head injury was categorized according to the GCS as follows:

- **Mild injury:** GCS > 13
- **Moderate injury:** GCS 9–13
- **Severe injury:** GCS < 9

Statistical Analysis

All data were entered into SPSS version 26.0 (IBM Corp., Armonk, NY, USA) for analysis. Categorical variables were summarized as absolute and relative frequencies (n, %), while continuous variables were expressed as mean ± standard deviation (SD). Descriptive statistics, frequency tables, and graphical representations (bar and pie charts) were used to present the results. Inferential statistics were applied, as appropriate, to examine associations between injury severity and clinical outcomes.

Ethical Considerations

The study protocol was reviewed and approved by the Ethics Committee of Zahedan University of Medical Sciences (approval code: IR.ZAUMS.REC.1403.449). All ethical principles of confidentiality and anonymity were strictly adhered to. Patient names and other identifiers were excluded from the data collection forms.

Results

Demographic Characteristics

Based on the predefined inclusion and exclusion criteria, a total of 112 pediatric patients with head trauma who presented to the Emergency Department of Khatam-Al-Anbia Hospital were enrolled in the study.

The 6–12 age group represented the most significant proportion of cases (n = 54, 48.2%), followed by children aged 1–5 years and adolescents.

Regarding gender distribution, 86 (76.8%) of the patients were male and 26 (23.2%) were female, yielding a male-to-female ratio of approximately 3.3:1.

Regarding the severity of traumatic brain injury, 56 (50.0%) children sustained mild head injury (GCS > 13), 30 (26.8%) had moderate injury (GCS 9–13), and 26 (23.2%) had severe injury (GCS ≤ 8).

Motor vehicle collisions were the most frequent mechanism of injury, accounting for 61 (54.5%) cases, followed by falls and other causes.

Neurological Outcomes

Out of the total study population, five patients (4.5%) died during hospitalization, while the remainder were discharged with clinical improvement.

