Research Article / Araştırma Makalesi

Selective Computed Tomography Use in Pediatric Head Trauma: Clinical Challenges and Recommendations for Children Under Two Years

Pediatrik Kafa Travmasında Seçici Bilgisayarlı Tomografi Kullanımı: İki Yaş Altı Çocuklarda Klinik Zorluklar ve Öneriler

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Abstract

Background: Head trauma in children under two years of age is a significant public health concern frequently encountered in emergency departments. Due to the unique anatomical and physiological characteristics of this age group, accurate clinical evaluation and appropriate management remain challenging. This study aimed to examine the epidemiological characteristics, clinical presentations, imaging practices, and clinical outcomes of pediatric head trauma cases in this vulnerable age group. Additionally, it assessed adherence to established international clinical guidelines and sought to provide practical suggestions to minimize the unnecessary use of computed tomography (CT) imaging.
Materials and Methods: In this retrospective observational study, medical records of 2,074 pediatric patients aged 0–24 months who presented to the emergency department of a tertiary care training and research hospital with head trauma between January 1, 2015, and December 31, 2015, were analyzed. Data collected included patient demographics, mechanisms of injury, clinical findings, Glasgow Coma Scale (GCS) scores, indications for CT imaging and results, and clinical follow-up information. All data were analyzed using descriptive statistics, logistic regression, and receiver operating characteristic (ROC) curve analysis.
Results: Falls were the most common mechanism of injury, accounting for 64.6% of cases. CT scans were performed in 64.6% of the patients; however, clinically significant intracranial injuries were detected in only 10.4%. Loss of consciousness (OR=1.75) and scalp hematoma (OR=1.62) were identified as the strongest independent predictors of positive CT findings. ROC analysis demonstrated moderate predictive performance (AUC=0.72), indicating that clinical assessment alone provides limited accuracy in guiding imaging decisions.
Conclusions: Despite well-established international guidelines, CT scans continue to be overused in pediatric head trauma cases among children under two years of age. Implementing structured clinical decision tools such as the *Pediatric Emergency Care Applied Research Network* (PECARN) criteria, along with targeted educational programs for healthcare providers and parents, is critical to minimizing unnecessary radiation exposure, enhancing patient safety, and improving clinical outcomes. Future studies should investigate alternative imaging modalities, such as rapid-sequence MRI, and structured observation protocols to better determine their practicality and effectiveness. Ultimately, reducing unnecessary CT use requires a multifaceted approach that includes strict adherence to guidelines, structured educational initiatives, active parental involvement, and exploration of safer imaging methods. Such a comprehensive strategy will help ensure optimal care and improved patient safety in pediatric head trauma.

Keywords: Pediatric Head Trauma, Computed Tomography, PECARN Guidelines, Emergency Department, Radiation Exposure

Öz

Amaç: İki yaşından küçük çocuklarda kafa travması, acil servislerde sık karşılaşılan önemli bir halk sağlığı sorunudur. Bu yaş grubunun kendine özgü anatomik ve fizyolojik özellikleri nedeniyle, doğru klinik değerlendirme ve uygun yönetim stratejileri önemli bir güçlük olmaya devam etmektedir. Bu çalışma, iki yaş altı çocuklarda görülen kafa travması olgularının epidemiyolojik özelliklerini, klinik bulgularını, görüntüleme uygulamalarını ve klinik sonuçlarını değerlendirmeyi amaçlamıştır. Ayrıca, uluslararası klinik kılavuzlara uyum düzeyini belirleyerek gereksiz bilgisayarlı tomografi (BT) kullanımını azaltmaya yönelik pratik öneriler sunmayı hedeflemiştir.
Materyal ve Metod: Retrospektif, gözlemsel nitelikteki bu çalışmada, 1 Ocak – 31 Aralık 2015 tarihleri arasında üçüncü basamak bir eğitim ve araştırma hastanesi acil servisine kafa travması nedeniyle başvuran 0–24 ay arasındaki 2074 çocuğun tıbbi kayıtları incelendi. Hastaların demografik özellikleri, travma mekanizmaları, klinik bulguları, Glasgow Koma Skalası (GKS) skorları, BT görüntüleme endikasyonları ve sonuçları ile klinik izlem verileri kaydedildi. Toplanan veriler tanımlayıcı istatistikler, lojistik regresyon ve ROC analizleri kullanılarak değerlendirildi.
Bulgular: Çalışmaya dahil edilen 2074 hastanın en sık travma mekanizması düşme olarak saptandı (%64,6). Hastaların %64,6'sına BT uygulandı; ancak bunların yalnızca %10,4'ünde klinik olarak anlamlı intrakraniyal bulgular tespit edildi. Pozitif BT bulguları açısından en güçlü belirleyiciler bilinç kaybı (OR=1,75) ve saçlı deri hematomu (OR=1,62) olarak belirlendi. ROC analizi, klinik değerlendirmenin tek başına görüntüleme kararı vermede orta düzeyde güvenilir olduğunu gösterdi (AUC=0,72).
Sonuç: Uluslararası kılavuzlara rağmen, iki yaş altı pediatrik kafa travması vakalarında BT kullanımı halen gereğinden fazladır. Gereksiz radyasyon maruziyetini en aza indirmek, hasta güvenliğini artırmak ve klinik sonuçları iyileştirmek için *Pediatrik Acil Bakım Uygulamalı Araştırma Ağı (*PECARN) gibi yapılandırılmış klinik karar protokollerinin uygulanması ve sağlık profesyonelleri ile ebeveynlere yönelik eğitim programlarının hayata geçirilmesi kritik öneme sahiptir. Gelecekteki çalışmalar, hızlı-sekanslı MR gibi alternatif görüntüleme yöntemlerinin ve yapılandırılmış gözlem protokollerinin uygulanabilirliğini ve etkinliğini daha detaylı olarak incelemelidir. Nihayetinde, gereksiz BT kullanımının azaltılması, kılavuzlara tam uyum, yapılandırılmış eğitim programları, aktif ebeveyn katılımı ve daha güvenli görüntüleme yöntemlerinin araştırılmasını içeren çok yönlü bir strateji gerektirir. Böyle bir yaklaşım, pediatrik kafa travmalarında optimal bakım ve hasta güvenliğini sağlayacaktır.

