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Original Research Article

Analysis of Fatal Road Traffic Injuries and Their Distribution: A Retrospective Autopsy-Based Study

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Abstract

Background: Road traffic accidents (RTAs) are a leading cause of injury-related mortality worldwide and constitute a major public health challenge in developing countries. Understanding the pattern and distribution of injuries among fatal RTA victims is essential for improving trauma care, forensic investigations, and road safety strategies. The present study aimed to evaluate the injury profile, organ involvement, and causes of death among fatal road traffic accident victims undergoing medico-legal autopsy.

Methods: A retrospective descriptive autopsy-based study was conducted in the Department of Forensic Medicine and Toxicology of a tertiary care teaching hospital. A total of 343 fatal road traffic accident victims subjected to medico-legal autopsy during the study period were included. Data regarding demographic characteristics, road-user category, external and internal injury patterns, organ involvement, survival period, and cause of death were collected from autopsy records and analyzed using SPSS version 26.0. Associations between categorical variables were assessed using the Chi-square test, with $p<0.05$ considered statistically significant.

Results: The mean age of victims was 36.8±14.7 years, with the majority belonging to the 21–30 years age group (28.6%). Males constituted 81.9% of cases, and 62.4% were from rural areas. Two-wheeler riders (38.5%) and pedestrians (25.9%) were the most commonly affected road users. Abrasions (86.9%), contusions (67.3%), and lacerations (63.8%) were the predominant external injuries, while head and facial injuries were observed in 80.5% of victims. Intracranial hemorrhage (72.3%), skull fractures (64.4%), and brain contusions/lacerations (51.6%) were the most frequent internal injuries. Cranio-cerebral injury was the leading cause of death (47.8%), followed by polytrauma (21.3%) and hemorrhagic shock (14.0%). A significant association was found between road-user category and fatal head injury ($\chi^2=24.83$, $p<0.001$), while polytrauma was significantly associated with shorter survival duration ($\chi^2=11.74$, $p=0.008$).

Conclusion: Fatal road traffic accidents predominantly involved young male two-wheeler users and were characterized by extensive head injuries and intracranial trauma. Cranio-cerebral injury was the principal cause of death, highlighting the importance of effective preventive measures, including strict helmet compliance, improved road safety enforcement, and strengthening of emergency trauma care systems to reduce road traffic mortality.

Keywords: Road Traffic Accident; Autopsy; Injury Pattern; Fatal Injuries; Cranio-Cerebral Injury.

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Introduction

Road traffic accidents (RTAs) are a major public health concern and represent one of the leading causes of injury-related mortality and disability worldwide [1]. According to the World Health Organization, approximately 1.19 million people die annually as a result of road traffic crashes, while millions more sustain non-fatal injuries that often result in long-term physical, psychological, and economic consequences [2]. The burden of road traffic injuries is disproportionately higher in low- and middle-income countries, which account for more than 90% of global road traffic deaths despite having fewer motor vehicles [3]. India, with its rapidly expanding road network, increasing vehular population, urbanization, and industrial growth, continues to experience a substantial

burden of road traffic fatalities [4]. Road traffic accidents are among the leading causes of death in the economically productive age group, resulting in significant loss of human resources and socioeconomic productivity [5]. Factors such as overspeeding, non-compliance with traffic regulations, driving under the influence of alcohol, distracted driving, poor road conditions, and inadequate use of safety devices contribute significantly to the occurrence and severity of road traffic injuries [6].

The pattern and distribution of injuries sustained in road traffic accidents depend on several factors including the type of vehicle involved, mechanism of impact, speed of collision, use of protective equipment, and the position of the victim at the time of the accident [7]. Injuries may involve multiple body regions and range from superficial abrasions and contusions to severe cranio-cerebral, thoracic, abdominal, and musculoskeletal trauma [7]. Among fatal cases, head injuries have consistently been reported as the most common cause of death, followed by multiple injuries and hemorrhagic shock [8]. The distribution and severity of injuries provide valuable insights into the biomechanics of trauma and circumstances surrounding the accident [8]. Autopsy-based offer studies a unique opportunity to comprehensively evaluate both external and internal injuries in fatal road traffic accident victims [9,10]. Detailed post-mortem examination helps in accurately identifying injury patterns, affected organs, and the exact cause of death, thereby contributing to forensic investigations and trauma epidemiology [10]. Understanding the pattern and distribution of injuries among fatal RTA victims is essential for developing targeted preventive strategies, improving trauma care services, and strengthening road safety policies. Therefore, the present study aimed to analyze the pattern and distribution of injuries associated with road traffic accidents based on medico-legal autopsy findings.

