

A Retrospective Evaluation of Cranio-Cerebral Injuries of Fatal Road Traffic Incidents in Southern part of Assam that have been brought for Medico-Legal Autopsy

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Abstract:

Road traffic accidents currently represent a severe global public health crisis and serve as the leading etiology of traumatic cranio-cerebral injuries. This retrospective autopsy-based study aims to comprehensively evaluate the pattern and distribution of cranio-cerebral injuries among fatal road traffic accident victims in the southern part of Assam. Out of 938 medico-legal autopsies conducted during the one-year study period, 168 cases (17.91%) were confirmed fatalities resulting from road traffic accidents involving head injuries. Demographic analysis revealed a pronounced male preponderance, accounting for 88.10% of the cases. The most vulnerable demographic was the 41–50 years age group (29.76%), with businessmen comprising the most frequently affected occupational cohort (26.19%). Polytrauma was highly prevalent, with combined injuries to the head and limbs observed in 25.00% of cases. Pathological evaluation of the head injuries demonstrated that contusions were the most common primary scalp injury (53.57%). Fractures predominantly involved the base of the skull (34.69%) and the frontal bone (28.57%). Intracranial analysis revealed that subdural haemorrhage was the principal cause of terminal brain injury, present in 55.36% of cases. The findings indicate a clear vulnerability among the economically active male population and underscore the distinct biomechanical forces—specifically angular acceleration and rapid deceleration—responsible for fatal intracranial haemorrhages. The study highlights the urgent

requirement for stringent traffic regulations, infrastructure enhancement, and advanced regional neuro-trauma care facilities to mitigate the escalating mortality associated with high-velocity vehicular impacts in the region.

Keywords: Cranio-cerebral injuries; Road traffic accidents; Forensic autopsy; Subdural haemorrhage; Skull fractures

Introduction:

Road traffic accidents (RTAs) have evolved into a man-made global epidemic, representing one of the most prominent causes of preventable mortality, morbidity, and long-term disability worldwide. The World Health Organization continually identifies road traffic injuries as a leading cause of death across all age groups, but particularly among the economically productive demographics. In developing nations, rapid motorization, extensive urbanization, inadequate road engineering, and sub-optimal enforcement of traffic safety regulations have catalysed an exponential rise in vehicular fatalities. Within the Indian subcontinent, the epidemiological burden of RTAs is exceptionally high, with traumatic brain injury (TBI) acting as the primary determinant of death among accident victims.

The southern part of Assam, prominently encompassing the Barak Valley region, serves as a critical geographic and commercial transit corridor connecting neighbouring states such as Mizoram, Meghalaya, Tripura, and Manipur. This dense inter-state traffic, compounded by challenging topographical terrain, variable weather conditions, and the frequent movement of heavy commercial vehicles along national highways, creates a high-risk environment for severe road traffic collisions. Epidemiological data from tertiary care centres in this region indicate a rising trend in medico-legal admissions, with RTAs consistently ranking as the leading cause of unnatural death and emergency medical interventions.

Among RTA fatalities, cranio-cerebral trauma is the most devastating and complex injury mechanism. The biomechanical forces involved in vehicular impacts—ranging from direct blunt force and angular acceleration to rapid deceleration—render the skull and its intracranial contents highly susceptible to catastrophic structural and functional damage. The morphological patterns of scalp injuries, the trajectories of skull fractures, and the anatomical distribution of intracranial haemorrhages provide crucial forensic and clinical insights into the nature of the impact, the kinematics of the collision, and the exact sequence leading to death.

Despite the high incidence of RTA fatalities in Southern Assam, comprehensive autopsy-based evaluations focusing specifically on the pathological spectrum of cranio-cerebral injuries remain scarce. Therefore, the primary purpose of this study is to systematically analyse the demographic profiles, injury patterns, and specific cranio-cerebral pathological findings in fatal RTA cases subjected to medico-legal autopsy. The rationale for this investigation is to generate robust, localized epidemiological and pathological data. It is hypothesized that distinct demographic vulnerabilities and specific biomechanical impact patterns dictate the severity of cranio-cerebral RTA fatalities. Such insights are essential for informing public health policies, optimizing pre-hospital emergency transport protocols, and reinforcing the necessity for advanced neurosurgical trauma interventions in the region.

