

Original Research Article

PATTERN OF FATAL INJURIES AND ORGAN INVOLVEMENT IN DEATHS DUE TO FALL FROM HEIGHT: AN AUTOPSY-BASED STUDY FROM SOUTH INDIA

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ABSTRACT

Background: Fatal falls from height constitute an important cause of unnatural death and represent a unique form of blunt force trauma characterized by complex injury patterns involving multiple body regions and vital organs. Detailed evaluation of injury distribution and organ involvement is essential for forensic reconstruction and determination of the cause of death.

Materials and Methods: A **prospective** autopsy-based descriptive study was conducted in the Department of Forensic Medicine of a tertiary care teaching hospital in South India **over a period of three years** from **June 2012 to May 2015**. Thirty-five medico-legal autopsy cases of deaths due to falls from height were included. Data regarding height of fall, external injuries, skeletal injuries, internal soft tissue injuries, organ involvement, survival interval, and cause of death were collected from autopsy records and analyzed using descriptive statistics.

Results: Among the 35 cases studied, the majority of victims had fallen from heights of 30–39 feet (25.71%). External injuries were most commonly observed in the limbs (77.14%), followed by the head and neck region (71.42%). Thoracic skeletal injuries were the most frequent fractures (74.28%), while internal soft tissue injuries predominantly involved the head and neck region (80.00%). The brain was the most commonly injured organ (82.86%), followed by the lungs (77.14%) and liver (57.14%). Most victims died at the scene or within 30 minutes of injury (65.71%). Shock and hemorrhage accounted for the majority of deaths (65.71%), followed by severe head injury (31.43%).

Conclusion: Fatal falls from height are associated with extensive multisystem trauma, predominantly affecting the brain, lungs, and liver. Thoracic skeletal injuries and cranio-cerebral trauma were the most characteristic injury patterns observed. The high proportion of immediate deaths highlights the severity of injuries sustained. Comprehensive autopsy evaluation of injury patterns and organ involvement plays a crucial role in determining the cause of death and reconstructing the circumstances surrounding fatal falls.

Keywords: Fall from height; Autopsy; Injury pattern; Organ involvement; Blunt force trauma.

INTRODUCTION

Falls from height represent a significant cause of traumatic mortality worldwide and constitute an important category of unnatural deaths encountered in medico-legal practice.^[1] Rapid urbanization, increasing construction activities, and the growing number of high-rise residential and commercial buildings have contributed to a rise in fall-related fatalities, particularly in developing countries.^[2] Such incidents may occur in occupational settings, domestic environments, recreational activities, or as a result of suicidal and, rarely, homicidal events. Determining the cause and manner of death in these cases remains a challenging task for forensic experts.^[3]

Fatal falls from height are characterized by rapid vertical deceleration, resulting in the transfer of substantial kinetic energy to the body upon impact.^[4] The severity and distribution of injuries depend on several factors, including the height of fall, body orientation at impact, nature of the landing surface, and the anatomical region that first contacts the ground.^[5] Consequently, victims often sustain multiple injuries involving the skeletal system, soft tissues, and internal organs, leading to immediate death or rapid clinical deterioration due to severe trauma and haemorrhage.^[4,5]

The analysis of injury patterns in fatal falls has considerable forensic importance. Detailed evaluation of external injuries, skeletal fractures, and internal organ damage can assist in reconstructing the mechanism of injury and identifying the probable site of primary impact.^[6] Such findings may also help distinguish accidental falls from suicidal or homicidal incidents when interpreted in conjunction with scene investigation and circumstantial evidence.^[7] Literatures have reported that head injuries, thoracic trauma, and injuries to vital organs such as the brain, lungs, liver, and heart are among the most common findings in fatal falls from height.^[8,9] The prevalence and severity of these injuries tend to increase with greater heights of fall.

Understanding the patterns of fatal injuries is essential not only for accurate forensic interpretation but also for identifying high-risk groups and developing preventive strategies. Therefore, the present study was aimed to evaluate the pattern of fatal injuries and organ involvement in deaths due to falls from height among cases subjected to medico-legal autopsy at a tertiary care center in South India.

MATERIALS AND METHODS

Study Design and Setting

A prospective autopsy-based descriptive study was conducted in the Department of Forensic Medicine of a tertiary care teaching hospital in Bengaluru, South India after obtaining institutional ethics committee clearance. The study included all

medico-legal autopsies performed over a period of three years from June 2012 to May 2015 in which death was attributed to fall from height. During the study period, approximately 900 medico-legal autopsies were conducted, of which 35 cases fulfilled the eligibility criteria and were included for analysis.