Materials and Methods

Study Design and Setting: This retrospective descriptive autopsy-based study was conducted in the Department of Forensic Medicine and Toxicology of a tertiary care teaching hospital. The study included all medico-legal autopsies of victims who died due to road traffic accidents and were subjected to post-mortem examination during the study period from January 2022 to December 2024. The institute caters to a large urban and rural population and receives medico-legal cases referred from multiple healthcare facilities and law enforcement agencies within the region.

Study Population: The study population comprised all deceased victims of road traffic accidents brought for medico-legal autopsy during the study period. Cases were identified from autopsy registers, post-mortem reports, police inquest papers, hospital records, and relevant medico-legal documents. Victims of all age groups and both sexes were included if the cause of death was attributable to injuries sustained in a road traffic accident. Cases with incomplete autopsy records, advanced decomposition obscuring injury assessment, charred bodies, skeletal remains, and deaths due to causes unrelated to road traffic accidents were excluded from the study.

Autopsy Procedure and Injury Assessment: All autopsies had been conducted according to standard medico-legal autopsy protocols. External examination included documentation of clothing, bodily identification marks, and detailed recording of injury characteristics such as type, size, location, orientation, and number. Internal examination involved systematic dissection of cranial, thoracic, abdominal, and musculoskeletal structures. Skull fractures were classified according to anatomical location and pattern, while intracranial hemorrhages were categorized as extradural, subdural, subarachnoid, intracerebral, or mixed hemorrhages. Organ injuries were documented based on gross pathological findings observed during post-mortem examination.

The cause of death was determined after correlation of external and internal injuries with available clinical and investigative records. Fatal injuries were categorized as head injury, thoracoabdominal injury, hemorrhagic shock, multiple injuries (polytrauma), spinal injury, or other causes as appropriate.

Data Collection: Data were collected retrospectively using a predesigned structured proforma. Information regarding age, sex, type of road user (pedestrian, rider, pillion rider, driver, or occupant), manner and mechanism of accident, survival period following injury, and circumstances surrounding the accident were obtained from police records and hospital case sheets whenever available. Detailed findings from post-mortem examination reports were reviewed to document the pattern and distribution of injuries.

A thorough assessment of external injuries was performed from autopsy records, including abrasions, contusions, lacerations, incised wounds, avulsions, crush injuries, and degloving injuries. The anatomical distribution of injuries was categorized into head and neck, thorax, abdomen, pelvis, upper limbs, and lower limbs. Internal examination findings were reviewed to identify skull fractures, intracranial hemorrhages, brain injuries, rib fractures, lung injuries, cardiac injuries, abdominal visceral injuries, pelvic fractures, spinal injuries, and long-bone fractures. The nature of

organ involvement and associated complications were also documented.

Outcome Measures: The primary outcome measure was the pattern and anatomical distribution of injuries among fatal road traffic accident victims. Secondary outcome measures included frequency of various external and internal injuries, organ involvement, fracture patterns, and determination of the immediate cause of death.

Statistical Analysis: The collected data were entered into Microsoft Excel and analyzed using Statistical Package for the Social Sciences (SPSS) software version 26.0 (IBM Corp., Armonk, NY, USA). Continuous variables, such as age, were expressed as mean ± standard deviation (SD), while categorical variables were presented as frequencies and percentages. Descriptive statistics were used to summarize demographic characteristics, road-user categories, injury patterns, organ involvement, causes of death, and survival periods. Inferential statistical analysis was performed to assess associations between selected categorical variables. The relationship between road-user category and occurrence of fatal head injury was evaluated using the Chi-square test. Similarly, the association between survival period and presence of polytrauma was analyzed using the Chi-square test. Chi-square values (χ^2) along with corresponding p-values were calculated. A p-value of less than 0.05 was considered statistically significant.

Ethical Considerations: The study was conducted after obtaining approval from the Institutional Ethics Committee. As the study was based on retrospective analysis of medico-legal autopsy records, no direct contact with subjects or relatives was involved. Confidentiality and anonymity of all deceased individuals were strictly maintained throughout data collection, analysis, and reporting of study findings.

Results

Among the 343 fatal road traffic accident victims, the majority belonged to the 21–30 years age group (28.6%), followed by 31–40 years (25.1%), indicating that over half (53.7%) of the fatalities occurred among young adults in their most economically productive years. The mean age of the victims was 36.8 ± 14.7 years.