Anahtar Kelimeler: Pediatrik Kafa Travması, Bilgisayarlı Tomografi, PECARN Kılavuzları, Acil Servis, Radyasyon Maruziyeti

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Introduction

Head trauma is among the most frequent reasons for pediatric emergency department visits worldwide, especially in children younger than two years of age. Due to specific anatomical and physiological features at this age - including incomplete skull ossification, a relatively larger head-to-body size ratio, and developmental immaturity - infants and toddlers are highly vulnerable to serious intracranial injury even from apparently minor trauma (1, 2). Clinical assessment and management decisions in this population are particularly challenging because of limited verbal communication and often nonspecific symptoms (3, 4).

Computed tomography (CT) is a critical diagnostic tool for detecting traumatic brain injuries in children; however, it carries substantial risks associated with ionizing radiation. Childhood exposure to CT scan radiation has been linked to an increased long-term risk of malignancies, underscoring the need to avoid unnecessary CT use (5-7). This creates a complex clinical dilemma, as physicians must balance the imperative of not missing a potentially life-threatening injury against the risks associated with unnecessary imaging.

A pivotal development in the rational management of pediatric head trauma has been the creation of the Pediatric Emergency Care Applied Research Network (PECARN) clinical prediction rule. Derived from the largest prospective pediatric head injury study to date, PECARN is designed to identify children at very low risk of clinically important traumatic brain injury (ciTBI), allowing for safe avoidance of CT scanning in such cases (8). The rule is particularly notable for its validation in infants under two years of age, where it incorporates key high-risk indicators such as a Glasgow Coma Scale score less than 15, altered mental status, palpable skull fracture, and non-frontal scalp hematoma. In this high-vulnerability group, the PECARN algorithm has demonstrated nearly 100% sensitivity and negative predictive value for ciTBI, with multiple validation studies confirming its reliability and safety across diverse emergency department settings (8, 9). Subsequent multicenter research from different healthcare systems has also reinforced the robust performance of PECARN, supporting its use as a standard of care for selective imaging in pediatric head trauma (10). The widespread implementation of PECARN in clinical protocols has been associated with significant reductions in unnecessary CT scans without an increase in missed clinically important injuries, highlighting its critical role in improving both diagnostic accuracy and patient safety (10-13).

Despite the availability of these evidence-based guidelines, CT imaging continues to be over-utilized in the management of pediatric head trauma in real-world practice (11). In our setting, as in many others, the excessive use of CT in young children may stem from medicolegal concerns (physicians' fear of missing a diagnosis) as well as the inherent difficulty of accurately assessing neurological status in preverbal patients. These factors can contribute to variability in practice and may lead clinicians to order CT scans even when clinical decision rules suggest that imaging is not necessary, thereby increasing children's exposure to radiation.

Therefore, the present study aimed to provide detailed epidemiological data, clinical characteristics, and imaging outcomes for children under two years old presenting with head trauma at a tertiary emergency department. Additionally, we sought to evaluate adherence to international head trauma guidelines in this context and to discuss strategies for reducing unnecessary radiation exposure in this vulnerable patient group.

Materials and Methods

Study Design and Setting

This study was a retrospective observational analysis of pediatric head trauma cases. We reviewed the records of patients aged 0-24 months who presented with head injury to the emergency department of a tertiary care center in Turkey between January 1, 2015 and December 31, 2015. The hospital is a high-volume referral center for pediatric emergencies, including trauma. During the study period, no formal institutional protocol (such as PECARN) was mandated for pediatric head trauma imaging; decisions to perform a CT scan were made according to the treating physician's clinical judgment and prevailing standard practices.

