Trauma Monthly 2026; 31(1): 1716-1726

10.30491/tm.2026.510651.1811

Trauma Monthly

Mini-review Article

Pediatric Head Trauma in Traffic and Non-Traffic Accidents: Epidemiology, Prevention, Management, and Diagnosis

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Received 2025-08-08; **Accepted** 2025-12-25; **Online Published** 2026-02-25

Abstract

Introduction: This systematic review investigates pediatric head trauma caused by traffic and non-traffic accidents, focusing on epidemiology, prevention, management, and diagnosis in accordance with PRISMA 2020 guidelines. Head trauma in children most commonly results from falls or traffic accidents. To reduce the number of head injuries, wearing seat belts and using child restraint seats are recommended. In most cases, computed tomography (CT) is used to detect intracranial bleeding; however, due to the potential risk of various types of cancer, the effectiveness of other diagnostic tools, as well as prevention and management methods, is being considered.

Keywords: Brain Injuries, Accidents, Traumatic, Pediatrics, Adolescent.

Introduction

Head injuries in children can change the course of their lives instantly, often leading to long-term health challenges. Statistics show that the global burden of injuries among children between 0 and 19 years of age has been decreasing from 1990 to 2019 [1]. Unintentional injuries, traffic accidents, and self-harm are the three main causes of injury in children.[1]

Road accidents are the leading cause of death in children under 12 years of age, with hundreds of fatalities and thousands of injuries occurring annually [3]. Among the various injuries, head trauma is the most common and dangerous by far, accounting for up to 80% of all cases [4-6]. Children's heads are especially vulnerable due to their unique anatomical features: a larger head relative to their body size (1:4 in infants versus 1:7 in adults), a smaller face-to-skull ratio, and larger frontal and parietal lobes, all of which make them more prone to serious injury during accidents [7].
The rates of head trauma in children differ significantly across countries and are influenced by various factors such as local laws, healthcare policies, parental awareness, and regulations on alcohol consumption for drivers. Additionally, the enforcement of safety measures, such as the use of helmets and seatbelts for children, plays a critical role [8, 9]. In the United States, head and neck injuries in children decreased by 4.37% from 2007 to 2019 [6]. This improvement is likely due to a combination of factors, including better vehicle safety features, stricter traffic regulations, and effective public awareness campaigns promoting the use of child safety seats and seatbelts [3,6].

The Glasgow Coma Scale [10] and neurological focal signs play a vital role in assessing and managing head trauma complications in children. These tools provide important insights into the severity of injuries and help guide treatment decisions [11, 12]. CT remains the gold standard for detecting intracranial injuries, as it can quickly identify critical issues such as brain bleeding, swelling, and fractures [13]. However, children tend to undergo CT scans more frequently than adults, primarily because their symptoms can worsen rapidly, and an accurate diagnosis is crucial. Despite its effectiveness, CT scans pose a significant concern due to radiation exposure, which is more harmful to children because of their developing tissues and faster cell division [14]. The long-term risk of developing conditions such as brain tumors from repeated radiation exposure has sparked debate among healthcare professionals [15].

To mitigate these risks, alternative imaging methods have been explored. One promising option is AB-MRI (Advanced Brain MRI), which eliminates the need for radiation while providing high-resolution images of the brain. AB-MRI has been found to have several advantages, such as reducing unnecessary imaging sequences, saving valuable time, and offering a safer and equally effective diagnostic alternative in specific cases. Although AB-MRI is not a complete replacement for CT scans, it offers a compelling option, especially when repeated imaging is needed or when minimizing radiation exposure is a priority [16-18].

According to statistics on children's head trauma during accidents, this review focuses on evaluating management methods, the effectiveness of prevention strategies, and imaging techniques. The goal is to reduce the complications of head injuries in children and the strain they place on healthcare systems.

Methods

This systematic review was conducted and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines [19].