Material and Methods

Study Design and Setting

This was a retrospective, observational, cross-sectional autopsy-based study conducted at the Department

of Forensic Medicine of a tertiary care medical college and hospital serving the southern part of Assam. The institution functions as the principal referral and medico-legal autopsy centre for the entire Barak Valley and its adjacent territories, ensuring a highly representative sample of the regional mortality profile.

Selection Criteria

The study population comprised deceased individuals brought for medico-legal autopsy during the stipulated one-year study period. The selection of cases was governed by strict inclusion and exclusion parameters to ensure data integrity.

- **Inclusion Criteria:** The study included victims of fatal road traffic accidents of all age groups and both genders who sustained documented cranio-cerebral injuries. This encompassed individuals who died instantaneously at the crash site, those brought dead to the emergency department, and those who subsequently succumbed to their head injuries during hospitalization.
- **Exclusion Criteria:** Cases were strictly excluded if the bodies were highly putrefied or decomposed to an extent that the exact pattern of cranial injury could not be reliably ascertained. Furthermore, fatalities resulting from head injuries sustained through non-vehicular mechanisms—such as falls from a height, physical assaults, or railway track accidents—were excluded to isolate the specific biomechanical variables associated with RTAs. Cases where death was unequivocally attributed to non-cranial polytrauma or secondary medical complications (e.g., late-onset septicaemia) without significant primary head injury were also omitted.

Tool Used and Validation

Data extraction was facilitated utilizing a pre-designed, semi-structured medico-legal proforma. The development of this tool was guided by standard forensic pathology protocols for trauma evaluation. Prior to data collection, the tool underwent a rigorous validation process by a panel of senior forensic medicine experts and neurosurgeons to ensure it comprehensively captured all necessary domains. These domains included socio-demographic variables, pre-hospital chronological parameters, and detailed gross pathological findings of the scalp, skull, and brain. Pilot testing was conducted on a small subset of historical autopsy records to refine the data capture fields and eliminate ambiguities.

Technical Information and Autopsy Protocol:

The post-mortem examinations adhered to standardized medico-legal autopsy protocols. A meticulous external examination was initially conducted to document the precise anatomical location and morphological characteristics of scalp injuries, classifying them as abrasions, contusions, lacerations, or crush injuries. The cranial evaluation commenced with a standard coronal incision and reflection of the scalp, allowing for the inspection of sub-galeal haemorrhages and the outer table of the skull. A Stryker saw was utilized to open the cranial vault. The calvaria and the base of the skull were subsequently examined for fracture lines, distinguishing between linear, depressed, comminuted, diastatic, and ring fractures. The dura mater, arachnoid mater, and cerebral hemispheres were systematically inspected to identify the exact anatomical location, volume, and type of intracranial haemorrhages (extradural, subdural, subarachnoid, and intracerebral). Concurrently, a thorough examination of other body regions (chest, abdomen, pelvis, and limbs) was performed to assess the full extent of kinetic energy transfer and document associated polytrauma.

Institutional Ethics Committee Approval:

The study protocol, emphasizing the methodology for retrospective data collection and the absolute guarantee of victim anonymity and data confidentiality, was submitted to the Institutional Ethics Committee. Formal approval was granted prior to the commencement of data extraction, ensuring adherence to the ethical standards laid down in the Declaration of Helsinki.

Statistical Methods:

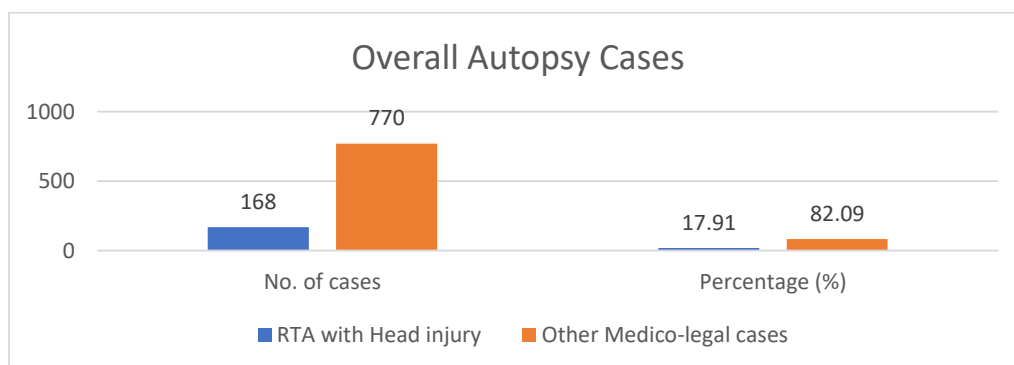
Data acquired from the structured proformas were systematically digitized into a secure spreadsheet database. Statistical analysis was performed using standard statistical software packages (such as SPSS). The analytical approach was predominantly descriptive, intended to delineate the epidemiological and pathological trends within the cohort. Categorical variables, including gender, occupation, injury types, and anatomical locations, were expressed as frequencies and percentages. To ensure clarity and avoid the fragmentation of the narrative flow, the results were synthesized into comprehensive tables, deliberately avoiding simplistic 2x2 matrices. Cross-tabulation techniques were employed to assess the distribution of injuries across different demographic strata. A p-value of <0.05 was considered statistically significant where comparative correlational analysis was applicable, though the primary focus remained on descriptive pathological distributions.

Results:

Incidence and Demographic Profile

Table 1: Overall Autopsy Cases

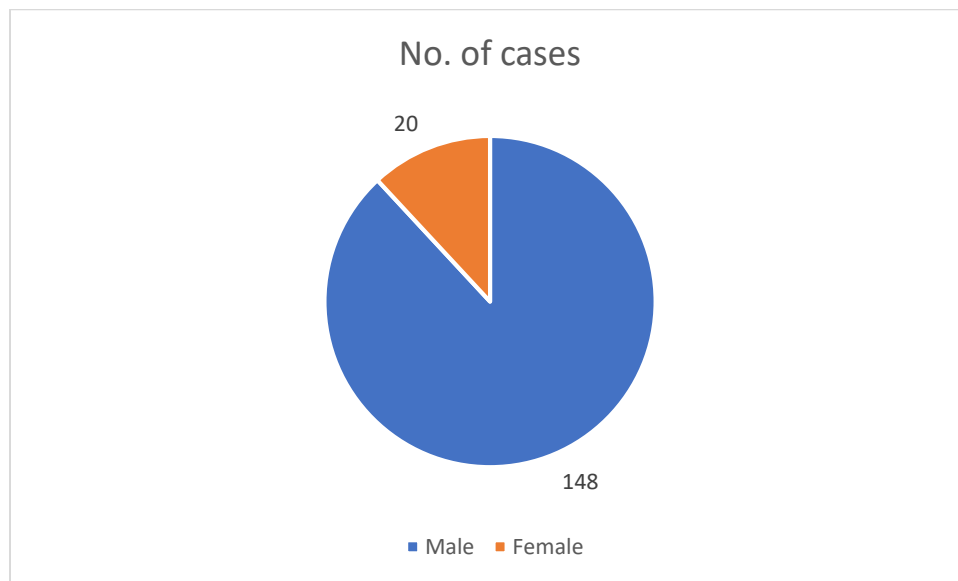
Type of cases	No. of cases	Percentage (%)
RTA with Head injury	168	17.91
Other Medico-legal cases	770	82.09
Total	938	100.00



During the designated one-year study period, the Department of Forensic Medicine conducted a total of 938 medico-legal autopsies. Upon application of the strict inclusion criteria, 168 cases (17.91%) were identified as fatalities resulting from road traffic accidents characterized by primary cranio-cerebral injuries.

Table 2: Gender-wise Distribution of RTA Fatalities

Gender	No. of cases	Percentage (%)
Male	148	88.10
Female	20	11.90
Total	168	100.00