Data Collection

Data were collected retrospectively from electronic medical records using a structured form. The variables recorded included patient demographics (age, sex), mechanism of injury (e.g., fall, blunt trauma, motor vehicle collision, suspected abuse), clinical findings on presentation (such as loss of consciousness, vomiting, scalp hematoma, irritability or abnormal behavior), initial GCS score, indications for obtaining a CT scan (if performed), the results of cranial CT imaging, and patient outcomes (disposition from the emergency department, need for hospital admission, or death).

Inclusion and Exclusion Criteria

We included all patients between 0 and 24 months of age who presented with isolated head trauma (with or without minor extracranial injuries). Patients with polytrauma involving other major injuries, those with incomplete medical records, or those who were transferred to another facility for specialized care were excluded from the analysis to maintain a focused and reliable dataset. A total of 2,293 eligible patients were identified during the study period; of these, 219 were excluded based on the criteria above, leaving 2,074 patients in the final study cohort.

Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics version 21.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics (means, standard deviations, frequencies, and percentages) were used to summarize patient demographic and clinical characteristics. Logistic regression analysis was conducted to identify independent predictors of clinically significant findings on CT (such as skull fractures or intracranial hemorrhages). Variables for the regression model were chosen based on clinical relevance and initial univariate analyses. We reported odds ratios (OR) with 95% confidence intervals (CI) for significant predictors. The discriminatory ability of clinical features to predict CT outcomes was further evaluated using ROC curve analysis. The area under the ROC curve (AUC) was calculated as an aggregate measure of test performance. An AUC of 0.5 indicates no discrimination (no better than chance), whereas an AUC of 1.0 indicates perfect discri mination; we interpreted the AUC values using conventional thresholds (e.g., ~0.7 as moderate accuracy). A p-value < 0.05 was considered statistically significant for all analyses.

Results

Patient Characteristics

A total of 2,074 pediatric patients aged 0-24 months were included in the study (after excluding 219 cases that did not meet the inclusion criteria). The cohort was 55.2% male (n = 1,145), and the mean age was 13.4 ± 6.1 months. The vast majority of injuries were minor, with 99.9% of patients (n = 2,072) presenting with a mild traumatic brain injury (GCS 13-15). Only 2 patients (0.1%) had severe trauma with GCS ≤ 8 on arrival. Table 1 summarizes the demographic and clinical characteristics of the study population

Table 1. Demographic and Clinical Characteristics of Patients

Characteristic	**Number (n=2074)**	**Percentage (%)**
Gender (Male)	1145	55.2
Mean age (months ± SD)	13.4 ± 6.1	-
Injury Mechanism		
Falls	1340	64.6
Blunt trauma	493	23.8
Motor vehicle accidents	40	1.9
Suspected child abuse	3	0.1
Clinical Findings		
Scalp hematoma	348	16.8
Scalp laceration	327	15.8
Vomiting	217	10.5
Irritability or abnormal behavior	191	9.2
Loss of consciousness	77	3.7
Glasgow Coma Scale (GCS)		
Mild (13–15)	2072	99.9
Severe (≤8)	2	0.1
Hospital admission rate	127	6.1
Mortality	2	0.1

Mechanisms of Injury

Falls were by far the most common mechanism of head injury, accounting for 64.6% of cases (n = 1,340) (Figure 1). Other documented mechanisms included blunt trauma (23.8%, n = 493), motor vehicle collisions (1.9%, n = 40, often involving the child as a passenger in car accidents), and suspected non-accidental trauma (child abuse), which was rare (0.1%, n = 3). The predominance of falls highlights the typical injury pattern in this age group, where infants and toddlers often fall from furniture, beds, or while being carried.

Clinical Findings on Presentation

Notably, 39.7% of patients (n = 824) had no remarkable clinical symptoms or signs reported at presentation, despite the history of head injury. Among those who did exhibit symptoms or exam findings, the most frequent was scalp hematoma, observed in 16.8% of patients (n = 348). Scalp lacerations were present in 15.8% (n = 327), and vomiting was documented in 10.5% (n = 217). Irritability or other changes in behavior (suggestive of possible concussion in a preverbal child) were noted in 9.2% (n = 191).

A history of loss of consciousness (even a brief LOC, as could be determined from witness accounts) was recorded in 3.7% of cases (n = 77) (Figure 2).
It is important to note that in many infants it can be challenging to ascertain symptoms like headache or dizziness; thus, these percentages likely underestimate the true prevalence of milder symptoms that cannot be communicated by the patient.

