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Skull Fractures and Intracranial Lesions in Neonates and Infants After Low-Height Falls: A Retrospective Cohort Study

Mustafa Balevi

mbalevi@gmail.com

Konya City Hospital

Research Article

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Abstract

Purpose

To evaluate the relationship between skull fracture patterns and intracranial findings in neonates and infants following low-energy falls and to assess whether skull fractures alone predict clinically significant intracranial injury.

Methods

This retrospective cohort study included 131 neonates and infants presenting with head trauma caused by low-energy falls from heights of ≤1 m. Patients were evaluated for the presence and type of skull fracture, intracranial lesions on imaging, Glasgow Coma Scale (GCS) score, and clinical outcomes. Fracture types were categorized as linear, ping-pong, basilar, or diastatic. Intracranial findings and neurological outcomes were analyzed descriptively.

Results

Skull fractures were identified in 91 patients (69.5%), including 74 linear (56.5%), 13 basilar (9.9%), 3 ping-pong (2.3%), and 1 diastatic fracture (0.8%). Intracranial lesions were uncommon. Among infants with skull fractures, minimal cerebral contusion was observed in 6 patients (4.6%), epidural hematoma in 1 (0.8%), and traumatic subarachnoid hemorrhage in 1 (0.8%). In neonates without skull fractures, small cerebral contusions were detected in 4 patients (3.1%). Intracranial lesion rates were comparable between infants with fractures (8.8%) and neonates without fractures (10%). No patient required surgical intervention, and no neurological deficits were observed.

Conclusion

Skull fractures following low-energy falls are common in neonates and infants, but clinically significant intracranial injury is rare. When present, associated brain lesions are typically minor, such as small contusions. These results highlight that clinical assessment considering age, trauma mechanism, and neurological status should guide management rather than the presence of a skull fracture alone.

Introduction

Head trauma in neonates and infants presents different patterns compared to adults due to developmental anatomical and biomechanical differences. The elasticity of the skull bones and open sutures directly influence the distribution of trauma energy and the mechanisms of brain injury [1,2].

While skull fractures are often considered markers of severe intracranial injury, this relationship may not always hold in neonates and infants.

Infant skulls have different biomechanical characteristics than adult skulls. Their more compliant bones and open sutures allow greater deformation during impact, resulting in different patterns of energy

transfer and injury mechanisms in head trauma. Previous studies show that infant skulls deform more and absorb impact energy differently than adult skulls, which may influence intracranial injury outcomes [1-3].

The literature suggests that skull fractures in infants frequently occur as isolated lesions and may not be associated with major intracranial hemorrhage [4]. The elastic skull absorbs a portion of the trauma energy, potentially protecting the brain parenchyma [1]. In neonates, contusions may develop without skull fractures, highlighting age-specific biomechanical differences.

In light of these considerations, a more nuanced evaluation of skull fractures in neonates and infants is warranted. Given that fracture presence alone may not reliably predict intracranial pathology and that significant intracranial injury may occur even in the absence of bony disruption, there remains a need to clarify the clinical and radiological correlation between skull fracture patterns and intracranial lesions in this age group. Therefore, the aim of this study was to evaluate the relationship between skull fractures and intracranial lesions in neonates and infants and to determine the clinical relevance of skull fractures for major intracranial hemorrhage.

Materials and Methods

A total of 131 patients were retrospectively evaluated. The requirement for informed consent was waived due to the retrospective nature of the study.

All injuries resulted from low-energy falls from heights of ≤1 m (approximately 100 cm).

Neurological status at admission was evaluated using the Glasgow Coma Scale (GCS), and scores were recorded for all patients at the time of initial clinical assessment.

This study was designed as a retrospective observational cohort study including neonates and infants presenting with head trauma.

Study Design and Population

This retrospective observational cohort study included neonates and infants (aged 0–12 months) presenting with head trauma. A total of 131 patients were included. All injuries resulted from low-energy falls from heights of ≤1 m (approximately 100 cm). Neurological status at admission was assessed using the Glasgow Coma Scale (GCS).

Inclusion and Exclusion Criteria

This retrospective observational cohort study included neonates and infants (aged 0–12 months) presenting with head trauma. A total of 131 patients were evaluated. All injuries resulted from low-energy falls from heights of ≤1 m (approximately 100 cm).

Neurological status at admission was assessed using the Glasgow Coma Scale (GCS), and scores were recorded at the time of initial clinical evaluation.