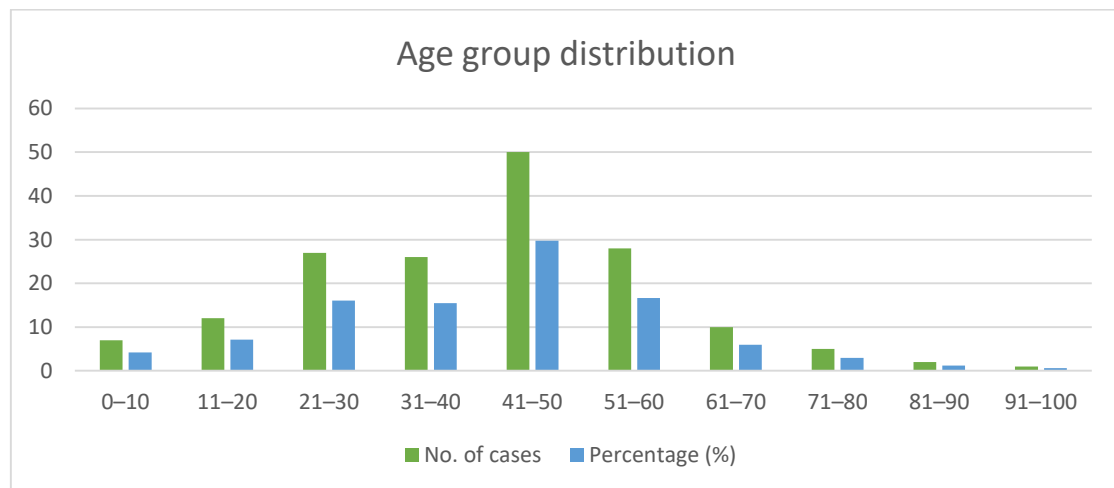


The demographic evaluation of the cohort revealed a highly skewed gender distribution. Male victims accounted for the overwhelming majority of the fatalities, representing 88.10% of the cases, while female victims constituted a significantly smaller fraction.

Table 3: Age-wise Distribution of RTA Fatalities

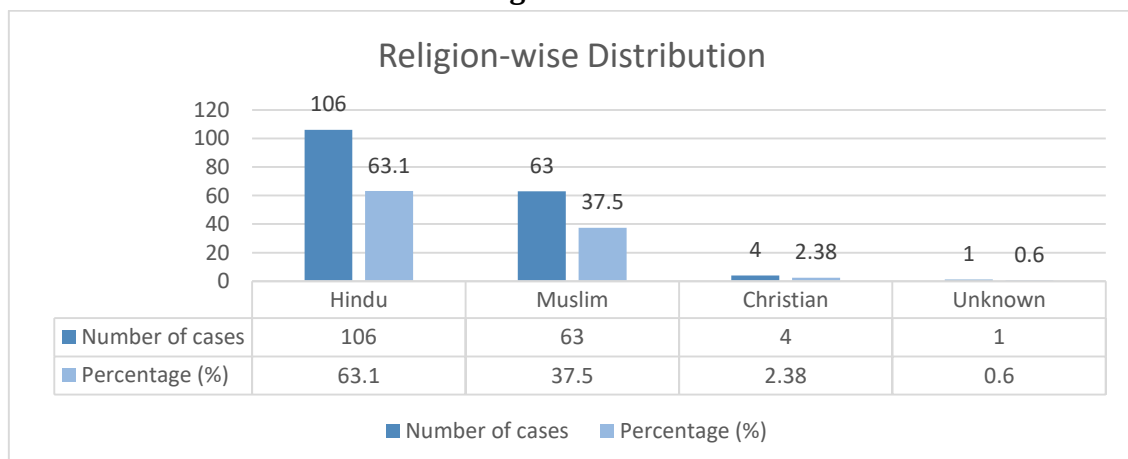
Age group (years)	No. of cases	Percentage (%)
0–10	7	4.17
11–20	12	7.14
21–30	27	16.07
31–40	26	15.48
41–50	50	29.76
51–60	28	16.67

Age group (years)	No. of cases	Percentage (%)
61–70	10	5.95
71–80	5	2.98
81–90	2	1.19
91–100	1	0.60
Total	168	100.00



