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Skull Fractures Following Head Trauma in the First Year of Life: Epidemiology, Mechanisms and Outcomes

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Background: Head trauma during infancy represents a distinctive clinical entity due to the rapid developmental changes in the first year of life. Skull fractures are a clinically relevant marker of traumatic head injury in infants and frequently prompt hospital admission and specialist evaluation. Understanding mechanisms and clinical characteristics is essential for improving diagnostic assessment and prevention strategies.

Methods: This retrospective study included infants <12 months admitted to our Institution between 2021 and 2025, diagnosed with a skull fracture. Birth-related trauma was excluded. Demographic, radiological, and clinical data were analyzed. Trauma mechanisms were classified as accidental, non-accidental, medical condition–related, or other. Accidental mechanisms were further subdivided according to the circumstances of the fall.

Results: A total of 156 infants were included. Accidental trauma accounted for 89.7% of cases; 4.5% were classified as non-accidental trauma. The fractures were mostly parietal (72.4%); intracranial hemorrhage occurred in 43.6%. Seventeen patients (10.9%) required neurosurgical intervention; 24 (15.4%) required intensive care admission. Fundoscopic abnormalities were identified in six infants, predominantly in cases of non-accidental trauma. Analysis by developmental age groups demonstrated clear age-related patterns of injury mechanisms, with caregiver-related falls predominating during the first months of life and lack of supervision-related injuries increasing with the onset of mobility.

Conclusions: Head trauma resulting in skull fractures during the first year of life demonstrates distinct developmental patterns of injury. These findings highlight the importance of developmental context in clinical assessment and suggest that many injuries may be preventable through targeted caregiver education and improved domestic safety measures.

Keywords: craniocerebral trauma; skull fracture; traumatic brain injury; child abuse; prevention

INTRODUCTION

Traumatic brain injury (TBI) is a major public health concern in the pediatric population and represents a leading cause of morbidity and mortality in children worldwide. The incidence of pediatric TBI has been estimated to range between 47 and 280 cases per 100,000 children annually, with a bimodal age distribution involving very young children and adolescents [1]. In the United States, infants account for 81,000 emergency

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department visits each year, due to head trauma and skull fractures occur in up to 10% of infants following minor head injury [2] .

Infants younger than 12 months represent a particularly vulnerable population. Rapid developmental changes during the first year of life, combined with anatomical characteristics such as thinner and more compliant skull bones, increase susceptibility to cranial injury following even relatively low-energy trauma. In addition, the clinical evaluation of infants can be challenging due to their non-verbal status, the frequent absence of witnesses, and the difficulty of obtaining a reliable history.

Skull fractures represent an important clinical marker of head trauma severity in infancy. While traumatic brain injury encompasses a broad spectrum of presentations, the presence of a skull fracture typically indicates a biomechanical impact sufficient to justify hospital admission, neuroimaging, and specialist evaluation. Focusing on this subgroup, therefore, allows a clinically meaningful analysis of injury mechanisms and outcomes in infants.

Previous studies have shown that mechanisms of head trauma vary substantially across childhood and are strongly influenced by developmental stage. However, many investigations have either focused on narrow age ranges within early infancy or included broader pediatric populations extending beyond the first year of life [3–6] . As a result, the first year of life has often been treated as a single homogeneous period despite the rapid and heterogeneous developmental changes occurring during this time.

Motor development during infancy progresses from complete dependence on caregivers to increasing mobility through rolling, sitting, crawling, and eventually standing. Each developmental stage may expose infants to distinct injury mechanisms and environmental risks. A better understanding of these age-related patterns may improve diagnostic evaluation and help identify opportunities for targeted prevention.

Thus, this study aimed to analyze the epidemiology, mechanisms, and clinical outcomes of skull fractures in infants during the first year of life, with particular attention to the relationship between injury mechanisms and developmental stage.

MATERIALS AND METHODS

Study design and setting

A retrospective observational study was conducted at our Institution, a tertiary pediatric neurosurgery center. All infants younger than 12 months admitted to the Pediatric Neurosurgery Department of Hôpital Femme-Enfant, Lyon, France, between January 2021 and December 2025 with a diagnosis of skull fracture at cerebral computed tomography (CT) were included. Birth-related cranial trauma, including injuries associated with vacuum extraction, forceps delivery, or complicated labor, was excluded.