Males constituted a predominant proportion of cases (81.9%), while females accounted for 18.1%. Most victims were from rural areas (62.4%). Regarding road-user category, two-wheeler riders represented the largest group (38.5%), followed by pedestrians (25.9%), four-wheeler occupants (15.2%), and pillion riders (12.0%), highlighting the increased vulnerability of motorcyclists and pedestrians to fatal road traffic injuries (Table 1).

Table 1: Demographic and Accident Characteristics of Road Traffic Accident Fatalities (n=343)

Variable	Frequency	%
Age Group (Years)		
<20	34	9.9
21–30	98	28.6
31–40	86	25.1
41–50	57	16.6
51–60	39	11.4
>60	29	8.5
Mean age (years)	36.8 ± 14.7	
Gender		
Male	281	81.9
Female	62	18.1
Residence		
Rural	214	62.4
Urban	129	37.6
Type of Road User		
Two-wheeler rider	132	38.5
Pillion rider	41	12
Pedestrian	89	25.9
Four-wheeler occupant	52	15.2
Cyclist	17	5
Others	12	3.5

Abrasions were the most common external injury, observed in 86.9% of victims, followed by contusions (67.3%) and lacerations (63.8%). Crush injuries, degloving injuries, avulsion injuries, and incised wounds were less frequently encountered.

With respect to anatomical distribution, injuries to the head and face were the most common (80.5%), followed by lower limb injuries (59.5%) and upper limb injuries (48.7%). Injuries involving the chest, abdomen, pelvis, and neck were observed in

32.7%, 23.6%, 17.2%, and 10.8% of cases, respectively. The predominance of head and extremity injuries reflects the typical impact patterns encountered in fatal road traffic accidents (Table 2).

Table 2: Distribution of External Injuries Among Victims (n=343)

Parameters	Frequency	%
Type of External Injury*		
Abrasions	298	86.9
Contusions	231	67.3
Lacerations	219	63.8
Degloving injuries	38	11.1
Crush injuries	54	15.7
Avulsion injuries	26	7.6
Incised wounds	11	3.2
Anatomical Site Involved*		
Head and face	276	80.5
Upper limbs	167	48.7
Lower limbs	204	59.5
Chest	112	32.7
Abdomen	81	23.6
Pelvis	59	17.2
Neck	37	10.8

*Multiple injuries present in the same victim.

Intracranial hemorrhage was the most frequently identified internal injury, occurring in 72.3% of victims, followed by skull fractures (64.4%) and brain contusions or lacerations (51.6%). Long bone fractures were present in nearly half of the cases (49.3%). Thoracic injuries included rib fractures (30.0%) and lung injuries (25.7%), while abdominal organ injuries involved the liver (21.0%), spleen (15.5%), kidneys (9.0%), and bowel (6.4%). Pelvic fractures and vertebral injuries were documented in 14.0% and 7.9% of cases, respectively. Among the 248 victims with intracranial hemorrhage, subdural hemorrhage was the most common subtype (39.1%), followed by subarachnoid hemorrhage (27.8%), mixed hemorrhage (14.5%), extradural hemorrhage (11.3%), and intracerebral hemorrhage (7.3%) (Table 3).

Table 3: Pattern of Internal Injuries and Organ Involvement (n=343)

Parameters	Frequency	%
Internal Injury		
Skull fracture	221	64.4
Intracranial hemorrhage	248	72.3
Brain contusion/laceration	177	51.6
Rib fractures	103	30
Lung injury	88	25.7
Cardiac injury	19	5.5
Liver injury	72	21
Splenic injury	53	15.5
Renal injury	31	9
Bowel injury	22	6.4
Pelvic fracture	48	14
Vertebral injury	27	7.9
Long bone fractures	169	49.3
Type of Intracranial Hemorrhage (n=248)		
Subdural hemorrhage	97	39.1
Subarachnoid hemorrhage	69	27.8
Extradural hemorrhage	28	11.3
Intracerebral hemorrhage	18	7.3
Mixed hemorrhage	36	14.5

Cranio-cerebral injury emerged as the leading cause of death, accounting for 47.8% of fatalities. Polytrauma involving multiple organ injuries was responsible for 21.3% of deaths, followed by

hemorrhagic shock (14.0%) and thoraco-abdominal injuries (9.0%). Less common causes included septicemia/MODS (4.4%), cervical spinal injury (2.3%), and pulmonary embolism or fat embolism (1.2%). Analysis of survival duration demonstrated that 34.7% of victims died at the scene of the accident, while 29.7% succumbed within 24 hours. Only 12.5% survived beyond seven days, indicating the severe nature of injuries sustained by most victims (Table 4).

