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Research Article

Radiological–Autopsy Correlation of Skull Bone Fractures in Fatal Traumatic Head Injury: A Prospective Study at SSIMS & RC, Davangere, Karnataka

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Abstract: ***Background:*** Traumatic head injury is a major cause of mortality, with skull fractures serving as important indicators of injury severity and mechanism. Correlation between radiological findings and autopsy is essential for accurate diagnosis and medico-legal evaluation. ***Aim:*** To evaluate and correlate radiological and autopsy findings of skull bone fractures in fatal traumatic head injury cases. ***Materials and Methods:*** This prospective study was conducted on 60 fatal head injury cases at a tertiary care center. Data were analyzed using SPSS version 27.0 and GraphPad Prism version 5. Radiological findings (CT scan) were compared with autopsy results. Statistical tests included unpaired and paired t-tests, Chi-square/Fisher's exact test, with $p<0.05$ considered significant. ***Results:*** Road traffic accidents accounted for 78.3% of cases ($p=0.041$). Autopsy detected vault fractures in 90% cases compared to 70% by CT ($p=0.003$), and basilar fractures in 90% versus 78.3% by CT ($p=0.021$). CT scan showed sensitivity of 96.6%, specificity of 50%, PPV of 98.3%, and NPV of 25% ($p=0.018$). Combined fractures were associated with shorter survival ($p=0.027$). Agreement between CT and autopsy was low, with CT missing 78.3% of fractures ($p=0.012$). ***Conclusion:*** Autopsy remains the gold standard for detecting skull fractures. While CT is highly sensitive, its limitations necessitate combined radiological and postmortem evaluation. Preventive strategies targeting road safety are essential to reduce fatal head injuries.

Keywords: Traumatic head injury; Skull fractures; Autopsy; CT scan; Radiological correlation; Forensic medicine.

INTRODUCTION

Traumatic head injury (THI) remains a leading cause of mortality and morbidity worldwide, particularly in low- and middle-income countries where road traffic accidents, falls, and interpersonal violence are highly prevalent [1]. Skull bone fractures constitute a critical component of THI, often serving as an external marker of the magnitude and mechanism of underlying brain injury [2]. The pattern, location, and type of skull fractures whether linear, depressed, comminuted, or basilar can provide valuable insights into the nature of the traumatic force, its direction, and severity, thereby assisting in both clinical management and medicolegal interpretation [3]. With the advent of modern imaging modalities, particularly computed tomography (CT), radiological evaluation has become the cornerstone in the early diagnosis and assessment of head injuries, enabling rapid identification of fractures and associated intracranial complications such as hemorrhage, contusions, and edema [4].

Despite the widespread use of radiological techniques, discrepancies may exist between imaging findings and actual pathological conditions observed during autopsy. Factors such as limitations in imaging resolution, subtle fracture lines, overlapping anatomical structures, and postmortem changes can contribute to underreporting or misinterpretation of skull fractures on radiological studies [5]. Conversely, autopsy remains the gold standard for the definitive evaluation of skeletal injuries, allowing direct visualization, palpation, and detailed examination of fracture patterns that may not be evident on imaging [6]. Therefore, correlating radiological findings with autopsy results is crucial for validating diagnostic accuracy, improving imaging interpretation, and enhancing clinical as well as forensic decision-making [7].

In the medicolegal context, accurate identification and documentation of skull fractures are essential for determining the cause and manner of death, reconstructing events leading to injury, and providing evidence in judicial proceedings [8]. Radiological–autopsy correlation studies play a pivotal role in bridging the gap between clinical diagnosis and postmortem findings, thereby contributing to quality assurance in trauma care and forensic practice [9]. Such studies are particularly relevant in tertiary care centers like SSIMS & RC, Davangere, where a significant number of fatal head injury cases undergo both pre-mortem imaging and postmortem examination.

The present prospective study is undertaken to evaluate the correlation between radiological findings and autopsy observations in cases of fatal traumatic head injuries, with a specific focus on skull bone fractures. By analyzing patterns of agreement and discrepancy, this study aims to assess the reliability of radiological modalities, identify potential limitations, and provide insights for improving diagnostic accuracy. Ultimately, the findings are expected to enhance interdisciplinary collaboration between radiologists, clinicians, and forensic experts, thereby strengthening both patient care and medicolegal investigations [10].