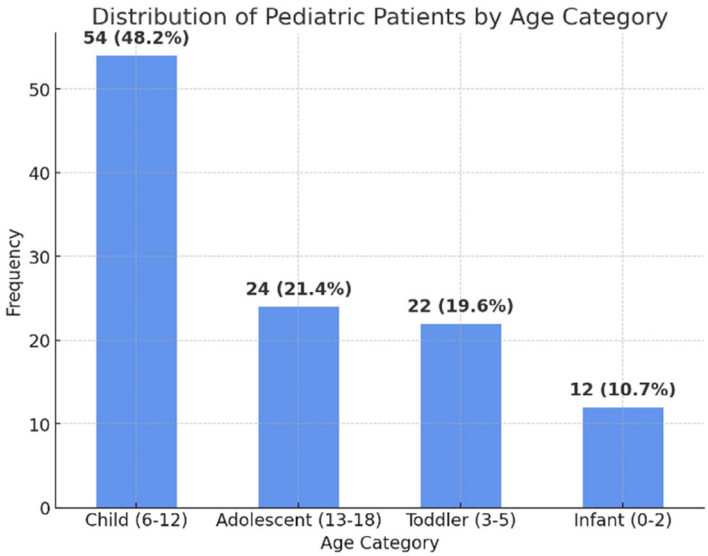

Figure 1. Age distribution of pediatric patients with head trauma

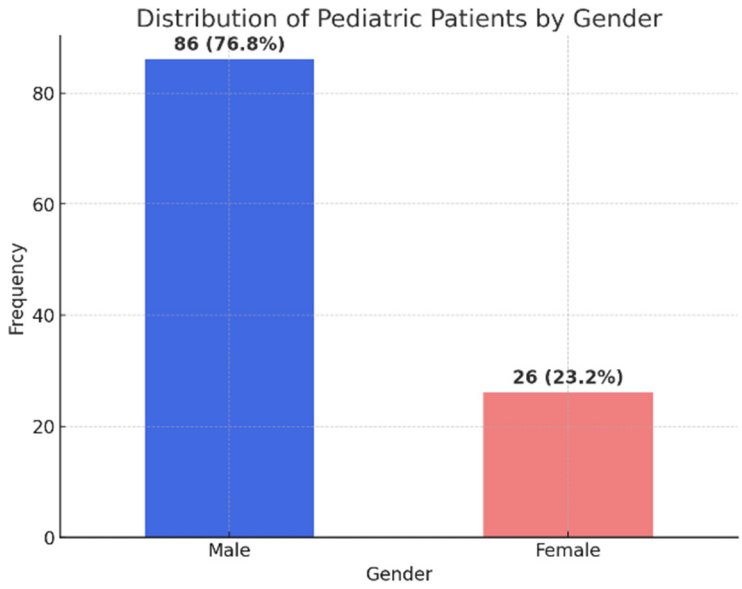

Figure 2: Gender distribution of pediatric head injury cases

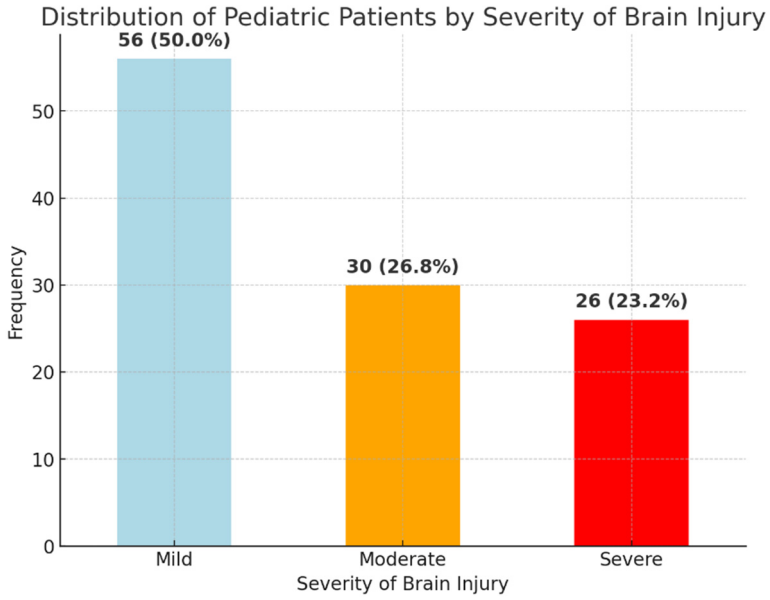

Figure 3: Distribution of pediatric patients by severity of brain injury

Relationship between Age and Neurological Outcome

When neurological outcomes were analyzed across age groups, the highest mortality rate was observed among children aged 6–12 years (3 cases, 5.6%), followed by toddlers (4.5%) and adolescents (2.4%). No deaths were recorded among infants. Statistical analysis using the Chi-square test revealed no significant association between age group and neurological outcome ($p = 0.65$).

Relationship between Gender and Neurological Outcome

Neurological outcomes were comparable between males and females. The majority of cases in both groups were discharged (males: 57 cases, 94.9%; females: 50 cases, 94.3%). Mortality was slightly higher among females (5.7%) compared to males (5.0%). However, Chi-square analysis revealed no statistically significant association between gender and neurological outcome ($p = 0.10$).

