



PATTERN OF SKULL FRACTURES AND INTRACRANIAL HEMORRHAGES IN FATAL BLUNT FORCE HEAD TRAUMA: AN AUTOPSY STUDY FROM THE MAHAKAUSHAL REGION, CENTRAL INDIA

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Abstract

Background: Blunt force head trauma is a leading cause of mortality in medico-legal practice. The interplay between skull fractures and intracranial hemorrhages provides vital clues for establishing the cause of death and reconstructing the mechanism of injury.

Methods: A prospective autopsy-based study was conducted on **600 cases** of fatal blunt force head injury at N.S.C.B. Medical College, Jabalpur. Detailed analysis included demographic profile, cause of injury, fracture type and site, and intracranial hemorrhage distribution. Correlations between fracture site/type and hemorrhage patterns were evaluated.

Results: The majority of victims were male (80%) with peak incidence in the 21–40 year age group. Road traffic accidents (RTA) accounted for 58.33% of cases, followed by falls (29%), railway accidents (9%) and assaults (3%). Linear fractures were the most common (51.74%), followed by comminuted (22.46%), chrushed (6.32%) and depressed (4.43%). Temporal bone was the most frequently fractured site (40%). Subarachnoid hemorrhage (92.6%) was the leading intracranial lesion, followed by subdural hemorrhage (82.1%), extradural hemorrhage (9.8%), and intracerebral hemorrhage (8.3%). Coup injuries were observed in 34% of cases, contre-coup in 41%, and both in 25%. A strong correlation was found between temporal bone fractures and EDH, while frontal and parietal fractures were more often associated with SDH and SAH.

Conclusion: Temporal bone fractures and subarachnoid hemorrhage were the predominant findings in blunt force trauma deaths. These patterns underscore the forensic significance of correlating external injuries, fracture morphology, and hemorrhage distribution in death investigation.

Keywords: Blunt force trauma; Skull fractures; Intracranial hemorrhage; Coup–contrecoup; Forensic autopsy

Introduction

Head injuries continue to represent a substantial proportion of unnatural deaths worldwide, and their forensic relevance is paramount. Nearly one-third to one-half of traumatic fatalities are attributed to head injury alone^{1}. Blunt force trauma, frequently encountered in road traffic accidents, railway accidents, assaults, and falls, exerts a spectrum of effects ranging from scalp injuries to complex skull fractures and intracranial hemorrhages^{2}. Autopsy remains the gold standard for establishing precise injury patterns in dead. Knowledge of the type and site of fractures and hemorrhages aids not only in cause-of-death certification but also in reconstructing the sequence of events, weapon type, and mechanism of injury^{3}. While numerous studies have been conducted globally, data from Central India, particularly the Mahakaushal region, remain limited despite high trauma incidence due to dense traffic and railway networks. The present study was undertaken to delineate the **demographic profile, fracture patterns, and intracranial hemorrhage distribution** in fatal blunt force trauma, with emphasis on correlations that carry medico-legal importance.

Material and Methods

Study design

A **prospective observational autopsy-based study** was conducted to evaluate the patterns of skull fractures and intracranial hemorrhages in fatal blunt force head trauma. The study followed a consecutive sampling strategy to minimise selection bias and enhance external validity.

Study setting

The study was carried out in the Department of Forensic Medicine and Toxicology at N.S.C.B. Medical College, Jabalpur, Madhya Pradesh, India. The institution functions as a tertiary referral centre for medico-legal autopsies from Jabalpur district and surrounding areas of the Mahakaushal region.

Study duration

The study was conducted over an **18-month period**, from **August 2022 to January 2024**.

Study population and sample size

All medico-legal autopsies in which death was attributed primarily to **blunt force trauma to the head** during the study period were assessed for eligibility. A total of **600 cases** met the inclusion criteria and were enrolled. Since the study aimed to include all eligible cases within the defined time frame, formal sample size estimation was not performed.

Inclusion criteria

- Deaths resulting from blunt force head injury
- Cases subjected to complete medico-legal autopsy
- Availability of intact cranial cavity for detailed examination
- Complete case records with documented history

Exclusion criteria

- Advanced decomposition interfering with assessment of cranial structures
- Cases with incomplete autopsy findings or missing records
- Deaths following neurosurgical intervention
- Penetrating head injuries and burn-related deaths

Data collection methodology

Data were collected using a **standardised, pre-structured proforma** to ensure uniformity. Information regarding age, sex, alleged manner of injury, and circumstances of death was obtained from police inquest reports, hospital records, and accompanying documents.