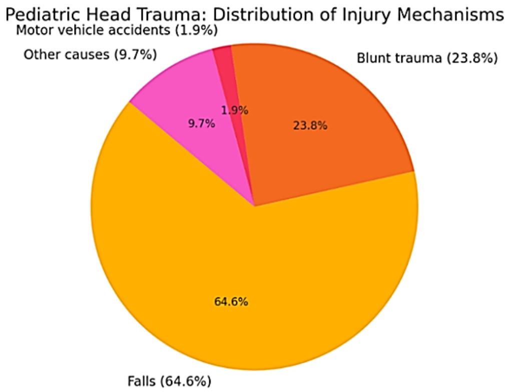

Figure 1. Distribution of Injury Mechanisms in Pediatric Head Trauma (n = 2,074)

CT Imaging Utilization
Out of the 2,074 patients, 1,340 (64.6%) underwent CT imaging of the head during the initial evaluation (Figure 3). The decision to perform a CT was made by the treating emergency physician based on clinical judgment, as per our institutional practice.
Nearly all of the patients who received a CT scan had presented with a mild TBI (GCS 13–15), reflecting that many scans were done in cases with relatively good initial neurological status. Among those who had a head CT, clinically significant findings (i.e., traumatic injuries identified on CT) were present in 140 patients, yielding a positive scan rate of 10.4% among imaged children (or 6.8% of the entire cohort). In other words, approximately 9 out of 10 scanned infants had no acute traumatic pathology visible on CT.

CT Findings
The most common significant injury detected on CT was a linear skull fracture, which was found in 97 patients (7.2% of scanned patients, corresponding to 4.7% of the total cohort). The second most common finding was intracranial hemorrhage, identified in 37 patients (2.8% of those who had CT, 1.8% of total) (Figure 4).
Based on the detailed analysis of cranial CT findings, isolated epidural hematoma was identified in 5 patients (0.4% of all scanned), while isolated subdural hematoma was detected in 8 patients (0.6%). Isolated subarachnoid hemorrhage (SAH) was observed in 9 cases (0.7%), and cerebral contusion was present in 5 patients (0.4%). Additionally, several patients exhibited combined lesions, such as linear skull fracture with epidural hematoma (n = 4), subdural hematoma (n = 4), or subarachnoid hemorrhage (n = 3). No cases of diffuse axonal injury were observed in this cohort (Table 2). These findings indicate that, in children under two years of age, intracranial hemorrhages detected on CT were predominantly focal events—most commonly epidural, subdural, or subarachnoid in nature, often associated with skull fractures or contusions. The absence of diffuse axonal injury and the generally low frequency of severe parenchymal involvement reflect the predominance of low-energy trauma mechanisms and the rarity of extensive brain injury in this young population.

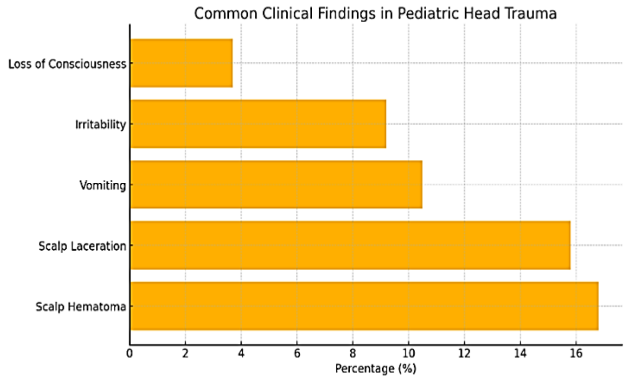

Figure 2. Common Clinical Findings in Pediatric Head Trauma and their frequencies.

Predictors of Positive CT Results: We performed a logistic regression analysis to determine which clinical variables were independently associated with having a positive CT scan (i.e., showing a skull fracture or intracranial injury). The analysis revealed two significant predictors: loss of consciousness and scalp hematoma. Patients with a reported loss of consciousness had an OR = 1.75 (95% CI: 1.30–2.32, $p < 0.01$) for a positive CT finding, meaning they were about 1.75 times more likely to have an injury on CT than those without an LOC, holding other factors constant. Similarly, patients who had a scalp hematoma on exam had an OR = 1.62 (95% CI: 1.22–2.18, $p < 0.01$) for a positive CT. These two factors remained significant in the multivariable model, whereas other clinical features did not. Notably, other symptoms such as vomiting or irritability (which were relatively common in the cohort) were not found to be independent predictors of intracranial injury after controlling for the presence of LOC and scalp hematoma. Table 3 presents the summary of CT findings and the odds ratios for key clinical predictors.
To assess the overall performance of these clinical factors in predicting traumatic brain injuries, we conducted an ROC curve analysis.

Table 2. Distribution of Cranial CT Findings, Including Intracranial Hemorrhage Subtypes, in Patients Under Two Years Old.