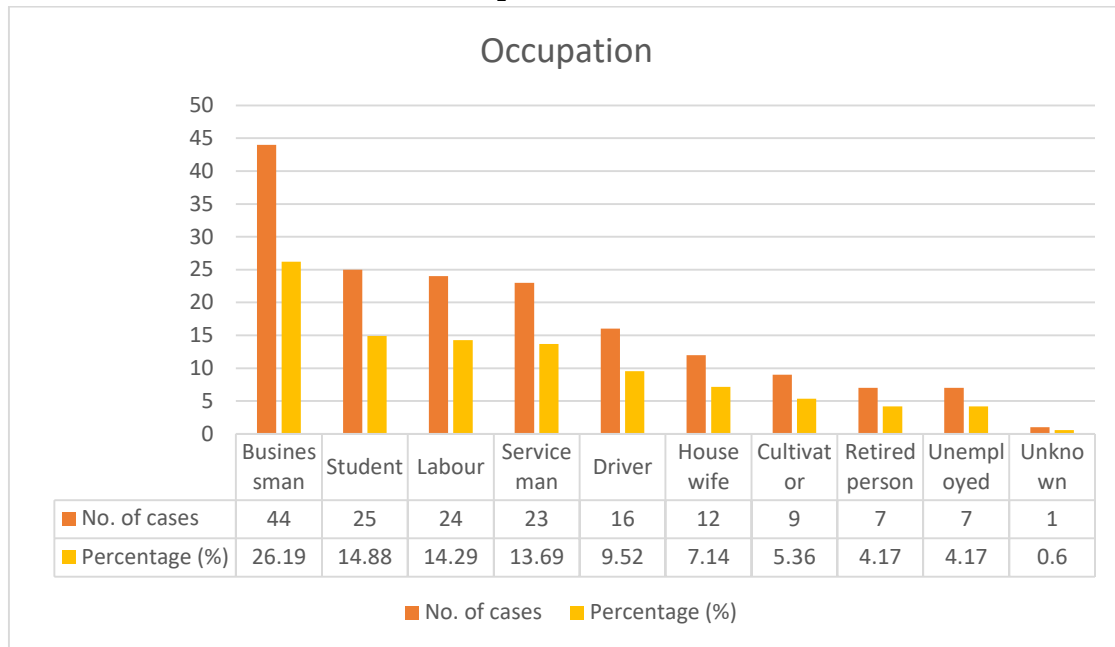
Analysis of the age distribution demonstrated that vulnerability to fatal RTA-induced head injuries was concentrated among the middle-aged population. The peak incidence was observed in the 41–50 years age group, representing nearly one-third of all cases. This was followed closely by the 51–60 years group and the 21–30 years group. The extremes of age, specifically paediatric cases under 10 years and geriatric cases over 80 years, were the least frequently affected demographics.

Table 4: Religion-wise Distribution



The religious demographics of the deceased reflected the general population distribution of the Barak Valley region, with the majority being Hindu, followed by a substantial Muslim cohort.

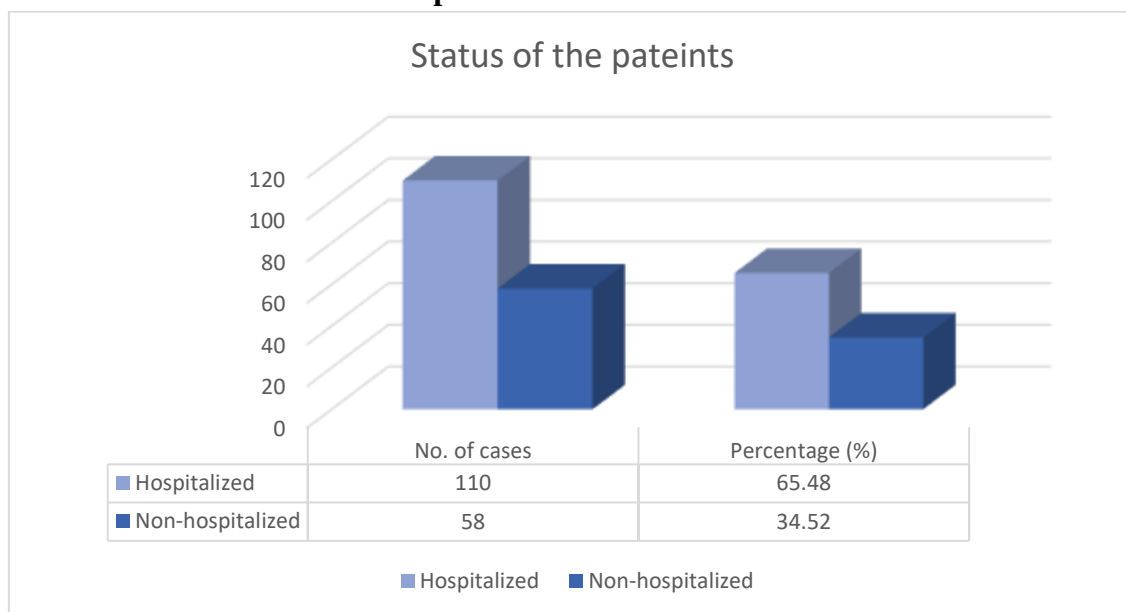
Table 5: Occupation-wise Distribution



Occupational profiling yielded critical insights into the exposure risks associated with different professions. Businessmen constituted the most frequently involved occupational group, accounting for over a quarter of the fatalities. This was followed by students, labourers, and servicemen. Professional drivers and agricultural cultivators represented smaller segments of the overall mortality.