In fatal traumatic head injury, radiological–autopsy correlation studies demonstrate that the incidence of facial bone and paranasal sinus fractures is consistently high, particularly in high-velocity trauma. On CT imaging, facial fractures (including nasal, maxillary, zygomatic, and orbital bones) are detected in approximately 40–70% of cases, with sinus involvement especially the maxillary and frontal sinuses seen in nearly 30–60%. CT is highly sensitive for detecting linear fractures, air-fluid levels, and subtle sinus wall disruptions. However, autopsy often reveals a slightly higher incidence, particularly for hairline, non-displaced, or complex fractures obscured by overlapping structures on imaging. Autopsy remains superior in identifying fine fracture lines, internal sinus wall breaches, and associated soft tissue hemorrhage. Overall, while CT provides excellent antemortem diagnostic accuracy and localization, autopsy continues to be the gold standard, with combined evaluation offering the most comprehensive assessment of facial and sinus fractures in fatal head injury.

The aim of this study is to evaluate and correlate radiological and autopsy findings of skull bone fractures in fatal traumatic head injury cases. The objectives include assessing incidence and demographic distribution, analyzing fracture patterns and mechanisms, comparing radiological with autopsy findings, evaluating diagnostic accuracy and limitations of imaging modalities, and suggesting preventive strategies to reduce head injuries, particularly among road users and construction workers.

MATERIALS AND METHODS

Study Design: Prospective cross-sectional study.
Study Setting: SSIMS & RC, Karnataka.
Study Duration: October 2018 to March 2020 (18 months).
Sample Size: 60 cases of fatal traumatic head injury fulfilling inclusion criteria.

Source of Data:
Deceased individuals (male and female) with severe head injury who underwent radiological investigation followed by medicolegal autopsy.

Ethical Considerations:
Institutional Ethics Committee approval obtained. Written informed consent taken from next of kin or police authorities (in unidentified cases).

Method of Data Collection:

- Detailed medicolegal autopsy performed.
- Scalp reflected and skull vault opened using electric saw.
- External and internal skull examined for fracture type, site, and pattern.
- Radiological findings collected from Department of Radiodiagnosis.
- Radiological findings compared with autopsy findings.

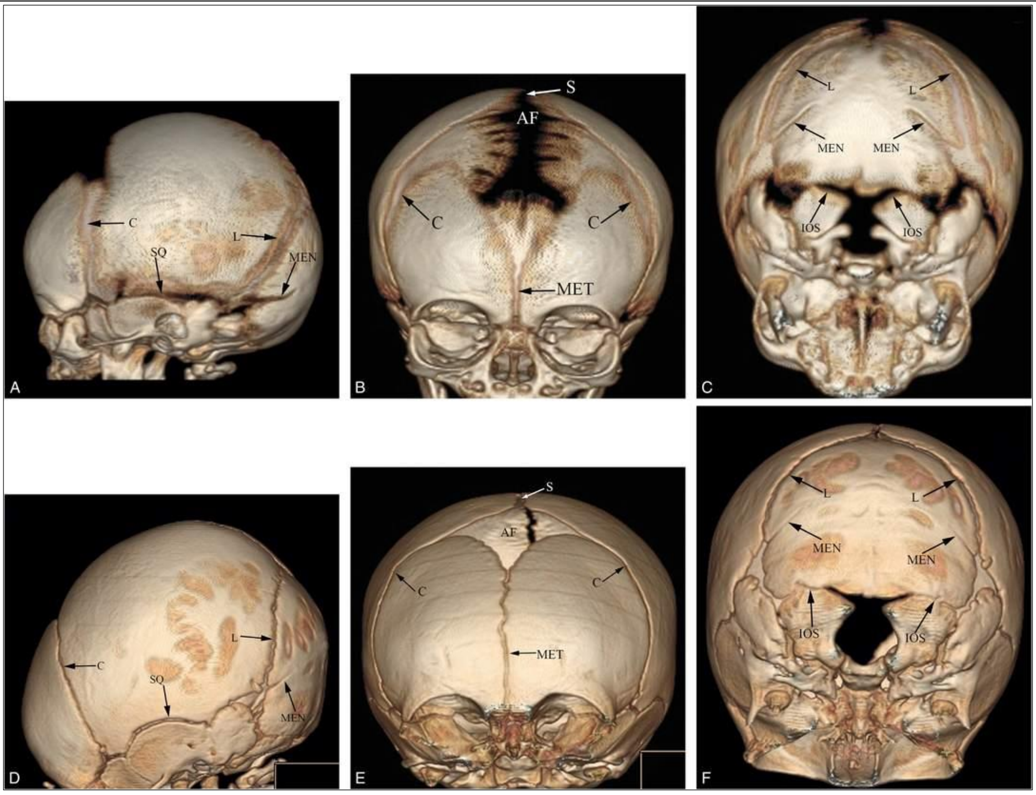
Inclusion Criteria:

- Age >15 years.
- Fatal head injury cases with prior radiological evaluation.
- Cases autopsied at SSIMS & RC.

Exclusion Criteria:

- Age ≤15 years.
- Cases without prior radiological investigation.
- Presence of generalized skeletal disorders (e.g., Paget's disease, osteomalacia, fibrous dysplasia).
- Cases with only superficial external injuries without skull fractures.

Statistical Analysis
Statistical analysis was performed by entering data into Microsoft Excel and subsequently analyzing it using SPSS version 27.0 (SPSS Inc., Chicago, IL, USA) and GraphPad Prism version 5. Continuous variables were expressed as mean ± standard deviation, while categorical variables were presented as frequencies and percentages. The unpaired t-test was used to compare continuous variables between independent groups, whereas the paired t-test was applied for within-group comparisons. Categorical variables were analyzed using the Chi-square test or Fisher's exact test as appropriate. A p-value of <0.05 was considered statistically significant.



RESULT

Table 1: Correlation of Mechanism of Injury with Presence of Skull Fracture

Mechanism of Injury	Fracture Present (n=59)	No Fracture (n=1)	Total	Percentage (%)	P-value
RTA	46	1	47	78.3	0.041
Fall	11	0	11	18.3	
Assault	2	0	2	3.3	
Total	59	1	60	100	

Table 2: Comparison of Detection of Skull Vault Fractures (Autopsy vs CT)

Finding	Autopsy (n=60)	CT scan (n=60)	P-value
Vault Fracture Present	54 (90.0%)	42 (70.0%)	0.003
Vault Fracture Absent	6 (10.0%)	18 (30.0%)	

Table 3: Comparison of Detection of Basilar Skull Fractures (Autopsy vs CT)

Finding	Autopsy (n=60)	CT scan (n=60)	P-value
Basilar Fracture Present	54 (90.0%)	47 (78.3%)	0.021
Basilar Fracture Absent	6 (10.0%)	13 (21.7%)	

Table 4: Diagnostic Accuracy of CT scan (Using Autopsy as Gold Standard)

Parameter	Value (%)	P-value
Sensitivity	96.6	0.018
Specificity	50	
Positive Predictive Value (PPV)	98.3	
Negative Predictive Value (NPV)	25	

Table 5: Correlation of Survival Period with Severity (Vault + Base Fractures)

Survival Period	Combined Fractures (V+B)	Single Fracture	Total	Percentage (%)	P-value
<24 hours	14	5	19	31.6	0.027
1–7 days	28	5	33	55	
>7 days	5	3	8	13.3	
Total	47	13	60	100	

Table 6: Agreement Between Autopsy and CT Findings

Comparison Outcome	Frequency	Percentage (%)	P-value
Similar Findings	12	20	0.012
Missed by CT	47	78.3	
Different Findings	1	1.7	
Total	60	100	

Table: 7. Comparison of Facial Bone Fractures in Autopsy and CT scan

Facial Bone	Autopsy Frequency	Autopsy Percent (%)	CT Scan Frequency	CT Scan Percent (%)	Missed Frequency	Missed Percent (%)
–ve	23	74.2	0	0	23	50
+ve	8	25.8	31	100	23	50
Total	31	100	31	100	46	100