This study was performed in line with the principles of the Declaration of Helsinki. This retrospective study was submitted to and approved by our Institutional Ethics Committee, IRB de Neurochirurgie, n° IRB00011687, Collège de Neurochirurgie protocol reference IRB #1: 2025/39. Since the retrospective nature of the study, consent to participate in the study was considered not necessary because: all the collected data represented standard data included in every chart at our Institution to guarantee the best practice; and, in compliance with the French data protection law (Loi Informatique et Libertés) and the General Data Protection Regulation (GDPR), all patient data was anonymized prior to analysis to ensure confidentiality. Families of patients whose computed tomography (CT) scan images appear in this study did not oppose to their use in a completely anonymized form.

Strengthening the Reporting of Observational studies in Epidemiology (STROBE) guidelines were followed for reporting data.

Medical records were reviewed to collect demographic data, clinical presentation, imaging findings, mechanism of injury, and clinical outcomes.

Classification of trauma mechanisms

Trauma mechanisms were classified into five categories: (i) Accidental trauma, (ii) Non-accidental trauma, i.e. abuse-related, (iii) Medical condition–related trauma, (iv) Road traffic accident, and (v) Unexplained trauma. Accidental mechanisms were further subdivided into: (a) Falls from or with a caregiver, (b) Lack of supervision-related injuries (i.e., falls from bed, sofa, child furniture, etc.), (c) Child falls (self-induced ground-level falls), and (d) Other accidental mechanisms.

Non-accidental trauma was defined following multidisciplinary evaluation based on clinical, radiological, and social findings. Cases were suspected for non-accidental, i.e. inflicted head injury, when at least two major red-flag criteria were present, including cutaneous injuries suggestive of trauma, bilateral subdural collections, bridging vein thrombosis, retinal hemorrhages, additional skeletal fractures, seizure-associated EEG abnormalities, altered consciousness requiring intubation, or documented admission of inflicted injury. All suspected cases of non-accidental trauma were discussed in a multidisciplinary meeting including pediatric neurosurgeons, pediatricians, neuroradiologists, ophthalmologists, and child protection specialists.

Clinical variables

Clinical course was assessed by recording fracture location, presence of intracranial hemorrhage, presence of additional skeletal fractures, need for intensive care unit (ICU) admission and duration, and requirement for neurosurgical intervention. During hospitalization, ophthalmologic examination and electroencephalography (EEG) findings were collected when available, and abnormalities were documented.

Follow-up duration was not standardized and varied according to clinical severity. Infants with isolated simple skull fractures were generally followed for a short period, whereas patients requiring neurosurgical intervention or presenting with more severe injuries underwent longer clinical follow-up, often extending up to one year or more in selected severe cases.

Statistical analysis

Data were analyzed using descriptive statistics. Continuous variables are presented as median or mean values, and categorical variables are reported as absolute numbers and percentages.

RESULTS

Demographics, injury characteristics, and further examinations

A total of 156 infants met the inclusion criteria. The median age at presentation was 5 months (range 0.5–11 months). Males represented 64.1% of the cohort.

Parietal fractures were the most frequent location, accounting for 72.4% of cases. Occipital fractures were identified in 9.2%, frontal fractures in 3.1%, and temporal fractures in 1.5%. Multiple skull fractures were observed in 16% of infants. Intracranial hemorrhage was present in 43.6% of patients. Epidural hematoma represented the most frequent hemorrhagic lesion, followed by subarachnoid and subdural hemorrhage.

Accidental trauma accounted for the majority of cases (140/156, 89.7%). Seven infants (4.5%) were classified as victims of non-accidental trauma, while seven (4.5%) presented with no reported mechanism; one injury (0.6%) resulted from a road-traffic injury, and one (0.6%) occurred in the context of an underlying metabolic condition suggestive of bone fragility.