Inclusion Criteria

- Age 0–12 months
- Head trauma confirmed by CT or MRI

Exclusion Criteria

- Coagulopathy, metabolic, or vascular disorders
- Non-traumatic intracranial hemorrhage

Parameters Evaluated

The following variables were analyzed:

• Skull fracture type (linear, ping-pong, basilar, diastatic)

• Intracranial lesions (contusion, epidural hematoma, subarachnoid hemorrhage)

• Surgical intervention requirement and neurological deficits

Statistical Analysis

All data were analyzed descriptively. Categorical variables (presence/absence of skull fracture, fracture type, intracranial lesion type, surgical requirement, neurological deficit) were presented as frequency and percentage. Continuous variables (age, trauma height) were reported as mean ± standard deviation (SD). Observational comparisons were made between patients with and without fractures. No significance testing or p-values were applied.

Statistical analysis was performed using SPSS software (IBM Corp., Armonk, NY, USA). Categorical variables were summarized as frequencies and percentages, while continuous variables were presented as mean ± standard deviation (SD).

Ethics Approval

This retrospective study was approved by the Institutional Review Board (approval no. 21-69, 06.11.2025). The requirement for informed consent was waived due to the retrospective design of the study.

Results

A total of 131 patients were retrospectively evaluated. All injuries resulted from low-energy falls from heights of ≤1 m (approximately 100 cm). All patients presented with mild head trauma, with Glasgow

Coma Scale (GCS) scores ranging from 13 to 15.

The flow diagram in **Figure 1** depicts the screening, inclusion, and categorization of patients according to the presence or absence of skull fractures and intracranial findings.The clinical and demographic characteristics of the cohort are summarized in Table 1.

Skull fractures were identified in 91 patients (69.5%). Among these, 74 (56.5%) were linear fractures, 3 (2.3%) were ping-pong fractures, 13 (9.9%) were basilar fractures, and 1 (0.8%) was a diastatic fracture (Table 2).

Intracranial findings were uncommon in this cohort. Among infants with skull fractures, minimal cerebral contusion was observed in 6 patients (4.6%), epidural hematoma in 1 patient (0.8%), and traumatic subarachnoid hemorrhage in 1 patient (0.8%). In neonates without skull fractures, small cerebral contusions were detected in 4 patients (3.1%) (Table 2). None of the patients required surgical intervention, and no neurological deficits were observed during follow-up.

No patient required surgical intervention, and no neurological deficits were observed during follow-up.

Discussion

The interpretation of skull fractures in neonates and infants following head trauma remains challenging, as injury patterns and clinical implications differ substantially from those observed in older children and adults. Developmental anatomical and biomechanical characteristics of the immature skull including increased elasticity, incomplete mineralization, and the presence of open sutures and fontanelles play a central role in modulating force transmission and intracranial injury risk after impact [5,6]. Consequently, skull fractures in this age group may reflect cranial deformation rather than severe intracranial pathology. Within this context, the present study evaluates the relationship between fracture type and intracranial hemorrhage in neonates and infants sustaining low-energy falls, aiming to clarify whether skull fractures alone constitute reliable indicators of clinically significant brain injury.

This study demonstrates that skull fracture patterns and intracranial hemorrhage following low-energy falls differ substantially between neonates and infants compared with adults. Age-dependent cranial biomechanical differences form the basis of this distinction, and experimental and computational modeling studies have long demonstrated that sutures and fontanelles play a critical role in deformation and energy dissipation, thereby shaping infant-specific head trauma patterns [5,6]. Within this framework, the finding that linear fractures were the most common fracture type in the infant group (n = 74, 56.5%) is expected; however, the observation that these fractures were associated with a lower rate of clinically significant intracranial hemorrhage compared with adult head trauma series appears consistent with the elastic properties of the infant skull and the low-energy trauma mechanism. In our cohort, no significant difference in intracranial hemorrhage development was observed between linear and basilar fracture types. Pediatric clinical decision-making literature, most notably the PECARN head trauma rule, emphasizes that neurological status (Glasgow Coma Scale) and high-risk clinical features

are stronger predictors of clinically important traumatic brain injury than the presence of a skull fracture alone, particularly in younger children [7]. Accordingly, the fact that all patients in our series had GCS scores between 13 and 15, with no neurological deficits and no requirement for surgical intervention, is consistent with the clinical spectrum of low-risk head trauma. However, basilar skull fractures were identified in 9.9% of our cohort. This proportion is markedly higher than the approximately 1% prevalence reported in large prospective pediatric head trauma cohorts, including the PECARN study led by Nathan Kuppermann and the CHALICE study by Dunning J, and also exceeds the incidence ranges described in general pediatric head injury series [8,9]

This discrepancy may be attributable to referral bias, differences in imaging practices particularly the liberal use of computed tomography or specific characteristics of our study population.

