

Injury Pattern of the Face and Skull in Fatal Road Traffic Accidents: Evidence from Autopsy Cases

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Abstract

Background: Road traffic accidents (RTAs) are a leading cause of mortality worldwide, with head and facial injuries contributing significantly to deaths. Understanding the pattern of craniofacial trauma in fatal RTAs is crucial for guiding preventive strategies, trauma care, and policymaking.

Aims & Objectives: To analyze the demographic profile, victim categories, and patterns of face and skull injuries in fatal RTAs based on medicolegal autopsy cases.

Methods: A cross-sectional study was conducted on 380 autopsy cases of fatal RTAs at a tertiary care hospital. Data on age, sex, type of victim, and injury patterns were collected and analyzed. The distribution of skull fractures and intracranial hemorrhages was studied. Statistical analysis was performed to identify significant associations.

Results: The majority of victims were males (73.2%), with the highest incidence in the 21–40-year age group (46.8%). Pedestrians (39.5%) and two-wheeler riders (31.1%) were the most common victims. Basal skull fractures (31.8%) and frontal bone fractures (21.6%) were predominant. Subdural hemorrhage (33.2%) was the most frequent intracranial lesion, followed by subarachnoid hemorrhage (41.6%).

Conclusion: Head and facial injuries are central to fatal RTAs, with young adult males and pedestrians being most vulnerable. The predominance of basal skull fractures and subdural hemorrhage underscores the lethality of craniofacial trauma.

Keywords: Road Traffic Accidents, Autopsy, Skull Fracture, Intracranial Hemorrhage, Pedestrians, Helmet Use.

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Introduction

Road traffic accidents (RTAs) remain one of the leading causes of morbidity and mortality worldwide and are increasingly recognized as a major public health concern. According to the World Health Organization (WHO) Global Status Report on Road Safety (2023), road traffic injuries account for approximately 1.19 million deaths annually, with a disproportionate burden falling on low- and middle-income countries [1]. India alone contributes nearly 11% of global RTA-related deaths, with over 150,000 fatalities recorded annually [2]. RTAs predominantly affect young and economically productive age groups, thereby exerting a profound socioeconomic impact on families and healthcare systems.

Among the various types of trauma sustained in RTAs, head and facial injuries are particularly significant due to their direct association with mortality, disability, and disfigurement. The head is highly vulnerable in collisions because of its exposed anatomical position and the biomechanical forces transmitted during impact. The skull often absorbs the primary force of collision, resulting in fractures, intracranial hemorrhages, and brain injuries. Facial injuries, although not always fatal, are common markers of severe trauma and can be associated with airway compromise, hemorrhage, and cosmetic deformity [3]. In fatal cases, patterns of injury to the face and skull provide critical

insights into the mechanism of trauma, seating position of the victim, use of safety devices such as helmets or seat belts, and the type of collision [4].

Autopsy-based studies remain one of the most reliable means of documenting and analyzing patterns of injury in RTAs. Unlike hospital-based series, autopsies include individuals who succumb at the scene of the accident or shortly thereafter, ensuring a more comprehensive understanding of the fatal injury spectrum [5]. Post-mortem examination of craniofacial injuries helps not only in medico-legal documentation but also in identifying preventive strategies by highlighting vulnerable anatomical regions. Globally, studies have consistently demonstrated that head injuries are the most common cause of death in RTAs, accounting for 50–70% of fatalities [6]. The spectrum of skull injuries ranges from linear fractures to depressed and comminuted fractures, often associated with subdural, epidural, subarachnoid, or intracerebral hemorrhages [7].

Facial injuries, particularly fractures of the maxilla, mandible, nasal bones, and orbital structures, have been reported in 30–60% of victims depending on the mechanism of impact [8]. Importantly, the distribution and severity of these injuries differ between pedestrians, two-wheeler riders, and occupants of four-wheelers, reflecting variations in biomechanics and protective measures [9].