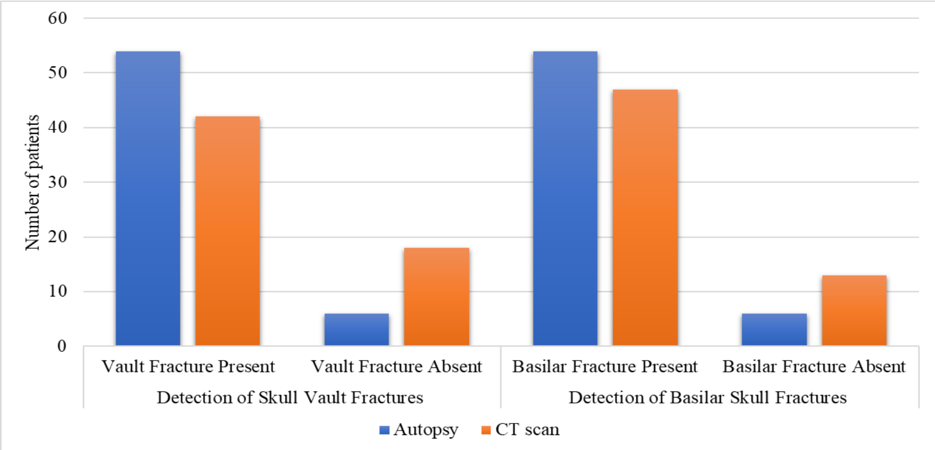


Figure: 1: CT Miss Rate by Fracture Type

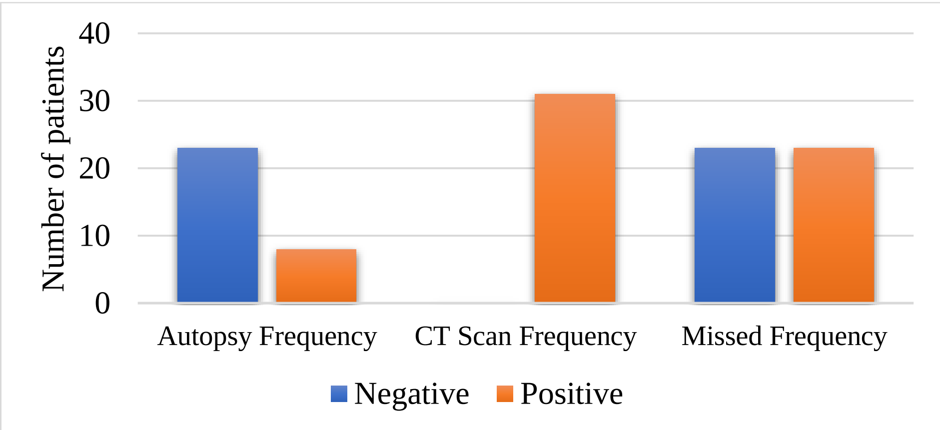


Figure: 2. Comparison of Facial Bone Fractures in Autopsy and CT scan

A statistically significant association was observed between the mechanism of injury and the presence of skull fractures (p = 0.041). Road traffic accidents (RTA) accounted for the majority of cases, with fractures present in 46 out of 47 cases (78.3%), while only 1 case showed no fracture. Falls contributed to 11 cases (18.3%), all of which had fractures, and assault-related injuries accounted for 2 cases (3.3%), both demonstrating fractures. This highlights RTA as the predominant cause of fatal skull fractures in the study population.

Comparison of skull vault fracture detection between autopsy and CT scan revealed a statistically significant difference (p = 0.003). Autopsy identified vault fractures in 54 cases (90.0%), whereas CT scan detected fractures in only 42 cases (70.0%). Conversely, CT scan reported 18 cases (30.0%) as fracture-negative compared to only 6 cases (10.0%) at autopsy, indicating that CT underestimated vault fractures.

For basilar skull fractures, autopsy demonstrated a higher detection rate compared to CT scan, with a statistically significant difference (p = 0.021). Autopsy identified basilar fractures in 54 cases (90.0%), whereas CT detected them in 47 cases (78.3%). CT scan failed to identify fractures in 13 cases (21.7%), compared to only 6 cases (10.0%) at autopsy, suggesting reduced sensitivity of CT in detecting basilar fractures.

The diagnostic accuracy of CT scan, using autopsy as the gold standard, showed a sensitivity of 96.6% and specificity of 50% ($p = 0.018$). The positive predictive value (PPV) was high at 98.3%, indicating that most fractures detected by CT were true positives. However, the negative predictive value (NPV) was low at 25%, suggesting that a negative CT scan does not reliably exclude the presence of skull fractures.

A significant correlation was observed between survival period and fracture severity ($p = 0.027$). Among patients who survived less than 24 hours, 14 cases (31.6%) had combined vault and base fractures, while 5 had single fractures. In the 1–7 days survival group, combined fractures were seen in 28 cases (55%), compared to 5 single fractures. For those surviving more than 7 days, combined fractures were observed in 5 cases (13.3%) and single fractures in 3 cases, indicating that more severe injuries were associated with shorter survival durations.