Ophthalmologic examination was performed in 125 infants. Fundoscopy was not performed whenever the history of accidental trauma was corroborated by several witnesses, and the child was not suspected of having a raised intracranial pressure. Electroencephalography (EEG) was performed in 95 infants. Conversely, 61 infants did not undergo EEG because the clinical presentation and radiological findings did not warrant further neurophysiological evaluation.

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Accidental trauma, medical-related condition trauma, road accident trauma, and unknown mechanism of injury (Figures 1 and 2)

Within accidental mechanisms (140/156, 89.7%), lack of supervision-related injuries represented the most frequent cause. These events occurred in common domestic settings, including falls from changing tables, beds, sofas, strollers, or infant car seats. Falls occurring while being carried by caregivers represented the second most common mechanism (Figure 1).

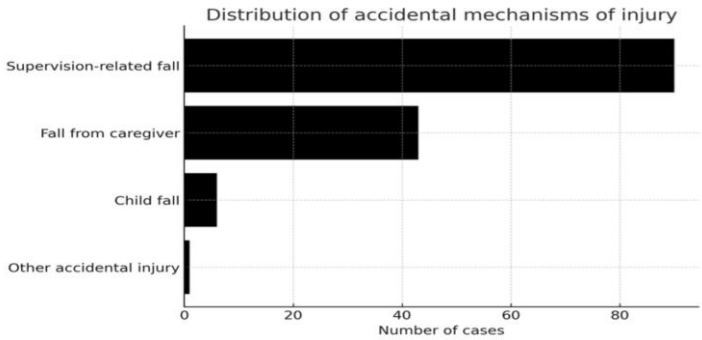

Figure 1. Scheme showing the distribution of accidental injuries (n = 140).

Analysis according to developmental age groups revealed distinct patterns. Caregiver-related falls predominated in the youngest infants, reflecting their dependence on adult handling. After three months of age, injuries related to lack of supervision increased markedly and remained the most common mechanism throughout the remainder of the first year. Self-induced falls became more frequent after six months, coinciding with the acquisition of independent mobility (Figure 2).

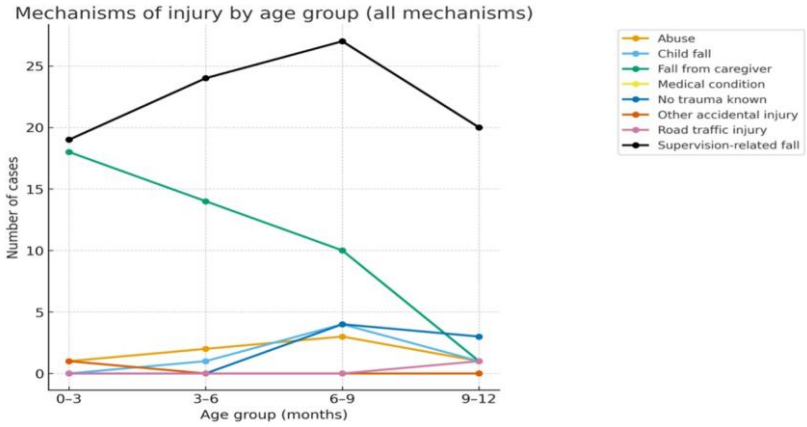

Figure 2. Scheme showing the number of cases for each mechanism of injury sorted by age group.

Examples of imaging of patients within this group are shown in Figures 3, 4 and 5.

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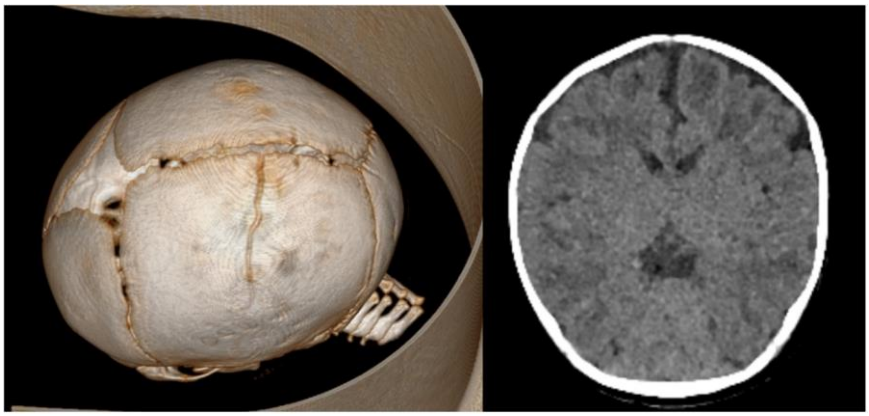

Figure 3. CT scan of a 1-month-old female infant showing a linear parietal skull fracture following accidental domestic trauma, without associated intracranial hemorrhage.