A comprehensive search was performed on August 21, 2024, in PubMed, Wiley, ScienceDirect, and Google Scholar using the following search strategy: (trauma* OR injury) AND (head OR brain OR craniocerebral) AND (child OR pediatric OR paediatric OR infant OR adolescent) AND (accident* OR traffic OR fall*).

The following filters were applied: publication date from January 1, 2019, to August 21, 2024; full-text availability; and English language. No geographical restrictions were imposed.

The initial search yielded 19,483 records (PubMed: 78, ScienceDirect: 558, Wiley: 1,347, Google Scholar: 17,500). The study selection process is illustrated in the PRISMA flow diagram (Figure 1). The inclusion criteria for this review focused strictly on articles addressing pediatric head injuries in the context of accidents. Eligible studies included original research articles with clearly described study designs (e.g., cross-sectional, cohort, case–control, or clinical trials). Only full-text articles published between 2019 and 2024 were considered. Case reports, review papers, conference abstracts, and studies lacking sufficient methodological description were excluded. Studies specifically examining adult populations or head trauma caused by child abuse were also excluded. To ensure reliability, only studies that presented measurable outcomes relevant to epidemiology, prevention, management, or diagnostic methods in pediatric head trauma were included. Article screening and data extraction were performed independently by two reviewers to minimize the risk of selection bias. Any disagreements were resolved through discussion or consultation with the corresponding author.

To ensure consistency and reliability, eligible studies were required to present a clearly described methodology, a defined study population, and measurable outcomes related to pediatric head trauma. These criteria provided a structured basis for evaluating the strength of evidence and minimizing the inclusion of studies with insufficient methodological transparency.

The included articles were then categorized into four groups for detailed analysis: (1) Epidemiology and Prevention, (2) Management, (3) Diagnosis, and (4) Imaging Findings. Each section was synthesized and integrated by the authors, with the corresponding author supervising the final manuscript to ensure clarity and coherence.

This approach ensured a systematic and rigorous review of the literature, providing valuable insights into pediatric head trauma across multiple disciplines—from epidemiology and prevention to diagnostic methods and imaging techniques. The team-based approach ensured that each area was thoroughly explored, and all contributions were carefully reviewed for accuracy and consistency.