Table 4: Cause of Death and Survival Period Among Road Traffic Accident Victims (n=343)

Parameters	Frequency	%
Cause of Death		
Cranio-cerebral injury	164	47.8
Polytrauma with multiple organ injuries	73	21.3
Hemorrhagic shock	48	14
Thoraco-abdominal injury	31	9
Septicemia/MODS	15	4.4
Cervical spinal injury	8	2.3
Pulmonary embolism/fat embolism	4	1.2
Survival Period		
Died on spot	119	34.7
<24 hours	102	29.7
1–7 days	79	23
>7 days	43	12.5

MODS = Multiple Organ Dysfunction Syndrome.

A significant association was observed between road-user category and the occurrence of fatal head injury ($\chi^2 = 24.83$, $p < 0.001$). Head injuries were most prevalent among two-wheeler riders and pillion riders, affecting 86.1% of victims in this group. Pedestrians also exhibited a high proportion of head injuries (74.2%), whereas four-wheeler occupants showed a comparatively lower prevalence (61.5%). These findings indicate that vulnerable road users, particularly motorcyclists and pedestrians, are at a substantially higher risk of sustaining fatal head trauma (Table 5).

Table 5: Association Between Type of Road User and Fatal Head Injury (n=343)

Road User Category	Head Injury Present (n=264)	Head Injury Absent (n=79)	Test of significance
	Frequency (%)		
Two-wheeler rider/pillion (n=173)	149 (86.1)	24 (13.9)	$\chi^2 = 24.83$, $p < 0.001$
Pedestrian (n=89)	66 (74.2)	23 (25.8)	
Four-wheeler occupant (n=52)	32 (61.5)	20 (38.5)	
Others (n=29)	17 (58.6)	12 (41.4)	

The prevalence of polytrauma demonstrated a declining trend with increasing survival duration following the accident. Polytrauma was present in 39.5% of victims who died at the scene, compared with 30.4% of those surviving less than 24 hours, 22.8% of those surviving 1–7 days, and only 14.0% of those surviving beyond seven days. This association was statistically significant ($\chi^2 = 11.74$, $p = 0.008$), suggesting that victims sustaining multiple severe injuries were more likely to experience early mortality after the accident (Table 6).

Table 6: Relationship Between Survival Period and Presence of Polytrauma (n=343).

Survival Period	Polytrauma Present (n=102)	Polytrauma Absent (n=241)	Test of significance
	Frequency (%)		
Died on spot (n=119)	47 (39.5)	72 (60.5)	$\chi^2 = 11.74$, $p = 0.008$
<24 hours (n=102)	31 (30.4)	71 (69.6)	
1–7 days (n=79)	18 (22.8)	61 (77.2)	
>7 days (n=43)	6 (14.0)	37 (86.0)	

Discussion

The present autopsy-based study evaluated the pattern and distribution of injuries among 343 fatal road traffic accident (RTA) victims and demonstrated that young adult males, particularly two-wheeler users, constituted the majority of fatalities. In this study, the highest proportion of fatalities occurred among individuals aged 21–30 years (28.6%), followed by those aged 31–40 years (25.1%), with a mean age of 36.8±14.7 years. Similar age distributions have been reported in studies by Marak et al., Nair et al., and Husain et

al., where the majority of victims belonged to the third and fourth decades of life [11,12,13]. Young adults are more frequently exposed to road traffic environments due to occupational commitments, social mobility, and increased vehicle usage [11]. Furthermore, risk-taking behaviors such as overspeeding, distracted driving, and non-compliance with traffic regulations are more common in this age group, contributing to their increased vulnerability [11]. The predominance of males (81.9%) observed in the present study is also consistent with previous Indian and international reports by Kaya et al., and Nair et al., where males generally account for over three-fourths of fatal RTA victims [7,12]. Greater outdoor exposure, longer driving durations, and higher participation in high-risk driving activities likely explain this finding [13].

The distribution of victims according to road-user category revealed that two-wheeler riders constituted the largest group (38.5%), followed by pedestrians (25.9%). This observation aligns with national road safety statistics and several autopsy studies by Chary et al., Varun et al., and Salam et al., from India, which consistently identify motorcyclists and pedestrians as the most vulnerable road users [14,15,16]. The widespread dependence on motorcycles as an affordable means of transportation, coupled with inadequate helmet use and poor adherence to traffic safety measures, substantially increases the risk of severe injury [14]. Pedestrians remain highly susceptible because they lack any structural protection against impact forces generated during collisions [16].