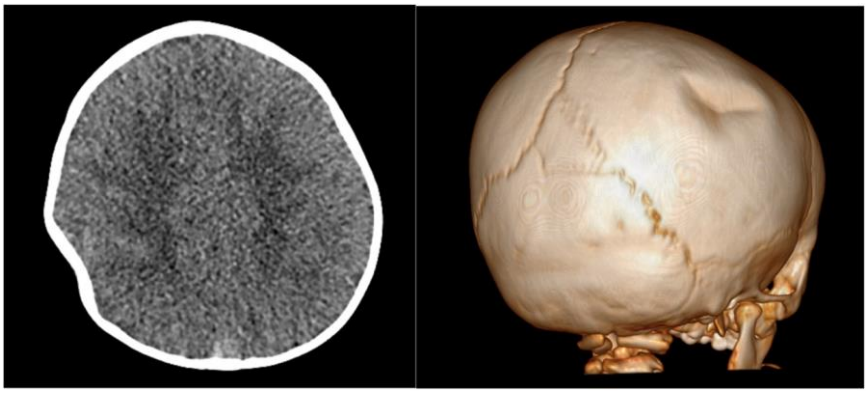

Figure 4. CT scan of a 10-month-old male infant showing a depressed parietal skull fracture associated with focal subarachnoid hemorrhage following an accidental fall from a changing table. The patient underwent surgical elevation of the depressed fracture.

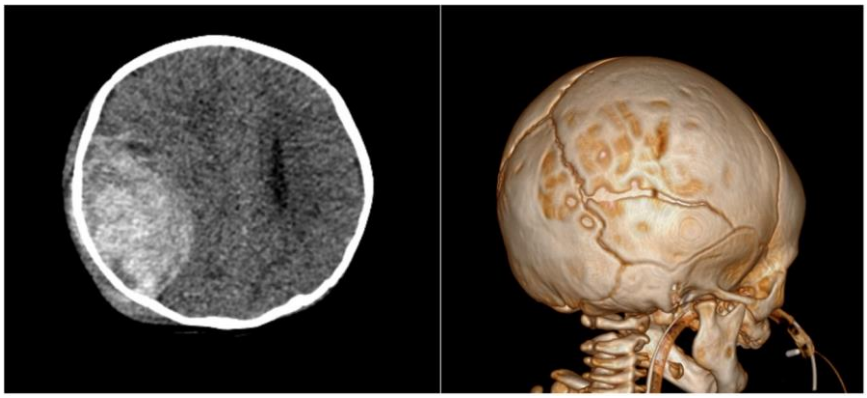

Figure 5. CT scan of a 5-month-old male infant showing a parietal skull fracture associated with epidural hematoma following an accidental fall from an infant carrier. The patient underwent surgical evacuation of the epidural hematoma and required intensive care admission.

In this subgroup, two patients presented with alterations at ophthalmologic consultation, and they both showed intracranial hemorrhage. The first patient had papilledema associated with subarachnoid hemorrhage, the second one had sustained a fall from a changing table and underwent emergency surgery for a right epidural hematoma; he presented with unilateral retinal hemorrhage. Although this last case exhibited a retinal finding, no other red flag of abuse was identified, and the clinical

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context was considered consistent with a direct traumatic mechanism. No infant without intracranial hemorrhage had abnormal fundoscopic findings.

On the other hand, three patients presented with EEG abnormalities. One was the patient who also had unilateral retinal hemorrhage. The remaining two patients presented the first with an epidural hematoma, and the latter with a subdural hematoma requiring subduro-peritoneal drain. Mechanisms of injuries were clear and witnessed in these cases (2 falls from a changing table, 1 fall from the caregiver).