Study Population

The study population comprised deceased individuals who sustained fatal injuries following a fall from a higher level to a lower level, irrespective of the manner of death. Falls from buildings, construction sites, rooftops, trees, staircases, ladders, and similar elevated structures were considered eligible. Cases involving falls from moving vehicles such as trains, buses, or other transport-related incidents were excluded to avoid confounding injury mechanisms. All included cases underwent complete medico-legal autopsy as mandated by investigating authorities.

Data Collection and Case Evaluation

Information pertaining to demographic characteristics, circumstances of the fall, and medico-legal details was obtained from police inquest reports, requisition forms, eyewitness accounts, hospital records, and statements from relatives whenever available. Particular attention was given to documenting the estimated height of fall, location of occurrence, survival interval following injury, and suspected manner of death. In selected cases, information obtained from scene visits and scene photographs was also utilized to corroborate the history and circumstances of the incident.

All autopsies were performed according to standard forensic protocols. A systematic external and internal examination was undertaken in every case. External injuries were documented with respect to their type, distribution, and anatomical location. Internal examination included detailed assessment of the cranial cavity, thoracic cavity, abdominal cavity, vertebral column, pelvis, and extremities. Skeletal injuries and soft tissue damage were carefully recorded, and the involvement of major organs including the brain, lungs, heart, liver, spleen, and kidneys was evaluated. Where indicated, viscera were preserved and subjected to toxicological analysis to identify the presence of alcohol or other substances that could have contributed to the fall or influenced the circumstances of death.

Injury Pattern Assessment

For analytical purposes, injuries were categorized into external injuries, skeletal injuries, and internal soft tissue injuries. External injuries were classified according to the anatomical regions involved, namely head and neck, thorax, abdomen and pelvis, and limbs. Skeletal injuries were grouped based on the affected body region, while internal injuries were assessed according to both anatomical location and organ involvement. The immediate cause of death was determined based on autopsy findings in

conjunction with available clinical and investigative records.

Statistical Analysis

The collected data were entered into Microsoft Excel and analyzed using Statistical Package for the Social Sciences (SPSS) software version 20.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were used for data analysis. Categorical variables were summarized as frequencies and percentages, while continuous variables, where applicable, were expressed as mean $\pm$ standard deviation. The findings were presented using tables and graphical representations to illustrate the distribution of injury patterns, organ involvement, and causes of death among fatal fall victims.

Table 1: Distribution of Victims According to Height of Fall

Height of Fall (feet)	Number (n=35)	Percentage (%)
<10	2	5.71
10–19	8	22.86
20–29	8	22.86
30–39	9	25.71
40–49	4	11.44
50–59	2	5.71
>60	2	5.71

External injuries were observed predominantly over the extremities and head-neck region. Limb injuries were present in 77.14% of cases, while head and

During the three-year study period, 900 medico-legal autopsies were performed, of which 35 deaths were attributed to falls from height, accounting for 3.89% of all autopsies. The majority of victims had fallen from heights between 30 and 39 feet (25.71%), followed by 20–29 feet (22.86%) and 10–19 feet (22.86%). Most fatal falls occurred from heights ranging between 20 and 39 feet, which together accounted for nearly half of all cases (48.57%). [Table 1]

neck injuries were documented in 71.42%. Thoracic and abdominopelvic external injuries were comparatively less frequent. [Table 2]

Table 2: Regional Distribution of External Injuries

Region	Number (n=35)	Percentage (%)
Head and neck	25	71.42
Thorax	15	42.85
Abdomen and pelvis	9	25.71
Limbs	27	77.14

Thoracic skeletal injuries were the most frequently encountered fractures, followed by injuries involving the head and neck region. Skeletal injuries involving the abdomen, pelvis, and extremities were

less common. Thoracic fractures, predominantly involving the rib cage, constituted the most common skeletal injury pattern observed at autopsy. [Table 3 and Figure 1]

Table 3: Distribution of Skeletal Injuries According to Body Region

Region	Number (n=35)	Percentage (%)
Head and neck	23	65.71
Thorax	26	74.28
Abdomen and pelvis	3	8.57
Limbs	9	25.71

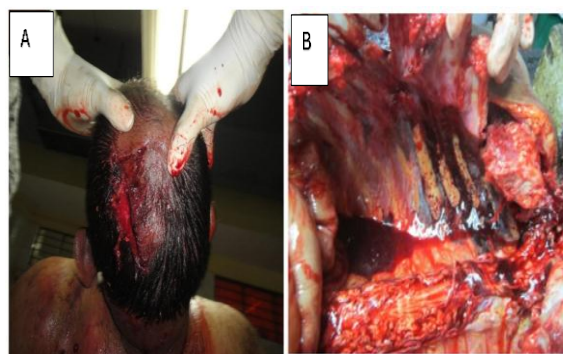


Figure 1: Skeletal Injuries in Fatal Falls from Height. A: Extensive scalp avulsion with associated skull fracture following high-impact fall. B: Multiple rib fractures with severe thoracic trauma observed at autopsy