Autopsy findings recorded included:

- External scalp injuries
- Type, number, and anatomical location of skull fractures
- Cranial fossa involvement
- Presence, type, and distribution of intracranial hemorrhages
- Occurrence of coup, contrecoup, or combined lesions

Autopsy technique

All post-mortem examinations were performed following **established medico-legal autopsy protocols**. The scalp was reflected in layers and examined for soft tissue injuries. The skull vault was opened using a circular saw, and fracture patterns were documented before removal.

Skull fractures were classified morphologically as:

- Linear (fissured)
- Comminuted
- Depressed
- Diastatic
- Ring fractures
- Pond fractures
- Elevated fractures
- Crushed fractures

The skull base was examined separately and categorised into anterior, middle, and posterior cranial fossae.

Examination of intracranial contents

The dura mater was inspected for extradural hemorrhage prior to opening. After dural reflection, the brain was removed carefully to avoid artefactual damage. Intracranial lesions assessed included:

- Subarachnoid hemorrhage
- Subdural hemorrhage
- Extradural hemorrhage
- Intracerebral hemorrhage

Hemorrhages were documented as isolated or multiple, along with their laterality and anatomical distribution.

Assessment of coup and contrecoup injuries

Coup and contrecoup injuries were identified based on the spatial relationship between the site of external impact, skull fracture location, and underlying brain lesions. Cases showing both patterns were categorised as combined injuries.

Operational definitions were standardised as follows:

- **Coup injury:** Brain injury located directly beneath the site of impact
- **Contrecoup injury:** Brain injury occurring opposite to the site of impact
- **Combined injury:** Presence of both coup and contrecoup lesions

Statistical analysis

Data were entered into Microsoft Excel and analysed using appropriate statistical software. Categorical variables were expressed as frequencies and percentages. The **Chi-square test** was applied to assess associations between skull fracture characteristics and intracranial hemorrhage patterns. A *p* value of **<0.05** was considered statistically significant.

Ethical considerations

The study involved deceased individuals subjected to medico-legal autopsy as part of routine forensic practice. No additional procedures beyond standard autopsy protocols were performed. Confidentiality and anonymity were maintained throughout the study. Ethical approval was obtained in accordance with institutional guidelines.

Results

A total of **600 fatal cases of blunt force head injury** were analysed during the study period.

Table 1. Distribution by age and sex (N = 600)

Age group (years)	Cases	%
0–20	87	14.5
21–40	278	46.33
41–60	172	28.33
>60	63	10.51

Demographic profile: The age and sex distribution of the victims is summarised in **Table 1**. The majority of cases belonged to the **21–40-year age group**, accounting for **278 cases (46.33%)**, followed by the **41–60-year group** with **172 cases (28.33%)**. Individuals aged **0–20 years** constituted **14.5%**, while those aged **above 60 years** accounted for **10.51%** of cases. Males predominated markedly, with **480 cases (80%)**, compared to **120 females (20%)**, resulting in a male-to-female ratio of approximately **4:1**.

Table 2. Causes of injury

Cause	Cases	%
Road traffic accidents (RTA)	350	58.33
Fall from height	174	29
Assaults	18	3
Railway accidents	54	9
Others	4	0.67

Cause of injury: The distribution of cases according to the cause of injury is shown in **Table 2**. **Road traffic accidents** were the leading cause, contributing **350 cases (58.33%)**. This was followed by **falls from height** in **174 cases (29%)**. **Railway accidents** accounted for **54 cases (9%)**, while **assaults** were responsible for **18 cases (3%)**. A small proportion of cases (**0.67%**) were attributed to other causes.