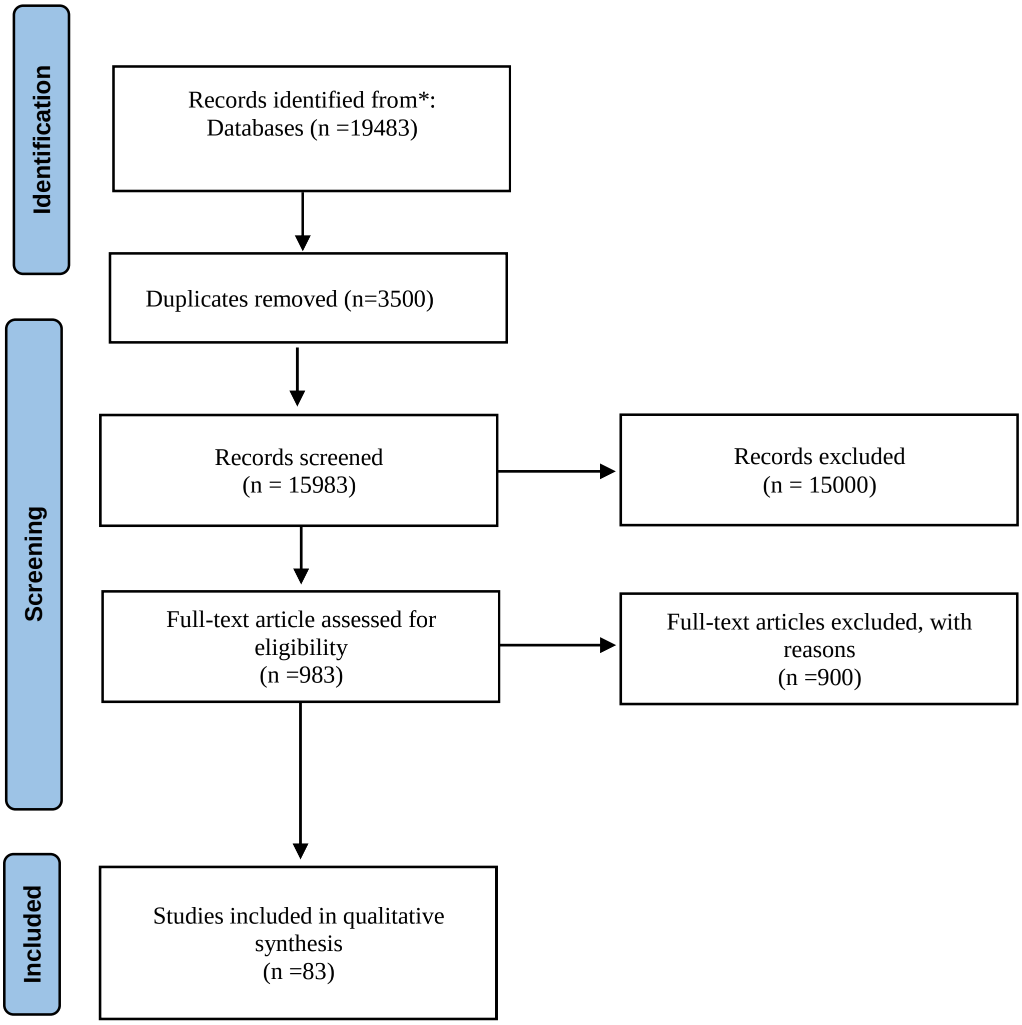

Fig 1. PRISMA Flow Diagram

Results

A total of 83 studies published between 2019 and 2024 were included in this systematic review (Figure 1). Most studies were retrospective cohort designs (n = 52, 62.7%), followed by cross-sectional (n = 19, 22.9%) and prospective cohort studies (n = 12, 14.5%). The studies were conducted in 28 countries, with the largest contributions from the United States (n = 18), Brazil (n = 7), Iran (n = 6), and Germany (n = 5). Sample sizes ranged from 91 to over 2.5 million children. Detailed characteristics of the included studies are presented in Table 1, and the quality assessment using the Newcastle-Ottawa Scale is summarized in Table 2.

Following the descriptive overview and tabulated presentation of study characteristics and quality scores, the results are further elaborated in the next subsections. This expanded synthesis organizes the findings into key domains—including epidemiology, prevention, management, diagnosis, and imaging—to provide a clearer understanding of the patterns and implications of pediatric traumatic brain injury.

3.1. Epidemiology

The incidence of pediatric TBI varies significantly across regions, ranging from 47 to 280 per 100,000 children [20]. In the United States, 2.5 million emergency department visits for TBI were recorded in 2014, with over 812,000 involving pediatric patients. Among these, 56,800 resulted in death, including 2,529 pediatric fatalities [21]. Additionally, hospitalization and mortality data have been reported in several countries, including the United States, Brazil, Germany, and France (Figure 2).

Prevention

Traffic accidents are a leading cause of head and facial injuries in children. The prevalence of non-use of safety devices is highest among children under 6 years old [25]. While seatbelts and airbags have been proven to reduce mortality, particularly in frontal and side-impact collisions [26], studies indicate that seat belts alone can increase the risk of head injuries by up to four times in children aged 2 to 5 years. For this reason, it is recommended that children remain in child restraint seats until at least the age of 4 or until they weigh 18 kilograms [27].