CT Finding	Number of Patients (n)	% of Total Patients (n=2,074)	% of Patients with CT (n=1,340)
Isolated linear skull fracture	86	4.1%	6.4%
Isolated depressed skull fracture	9	0.4%	0.7%
Linear + depressed fracture	2	0.1%	0.1%
Isolated epidural hematoma	5	0.2%	0.4%
Isolated subdural hematoma	8	0.4%	0.6%
Isolated subarachnoid hemorrhage (SAH)	9	0.4%	0.7%
Isolated intraparenchymal hemorrhage	2	0.1%	0.1%
Cerebral contusion	5	0.2%	0.4%
Linear fracture + epidural hematoma	4	0.2%	0.3%
Linear fracture + subdural hematoma	4	0.2%	0.3%
Linear fracture + subarachnoid hemorrhage (SAH)	3	0.1%	0.2%
Depressed fracture + subdural hematoma	1	0.0%	0.1%
Linear fracture + SAH + subdural hematoma	1	0.0%	0.1%
Traumatic cerebral edema	1	0.0%	0.1%
No acute traumatic finding (Normal CT)	1,200	57.9%	89.6%
CT not performed	734	35.4%	–
Total	2,074	100%	100%

The aggregate predictive ability of the clinical assessment (using the combination of features in our model) was moderate, with an area under the curve (AUC) of 0.72 (95% CI ~0.68–0.76). This AUC suggests that while our model was better than chance at identifying which patients had injuries, there were considerable limitations to its accuracy. In practical terms, an AUC of 0.72 indicates that there is overlap between the clinical profiles of children with and without injuries — no perfect separation. Therefore, using clinical judgment alone (even when informed by the predictors identified) would result in some missed injuries or, alternatively, a high rate of scans to catch all injuries.

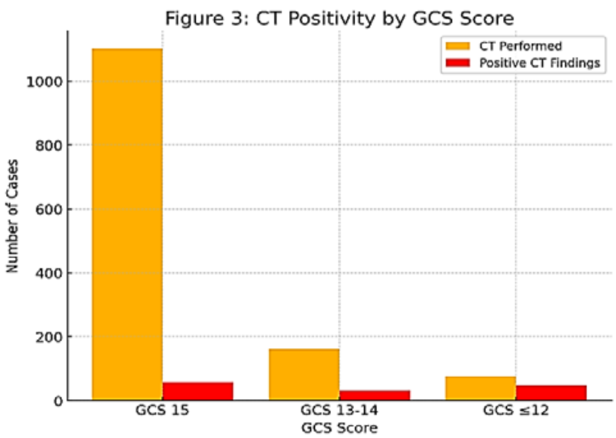

Figure 3. Proportion of Patients Undergoing CT Imaging, Stratified by GCS Score.

Based on the ROC analysis, we evaluated potential decision thresholds to translate this model into practice. Table 4 summarizes the diagnostic performance (sensitivity and specificity) of different approaches to deciding which patients should undergo CT imaging:

As shown in Table 4, our actual practice in this cohort (which involved liberal use of CT at the physicians' discretion) achieved nearly 100% sensitivity for detecting significant injuries, but at the cost of a very low specificity (~38%), meaning many children without injuries were scanned. The PECARN rule, if it had been strictly applied to our patients, would also have achieved 100% sensitivity (no missed injuries) with a moderate improvement in specificity (~53% of those without injury would avoid scanning). Using a simple two-factor rule based on our study's predictors (scanning if either LOC or a scalp hematoma is present) could further improve specificity to roughly 86%, but with a slight drop in sensitivity (we estimate ~93% in our dataset) as a few injuries would have been missed by this narrower criterion. Conversely, a very strict rule of scanning only if both LOC and scalp hematoma were present yields a very high specificity (~98%) but misses the majority of injuries (sensitivity ~20%), and thus would be an unsafe strategy. These analyses underscore the trade-offs involved in decision-making: rules that achieve higher sensitivity invariably do so at the expense of more false positives (lower specificity), whereas tightening criteria to improve specificity risks missing significant injuries.

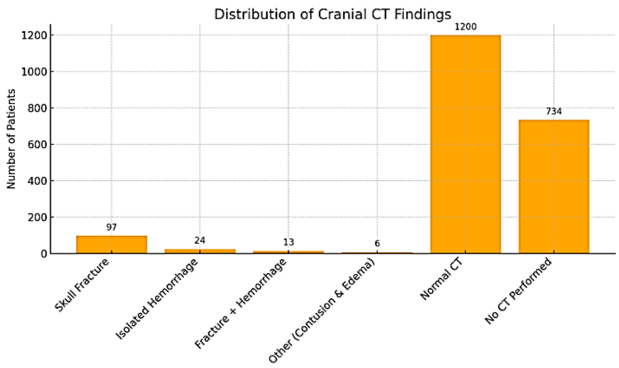

Figure 4. CT Utilization and Positive Findings (number of CT scans performed versus how many showed positive traumatic findings).

Patient Disposition and Outcomes

Despite the relatively low rate of significant findings on CT, a subset of patients required further care. In our cohort, 127 children (6.1%) were admitted to the hospital for observation or treatment following the emergency evaluation. The criteria for admission typically included the presence of a significant injury on CT, worrisome symptoms (like persistent vomiting or lethargy), or other clinical concerns such as suspected abuse. The vast majority of hospitalized patients were observed and managed conservatively; only a very small number required any neurosurgical intervention (for example, one patient underwent evacuation of an epidural hematoma).