Clinical Progression and Regional Polytrauma

Table 6: Hospitalization Status Prior to Death



An assessment of the survival interval and clinical progression revealed that a significant majority of the victims (65.48%) survived the initial impact long enough to be hospitalized prior to their demise.

Conversely, slightly over one-third of the cases either died instantaneously at the accident site or were pronounced dead upon arrival at the hospital emergency department.

Table 7: Topographical Distribution of Body Injuries

Site of the body involved	No. of cases	Percentage (%)
Head + Limbs	42	25.00
Head + Limbs + Chest	33	19.64
Head only	31	18.45
Head + Chest	17	10.12
Head + Limbs + Abdomen	11	6.55
Head + Chest + Abdomen	10	5.95
Head + Limbs + Pelvis	8	4.76
Head + Abdomen	7	4.17
Head + Pelvis	6	3.57
All region involved	3	1.79
Total	168	100.00

The transfer of kinetic energy during the vehicular collisions rarely resulted in isolated injuries. Polytrauma was a prominent clinical feature. Cases presenting strictly with isolated head trauma accounted for only 18.45% of the total cohort. The most frequent manifestation of systemic trauma involved simultaneous injuries to the head and the appendicular skeleton (limbs), followed closely by a triad of injuries encompassing the head, limbs, and the thoracic cavity.

Pathological Spectrum of Cranio-Cerebral Trauma

Table 8: Distribution of Scalp Injuries

Scalp Injuries	Number of cases	Percentage (%)
Contusion (CON)	90	53.57
CON + Laceration (LAC)	35	20.83
Abrasion (AB)	15	8.93

Scalp Injuries	Number of cases	Percentage (%)
AB + CON	10	5.95
No visible external injury	6	3.57
Haematoma	5	2.98
Laceration	3	1.79
Crush Injury	3	1.79
AB + LAC	1	0.60
Total	168	100.00

Detailed external examination of the cranial vault revealed that contusions were the paramount primary soft tissue injury, presenting as the sole scalp injury in over half of the cases. The concurrent presence of contusions and lacerations was the second most frequent presentation. Instances of severe crush injuries or hematomas without epidermal disruption were comparatively rare. Notably, a small fraction of the victims presented with no visible external soft tissue trauma to the scalp, despite harbouring lethal internal injuries.

Table 9: Anatomical Distribution of Skull Fractures

Bone involved	No. of cases	Percentage (%)
Base of Skull	34	34.69
Frontal Bone	28	28.57
Parietal Bone	12	12.24
Temporal Bone	8	8.16
Occipital Bone	5	5.10
Multiple bones involved	5	5.10
Maxilla	2	2.04
Mandible	2	2.04

Bone involved	No. of cases	Percentage (%)
Nasal Bone	2	2.04
Total	98	100.00

Osteological evaluation following scalp reflection identified skull fractures in 98 of the 168 cases. The base of the skull exhibited the highest susceptibility to fracturing. Among the bones comprising the cranial vault, the frontal bone was the most frequently fractured, followed by the parietal and temporal bones. Fractures involving multiple cranial bones simultaneously indicated high-impact collisions.

Table 10: Distribution of Intracranial Haemorrhages

Intracranial Haemorrhages	No. of cases	Percentage (%)
Subdural Haemorrhage (SDH)	93	55.36
More than 3 types combined	29	17.26
Extradural Haemorrhage (EDH)	26	15.48
Subarachnoid Haemorrhage (SAH)	9	5.36
Intracerebral Haemorrhage (ICH)	5	2.98
No macroscopic haemorrhage	3	1.79
Total	168	100.00

Internal evaluation of the cranial cavity provided a definitive understanding of the terminal hemorrhagic events. Subdural hemorrhage (SDH) emerged as the dominant pathology, recorded in more than half of the fatalities. Extradural hemorrhage (EDH) presented less frequently. A significant clinical finding was the presence of complex, multi-compartmental bleeding, where nearly one-fifth of the victims suffered from a catastrophic combination of more than three distinct types of intracranial hemorrhages.