Management

The management of head trauma varies based on the patient's age and clinical condition. To assess and control traumatic brain injury (TBI) in children, the Pediatric Glasgow Coma Score (PGCS) is utilized to evaluate consciousness levels [10], while focal neurological signs at the time of injury are used to monitor the progression of pathological manifestations [11, 12]. Age has been identified as a potential prognostic factor in some analyses. The mortality rate decreases beyond the first year of life, with pediatric mortality (2.5%) being lower than that observed in adults (10%) [28]. In a five-year follow-up of 100 pediatric neurosurgical patients, 88% achieved favorable recovery, 14% showed lesion progression on follow-up CT, and 10% developed new pathological findings. Surgical intervention was necessary in 73% of cases, with postoperative complications in 27% [29].

Diagnosis

Computed tomography (CT) remains the most frequently used diagnostic tool, and several studies confirmed its accuracy in detecting intracranial hemorrhage or structural damage [13]. A significant association between pediatric CT brain imaging and increased risk of brain tumors has been observed (P = 0.0003) [15]. Hospital observation has been described as an alternative for mild cases, although it is generally costlier than CT [8, 30].

Abbreviated brain MRI (AB-MRI) has been investigated as an alternative imaging modality. Reported advantages include patient-centered imaging that targets affected regions [17], removal of redundant sequences to reduce scan time while maintaining accuracy [16], and elimination of radiation exposure [18]. A comparative analysis of the advantages and disadvantages of CT, AB-MRI, and X-ray imaging is presented in Table 3.

The Pediatric Emergency Care Applied Research Network (PECARN) rule has demonstrated high sensitivity in identifying clinically significant TBI. In children under 2 years with mild head trauma, PECARN achieved a sensitivity of 94.3%, specificity of 41.3%, and a negative likelihood ratio of 0.14 [34]. Another study identified headache, dizziness, and scalp hematoma as significant predictors of TBI in mild blunt head trauma [37]. These results emphasize the role of clinical evaluation tools in enhancing diagnostic precision while reducing unnecessary CT imaging in children.

Imaging Findings

The most frequently reported abnormalities in pediatric head trauma include epidural hematoma, skull fracture, and parenchymal contusions [38]. In a one-year study of 43,389 ED visits, 2,515 patients (5.7%) underwent cranial CT, of which 1,152 (45.8%) were for traumatic injuries. Abnormal findings were present in 68 patients (5.9%), most commonly linear skull fractures [14]. Rates of CT utilization varied across centers, though the proportion of clinically significant TBI detected remained relatively stable [39]. This finding contrasts with other research, where injury rates and CT detection rates remained correlated, even after adjusting for injury prevalence [40-42]. Their study also suggested that some TBIs might go undiagnosed due to the relatively low imaging rates, which remained below 20% across different healthcare settings [42].

A summary of key parameters from the included studies, including population, mechanism of injury, diagnostic tools, incidence rates, and main outcomes, is presented in Table 4.

Table 1. Characteristics of included studies

First Author	Year	Country	Study Design	Sample Size	Age Range	Main Mechanism	Key Finding
Peterson	2019	USA	Registry	>2.5 million	0–19 y	Mixed	812,000 pediatric TBI ED visits
Bruns	2021	Germany	Population-based	National data	<18 y	Mixed	687/100 k hospitalizations
de Souza	2023	Brazil	National database	National data	Pediatric	Mixed	45.3 admissions/100 k/y
Alghnam	2020	Saudi Arabia	Cross-sectional	253	≤16 y	MVC	38.3% head injury
Winston	2000	USA	Crash analysis	~13,853	2–5 y	MVC	Seatbelt increases head injury risk 4×
Trifa	2024	Tunisia	Retrospective	100	Pediatric	Falls & RTA	88% favorable recovery
Kim	2023	South Korea	Retrospective	433	<2 y	Minor head trauma	PECARN sensitivity 94.3%
Song	2020	Malaysia	Retrospective	274	Pediatric	Minor head trauma	Headache & hematoma predictive
Stanley	2014	USA	Multicenter	Multiple centers	Pediatric	Minor head trauma	36% CT use
Egbohou	2019	Togo	Retrospective	91	Pediatric	RTA 79%	31.9% mortality
Guan	2023	Global	GBD 2019	Global data	0–19 y	Mixed	Falls leading cause globally