In the Indian context, RTAs assume particular importance due to factors such as rapid urbanization, poor road infrastructure, inadequate enforcement of traffic regulations, and low rates of helmet and seat belt use [10]. Two-wheelers account for the majority of road traffic crashes, and riders often sustain severe craniofacial trauma owing to inadequate or improper helmet usage [11]. Autopsy-based studies from different regions of India have reported that head injuries alone contribute to nearly 60–80% of deaths in RTAs, underscoring their lethal potential [12]. Facial injuries, although less commonly fatal, serve as vital indicators of the mechanism and severity of impact. [13]

Despite the increasing burden of RTAs in India, limited regional autopsy-based data are available on craniofacial injury patterns, particularly in tertiary care hospitals where medico-legal autopsies are routinely conducted. Most existing studies emphasize overall injury distribution but lack detailed focus on the face and skull, which are among the most critical anatomical sites in determining survival outcomes [14]. A systematic analysis of craniofacial injuries can bridge this gap and generate region-specific evidence to inform both clinical trauma management and public health policy.

With this background, the present study aims to analyze the pattern of face and skull injuries in fatal road traffic accidents based on medico-legal autopsies conducted in a tertiary care hospital. The objectives were to identify the prevalence and distribution of craniofacial injuries, evaluate their association with demographic and crash-related factors, and highlight potential preventive measures.

Material and Methods

Study Settings & Design: A prospective, descriptive, observational study was conducted on medico-legal autopsy cases of road traffic accident (RTA) victims. The study was carried out in the Department of Forensic Medicine and Toxicology at a Tertiary Care Teaching Hospital in North India, where medico-legal autopsies are routinely performed. This center caters to urban as well as semi-urban and rural populations, thereby providing a representative sample of regional RTA fatalities. The study focused specifically on analyzing the pattern of injuries involving the face and skull in fatal RTA cases. The study was conducted over a period of 12 months from September 2024 to August 2025, covering all consecutive eligible cases within the study timeframe. A total of 380 medico-legal autopsies of fatal RTA victims were studied during the period, forming the study cohort.

Study Population: All cases of fatal RTAs brought for medico-legal autopsy during the study period were included. Victims comprised pedestrians, two-wheeler riders, pillion riders, and occupants of three- and four-wheeled vehicles.

Inclusion Criteria

- All medico-legal autopsy cases of fatal RTAs irrespective of age, sex, or type of vehicle.
- Cases where the cause of death was attributable to injuries sustained during the RTA.

Exclusion Criteria

- Bodies in an advanced stage of decomposition where injury assessment was not possible.
- Cases with unclear history or inadequate documentation regarding involvement in RTA.
- Deaths due to non-traumatic causes or natural diseases, even if occurring after an accident.

Data Collection: Data were collected using a pre-designed proforma that included:

1. Demographic details – age, sex, residence.
2. Crash-related factors – type of victim (pedestrian, rider, and passenger), type of vehicle involved, and alleged circumstances of accident.

3. Autopsy findings – external and internal examination with specific emphasis on:

- Facial injuries (abrasions, lacerations, contusions, fractures of nasal bone, maxilla, mandible, zygoma, orbit, etc.).
- Skull injuries (linear, comminuted, depressed, base of skull fractures).
- Associated intracranial findings (epidural, subdural, subarachnoid, intraparenchymal hemorrhage, cerebral edema, brain lacerations).

Definitions and Classification

- Injuries were classified according to the WHO injury classification and standard forensic terminology.
- Skull fractures were categorized as vault fractures (frontal, parietal, temporal, occipital) or base fractures (anterior, middle, posterior cranial fossa).
- Facial fractures were grouped into upper, middle, and lower third of the face.

- Intracranial hemorrhages were documented as epidural, subdural, subarachnoid, and intracerebral.

Data Analysis: Data were entered into Microsoft Excel and analyzed using SPSS (Statistical Package for Social Sciences), version 21. Results were expressed in terms of frequency, percentage, mean $\pm$ SD.