Even in higher-risk mechanisms such as multi-level falls, basilar skull fracture rates of approximately 4.2% have been reported in pediatric cohorts, particularly in studies focusing on fall-related injury mechanisms. The 9.9% rate observed in our low-energy (≤1 m;~50 cm) cohort is therefore noteworthy and may be attributable to sample characteristics, referral patterns, or differences in fracture classification and detection [10-13].

Our findings suggest that basilar fractures may follow a relatively benign clinical course in neonates and infants, which is consistent with previous studies reporting low rates of clinically significant complications [10-13].

In the present cohort, no intracranial hemorrhage was observed in patients with ping-pong fractures (n = 3, 2.3%). Ping-pong skull fractures represent a distinctive subtype of depressed skull fracture predominantly observed in neonates and young infants, reflecting the increased plasticity and incomplete mineralization of the immature calvarium. Unlike typical depressed fractures seen in older children, these injuries are often deformational rather than true displaced fractures and may occur without significant underlying parenchymal damage. Previous clinical series and systematic reviews have similarly reported favorable neurological outcomes and a low rate of intracranial injury in neonates with ping-pong fractures, with conservative management or minimally invasive techniques frequently being sufficient for treatment [14–16].

A diastatic fracture was identified in only one patient (0.8%), in whom a minimal traumatic subarachnoid hemorrhage was detected; however, the clinical course remained benign, suggesting that even this rare fracture type may be associated with limited intracranial findings following low-energy trauma. In the neonatal subgroup, the presence of minimal intracranial hemorrhage in the absence of skull fractures supports the concept that neonatal hemorrhage does not necessarily reflect a fracture-related mechanical failure but may instead be related to intrinsic vulnerability of the germinal matrix vasculature and immature cerebral autoregulation, which are well-described contributors to intraventricular and periventricular hemorrhage in neonates [17]. Finally, evidence indicating that isolated pediatric skull fractures in children with a normal neurological examination carry a very low risk of emergency neurosurgical intervention or mortality further reinforces the favorable clinical outcomes observed in our

cohort. In a recent retrospective cohort of 431 children with isolated skull fractures, none of the patients with a normal neurologic exam and nondisplaced or minimally displaced fractures required neurosurgical intervention, and progression to intracranial hemorrhage was uncommon. Additionally, a systematic review and meta-analysis encompassing over 7,000 pediatric isolated skull fractures found an exceedingly low incidence of acute neurosurgical procedures and no reported deaths, supporting the generally benign natural history of this injury pattern in neurologically intact children[18,19].

Skull fractures alone may not reliably predict intracranial injury in neurologically normal infants [20]. Previous studies have shown that clinically significant intracranial injury following low-energy trauma in infants is uncommon, particularly in the absence of neurological abnormalities [20].

Based on the integrated assessment of age group, skull fracture subtype, trauma mechanism, and neurological status, a conceptual nomogram is proposed to support clinical risk stratification in neonates and infants with low-energy head trauma (Figure 2). Rather than relying solely on radiological fracture patterns, the nomogram emphasizes neurological examination and clinical presentation as primary determinants of management. In this framework, neurologically intact patients with linear or ping-pong fractures and low-energy mechanisms are categorized as low risk and may be managed conservatively with observation. Conversely, the presence of abnormal neurological findings or clinically significant intracranial hemorrhage shifts management toward closer monitoring or intervention, regardless of fracture type. This illustrative model underscores that skull fracture alone is an insufficient predictor of severe intracranial injury and highlights the importance of age-specific biomechanics and clinical context in guiding decision-making.

This study has inherent limitations related to its retrospective, single-center design, which may limit external validity and introduce selection bias. Injury severity could not be quantified objectively, and trauma mechanism was inferred from reported fall height and clinical documentation. Computed tomography served as the primary imaging modality; while representative of standard clinical practice, this approach may have led to detection bias for subtle fracture patterns and limited assessment of non-hemorrhagic parenchymal injury. The small number of uncommon fracture subtypes, including ping-pong and diastatic fractures, restricts meaningful subgroup analysis. In addition, long-term neurodevelopmental outcomes were not available, precluding evaluation of delayed sequelae.

Despite these limitations, the uniform low-energy mechanism, standardized neurological assessment, and systematic radiological review enhance the internal consistency and clinical applicability of the findings.

Overall, the findings of this study suggest that skull fractures in neonates and infants following low-energy falls are not necessarily associated with clinically significant intracranial injury. Although fractures were relatively common in our cohort, associated intracranial lesions were rare and generally mild. These results highlight the importance of integrating neurological examination findings, patient age, and trauma mechanism when evaluating pediatric head injuries. A careful clinical assessment,

rather than the presence of a skull fracture alone, should guide management decisions in this vulnerable population.