The overall outcomes were favorable in this population. The mortality rate in this study was extremely low. There were 2 deaths (0.1% of the total sample). Both fatal cases involved severe mechanisms: one infant suffered a fatal head injury in a high-speed motor vehicle accident, and the other was a child who fell from a significant height (greater than two stories). These cases underscore that while uncommon, severe trauma can result in catastrophic outcomes even in this young age group. Importantly, no deaths or life-threatening complications occurred among children who were initially sent home from the emergency department without a CT; both fatalities were among those appropriately identified as high risk, who underwent CT scanning and were admitted, but unfortunately succumbed to their injuries despite intervention.

Table 3. Summary of CT Findings and Odds Ratios for Clinical Predictors of Positive CT Results.

CT Scan Outcome	Number of Patients (% among scanned)	Clinical Predictor	OR (95% CI)	p-value
CT performed (total scanned)	1,340 (100%)	**Loss of consciousness**	1.75 (1.30–2.32)	< 0.01
– Positive for trauma	140 (10.4%)	**Scalp hematoma**	1.62 (1.22–2.18)	< 0.01
• Skull fracture	97 (7.2%)	**Vomiting**	1.10 (0.80–1.52)	0.55
• Intracranial hemorrhage	37 (2.8%)	**Irritability/behavior change**	0.96 (0.67–1.37)	0.82
– No acute traumatic finding	1,200 (89.6%)			

(The table shows that only loss of consciousness and scalp hematoma were significantly associated with positive CT findings in the multivariate model; other factors like vomiting and irritability did not show a statistically significant independent effect.)

Table 4. *Sensitivity and Specificity of Different Imaging Decision Strategies for Detecting Clinically Important Brain Injury on CT.*

Imaging Decision Strategy	Sensitivity (%)	Specificity (%)
Actual clinical practice (physician judgment; CT obtained in 64.6% of patients)	~100	~38
PECARN rule (under age 2; recommend CT if any PECARN risk factor present)	100	53
Presence of either loss of consciousness or scalp hematoma (CT if either present)	~93	~86
Presence of both loss of consciousness and scalp hematoma (CT only if both present; very strict/high-specificity)	~20	~98

Abbreviations: CT = computed tomography; LOC = loss of consciousness; PECARN = Pediatric Emergency Care Applied Research Network.
** The "either LOC or scalp hematoma" approach reflects a simple rule where CT is recommended if the patient has either a history of loss of consciousness or a scalp hematoma. The "both LOC and scalp hematoma" approach recommends CT only if both findings are present, representing a very restrictive, high-specificity and low-sensitivity strategy.*

Discussion

This study demonstrates the significant challenges in managing head trauma in infants and toddlers and highlights the persistent overuse of CT imaging in this population. Despite the existence of clearly defined international guidelines that advocate for selective imaging, we found that nearly two-thirds of children under two with head injury underwent CT scanning, while only about one-tenth of those scans identified clinically significant intracranial injuries. Our findings mirror those of previous reports which have noted high rates of CT utilization for minor pediatric head trauma in emergency settings, both in Turkey and internationally (11,12). The tendency toward liberal imaging in these cases appears to be driven by multiple factors. Emergency physicians face the "when in doubt, scan" dilemma — a combination of fear of missing a rare but serious injury (and the potential medicolegal repercussions of such an oversight) and the difficulty of assessing subtle neurological signs in a non-verbal, uncooperative infant — which can tilt the decision in favor of performing a CT "just to be safe." These real-world pressures can at times override guideline recommendations and contribute to variability in practice, leading to more frequent scanning than what objective decision rules would call for. Reducing this gap between guidelines and practice is a key challenge that needs to be addressed through education, system-level protocols, and culture change.

Our data provide insight into the epidemiology and risk factors of head trauma in young children. Falls were the predominant mechanism of injury (64.6% of cases), which is consistent with epidemiological patterns reported in other regions (14). Young children are naturally prone to falls due to their developing motor skills and lack of danger awareness, and they often fall from furniture, caregivers' arms, or down stairs. The high proportion of falls underscores the importance of preventive strategies, such as educating parents and caregivers about home safety (for example, never leaving an infant unattended on elevated surfaces, using safety gates for stairs, etc.). By contrast, intentional trauma (suspected non-accidental injury) was very uncommon in our series (only 3 cases, 0.1%), but this should not lead to complacency; clinicians must remain vigilant for signs of abuse in any infant with an inconsistent history or injury pattern, as abusive head trauma can be easily missed and carries high morbidity and mortality (2).

Despite the overall low rate of serious intracranial injuries in our cohort, the CT utilization rate was high, reflecting the clinical uncertainty in evaluating these patients. We identified loss of consciousness and scalp hematoma as the strongest clinical predictors of a positive CT scan. These findings align well with established pediatric head trauma decision rules. In fact, both of these factors feature prominently in the PECARN criteria for children under two years: the PECARN rule considers a GCS < 15 or any signs of altered mental status (which includes loss of consciousness or extreme drowsiness) and palpable skull fractures or scalp hematomas (especially non-frontal) as high-risk features that warrant CT (8). Our results reinforce that these two elements are important red flags for clinicians. It is noteworthy that other common symptoms like vomiting and irritability did not show independent predictive value for intracranial injury in the multivariate analysis (15). This does not mean those symptoms are unimportant – rather, in many cases they co-occur with the stronger predictors (or are absent in many injured children), reducing their apparent standalone impact when adjusted for other factors. Moreover, the presence of vomiting or behavioral changes can still influence a physician's decision to observe a child more closely or to image, especially if such symptoms persist or worsen.