- Chi-square test was used to analyze categorical variables (e.g., sex vs. type of injury).
- $p < 0.05$ was considered statistically significant.

Results & Observations

A total of 380 medico-legal autopsies of fatal RTA victims were analyzed during the study period. The results are presented under demographic details, accident-related factors, and autopsy findings with specific emphasis on facial and skull injuries.

Table 1: Age and Sex Distribution of Victims (n=380)

Age Group (years)	Male (n=278)	Female (n=102)	Total (%)
<20	25	18	43 (11.4)
21–40	142	36	178 (46.8)
41–60	82	31	113 (29.7)
>60	29	17	46 (12.1)
Total	278	102	380 (100)

Out of 380 cases, 278 (73.2%) were males and 102 (26.8%) were females, giving a male-to-female ratio of approximately 2.7:1. The majority of victims belonged to the 21–40 years age group (46.8%), followed by 41–60 years (29.7%). Elderly (>60 years) accounted for 12.1%, while children (<20 years) contributed 11.4% of cases.

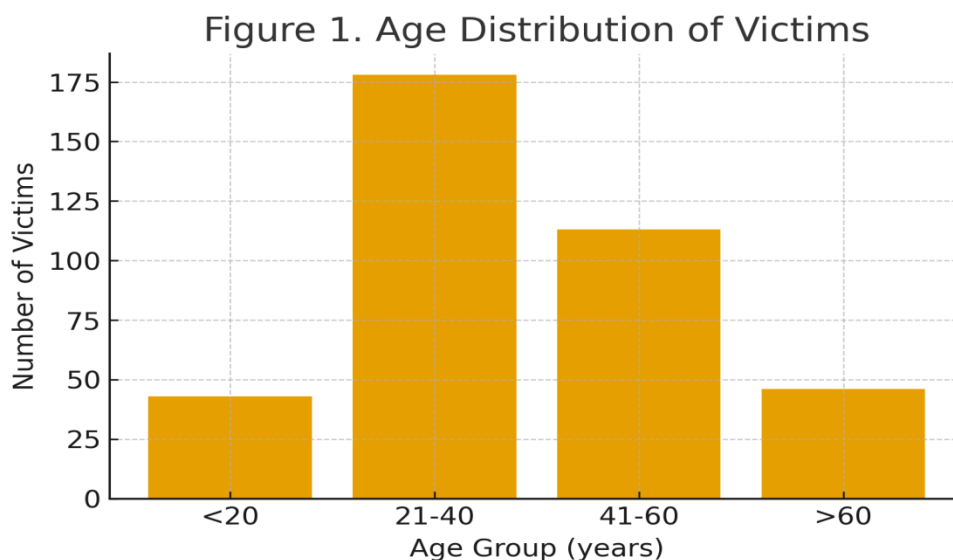


Figure 1: Age Distribution of Victims

(Bar graph showing maximum deaths in 21–40 years).

Table 2: Type of Victim in RTAs (n=380)

Victim Category	Frequency (%)
Pedestrian	150 (39.5)
Two-wheeler rider	118 (31.1)
Pillion rider	41 (10.8)
Occupant (LMV/HMV)	71 (18.6)
Total	380 (100)