Cases with no known trauma also showed a clear age-related trend, with a marked increase in the 6–9-month group. None of these patients had alterations at the fundoscopic examination.

Two infants presented additional skeletal fractures. One 10-month-old child sustained a femoral fracture after a fall from a bed. The other infant, involved in the road-traffic accident, presented with associated rib fractures.

Non-accidental traumas

As previously stated, seven infants (7/156, 4.5%) were classified as victims of non-accidental trauma (example of imaging in Figure 6).

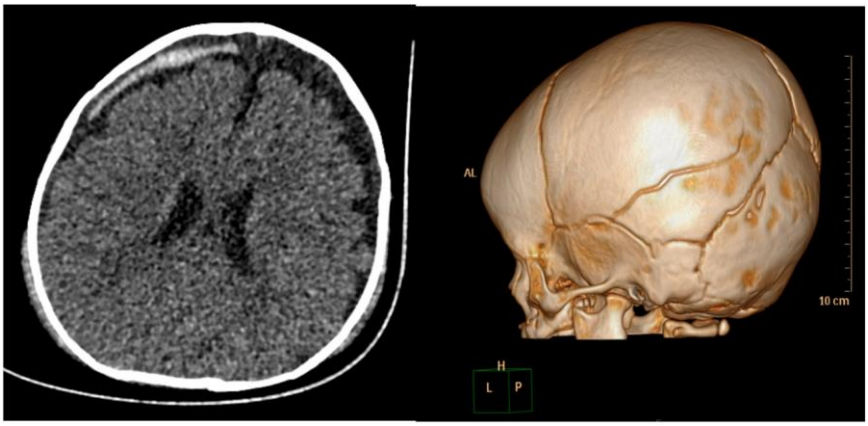

Figure 6. CT scan of a female infant showing a parietal skull fracture associated with subdural hemorrhage in the context of non-accidental trauma.

All of these patients had shown intracranial bleeding associated with the fracture: 7/7 had a uni or bilateral subdural hematoma, and 3/7 also had associated subarachnoid hemorrhage. One patient required a neurosurgical intervention of external subdural drain, while another one needed a subduro-peritoneal drain.

Abnormal findings at fundoscopic examination were detected in four cases, in particular retinal hemorrhages – bilateral in two cases and unilateral in the other two.

EEG abnormalities were observed in 3 infants, of whom one also had a retinal hemorrhage.

No additional skeletal abnormalities were found in this group, although systematically assessed for.

The cases presented as follows: 0 in 2021, 3 in 2022, 2 in 2023, 2 in 2024, and 0 in 2025.

CT scan timing

Timing between trauma and CT scan was considered not applicable in 15 infants (9.6%): 7/156 cases presenting without a reported history of trauma, 7/156 cases of non-accidental trauma (no witnessed traumatic event), and in 1/156 patient with a metabolic/bone fragility cause of fracture. In the remaining cases, most infants underwent CT scanning within 24 hours from the reported trauma

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(121/156, 77.6%), while a smaller proportion underwent imaging after more than 24 hours (13/156, 8.3%), and only a few cases after more than 48 hours (7/156, 4.5%).

Clinical management and outcomes

Twenty-four infants (15.4%) required admission to the intensive care unit, in particular, 5/7 children (71.4%) who had been victims of non-accidental trauma, and 19/149 (12.8%) of the ones classified in the group of other types of trauma (accidental trauma, medical condition–related trauma, road traffic accident, and unexplained trauma). The median ICU stay was two days.

Seventeen infants (10.9%) underwent neurosurgical intervention, of which two in the non-accidental trauma group and fifteen in the accidental trauma one. Surgical procedures included evacuation of epidural hematomas (n=8, all accidental), elevation of depressed skull fractures (n=6, all accidental), and treatment of subdural collection (n=3, one accidental and two non-accidental traumas). No postoperative complications or need for reoperation were observed.

The overall median hospital stay was four days. Infants requiring surgical intervention had longer hospitalizations, with a mean stay of approximately nine days.

Clinical outcomes were favorable in most cases. No child developed a skull growing fracture. Three infants required ongoing antiepileptic treatment at discharge. One death occurred in a patient with severe non-accidental trauma and extensive intracranial injury.