The ROC analysis (AUC = 0.72) in our study highlights the limitations of clinical judgment alone in accurately distinguishing which infants have serious head injuries. An AUC in the low 0.7 range indicates only moderate accuracy – meaning there is a considerable overlap in clinical presentation between children with and without injuries. In practical terms, to achieve near-perfect sensitivity (catch all true injuries), one would have to accept a high false-positive rate (scanning many children who are uninjured). Conversely, focusing on high specificity (scanning only those very likely to be injured) would inevitably miss some injuries given the overlap. This finding underscores why structured decision rules are so valuable: they intentionally err on the side of sensitivity. For example, the PECARN rule for under-2-year-olds achieves ~99–100% sensitivity for clinically important TBI (8), accepting a lower specificity to ensure almost no serious injuries are missed. Using such rules can standardize care and reduce unnecessary CT scans by identifying low-risk children who can be safely managed without imaging. Indeed, real-world validation studies have confirmed that the PECARN clinical prediction rules perform reliably in practice, reinforcing their value for routine use (13). Studies comparing rule-guided decisions to unstructured physician judgment have shown that decision aids can match or improve upon clinician accuracy, while also reducing variability in practice (16). In our context, better adherence to PECARN or similar guidelines could have avoided many of the CT scans performed on children who ultimately had normal findings, without compromising safety. When we retrospectively applied the PECARN criteria to our dataset, it achieved a sensitivity of 100% and a negative predictive value of 100% for detecting clinically important intracranial injuries (no ciTBI cases would have been missed). However, the specificity of the rule in this cohort was approximately 53%, with a positive predictive value of about 13%. In other words, roughly half of the children without a significant injury would have undergone CT scanning under strict PECARN-based criteria. This trade-off highlights the challenge in balancing the imperative to catch all serious injuries against the need to avoid exposing children to unnecessary radiation. Given the priority of safety in this age group, most clinicians and guidelines favor maximizing sensitivity (at the expense of specificity) to ensure that nearly no dangerous injuries are missed.

It is also important to discuss the role of symptoms like vomiting and irritability in the evaluation of head trauma. In our study, neither of these symptoms was an independent predictor of injury on CT after accounting for other factors. This is in line with research that has specifically examined vomiting in head-injured children. Isolated vomiting (vomiting in the absence of other high-risk signs such as altered mental status or signs of skull fracture) has been found to be rarely associated with significant traumatic brain injury (15). Borland et al. reported that children with minor head trauma who present with vomiting but no other risk factors have an exceedingly low rate of ciTBI, and therefore an observation approach can be justified in lieu of immediate CT (15). Our findings support this: many infants in our cohort who vomited once or twice were managed with observation and did well, which is consistent with the notion that brief, isolated vomiting can be managed safely without radiation in otherwise low-risk cases. Similarly, irritability or behavior change is a very subjective and non-specific sign in infants. It can stem from pain (like a scalp hematoma), hunger, or general distress, and not necessarily from a head injury. While persistent or severe irritability should raise concern (especially if a child cannot be consoled, which could indicate increased intracranial pressure), mild irritability did not correlate strongly with CT findings in our data. These observations underscore the importance of considering the overall clinical picture rather than any single symptom in isolation. Infants with isolated symptoms and no other worrisome findings can often be safely observed, whereas those with multiple risk factors or a concerning exam should be imaged.

In light of the risks associated with CT, alternative management strategies and imaging modalities are important to explore. For example, in infants with open fontanelles, cranial ultrasound can be performed at the bedside to identify skull fractures or intracranial hemorrhage without radiation exposure, making it a useful screening tool in selected minor head trauma cases (17, 18). Emerging technologies like near-infrared spectroscopy (NIRS) have also shown promise in detecting intracranial hematomas noninvasively (17). However, one of the most promising imaging alternatives is the use of rapid-sequence MRI as an alternative to CT for head trauma evaluation. MRI, of course, does not involve ionizing radiation and thus would eliminate the radiation risk. Traditionally, MRI has been impractical in the acute trauma setting for young children due to long scan times and the need for the child to remain still (often requiring sedation). However, recent advances have led to the development of fast MRI protocols that can be completed in only a few minutes. Studies have demonstrated the feasibility and safety of performing quick brain MRIs in children with head injuries, showing that it is possible to obtain diagnostic-quality images without sedation in many cases (19). Furthermore, investigators have reported that using rapid MRI in place of CT can substantially decrease radiation exposure for pediatric head trauma evaluation (20). Moreover, evidence from comparative studies is very encouraging: a fast MRI can detect most clinically significant injuries that a CT can, including skull fractures and intracranial hemorrhages, with high accuracy (21). For example, a 2019 multicenter study found that fast MRI had excellent agreement with CT for identifying traumatic brain injuries in young children, missing only a very small fraction of injuries that were mostly minor or clinically insignificant. While MRI in the emergency setting is not yet widely available (it requires specific protocols and immediate radiology support), these developments suggest a potential paradigm shift in the future. If rapid MRI can be implemented broadly, we could markedly reduce children's exposure to CT-related radiation. However, obstacles such as scanner availability, the need for radiologist expertise at off-hours, and the logistics of scanning an agitated toddler still need to be addressed. In the meantime, the judicious use of CT (when clearly indicated) and reliance on observation and clinical judgment for low-risk cases remain the mainstay of management.