Internal soft tissue injuries were most frequently observed in the head and neck region, followed by thoracic injuries. Abdominal and pelvic soft tissue injuries were identified in less than half of the cases. Head and neck soft tissue injuries represented the predominant internal injury pattern, indicating severe cranio-cerebral involvement in a substantial proportion of fatal falls. [Table 4 and Figure 2]

Table 4: Distribution of Internal Soft Tissue Injuries

Region	Number (n=35)	Percentage (%)
Head and neck	28	80.00
Thorax	24	68.57
Abdomen and pelvis	15	42.85

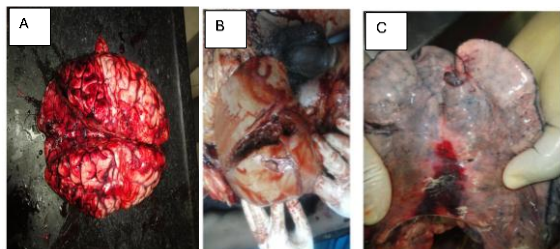


Figure 2: Representative Internal Organ Injuries. A: Severe cerebral injury with intracranial hemorrhage. **B:** Laceration of liver associated with hemoperitoneum. **C:** Bilateral pulmonary injury following blunt thoracic impact

Analysis of organ-specific injuries revealed that the brain was the most commonly injured organ, followed closely by the lungs. Liver injuries were also frequently encountered, whereas injuries to the kidneys, mesentery, and intestines were relatively uncommon. Brain injury was identified in more than four-fifths of cases, while pulmonary injury was observed in over three-fourths of victims. Together, cranio-cerebral and thoraco-pulmonary injuries constituted the predominant pattern of fatal organ damage. [Table 5]

Table 5: Frequency of Organ Involvement in Fatal Falls from Height

Organ Injured	Number (n=35)	Percentage (%)
Brain	29	82.86
Lungs	27	77.14
Liver	20	57.14
Heart	8	22.86
Spleen	7	20.00
Kidney	3	8.57
Mesentery	2	5.71
Intestine	1	2.86

Most victims succumbed shortly after the incident. Nearly two-thirds died at the scene or within 30 minutes of injury, while only one-fifth survived

beyond 24 hours. The high proportion of spot deaths reflects the severity of injuries sustained and the extensive involvement of vital organs. [Table 6]

Table 6: Survival Interval Following Fall

Survival Period	Number (n=35)	Percentage (%)
Spot death (<30 min)	23	65.71
30 min–24 h	5	14.29
>1 day	7	20.00

Shock and hemorrhage secondary to multiple traumatic injuries constituted the leading cause of death, followed by severe head injury. Shock and hemorrhage accounted for nearly two-thirds of

fatalities, emphasizing the contribution of multisystem trauma and major internal organ injury in deaths due to falls from height. [Table 7 and Figure 3]

Table 7: Causes of Death in Fatal Falls from Height

Cause of Death	Number (n=35)	Percentage (%)
Shock and hemorrhage	23	65.71
Head injury	11	31.43
Other causes	1	2.86



Figure 3: Multiple traumatic injuries involving different body regions demonstrating polytrauma following fall from height

DISCUSSION

Fatal falls from height represent a distinctive form of blunt force trauma characterized by rapid deceleration and transfer of substantial kinetic energy at impact. The resulting injury pattern is influenced by the height of fall, body orientation, impact surface, and the anatomical region that first contacts the ground. In the present study, the majority of fatal falls occurred from heights between 20 and 39 feet (48.57%), with the highest proportion observed in the 30–39 feet category (25.71%). Similar observations have been reported by Haggag

et al., and Prathapan et al., who found that most fatal falls occurred from heights of 31–40 feet, suggesting that even moderate-to-high falls can generate sufficient energy to produce fatal multisystem trauma.^[10,11] The predominance of fatalities within this height range may reflect the increasing number of residential and construction-related structures of comparable elevation in urban settings.^[11]

External injuries were most frequently observed over the limbs (77.14%), followed by the head and neck region (71.42%). The high frequency of limb injuries may be attributed to instinctive protective reactions during the fall, wherein victims attempt to break the impact using their upper or lower extremities.^[12] Similar findings were reported by Zaini et al., and Türkoğlu et al., who observed extremity injuries as the most common injuries among pediatric fall victims.^[12,13] In contrast, the high prevalence of head and neck injuries reflects secondary impacts and rotational forces occurring during descent and at ground contact.^[12] The coexistence of extremity and craniofacial injuries underscores the complex biomechanical nature of falls from height.^[12]