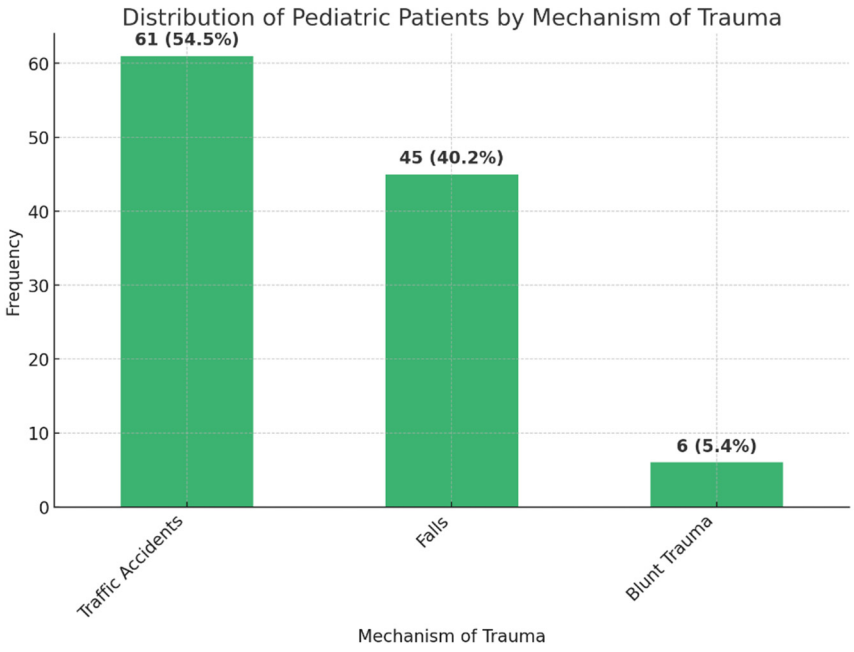

Figure 4: Mechanisms of pediatric head trauma

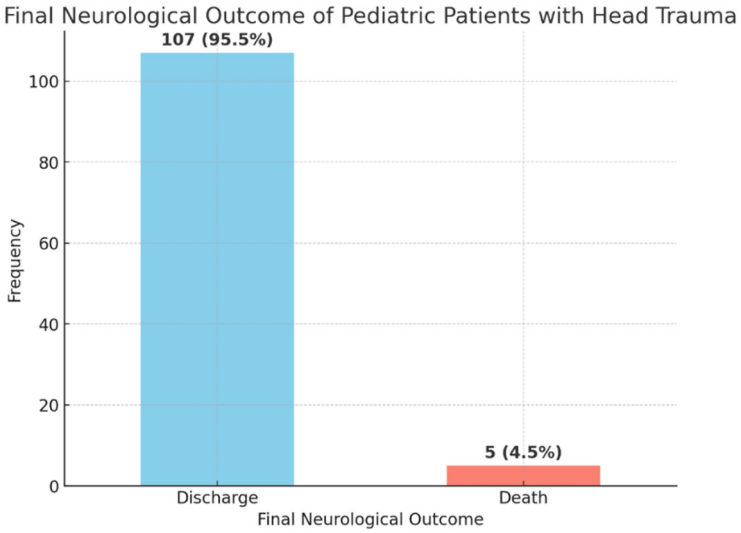

Figure 5: Neurological outcomes of pediatric head injury

Relationship between Injury Severity and Neurological Outcome

Among patients with mild head injury, all (100%) were discharged without mortality. In the moderate injury group, 27 patients (90%) were discharged and 3 (10%) died, while in the severe injury group, 24 patients (92.3%) were discharged and 2 (7.7%) died. Chi-square analysis demonstrated a borderline statistically significant relationship between injury severity and neurological outcome ($p = 0.076$), suggesting a potential association.

Discussion

This study provides a comprehensive overview of the epidemiological patterns, mechanisms, and neurological outcomes of pediatric traumatic brain injury (TBI) in Zahedan, Southeast Iran. The findings underscore the continuing public health importance of head trauma in children and are consistent with both national and international research trends.

Among the 112 analyzed cases, road traffic accidents were the most common cause of head trauma, accounting for 54.5% of all injuries. This