DISCUSSION

This study provides a comprehensive overview of skull fractures resulting from head trauma during the first year of life. The findings demonstrate that injury mechanisms, clinical severity, and outcomes vary considerably according to developmental stage.

Our findings are in accordance with previous studies that analyzed broad pediatric populations. Ibrahim et al. analyzed infants and toddlers up to four years of age, highlighting differences in injury mechanisms across developmental stages, with higher-energy mechanisms becoming more prevalent beyond the first year of life [4]. Similarly, Duhaime et al. reported that head injuries occurring before two years of age are predominantly accidental, emphasizing the role of developmental immaturity and caregiver-dependent mechanisms in younger children [7].

A major observation of this study is the clear age-dependent distribution of trauma mechanisms also within the first year of life. In the earliest months of life, injuries were primarily related to caregiver handling. As infants acquired motor abilities, lack of supervision-related injuries became increasingly frequent. After six months of age, cases with no known trauma also showed a clear age-related trend, with a marked increase in the 6–9-month group. This pattern likely reflects unwitnessed minor events occurring as infants begin rolling, sitting, crawling, and pulling to stand, rather than unrecognized trauma, suggesting that many such cases correspond to everyday low-energy incidents not interpreted as traumatic by caregivers.

These findings suggest that the first year of life should not be considered a single homogeneous risk period. Instead, it comprises several developmental phases, each associated with distinct mechanisms of injury. Recognizing these patterns may assist clinicians in evaluating reported histories and identifying situations that warrant further investigation.

Timing of CT imaging further reflects these age-related differences in clinical presentation and healthcare-seeking behavior. Infants undergoing CT imaging more than 24 hours after trauma were generally older. This likely reflects a caregiver-related bias, as even minor head injuries in very young infants tend to prompt earlier medical evaluation, whereas similar events in older infants may initially be perceived as less concerning and lead to delayed consultation, often triggered by the appearance or persistence of a scalp hematoma. In addition, our cohort includes hospitalized patients only. Infants

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presenting more than 48 hours after trauma, in the absence of concerning clinical or radiological findings, are less likely to be admitted, as a period of effective observation has already occurred. Consequently, late-presenting cases with mild clinical courses may be underrepresented in our cohort.

Although most injuries in this cohort were accidental, a small proportion were classified as non-accidental trauma. These cases were generally associated with more severe clinical presentations and additional diagnostic findings such as diffuse retinal hemorrhages and abnormal electroencephalography. Importantly, no single clinical or paraclinical finding is sufficient to define non-accidental trauma, underscoring the need for a comprehensive, multidisciplinary approach integrating neurological status, imaging, ophthalmologic and electroencephalographic assessments, skeletal survey results, cutaneous signs of injury, and social evaluation [8, 9]. Non-accidental injury remains, in fact, a major cause of traumatic brain injury and a leading cause of death and disability in very young children, with approximately 70% of affected patients being under one year of age [10-12].

Importantly, previous studies have reported a higher incidence of abusive head trauma in 2021, after some months of the COVID-19 pandemic [13]. Interestingly, at our Institution we did not have any abusive head trauma cases in 2021, as stated in the Results. Moreover, our cases could be considered almost completely post-pandemic, as from 2022 on, there were globally no more restrictions in our country due to COVID-19, and it can thus be considered a post-pandemic period.

Retinal hemorrhages were observed predominantly in infants with non-accidental trauma or severe intracranial injury, but were not exclusive to these cases. Although retinal hemorrhages are frequently reported in abusive head trauma and represent an important warning sign, our findings confirm that they may also occur in some accidental conditions, particularly in the presence of significant intracranial lesions [14, 15]. Retinal findings, especially when unilateral, should be interpreted with caution and always considered in conjunction with clinical presentation, neuroimaging, and other associated findings. In our series, bilateral retinal hemorrhages were found in a context of non-accidental injury.

Overall outcomes were favorable in most infants. Nevertheless, approximately one in ten patients required neurosurgical intervention, and a significant minority required intensive care management. These findings confirm that head trauma during infancy, even when relatively common, may occasionally result in severe complications.