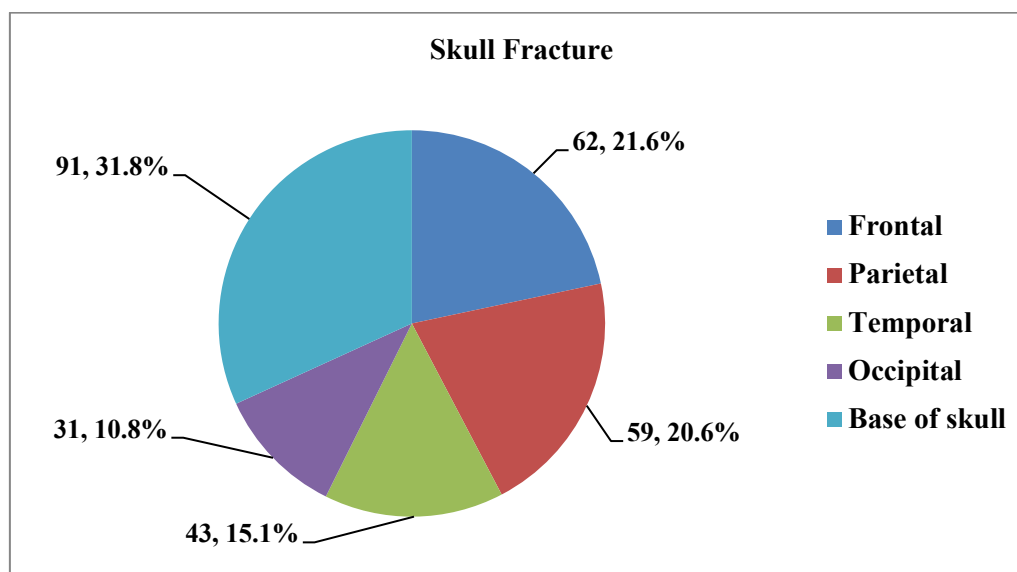
Pedestrians constituted the largest group (39.5%), followed by two-wheeler riders (31.1%), pillion riders (10.8%), and occupants of cars/buses/trucks (18.6%). Two-wheeler accidents were most common (42.4%), followed by heavy motor vehicles (27.6%) and light motor vehicles (22.1%).

Table 3: Distribution of Facial Injuries (n=244)

Type of Injury	Number (%)
Abrasions/Contusions	130 (53.3)
Lacerations	73 (29.9)
Fractures	41 (16.8)
Total	244 (100)

Out of 380 victims, 244 (64.2%) sustained facial injuries. Among them, abrasions and contusions were most common (53.3%), followed by lacerations (29.9%) and fractures (16.8%). Fracture analysis revealed:

- Nasal bone fractures – 28 cases (7.4%)
- Mandibular fractures – 22 cases (5.8%)
- Maxillary fractures – 18 cases (4.7%)
- Zygomatic and orbital fractures – 16 cases (4.2%)

**Figure 2: Pie Chart of Skull Fracture Distribution**

Skull fractures were present in 286 cases (75.3%). The majority were vault fractures (65.4%), followed by base of skull fractures (34.6%).

- Frontal bone: 62 cases (21.6%)

- Parietal bone: 59 cases (20.6%)
- Temporal bone: 43 cases (15.1%)
- Occipital bone: 31 cases (10.8%)
- Base fractures: 91 cases (31.8%)

Table 4: Types of Intracranial Hemorrhage (n=303)

Type of Hemorrhage	Number (%)
Subdural	126 (41.6)
Subarachnoid	87 (28.7)
Intracerebral	61 (20.1)
Epidural	29 (9.6)
Total	303 (100)

Intracranial hemorrhages were detected in 303 victims (79.7%).

Subdural hemorrhage was most common (41.6%), followed by subarachnoid (28.7%), intracerebral (20.1%), and epidural hemorrhage (9.6%).

Association of Skull Injuries with Age and Sex:

Skull fractures were more common in males (77.7%) than females (68.6%). Age-wise, younger adults (21–40 years) showed the highest frequency of skull fractures (80.3%). Statistical analysis showed a significant association between age and type of skull injury ($p < 0.05$).

Summary of Findings

- Majority of fatalities were young adult males.
- Pedestrians and two-wheeler riders were the most vulnerable groups.
- Facial injuries were present in nearly two-thirds of victims, with abrasions/contusions being the most common.
- Skull fractures were documented in three-fourths of cases, predominantly vault fractures.
- Subdural hemorrhage emerged as the leading intracranial lesion.