Table 2. Quality assessment using the Newcastle-Ottawa Scale (NOS)

First Author	Year	Selection (max 4★)	Comparability (max 2★)	Outcome/Exposure (max 3★)	Total Score	Quality
Peterson	2019	★★★★	★★	★★★	9/9	Good
Bruns	2021	★★★★	★★	★★★	9/9	Good
de Souza	2023	★★★★	★	★★★	8/9	Good
Alghnam	2020	★★★	★	★★	6/9	Fair
Trifa	2024	★★★	★	★★★	7/9	Good
Kim	2023	★★★★	★★	★★	8/9	Good
…						

Table 3. Summary of findings from included studies on pediatric head trauma(14, 16-18, 31-36)

	Advantages	Disadvantages
X-RAY	• Indicating bone fractures	• Failure to detect a large number of fractures (19.1%) compared to other methods • Not visualizing brain tissue • Not detecting intracranial haemorrhages i.e. extradural haemorrhage (EDH), intracerebral haemorrhage, haemorrhagic contusions • Very low diagnostic value in TBI; Less sensitivity and specificity than other methods
Abbreviated MRI	• Patient-centered radiology trends • Improving patient satisfaction • Reducing timetable • Eliminating external, redundant, or irrelevant sequences	• Lack of knowledge of radiology personnel about new technology • Expensive
Traditional brain MRI	• Accurate and sensitive imaging modality to identify brain injury as compared to head CT scan	• The duration of a conventional brain MRI (30 minutes or more) • Challenging for children to tolerate requirements for prolonged immobility • Confined space • loud mechanical noises • Lack of efficiency in emergencies
CT-SCAN	• New low-radiation protocol technology • Availability • High-quality and detailed images	• risk of high radiation almost 200 times that of lung X-ray • risk of contrast agent for kidney patients (If contrast agent is used) • inherent technical restrictions such as ray hardening artifact (This may lead to failure to visualize some of the intracranial lesions)

Table 4.Summary of Key Parameters from Included Studies

Population / Sample	Mechanism / Cause	Diagnostic Tool	Incidence / Rate	Main Outcome	Category	Ref No.
National US data (2014)	Mixed causes	—	2.8M ED TBI visits; 56,800 deaths (2,529 pediatric)	High national burden; 812k pediatric cases	Epidemiology	(21)
Germany, <18 y (2014–18)	—	CT	687/100k hospitalizations; 0.1% mortality	Low mortality, low neurosurgical rate	Epidemiology	(22)
Brazil national database (1992–2021)	—	—	45.3 admissions/100k/y; lethality 3.2%	Mean LOS 4.2 days; cost ≈ $417/admission	Epidemiology / Health-economics	(23)
Saudi Arabia, ≤16 y (n=253)	MVC	—	38.3% head injuries	53.8% unrestrained; 34.8% facial injuries	Epidemiology / Prevention	(25)
Crash victims, 2–5 y (n≈13,853)	Motor vehicle	—	RR head injury 4.2 (seatbelt vs CRS)	CRS much safer than seatbelt	Prevention	(27)
100 children, Tunisia	Falls, RTAs	—	Mortality 2.5%; recovery 88%	Early intervention improves outcomes	Management	(29)
<2 y mild TBI (n=433)	Falls, RTAs	PECARN rule	Sens 94.3%, Spec 41.3%	Accurate to exclude ciTBI	Diagnosis	(34)
Malaysia, n=274	Minor head trauma	CT	49% abnormal CT	Headache, dizziness, scalp hematoma = risk	Diagnosis	(37)
US pediatric hospitals	Minor head injury	CT	36% CT use (median)	Decrease over 5 years	Imaging utilization	(41)
ICU Lome, n=91	RTA 79.1%, Falls 19.8%	CT	Mortality 31.9%	Brain edema 72.9%, fractures 69.5%	Management / Imaging	(43)
Global (1990–2019)	Mixed causes	—	27.16M new cases (2019)	Falls leading cause globally	Epidemiology	(44)