Discussion

This retrospective autopsy-valuation comprehensively delineates the epidemiological constraints and the pathological architecture of cranio-cerebral injuries resulting from fatal road traffic accidents in Southern Assam. Cranio-cerebral trauma was definitively identified as the cause of death in 17.91% of all medico-legal autopsies during the study timeframe. This substantial disease burden corroborates broader national forensic trends, which continually identify traumatic brain injury as the dominant mechanism of RTA-induced mortality, often surpassing the lethality of isolated thoracic or abdominal exsanguination.

Demographic Vulnerabilities and Risk Profiling

The demographic findings in this study expose a stark gender disparity, with males constituting 88.10% of the fatalities. This overwhelming male preponderance is an established epidemiological pattern documented extensively across India and other developing nations. The disparity fundamentally stems from prevailing socio-cultural and economic dynamics wherein men serve as the primary active workforce. This results in a proportionally higher frequency of outdoor travel, daily commuting, and routine occupational exposure to vehicular traffic. Furthermore, behavioral studies consistently demonstrate that risk-taking behaviors—such as aggressive driving, high-speed maneuvers, and non-compliance with passive safety regulations like helmet usage—are statistically more prevalent among male riders.

An intriguing secondary outcome measure of this study is the age distribution of the victims. While numerous contemporary neuro-trauma and forensic studies in India consistently report the 21–30 year age group as the most vulnerable cohort, the present study observed a delayed peak, with the highest mortality concentrated in the 41–50 year demographic (29.76%), followed by the 51–60 years group (16.67%). This shift toward a slightly older demographic profile closely correlates with the regional occupational data. Businessmen (26.19%) and laborers (14.29%) formed the bulk of the fatalities. In the specific socio-economic context of the Barak Valley, individuals in their 40s and 50s are highly active in regional commerce and trade, which necessitates extensive and frequent travel on the accident-prone inter-state highways traversing Assam, Meghalaya, and Mizoram. The sudden traumatic death of individuals in this mature, highly productive phase of life exerts a profound and destabilizing secondary economic shock on their immediate dependents and the broader community.

Pre-Hospital Dynamics and Polytrauma Kinematics

A critical insight into the temporal dynamics of these fatalities emerges from the clinical progression data. Nearly two-thirds of the victims (65.48%) survived the initial traumatic impact long enough to be hospitalized prior to their demise, while 34.52% were brought dead or perished on site. The high hospitalization rate strongly indicates that despite the severity of the primary kinetic impact, a substantial window of survivability—often characterized in trauma surgery as the "golden hour"—exists for a majority of these patients. The inability to salvage these 110 hospitalized victims suggests critical systemic gaps in the regional trauma care infrastructure. This points toward potential deficiencies such as delayed pre-hospital transport, the absence of aggressive on-site airway management, or delays in obtaining emergency neurosurgical interventions such as decompressive craniectomy for rapidly expanding intracranial hematomas.

The pathological transfer of kinetic energy during vehicular collisions is rarely confined to the cranial vault. The study illustrates a high incidence of polytrauma, with combined injuries to the Head and Limbs (25.00%) and the Head, Limbs, and Chest (19.64%) being the most frequent topographical patterns. This precise distribution maps directly to the biomechanics of pedestrian and two-wheeler accidents, which dominate the Indian traffic landscape. During a typical collision, the initial impact (primary impact) from a vehicle's bumper typically strikes the victim's lower limbs or pelvis; the victim's body is subsequently rotated and thrown onto the vehicle's hood or windshield (secondary impact), causing profound thoracic and facial injuries. Finally, the victim is projected away from the vehicle, striking the rigid road surface (tertiary impact), which culminates in catastrophic cranial vault trauma.

Pathological Mechanisms of Cranio-Cerebral Trauma

External examination of the deceased confirmed that contusions (53.57%) and combinations of contusions and lacerations (20.83%) dominated the scalp injury profile. Scalp contusions act as direct macroscopic indicators of blunt force trauma. In forensic pathology, the morphology and location of these contusions are instrumental in estimating the precise point of primary cranial impact and extrapolating the geometry of the striking surface.