Analysis of external injuries demonstrated that abrasions (86.9%), contusions (67.3%), and lacerations (63.8%) were the most frequently encountered lesions. Similar findings have been reported by Adaappa et al., and Sharma et al., who identified abrasions and lacerations as the predominant external injuries in fatal RTAs [17,18]. Abrasions typically result from friction between the body and road surface during sliding impacts, whereas contusions and lacerations occur due to blunt-force trauma from vehicles, road infrastructure, or secondary impacts [17]. The high prevalence of these injuries reflects the substantial transfer of kinetic energy associated with high-speed collisions [18].

The anatomical distribution of injuries showed a clear predominance of head and facial injuries (80.5%), followed by lower limb (59.5%) and upper limb (48.7%) involvement. Similar injury patterns have been documented in numerous forensic studies by Yadav et al., Sharma et al., and Saxena et al., [19,20,21]. The exposed anatomical position of the head makes it particularly vulnerable during collisions, especially among motorcyclists and pedestrians [20]. Limb injuries are also common because extremities are frequently the first body parts to absorb impact forces during falls or vehicle strikes [21]. The high frequency of extremity injuries further suggests the occurrence of high-energy trauma mechanisms in the study population [19].

Internal injury assessment revealed that intracranial hemorrhage was the most common internal lesion, occurring in 72.3% of victims, followed by skull fractures (64.4%) and brain contusions or lacerations (51.6%). Among intracranial hemorrhages, subdural hemorrhage was the most frequent subtype (39.1%). These findings are comparable to those reported by Das et al., and Srivastava et al., who also identified traumatic brain injuries as the principal pathological findings in fatal road traffic accidents [22,23]. The predominance of intracranial injuries can be explained by rapid acceleration-deceleration forces that produce skull fractures, tearing of bridging veins, cerebral contusions, and diffuse axonal injury [22]. Such injuries often result in raised intracranial pressure, brain herniation, and irreversible neurological damage, leading to death [23].

Thoracic and abdominal injuries were also common, with rib fractures observed in 30.0% of victims, lung injuries in 25.7%, liver injuries in 21.0%, and splenic injuries in 15.5%. These organs are highly susceptible to blunt-force trauma and may cause massive internal hemorrhage. Long-bone fractures were present in nearly half of the victims (49.3%), indicating the high-energy nature of the accidents. Such fractures not only contribute to blood loss and shock but may also predispose victims to complications such as fat embolism and multi-organ dysfunction [24]. Cranio-cerebral injury emerged as the leading cause of death, accounting for 47.8% of fatalities, followed by polytrauma (21.3%) and hemorrhagic shock (14.0%). These findings closely resemble those reported in several autopsy-based studies by Sengupta et al., Tejpal et al., and Manoranjan et al., where head injury remains the primary cause of death in road traffic fatalities [25,26,27]. Furthermore, a significant association was observed between road-user category and fatal head injury (χ^2=24.83, $p<0.001$), with head injuries occurring most frequently among two-wheeler riders and pillion riders (86.1%) [26]. The study also demonstrated a significant relationship between survival duration and polytrauma (χ^2=11.74, $p=0.008$), as victims with multiple severe injuries were more likely to die at the scene or within the first 24 hours [27]. These findings emphasize the critical role of severe head injury and polytrauma in determining mortality outcomes following road traffic accidents and highlight the need for effective preventive measures, including strict helmet use,

improved road safety enforcement, and strengthened trauma care services [28,29].

Limitations

The present study was limited by its retrospective design and reliance on autopsy records, which restricted the availability of detailed information regarding crash circumstances, vehicle speed, helmet or seatbelt use, alcohol consumption, and pre-hospital care. As the study included only fatal cases undergoing medico-legal autopsy at a single tertiary care center, the findings may not fully represent all road traffic accident victims or regional variations in injury patterns.

Conclusion

Road traffic accident fatalities predominantly affected young adult males, with two-wheeler users and pedestrians constituting the most vulnerable groups. Head and facial injuries were the most frequently involved body regions, while intracranial hemorrhage and skull fractures were the commonest internal injuries. Cranio-cerebral trauma emerged as the leading cause of death, followed by polytrauma and hemorrhagic shock.

Significant associations were observed between road-user category and fatal head injury, as well as between polytrauma and early mortality. The findings emphasize the need for strict enforcement of helmet use, improved road safety measures, enhanced trauma care services, and targeted interventions aimed at reducing preventable road traffic deaths.

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