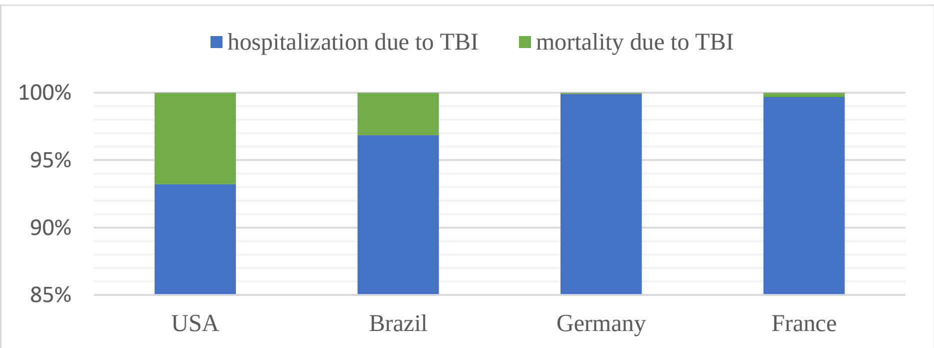

Fig 2. Hospitalization and mortality statistics of children with TBI (11, 22-24)

Discussion

Traffic accidents are the leading cause of death among children under 14 years of age in Iran, accounting for 37.5% of fatalities [19, 45], while in the United States, the same cause accounts for 56.06% of deaths in children aged 14–17 [6]. This disparity in age groups may be due to several factors. In Iran, over 85% of parents lack sufficient knowledge to select the appropriate child restraint seat based on their child's age and weight, and 98% are unaware of the role booster seats play in protecting children under 14 in cars [46]. In contrast, in the United States, the issue is often linked to children aged 14–17 driving without seat belts and engaging in risky, demonstrative driving influenced by peers [6]. Additionally, one of the most frequently cited reasons young people give for not using safety equipment is the perceived poor quality of materials used in these devices [47-52].

Head trauma in children is most commonly caused by road traffic accidents, accounting for 55.3% of pediatric injuries in Iran. Falls from heights are the second most frequent cause, accounting for 39.5% of cases, while isolated head trauma accounts for 5.3% [53]. Similar trends are seen in other parts of the world, including the United States and Togo, where traffic accidents and falls are the leading causes of pediatric head trauma [6, 43]. In children under 12 years, falls are more prevalent, while in adolescents, traffic accidents dominate [29]. Despite these age-related trends, some studies suggest that falls remain the leading cause of traumatic brain injury (TBI) across various populations, regardless of age [11]. This variation in causes across different regions and countries can be attributed to several factors, including socio-economic conditions, healthcare accessibility, and preventive measures. For instance, in some countries, the use of child safety seats, helmets, and other protective measures is more widespread, leading to lower injury rates from road accidents. Conversely, regions with limited access to healthcare or poor infrastructure may experience higher rates of severe injuries from road accidents and falls. Furthermore, cultural differences and parenting practices can also influence the prevalence of certain types of trauma. These disparities underscore the importance of addressing not only the immediate causes of head trauma but also the broader socio-economic and cultural factors that contribute to these injuries. Public health campaigns, improved safety regulations, and better access to emergency care are essential for reducing the incidence of traumatic head injuries, particularly in vulnerable populations such as children and adolescents [44].

Management of pediatric traumatic brain injury (TBI) requires the implementation of optimal healthcare practices, employing a multidisciplinary approach throughout each phase of care. Following the initial assessment, prompt diagnosis, continuous multimodal monitoring, and effective management of intracranial pressure are crucial to reducing or preventing further complications. The mortality rate in children with TBI is considerably lower than in adults (2.5% vs. 10%) [28]. This may be explained by differences in physiology and injury tolerance, as well as improvements in pediatric trauma management. The outcome of pediatric head injuries relies heavily on the availability of advanced imaging techniques and the ability to perform timely and accurate surgical procedures. These findings highlight the importance of early neurosurgical intervention and appropriate monitoring in reducing complications and improving long-term outcomes. However, prevention remains the most effective approach, which involves creating a safe and supportive environment for children [29].