Another well-recognized strategy to reduce unnecessary CT scans is the use of structured observation periods in the emergency department. Instead of immediately scanning every head-injured infant, a clinician may choose to observe the child for several hours to see if symptoms evolve or improve. This approach can filter out children who were initially symptomatic from the stress of the injury but are not truly intracranially injured – these children often improve with observation and can be discharged without ever undergoing CT. Research has shown that implementing observation protocols significantly reduces CT utilization without increasing missed injuries or adverse outcomes (22). In practice, many experienced clinicians already do this intuitively (for example, observing a child who had a brief LOC or one episode of vomiting but is now alert and playful in the ED). Formalizing such observation strategies as part of a guideline can further encourage their use.

Limitations

We acknowledge several limitations. First, this was a retrospective single-center study conducted at a tertiary care hospital using data from 2015, which may limit the generalizability of our findings to other settings or current practice and introduce potential information bias due to reliance on incomplete medical records. Second, we did not directly measure adherence to clinical decision rules (for example, by retrospectively applying PECARN criteria to each case), so guideline compliance was assessed only indirectly via overall imaging rates. In this context, a multicenter study by Babl et al. (2017) (10) directly comparing pediatric head trauma decision rules highlights the value of such analyses, but conducting a similar comparison was beyond our scope. Third, human factors such as medicolegal concerns or clinician risk tolerance were not captured in our data because we did not survey physicians; thus, we could only infer these influences from existing literature and clinical experience rather than measure them directly. Fourth, we lacked systematic data on observation duration for patients managed without CT and did not conduct any follow-up beyond the acute hospital visit, limiting our ability to detect delayed complications in those not scanned. Finally, as an observational study, we can identify associations but cannot establish causation. Despite these limitations, our findings align with those of larger studies and known trends (for example, high fall rates and a low yield of CT in mild head injuries), suggesting that our results are generalizable to similar clinical settings and can inform ongoing efforts to improve pediatric head trauma assessment.

Conclusion

Children under two years of age with head trauma continue to undergo CT imaging at high rates, even though international guidelines (such as PECARN) advise a more selective approach. Our study underscores that the majority of these scans do not find serious injuries, highlighting an opportunity to improve decision-making and avoid exposing infants to ionizing radiation unnecessarily. The drivers of CT overuse in this context include uncertainty in clinical evaluation of very young children, the difficulty of interpreting subtle signs in a preverbal patient, and concerns about medicolegal risks of missing an injury. Given the particular vulnerability of this age group to the long-term harms of radiation, it is imperative that emergency care providers strictly adhere to validated clinical decision rules for head trauma. By following these guidelines, clinicians can maintain a near-zero miss rate for significant injuries while safely reducing the number of CT scans.

To bridge the gap between evidence-based recommendations and practice, a multifaceted strategy is needed. Educational initiatives should be implemented to train and remind healthcare professionals about the proper use of head trauma algorithms and the risk trade-offs involved with CT imaging. Such training can increase physicians' confidence in identifying low-risk patients who can be observed instead of immediately scanned. In parallel, parental education is crucial – families should be informed about the rationale for avoiding unnecessary CT scans (emphasizing the radiation risks) and be made partners in the observation process when appropriate. Clear communication and written instructions on what warning signs to look for at home can empower parents and reduce their anxiety when a decision is made to forego imaging. Additionally, hospitals and healthcare systems should consider adopting protocols that encourage structured observation for mild head injuries and provide decision support tools to aid clinicians in adhering to guidelines. Where resources allow, exploring the use of rapid MRI techniques could offer a radiation-free diagnostic alternative for equivocal cases, although this requires infrastructural support.

In summary, effectively reducing unnecessary CT scans in infants with head trauma will require a comprehensive approach that combines rigorous guideline adherence, provider and caregiver education, and innovation in diagnostic methods. By doing so, we can ensure that children receive optimal care – benefiting from the life-saving capabilities of CT when needed, but shielded from its potential harms when it is not.

Ethical Approval: *The study was approved by the local Institutional Ethics Committee (Approval No: 50, Date: 09.02.2016). Because this was a retrospective review of de-identified patient records, informed consent was not required. Confidentiality of patient data was maintained throughout the study in accordance with the principles of the Declaration of Helsinki.*

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