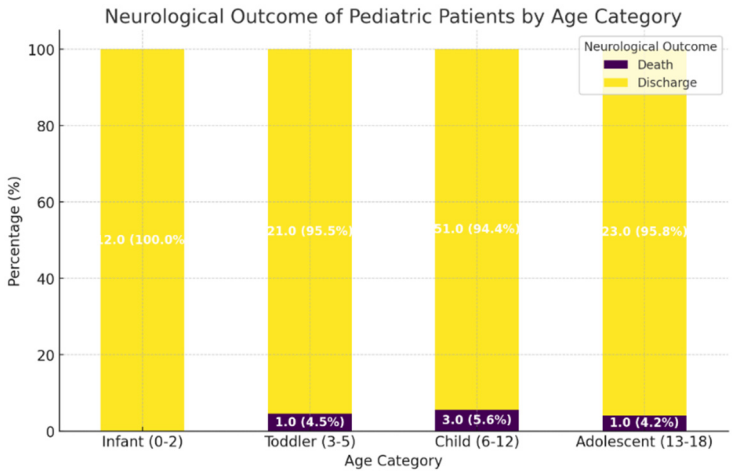

Figure 6: Relationship between injury severity and neurological outcome

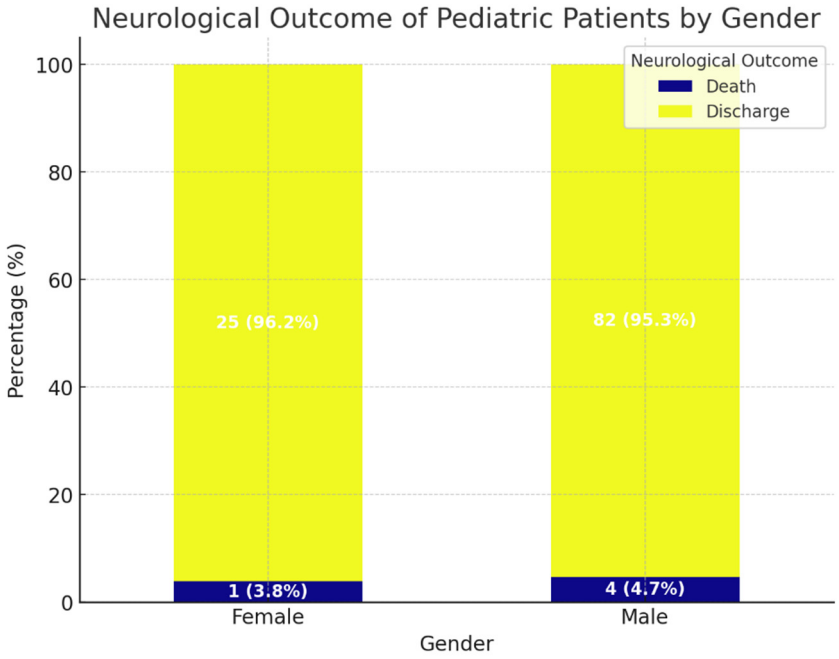

Figure 7: Neurological outcome of Pediatric Patients by Gender

result aligns with the national study by Badeh-Barin et al. (2021), which reported motor-vehicle collisions as the leading mechanism in 55.3% of pediatric TBI cases in Iran [18]. Similarly, Diallo et al. (2024) in Guinea found that road accidents and falls were predominant contributors to childhood head injuries, representing 12.6% of all trauma admissions [19]. Collectively, these findings highlight the universal challenge posed by inadequate traffic safety and domestic injury prevention measures for children.

Falls constituted the second most frequent mechanism of injury. Haydel et al. (2022) in the United States similarly identified road accidents and falls as the two dominant causes of pediatric TBI [20]. The high global prevalence of fall-related injuries underscores the importance of preventive education and the implementation of environmental safety protocols both at home and in schools.

The 6–12-year age group demonstrated the highest incidence of head trauma (48.2%), a pattern consistent with Badeh-Barin's report of a mean age of 6.5 years among pediatric TBI cases in Iran [18]. Increased physical activity, school attendance, and greater social mobility likely contribute to the elevated risk in this group. In contrast, Diallo et al. (2024) reported more frequent injuries among infants and toddlers in Guinea, which may reflect cultural and environmental differences.

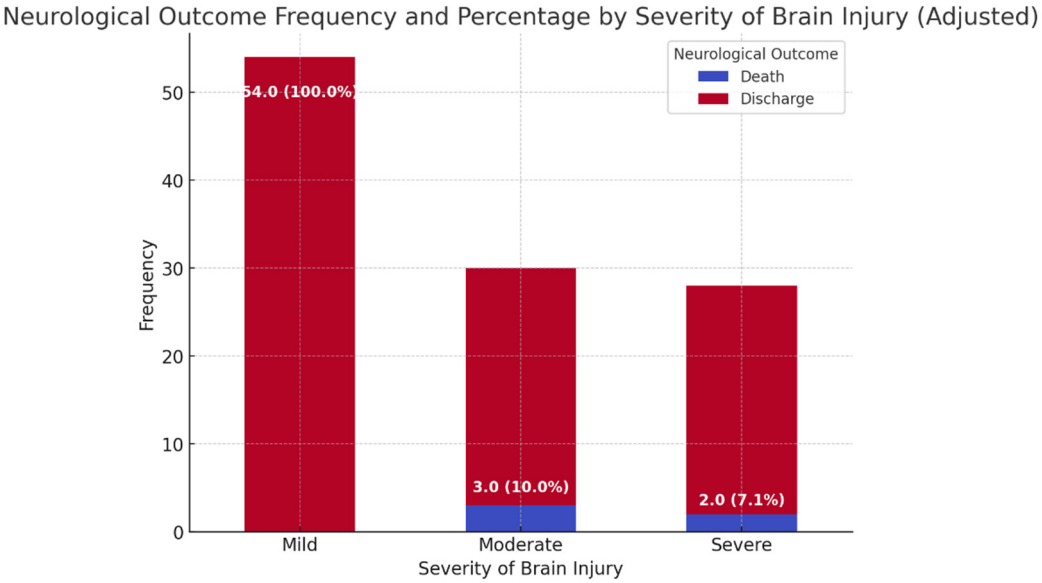

Figure 8: Neurological outcome frequency and percentage by severity of brain injury

A clear male predominance was observed (76.8%), consistent with the findings of Haydel et al. [20] and Badeh-Barin et al. [18], who each reported that over 70% of pediatric head trauma cases occurred in boys. This gender disparity has been attributed to behavioral tendencies, greater participation in physical activities, and lower parental supervision among boys in certain cultural contexts.