Although CT remains the gold standard for diagnosis, alternatives such as AB-MRI and the PECARN rule show promise in reducing unnecessary radiation exposure without compromising diagnostic accuracy [16-18, 35]. Wider implementation of these methods could improve patient safety. Radiation risks associated with CT scans have raised concern, particularly given children's increased sensitivity. Interpretation of neuroimaging data further emphasizes the limited diagnostic yield of CT in mild trauma cases. Despite the increasing availability of advanced imaging, many children still undergo CT unnecessarily, underscoring the importance of clinical decision rules.

Preventive strategies, including child restraint seats and seatbelts, remain critical. However, evidence shows that improper or premature use of seatbelts increases head injury risk, highlighting the need for parent education and stricter enforcement of traffic laws [26-28].

This study compared the variations and commonalities of pediatric TBI across different regions globally. However, data regarding pediatric head trauma in Iran are outdated and limited, emphasizing the need for future studies to update trauma statistics in children, investigate associated complications, and assess the burden on the healthcare system. Additionally, evaluating the effectiveness of current imaging practices in Iran is crucial, as is determining how many CT scans conducted were genuinely necessary and how many were performed unnecessarily.

Together, these findings highlight both advances and gaps in the management and prevention of pediatric head trauma. Future studies should aim to update regional epidemiological data, refine imaging protocols, and evaluate the effectiveness of safety interventions.

This systematic review was conducted following PRISMA 2020 guidelines. The majority of included studies were of good methodological quality according to the Newcastle-Ottawa Scale (Table 2). Limitations include the absence of a formal meta-analysis due to high heterogeneity of study designs and outcomes, and the restriction to English-language publications.

Limitations

Although this review followed PRISMA 2020 guidelines and included quality assessment using the Newcastle-Ottawa Scale, a formal meta-analysis was not feasible due to the high heterogeneity in study designs, populations, and outcome measures. Additionally, the search was limited to English-language publications, which may have excluded relevant studies in other languages.

Conclusion

Pediatric TBI is a major neurological issue that poses a significant burden on public health worldwide. Traffic accidents remain the leading cause of TBI in children. Improving road safety through stricter vehicle and traffic regulations, as well as educating parents about child restraint systems, can reduce this risk.

While CT scans are crucial for diagnosis, the potential long-term risks of radiation exposure—particularly in children—highlight the importance of alternative methods such as AB-MRI and clinical observation to reduce unnecessary imaging. This will help minimize health risks and improve patient care.

Future research should update statistics on pediatric head trauma, especially in regions with outdated data, and assess the effectiveness and necessity of current diagnostic methods. Optimizing these practices can improve outcomes and reduce the economic burden associated with pediatric TBI.

Acknowledgments

We want to express our sincere gratitude and appreciation to the Guilan Road Trauma Research Center, Guilan University of Medical Sciences.

Conflict of Interest Disclosures

The authors have no relevant financial or non-financial interests to disclose.

Funding Sources

No funding was received to assist with the preparation of this manuscript.

Authors' Contributions

Rezvaneh Varasteh (Writing an original draft, Conceptualization, Investigation), Hadise Azizi (Data curation, Formal Analysis), Tahoura Pourakobary (Writing an original draft and summarize), Fateme Rahmati (Investigation, Statistical analysis), Shiva Mohammadjani Kumeleh (Writing review & editing, Conceptualization), and Javad Vatani (Supervision, Project administration, Writing review & editing)

Ethical Statement

Ethical committee of Baqiyatallah University of Medical Sciences confirmed the protocol of this study.

Declaration of Generative AI and AI-assisted technologies

None.

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