Discussion

The present study analyzed 380 medico-legal autopsy cases of fatal road traffic accidents (RTAs) with emphasis on facial and skull injuries. Findings revealed that the majority of victims were young adult males, with pedestrians and two-wheeler riders constituting the most vulnerable groups. Skull fractures and intracranial hemorrhages were the leading fatal injuries, aligning with the central role of head trauma in RTA-related mortality.

Demographic Distribution: The predominance of males (73.2%) in the present study is consistent with previous autopsy-based studies across India and abroad. Chaurasia et al. (2019) [15] reported that nearly 70% of RTA fatalities were men, largely attributable to their higher exposure to outdoor activities, occupation-related travel, and greater use of two-wheelers. Young adults aged 21–40 years (46.8%) were the most affected group, highlighting the loss of economically productive life years. This mirrors the findings of Kumar et al. (2020), [16] who observed that individuals in this age range are more prone to risky driving behaviors, including speeding, alcohol consumption, and neglecting protective gear.

The relatively lower involvement of females may be linked to lower driving frequency, particularly in rural and semi-urban areas, though changing trends in urban settings suggest that female vulnerability is gradually increasing (World Health Organization, 2018). [17]

Type of Victim and Vehicle Involvement:

Pedestrians (39.5%) and two-wheeler riders (31.1%) were disproportionately represented among the deceased. This corroborates reports from the National Crime Records Bureau (NCRB, 2022), [18] which identified pedestrians and motorized two-wheeler riders as the most vulnerable road users in India.

Lack of pedestrian infrastructure, poor visibility, over speeding, and non-adherence to helmet use are major contributing factors. In a study from South India, Reddy et al. (2018) [12] also found pedestrians accounted for nearly 40% of fatalities, underscoring their exposure risk in mixed traffic conditions. The high proportion of two-wheeler-related fatalities (42.4%) in this study underlines the urgent need for stricter enforcement of helmet legislation. Notably, pillion riders accounted for 10.8% of cases, suggesting inadequate awareness about compulsory helmet use for passengers, despite legal mandates.

Facial Injuries: Facial injuries were observed in 64.2% of victims, with abrasions and contusions predominating. This pattern indicates direct impact on the face during collision, especially among two-wheeler riders and pedestrians struck by larger vehicles. Fractures of the nasal bone, mandible, and maxilla were frequent, consistent with biomechanical vulnerability of midfacial structures.

Previous studies have similarly noted high incidence of facial trauma in RTAs. Singh et al. (2017) [18] reported that the middle third of the face was most commonly injured due to frontal impacts. Although facial injuries are not always fatal, their presence serves as important forensic evidence of the direction and mechanism of impact. Moreover, fractures such as those of the mandible and orbit may be associated with concomitant basal skull fractures, a relationship that deserves closer medico-legal scrutiny.

Skull Fractures: Skull fractures were recorded in 75.3% of cases, with vault fractures (65.4%) more common than base of skull fractures (34.6%). Among vault fractures, the frontal and parietal bones were most frequently involved. These findings are in agreement with Sharma et al. (2016), [14] who reported frontal bone fractures as the most common due to direct frontal impacts, particularly in two-wheeler crashes.

Base of skull fractures (34.6%) are often associated with high-velocity impacts and may indicate severe head trauma with brainstem injury. Their identification at autopsy is crucial for reconstructing accident biomechanics. Temporal bone fractures, although less frequent, are clinically significant as they may cause middle ear hemorrhage and cranial nerve deficits (Reddy & Murty, 2018). [12]

Intracranial Hemorrhages: Intracranial hemorrhage was present in 79.7% of cases, with subdural hemorrhage (41.6%) most common, followed by subarachnoid (28.7%) and intracerebral hemorrhage (20.1%). Epidural hemorrhage was relatively rare (9.6%). This distribution is comparable to the observations of Gupta et al. (2017), [19] who reported subdural hemorrhage as the leading type of intracranial bleed in fatal RTAs. The predominance of subdural hemorrhage is explained by the tearing of bridging veins during acceleration-deceleration forces. Subarachnoid hemorrhage, on the other hand, reflects rupture of cortical vessels or traumatic aneurysms. The lower incidence of epidural hemorrhage may relate to under-reporting due to its potential rapid fatality, as highlighted by Dimaio & Dimaio (2001). [20]

Association with Age and Sex: The present study demonstrated that skull fractures were more common among males (77.7%) compared to females (68.6%). Young adults (21–40 years) showed the highest prevalence of skull fractures (80.3%).