Conclusion

Skull fractures following low-energy falls are relatively common in neonates and infants; however, clinically significant intracranial injury is uncommon. In this cohort, most associated intracranial findings were limited to minimal contusions or small hemorrhages that did not require surgical intervention. These findings suggest that the presence of a skull fracture alone may not reliably predict severe intracranial injury. Clinical assessment integrating neurological status, patient age, and trauma mechanism remains essential in the evaluation of head injuries in this age group.

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Tables

Table 1. Characteristics of patients with skull fracture (n = 91)

Variable	n	%
Age Group		
Neonate	4	4.4
Infant	87	95.6
Sex		
Male	46	50.5
Female	45	49.5
Glasgow Coma Scale (GCS)		
GCS 15	45	49.5
GCS 14	45	49.5
GCS ≤ 13	1	1.1
Intracranial hemorrhage		
Present	8	8.8
Absent	83	91.2

Values are presented as number and percentage. Percentages in this table are calculated within the skull-fracture subgroup (n = 91).

Table 2. Summary of skull fractures and intracranial findings in the cohort (n = 131)

Parameter	n	%
Total patients	131	100
Skull fracture		
Present	91	69.5
Absent	40	30.5
Fracture type		
Linear	74	56.5
Ping-pong	3	2.3
Basilar	13	9.9
Diastatic	1	0.8
Intracranial findings		
Minimal contusion (with skull fracture)	6	4.6
Epidural hematoma (with fracture)	1	0.8
Subarachnoid hemorrhage (with fracture)	1	0.8
Small cerebral contusion (no fracture)	4	3.1
Outcomes		
Surgical intervention required	0	0
Neurological deficit during follow-up	0	0

Percentages are calculated based on the total cohort (n = 131).