While the overall rate of neurosurgical intervention did not differ significantly between non-accidental and accidental trauma, the indications for surgery varied substantially between groups. In accidental injuries, surgical procedures were most often related to focal post-traumatic lesions, such as epidural hematomas or depressed skull fractures, typically occurring at the site of impact. In contrast, non-accidental trauma more frequently involved diffuse intracranial pathology, reflecting a different underlying biomechanical pattern. This distinction is clinically important and may not be fully captured by comparisons limited to surgical rates alone.

From a preventive perspective, the predominance of accidental mechanisms suggests that many injuries during infancy occur in everyday domestic environments. Falls from changing tables, beds, sofas, and infant equipment represented a substantial proportion of events. These observations highlight the importance of anticipatory guidance for caregivers, particularly during periods of rapid developmental change when new motor abilities emerge [16].

Limitations

This study has several limitations. Its retrospective design may introduce information bias regarding the exact circumstances and characteristics of trauma, particularly fall height and pediatric Glasgow Coma Scale (pGCS) at emergency admission (these elements could not be analyzed because they were missing from most of our population's medical charts). The relatively small number of non-accidental trauma cases limited statistical comparisons between groups, in particular comparing outcomes in the different mechanism-of-trauma groups. Moreover, as previously stated, our cohort includes hospitalized patients only. For this reason, late-presenting cases with mild clinical courses may be underrepresented

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in this study, and thus some mechanisms of injury might show a different rate in real-life settings. Finally, long-term neurodevelopmental outcomes were not systematically available.

All these aspects, possibly aiming to find prognostic factors for trauma in infants, are still poorly known and should be further investigated in future studies.

Despite these limitations, the relatively large cohort of infants with skull fractures and the detailed characterization of mechanisms across the entire first year of life provide valuable insight into head trauma during this critical developmental period.

CONCLUSION

Skull fractures during the first year of life demonstrate clear developmental patterns of injury mechanisms. Caregiver-related falls predominate in the earliest months, whereas lack of supervision-related injuries and self-induced falls increase as mobility develops. Although most infants experience favorable outcomes, a meaningful proportion require neurosurgical or intensive care management.

Understanding the developmental context of these injuries may improve clinical assessment and support targeted preventive strategies aimed at reducing head trauma during infancy.

DISCLOSURES

Ethical approval

This study was performed in line with the principles of the Declaration of Helsinki. This retrospective study was submitted to and approved by our Institutional Ethics Committee, IRB de Neurochirurgie, n° IRB00011687, Collège de Neurochirurgie protocol reference IRB #1: 2025/39.

Consent to participate

Since the retrospective nature of the study, consent to participate in the study was considered not necessary because: all the collected data represented standard data included in every chart at our Institution to guarantee the best practice; and, in compliance with the French data protection law (Loi Informatique et Libertés) and the General Data Protection Regulation (GDPR), all patient data was anonymized prior to analysis to ensure confidentiality. Families of patients whose computed tomography (CT) scan images appear in this study did not oppose to their use in a completely anonymized form.

Conflict of interest

The authors report no conflict of interest regarding the materials or methods used in this study or the findings reported in this paper.

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Artificial intelligence

The authors used a large language model (ChatGPT, OpenAI) for editing support for the English language. All AI-assisted outputs were reviewed and verified by the authors.

CONTRIBUTIONS

Alessandra Musarra: Conceptualization; Methodology; Data curation; Formal analysis; Investigation; Writing – original draft.
Pierre Petitet: Data curation; Formal analysis; Investigation; Writing – review & editing.
Camilla de Laurentis: Conceptualization; Supervision; Validation; Writing – review & editing.
Audrey Mittelman: Data curation; Investigation.
Pierre-Aurélien Beuriat: Conceptualization; Supervision; Validation; Writing – review & editing.
Alexandru Szathmari: Conceptualization; Supervision; Validation; Writing – review & editing.
Matthieu Vinchon: Conceptualization; Supervision; Validation; Writing – review & editing.
Nicolas Pianton: Data curation; Investigation.
Yves Gillet: Data curation; Investigation.
Federico Di Rocco: Supervision; Validation; Writing – review & editing.

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