The overall mortality rate in this study was 4.5%, considerably lower than the 17.7% reported by Badeh-Barin et al. [18], suggesting a relatively favorable outcome and possibly reflecting effective acute management at Khatam-Al-Anbia Hospital. The severity of head injury, as measured by the Glasgow Coma Scale (GCS), demonstrated a strong correlation with outcome: children with mild injuries (GCS 13–15) were all discharged, whereas those with moderate (GCS 9–12) and severe (GCS $\leq$ 8) injuries experienced mortality rates of 10% and 7.7%, respectively. Although this association was only borderline significant ($p = 0.076$), it reinforces previous evidence supporting GCS as a reliable prognostic indicator (20,21).

Although biochemical parameters such as serum sodium, potassium, and osmolality were not assessed in the current dataset, previous Iranian and international studies have highlighted their prognostic importance. Amini et al. (2004) demonstrated a significant association between hypernatremia and mortality (81.8%) among head-injured patients [22]. Wang et al. (2021) reported a U-shaped relationship between plasma osmolality and in-hospital mortality, noting that values above 290 mOsm/L were associated with unfavorable neurological outcomes [23]. Similarly, Jabal-Ameli et al. (2011) found that electrolyte levels alone did not correlate directly with injury severity but interacted with other physiological factors such as temperature, ventilation, and medication [24]. Collectively, these findings suggest that dysnatremia and osmotic imbalances may serve as valuable prognostic markers and should be integrated into future trauma management protocols.

Neonatal and early-childhood studies—including those by Howell et al. (2020) and Gravis et al. (2022)—have underscored the long-term neurological implications of early sodium disturbances, linking neonatal hypernatremia to adverse motor and neurodevelopmental outcomes [25, 26]. Although the current study did not include infants or evaluate long-term sequelae, these findings highlight an important direction for future pediatric TBI research, particularly in high-risk populations.

Another global concern in pediatric neurotrauma is injury resulting from child abuse, notably abusive head trauma (AHT), or "shaken-baby syndrome." Hung et al. (2020) identified AHT as an under-recognized yet lethal cause of brain injury among infants [27]. While the present study did not differentiate cases of AHT, future regional investigations should incorporate forensic, radiologic, and psychosocial assessments to identify potential abuse cases.

Experimental work, such as that of Reinert et al. (2000), demonstrated that increased extracellular potassium concentrations correlate with elevated intracranial pressure and poor neurological recovery [28]. Although such neurochemical monitoring is not yet part of routine emergency care in Zahedan, integrating these insights into pediatric intensive care

protocols could significantly enhance early detection of secondary brain injury.

Conclusion and Recommendations

This study demonstrated that pediatric head trauma remains a major cause of emergency admissions in Zahedan, with road traffic accidents and falls identified as the predominant mechanisms. The majority of cases occurred in boys aged 6–12 years. Although no significant association was observed between age or sex and neurological outcome, injury severity, as measured by the Glasgow Coma Scale (GCS), emerged as the principal determinant of prognosis. The overall mortality rate was 4.5%, which is relatively low and may reflect efficient initial management and timely emergency response.

Recommendations

- Strengthen parental awareness regarding environmental hazards and the consistent use of safety equipment such as helmets and seat belts for children.
- Implement school-based preventive education programs focusing on safe behavior, particularly in the 6–12-year age group.
- Improve urban and traffic infrastructure, including installation of speed bumps and pedestrian crossings near schools and playgrounds.
- Equip emergency departments with rapid electrolyte and osmolality monitoring tools to identify early biochemical derangements in head-injured patients.
- Encourage future studies incorporating laboratory evaluations and long-term cognitive follow-up to understand the neurobiological sequelae of pediatric TBI better.

Limitations

This study was retrospective and single-centered, which may limit the generalizability of its findings. Laboratory variables such as serum electrolytes and osmolality were not included, preventing biochemical correlations with clinical outcomes. Future multicenter, prospective studies incorporating broader laboratory data are therefore recommended. Moreover, the absence of follow-up data limited the assessment of long-term neurological outcomes.

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Conflict of Interest

The authors declare that they have no conflicts of interest.

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Author Contributions

M.Z, A.B. conceptualized the study, supervised data collection, and reviewed the final manuscript. M.G, A.H performed statistical analysis and drafted the initial version of the manuscript. All authors read and approved the final version.

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