Figures

Figure 1. Patient distribution and intracranial findings

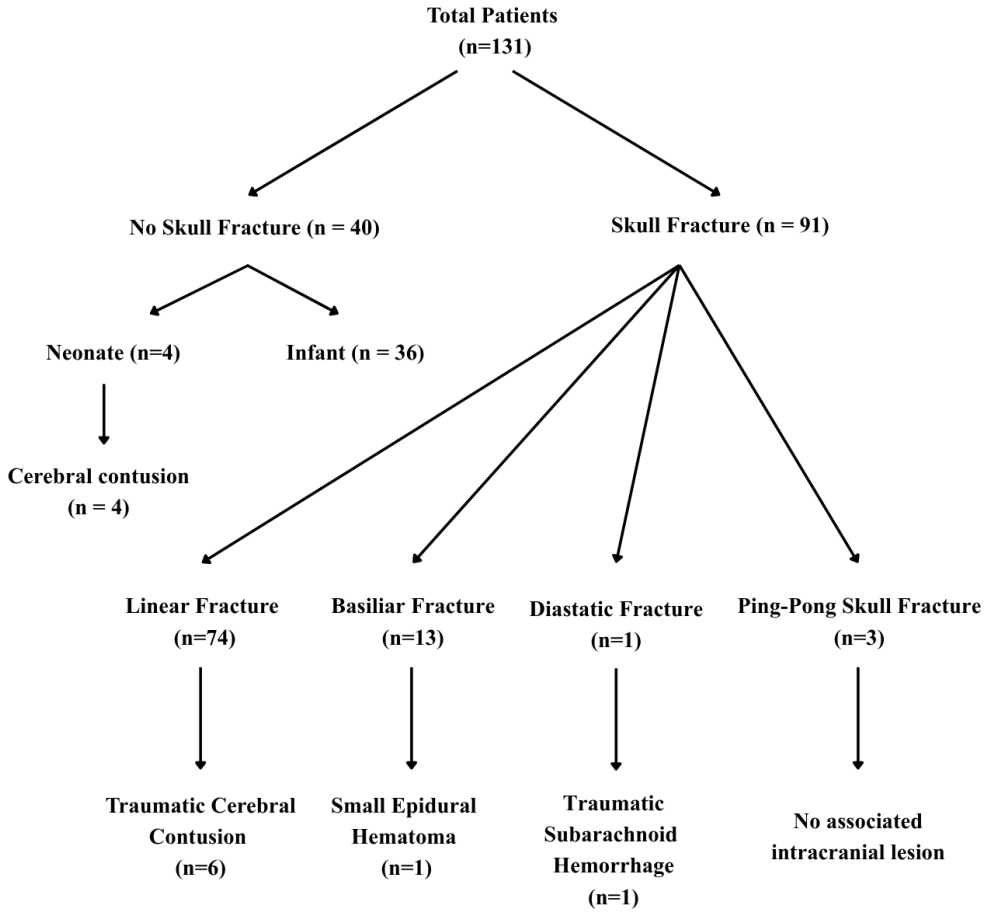


Figure 1

Flowchart of patient selection and intracranial findings.
All 131 patients were evaluated retrospectively. Patients were categorized according to the presence or absence of skull fracture. In patients with skull fractures, fracture subtypes were classified as linear, ping-pong, basilar, or diastatic. In neonates without skull fractures, minimal cerebral contusion and intracranial hemorrhage were observed.

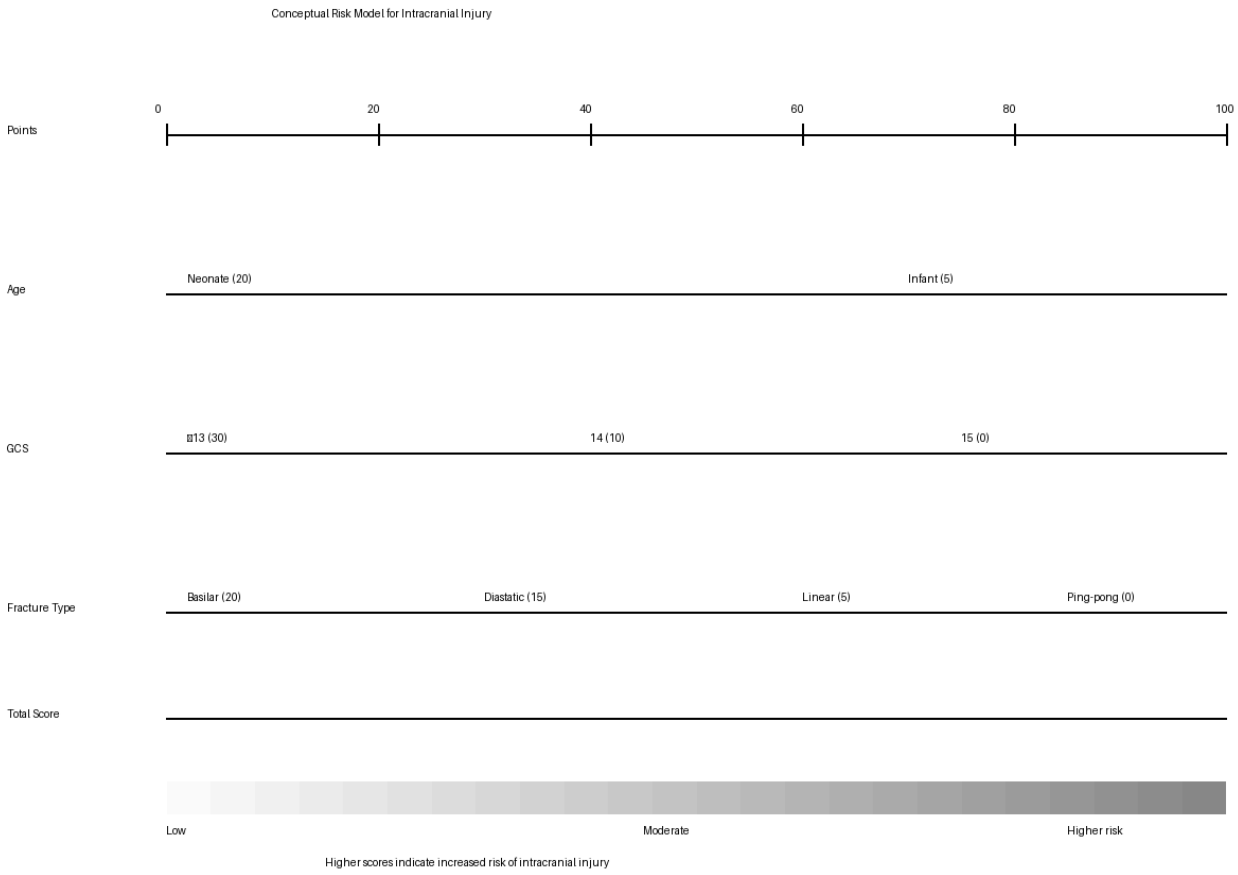


Figure 2

Conceptual model illustrating the contribution of age, Glasgow Coma Scale, and skull fracture type to intracranial injury risk.

This model is intended for conceptual illustration and does not represent a validated predictive tool.