Table 3. Types of fractures (N = 600)

Fracture Type	Cases	%
Linear/ Fissured	327	51.74
Comminuted	142	22.46
Depressed	27	4.43
Ring fractures	28	5
Elevated	5	0.79
Pond Fracture	24	3.09
Crushed	40	6.32
Diastatic	39	6.17

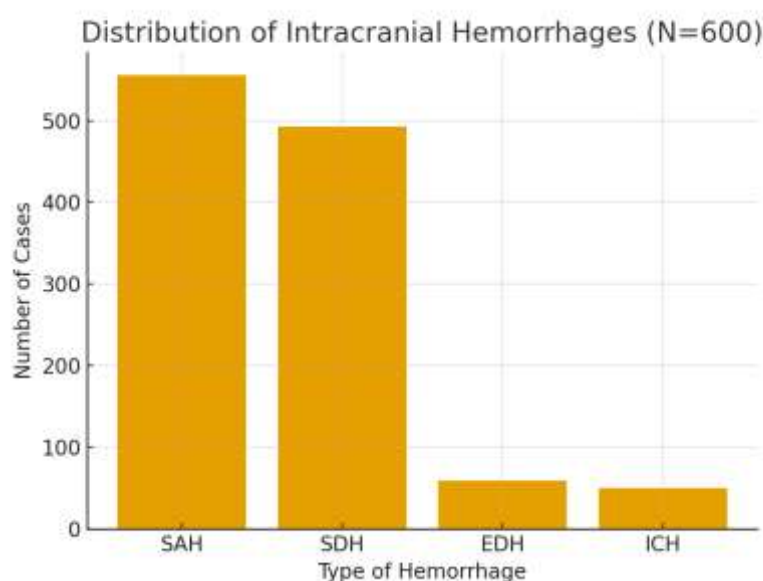
Pattern of skull fractures: The types of skull fractures observed are detailed in **Table 3**. **Linear (fissured) fractures** were the most common, identified in **327 cases (51.74%)**. **Comminuted fractures** were seen in **142 cases (22.46%)**. Less frequent fracture types included **crushed**

fractures (6.32%), ring fractures (5%), depressed fractures (4.43%), diastatic fractures (6.17%), pond fractures (3.09%), and elevated fractures (0.79%). With regard to anatomical distribution, the **temporal bone** was the most frequently involved site (40%), followed by the **parietal bone** (21.04%). Fractures of the **frontal bone** (9.01%) and **occipital bone** (6.08%) were less common. Involvement of the cranial fossae included the **anterior cranial fossa** (10.75%), **middle cranial fossa** (8.06%), and **posterior cranial fossa** (7.59%).

Table 4. Intracranial hemorrhage distribution (N = 600)

Hemorrhage Type	Cases	%
Subarachnoid (SAH)	556	92.66
Subdural (SDH)	493	82.16
Extradural (EDH)	59	9.83
Intracerebral (ICH)	50	8.33

Intracranial hemorrhages: The distribution of intracranial hemorrhages is presented in **Table 4**. **Subarachnoid hemorrhage** was the most frequent finding, observed in **556 cases (92.66%)**. This was followed by **subdural hemorrhage** in **493 cases (82.16%)**. **Extradural hemorrhage** was identified in **59 cases (9.83%)**, while **intracerebral hemorrhage** was present in **50 cases (8.33%)**. Multiple types of intracranial hemorrhage were noted in **243 cases (40.5%)**, with the combination of **subarachnoid and subdural hemorrhage** being the most common.



Coup vs. Contrecoup

Coup lesions alone: 204 cases (34%). Contrecoup lesions alone: 246 cases (41%). Combined coup-contrecoup: 150 cases (25%).

Correlation Between Fracture Site and Hemorrhage

Statistical analysis demonstrated a **significant association between temporal bone fractures and extradural hemorrhage** (χ^2 test, $p < 0.05$). EDH was disproportionately observed in cases involving temporal bone fractures compared to other fracture sites. Fractures involving the **frontal and parietal bones** showed a **statistically significant association with subdural and subarachnoid hemorrhages** ($p < 0.05$). Base of skull fractures, particularly those involving the **posterior cranial fossa**, were significantly associated with the presence of **subarachnoid hemorrhage** ($p < 0.05$). No statistically significant association was observed between fracture type and intracerebral hemorrhage ($p > 0.05$).

Discussion

The present study of 600 autopsies provides one of the largest datasets on blunt force head injury patterns from Central India.

Demographic profile: The predominance of young adult males (21–40 years, 46.33%) parallels national data^{4}. This reflects greater exposure to occupational hazards, travel, and high-risk behaviors such as speeding.