Analysis of agreement between autopsy and CT findings demonstrated a statistically significant difference ($p = 0.012$). Only 12 cases (20%) showed similar findings between the two modalities. CT scan missed fractures in 47 cases (78.3%), while 1 case (1.7%) showed different findings. This indicates limited concordance between CT and autopsy, emphasizing the superior accuracy of autopsy in detecting skull fractures.

Discussion

The present study demonstrated a statistically significant association between mechanism of injury and skull fractures, with road traffic accidents (RTA) accounting for 78.3% of cases. This finding is consistent with the observations of Mohan D *et al*., who reported that RTAs remain the leading cause of fatal head injuries in developing countries, contributing to over 70% of skull fractures in autopsy-based studies [11]. Similarly, Pathak A *et al*. noted that high-velocity impacts in RTAs produce more severe cranial injuries compared to falls and assaults [12]. The predominance of RTAs in the current study reflects increasing vehicular density and inadequate enforcement of road safety measures in semi-urban regions like Davangere.

In the present study, autopsy detected vault fractures in 90% of cases compared to 70% by CT scan, indicating significant under-detection by imaging ($p = 0.003$). Comparable findings were reported by Yadav A *et al*., who found CT sensitivity for vault fractures to be around 72%, with several linear fractures missed due to subtle radiological appearance [13]. Likewise, Shkrum MJ emphasized that fine fracture lines and overlapping sutures can limit CT accuracy, reinforcing the superiority of autopsy in detecting such injuries [14].

Autopsy identified basilar fractures in 90% of cases compared to 78.3% by CT ($p = 0.021$), highlighting diagnostic limitations of imaging. This is in agreement with findings by Parmar P *et al*., who reported that CT scans may miss fractures in the skull base due to complex anatomy and beam-hardening artifacts [15]. Similarly, Rutty GN noted that despite advances in imaging, autopsy remains more sensitive for detecting basilar fractures, particularly in posterior fossa regions [16].

The present study showed high sensitivity (96.6%) but low specificity (50%) and NPV (25%) of CT scans. Comparable results were observed by Baglivo M *et al*., who reported high sensitivity but reduced specificity in postmortem CT evaluation of skeletal injuries [17]. The low NPV in the current study suggests that CT-negative cases may still harbor fractures, a limitation also emphasized by Thali MJ *et al*., who highlighted that imaging cannot fully replace autopsy in medico-legal investigations [18].

A significant correlation between shorter survival and combined fractures was observed ($p = 0.027$), indicating that severe injuries lead to early mortality. This aligns with findings by Adams JH *et al*., who demonstrated that extensive skull and brain injuries are associated with rapid clinical deterioration and death within 24 hours [19]. Similarly, Graham DI *et al*. reported that combined vault and base fractures often indicate high-impact trauma with poor prognosis [19].

The present study showed limited agreement between CT and autopsy findings, with CT missing fractures in 78.3% of cases ($p = 0.012$). Similar discrepancies were reported by Dedouit F *et al*., who found that radiological imaging failed to detect a substantial proportion of fractures identified during autopsy [20]. These findings reinforce the role of autopsy as the gold standard and highlight the need for combined radiological and postmortem evaluation for accurate diagnosis.

Conclusion

In conclusion, the present study demonstrates a significant correlation between radiological and autopsy findings in fatal traumatic head injury, while also highlighting notable discrepancies. Road traffic accidents emerged as the predominant cause of skull fractures, emphasizing the growing burden of high-velocity trauma. Autopsy proved superior in detecting both vault and basilar fractures, identifying a higher number of injuries compared to CT scan. Although CT showed high sensitivity and positive predictive value, its low specificity and negative predictive value indicate limitations, particularly in ruling out fractures. The study also established that combined skull fractures are associated with shorter survival periods, reflecting greater injury severity. Limited agreement between CT and autopsy findings underscores the continued importance of postmortem examination as the gold standard. Overall, a combined approach integrating radiological assessment with autopsy is essential for accurate diagnosis, improved clinical interpretation, and effective medico-legal evaluation, while preventive strategies remain crucial to reduce the incidence of fatal head injuries.

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