Analysis of skeletal injuries revealed that thoracic fractures were the most common injury pattern (74.28%), followed by fractures involving the head and neck region (65.71%). Multiple rib fractures were particularly frequent and likely resulted from compression forces transmitted through the thoracic cage during impact.^[14] Similar observations were reported by Casali et al., who documented rib fractures in nearly half of fatal fall victims, and by Fayyaz et al., who identified rib cage injuries as the most commonly affected skeletal structures in fatal falls.^[15] The high prevalence of skull fractures in the present study further emphasizes the vulnerability of the craniofacial region to high-energy impacts. Such injuries are of considerable forensic significance, as they may help identify the probable site of primary or secondary impact during reconstruction of the event.^[15]

Internal soft tissue injuries were most commonly encountered in the head and neck region (80.0%), followed by the thorax (68.57%). This pattern is consistent with the pathophysiology of fatal falls, wherein sudden deceleration results in substantial shearing forces affecting intracranial and intrathoracic structures.^[16] Cranio-cerebral trauma remains one of the most important determinants of mortality following falls from height, particularly when associated with skull fractures and intracranial haemorrhage.^[16] The predominance of thoracic soft tissue injuries may be explained by the transmission of impact forces through the rib cage to the underlying lungs, heart, and major vessels.^[16]

Among individual organs, the brain was the most frequently injured structure (82.86%), followed by the lungs (77.14%) and liver (57.14%). These findings closely parallel those reported by ElGohary et al., and Jadav et al., who observed brain

involvement as the commonest soft tissue injury, followed by injuries to the liver and lungs.^[17,18] Similarly, Casali et al., reported intracranial injuries in 72% of fatal falls, while Fayyaz et al. documented high frequencies of pulmonary (76%) and hepatic (58%) injuries.^[14,15] The predominance of brain injury reflects both direct impact and acceleration-deceleration mechanisms producing cerebral contusions and intracranial hemorrhages.^[19] Lung injuries are frequently associated with multiple rib fractures, pulmonary contusions, and lacerations, whereas liver injuries occur because of the relatively fixed anatomical position and friable nature of hepatic tissue.^[19] The comparatively lower frequency of splenic, renal, mesenteric, and intestinal injuries observed in the present study is consistent with previous reports by Prathapan et al., and Vadysinghe et al., which indicate that these organs are less commonly involved unless falls occur from considerable heights.^[11,19]

The survival analysis demonstrated that 65.71% of victims died at the scene or within 30 minutes of the incident. This finding indicates the severity of injuries sustained and the extensive involvement of vital organs.^[19] Casali et al., reported that more than three-fourths of victims died at the scene, while Kumar et al., observed high mortality among victims sustaining multiple severe injuries following suicidal jumps.^[14,20] Immediate death following a fall is generally attributable to catastrophic cranio-cerebral trauma, major vascular disruption, or extensive polytrauma leading to rapid circulatory collapse.^[20] The small proportion of victims surviving beyond 24 hours in the present study likely reflects advances in emergency transportation and trauma care, although survival remains heavily dependent on the extent of organ damage.^[20]

Shock and hemorrhage constituted the leading cause of death in the present study (65.71%), followed by head injury (31.43%). These findings are consistent with the recognized pathophysiological mechanisms underlying fatal falls from height.^[21] Extensive internal injuries involving the thoracic and abdominal organs often result in massive blood loss, hypovolemic shock, and subsequent death.^[21] Cranio-cerebral injuries represent another major mechanism of mortality due to raised intracranial pressure, brainstem damage, and irreversible neurological compromise.^[21] Similar observations have been reported in previous forensic studies by Basak et al., Sacco et al., and Min et al., where polytrauma-associated hemorrhage and severe head injury accounted for the majority of fatalities.^[21,22,23]

Limitations

The present study was limited by its relatively small sample size and single-center design, which may restrict the generalizability of the findings. Information regarding the exact body position at impact and characteristics of the landing surface was unavailable in several cases. Being an autopsy-based descriptive study, detailed correlation between

injury patterns, fall height, and survival outcomes could not be statistically evaluated.

CONCLUSION

Fatal falls from height produce characteristic patterns of skeletal and visceral injuries that reflect the biomechanics of high-energy vertical deceleration trauma. In the present study, thoracic skeletal injuries and cranio-cerebral soft tissue injuries predominated, while the brain, lungs, and liver were the most frequently affected organs. Most victims sustained severe multisystem trauma and succumbed rapidly following the incident, with shock and hemorrhage being the leading cause of death. Detailed assessment of injury distribution and organ involvement during medico-legal autopsy provides valuable information for determining the cause of death, reconstructing the circumstances of the fall, and assisting forensic investigations in cases of fatal falls from height.

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