The distribution of skull fractures offers profound insights into the magnitude and directionality of the traumatic force. Base of skull fractures were the most prominent osteological injury (34.69%), followed by frontal bone fractures (28.57%). The disproportionately high incidence of basilar fractures is indicative of massive, systemic force transmission. In the context of RTAs, basilar fractures commonly occur via indirect force transmission. For instance, a sharp blow to the mandible (chin impact) can transfer immense energy through the temporomandibular joints into the middle cranial fossa, resulting in transverse basilar fractures. Alternatively, vertical loading—where the victim lands on their head or buttocks—can drive the cervical spine upward into the occiput, producing lethal ring fractures around the foramen magnum. Conversely, frontal bone fractures correlate closely with direct anterior impacts. This pattern is frequently observed in unrestrained automobile drivers whose heads strike the steering wheel or dashboard, or in two-wheeler riders who are vaulted over the handlebars and strike the pavement face-first.

Intracranial hemorrhage represents the ultimate terminal event in these fatalities, with Subdural Hemorrhage (SDH) definitively recorded as the most prevalent pathology (55.36%). The disproportionate occurrence of SDH over other forms of hemorrhage is a direct consequence of the unique biomechanics of high-speed vehicular crashes. During a collision, the brain is subjected to violent angular acceleration and rapid, non-linear deceleration. Because the brain possesses a different specific gravity and viscoelastic profile than the rigid skull and the surrounding cerebrospinal fluid, it shifts and rotates within the cranial vault during impact. This relative motion exerts extreme tensile shear stress on the parasagittal bridging veins that drain from the cerebral cortex into the superior sagittal sinus. When the applied strain exceeds the biomechanical tolerance of these vessels (often occurring at pulse durations shorter than 10 milliseconds and rotational accelerations exceeding 10,000 rad/s²), they tear, causing blood to accumulate under high pressure in the subdural space. The high mortality associated with SDH in this cohort highlights the rapid onset of intracranial hypertension, mass effect, midline shift, and subsequent fatal brain herniation.

Extradural hemorrhage (EDH), present in 15.48% of cases, relies on a distinctly different biomechanical pathway. EDH typically requires a direct, focused blow to the lateral aspect of the skull, leading to a linear or depressed fracture of the squamous temporal or parietal bone, which subsequently lacerates the underlying middle meningeal artery. Furthermore, 17.26% of the victims sustained more than three types of hemorrhages concurrently. This complex multi-compartmental bleeding reflects an overwhelming, non-survivable level of primary brain parenchymal destruction, synonymous with extreme high-speed crashes and massive kinetic energy transfer.

Conclusions

This retrospective autopsy-valuation conclusively demonstrates that fatal road traffic incidents in the southern part of Assam predominantly claim the lives of middle-aged, economically active males, particularly those engaged in business and daily commuting. The pathological signature of these fatalities

is characterized by devastating polytrauma, high-energy basilar and frontal skull fractures, and massive subdural hemorrhages driven by violent angular acceleration-deceleration forces.

Crucially, the data showing that over 65% of victims survived the immediate impact and were subsequently hospitalized implies that a critical temporal window for life-saving medical intervention exists. To effectively combat this escalating public health crisis, the following systemic recommendations are proposed:

- 1. Strict Enforcement of Traffic Laws:** There must be mandatory, uncompromising enforcement of helmet laws for two-wheeler riders and seatbelt regulations for four-wheeler occupants. These measures are biomechanically proven to mitigate primary angular acceleration impacts to the cranial vault.
- 2. Infrastructure Enhancement:** Immediate improvement of road engineering along the Barak Valley's commercial corridors is required. This includes proper illumination, the installation of speed-calming measures, and the geometric correction of identified accident black-spots on inter-state highways.
- 3. Advanced Neuro-Trauma Corridors:** Establishment of rapid-response emergency medical services (EMS) equipped for on-site advanced airway management is vital. This must be coupled with the strategic upgrading of regional tertiary hospitals to include dedicated, 24-hour neurosurgical trauma units capable of executing emergency decompressive craniectomies to relieve fatal intracranial hypertension.

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