Cause of injury: Road traffic accidents (58.33%) overwhelmingly dominated, consistent with NCRB data^{2} and similar to findings by Banzal et al. (2015)^{4}. Assaults (3%) and railway accidents (9%) also contributed significantly, highlighting diverse trauma mechanisms in the region. This aligns with the National Crime Records Bureau (NCRB) report^{2} and with autopsy studies from Bhopal^{5}, Bangalore^{6} and Osmania^{7} where RTAs consistently dominated the etiology of fatal head injuries.

Fracture patterns: Linear fissure fractures (51.74%) were most frequent, comparable to international studies^{3}. Temporal fractures (40%) predominated, reaffirming the vulnerability of the thin squamous portion to lateral impacts. Similar observations were made by Ravikumar (2013) in Bangalore^{5}. With respect to fracture morphology, linear fissure fractures were the most common, corroborating findings from Bhopal,^{5} where linear fractures predominated. Temporal bone involvement was disproportionately higher in our study (40%), reflecting the vulnerability of the thin squamous temporal bone to lateral impacts. Ravikumar^{6} similarly highlighted the frequent occurrence of temporal fractures in two-wheeler accidents. The forensic significance of temporal fractures lies in their well-documented association with extradural hemorrhage due to laceration of the middle meningeal artery.^{9}

Intracranial hemorrhages: Subarachnoid hemorrhage (92.6%) emerged as the hallmark finding, surpassing subdural hemorrhage (82.1%). The high SAH prevalence suggests acceleration–deceleration forces typical of high-speed RTAs. Our SAH prevalence is higher than the 67% reported by Muataz and Jabor,^{10} but comparable to Indian data by Nair and Lakshmanan^{11} who reported SAH in 84.9% of cases. Extradural hemorrhage (9.8%) was less frequent but strongly correlated with temporal fractures, consistent with classical forensic teachings^{9}. SDH was commonly associated with frontal and parietal fractures, indicating venous tearing and shearing forces.

Coup and contrecoup: Nearly two-thirds of cases exhibited contre-coup or combined lesions, reflecting rotational forces and skull distortion. Similar conclusions were drawn by Bhateja et al. (2009)^{8}, who demonstrated greater mortality in coup–contrecoup injuries compared to coup alone. Forensic reconstruction of impact dynamics relies heavily on these patterns: coup injuries point toward direct force application, whereas contrecoup lesions support mobility of the head at impact, often seen in vehicular accidents.

Correlations: The association of temporal fractures with EDH is well documented due to laceration of the middle meningeal artery^{9}. SDH and SAH with frontal/parietal fractures emphasize shearing and venous injury mechanisms.

Forensic implications: External-internal correlation helps determine whether trauma was accidental or homicidal. Coup/contrecoup distribution can assist in reconstructing the direction and mechanism of impact. Recognition of fracture-hemorrhage associations strengthens medico-legal testimony in courts.

Conclusion

The present autopsy-based study of 600 cases provides overview of the pattern and correlation of skull fractures and intracranial hemorrhages in fatal blunt force head trauma from the Mahakaushal region of Central India. The findings underscore that head injuries continue to be a leading cause of death in medico-legal autopsies, with young adult males (21–40 years) forming the most vulnerable group due to their active mobility and risk-prone lifestyle. Linear fissured fractures, particularly involving the temporal bone, emerged as the most frequent morphological and anatomical type. This

dominance can be attributed to the structural delicacy of the squamous temporal bone and its exposure to lateral impacts during vehicular collisions. The strong association between temporal fractures and extradural hemorrhage reaffirms the classical forensic principle of middle meningeal artery laceration as a major cause of fatal epidural bleeding. In contrast, frontal and parietal fractures demonstrated significant correlation with subdural and subarachnoid hemorrhages, emphasizing the role of acceleration–deceleration forces and cortical vein tearing in their pathogenesis. Subarachnoid hemorrhage was the most common intracranial lesion, seen in over 90% of cases, often coexisting with subdural hemorrhage. In conclusion, fatal blunt force head trauma in this region is characterized by a triad of **linear temporal fractures, predominant subarachnoid hemorrhage, and road traffic–related etiology**, most frequently affecting young males. The study emphasizes the necessity for **preventive public health interventions**—such as strict enforcement of traffic regulations, helmet compliance, and awareness campaigns—to mitigate preventable head injury–related deaths.

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