This age-sex correlation reinforces the finding that young, risk-prone males are more susceptible to high-impact injuries, as documented by Singh et al. (2019). [21]

Forensic and Public Health Implications: The forensic analysis of craniofacial injuries provides vital insights into the mechanism, force, and direction of impact, assisting in accident reconstruction. High frequency of skull fractures and intracranial hemorrhages indicates that head injury remains the single most important determinant of mortality in RTAs.

From a public health standpoint, these findings emphasize the need for injury prevention strategies:

- Strict enforcement of helmet and seatbelt laws, extending to pillion riders.
- Improved pedestrian infrastructure including overbridges, sidewalks, and better lighting.
- Implementation of speed-calming measures in accident-prone zones.
- Awareness campaigns targeting young adults about safe driving practices.

Recommendations

Based on the findings, the following recommendations are proposed:

1. **Strengthening Road Safety Policies:** Enforcement of traffic rules such as mandatory helmet and seatbelt use should be intensified. Helmet laws must also cover pillion riders to reduce two-wheeler-related fatalities.
2. **Pedestrian Safety Measures:** Development of pedestrian-friendly infrastructure, including

footpaths, zebra crossings, overhead bridges, and traffic-calming devices, is crucial. Strict enforcement of speed limits, especially in urban and residential zones, will reduce pedestrian fatalities.

3. **Public Awareness Campaigns:** Targeted health education campaigns should address risky driving behaviors such as speeding, drunk driving, and distracted driving. Awareness programs can be tailored toward vulnerable age groups, particularly young adults.
4. **Trauma Care Strengthening:** Establishment of well-equipped trauma centers along highways and within cities, coupled with rapid response systems, could improve survival in cases where injuries are not instantly fatal.
5. **Policy and Legislation:** Strict penalties for traffic violations, combined with awareness, may deter risky behaviors. Integration of road safety education into school and college curricula will help inculcate safer practices among future drivers and riders.

Limitations

- First, as a single-center, hospital-based autopsy study, the findings may not be fully generalizable to the broader population, particularly rural or community-based settings where healthcare access and accident patterns may differ. The study's scope was restricted to fatal cases, excluding survivors, thereby limiting insights into the full spectrum of craniofacial trauma severity.
- Second, contextual factors such as alcohol consumption, vehicle type, speed at the time of crash, road conditions, and use of safety measures (helmets, seatbelts) were not consistently available and thus could not be analyzed. These factors are crucial for understanding the etiological pathways leading to specific injury patterns.
- Third, socioeconomic and behavioral determinants, such as driver fatigue, mobile phone use, or driving experience, were not assessed, although they are known contributors to RTAs.
- Lastly, the cross-sectional design precludes establishing causal relationships between victim categories, injury severity, and outcome. Prospective, multi-center studies incorporating detailed crash data and survivor follow-up would provide a more comprehensive understanding.

Conclusion

This study highlights the predominance of craniofacial trauma in fatal road traffic accidents, with basal skull fractures and subdural hemorrhage emerging as the most frequent injuries.

Young adult males and pedestrians were disproportionately affected, reflecting both behavioral and infrastructural vulnerabilities.

Two-wheeler users also contributed significantly, emphasizing the importance of protective gear such as helmets. The findings reinforce the role of head injuries as a major determinant of mortality in RTAs and underscore the urgent need for preventive measures, enforcement of traffic regulations, and infrastructure development to reduce the burden of these avoidable deaths.

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