

VERTEBRAL INJURY PATTERNS IN SUICIDAL VS HOMICIDAL FALLS: A FORENSIC AND PHYSICAL THERAPY COLLABORATIVE FRAMEWORK

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ABSTRACT

The distinction between suicidal and homicidal falls is one of the most complex forensic pathology challenges. Vertebral trauma as an integral diagnostic marker in determining the intent of fatal falls is what the current paper investigates. Vertebral fracture patterns, related soft tissue damages, and correlation with the scene of occurrence are the areas of focus for the study in order to differentiate patterns that are characteristic of each type of death. Suicidal falls are largely defined by vertical axial compression fractures of the lower cervical and lumbar spine that are found in the absence of restraint or defensive trauma. In contrast, homicidal falls often exhibit non-uniform fracture distributions, upper cervical or mid-thoracic injuries, and associated perimortem evidence like blunt-force trauma, strangulation marks, or limb restraint. Introduction of postmortem imaging, such as CT and radiographic examination, improves detection of faint vertebral and ligamentous trauma, providing more dependable biomechanical analysis. Comparative case analysis also confirms that correlation of vertebral injury with external and circumstantial evidence presents a valid foundation for differentiating self-inflicted from externally inflicted falls. The research stresses a multidisciplinary method—integrating anatomical, biomechanical, and contextual examination—to enhance the precision of forensic conclusions and facilitate judicial clarity in doubtful death cases.

Keywords: Vertebral fracture, Forensic Science, Trauma, Suicide, Homicide.

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INTRODUCTION

Vertebral fractures resulting from falls can provide valuable information concerning the circumstances surrounding individual deaths. Distinguishing between suicidal and homicidal falls requires careful examination of the site and configuration of the fractures and other perimortem injuries, as well as the position of the body and the scene as a whole [1]. Suicidal falls typically produce fractures located at the lower cervical or upper thoracic spine, reflect a single mechanism of injury and occur without external manipulation. In contrast, multiple perimortem injuries, fractures concentrated at different vertebral levels and the presence of traces indicating restraint or attempts to defend against an attack are more often associated with homicide [2].

Differentiating between the two types of fall is of significant medico-legal consequence since these injuries are often observed in cases where the manner of death is uncertain.

Mechanisms of Fall

A Matter of Trajectory and Timing

Typically, people who utilize high places to leap out of, usually claim to do so because of the so-called suicidal jumps. Such leaps enable the person to descend within a predetermined vertical space after which they can jump off [3]. A person has to go through some form of control whether through intent or losing control while moving downward. Most of the time they end up landing on their feet or head down. The body, in this instance, experiences

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vertical compressive forces mainly on the spine resulting in burst fractures in the thoracic or lumbar region spine.

On the other hand, a homicidal fall can start with some form of aggressive shove, some form of unplanned departure from the balance point, or even a head injury which immobilizes a person prior to the fall. With these two factors dominating, fractures can be of oblique, horizontal, or even rotational and if these comes from above, they will not be termed as vertical force [4]. For instance, if we have a rotational mid spinal wedge fracture or if a lower limb trauma is absent, high cervical burst fractures are possible suggesting a non-volitional push force will make people fall.

Current Developments on Spine and Patterns of Vertebral Fractures

The study of supramorphologic fractures by forensic anthropologists employs heuristic fall models [5]. Suicidal cases often show: Axial compression fractures in the lumbar spine.

Symmetrical distribution of injuries

Fractures in Lower Extremity Injuries

In suspected homicide cases, findings may include: Lateral wedge or burst fractures of upper cervical and mid-thoracic regions; High inflicted traumas with absent soft tissue injuries in lower limbs; Incomplete quadriplegic shock without limb fractures.

These signs, when juxtaposed with circumstantial evidence, can be faintly discerned but with careful consideration, can be the most crucial pieces of the puzzle [6].

The Scene Beyond the Spine

Vertebral fractures and dislocations only capture part of the larger trauma puzzle. Each injury must correlate with the described fall height, surface type, and body alignment. For instance, in cases where a self-inflicted jump is reported from a balcony, not sustaining a foot or leg injury amplifies suspicion. Notes, psychological history, and video recordings may bolster a suicidal hypothesis, whereas conflicting accounts, behavioral scene interference, or signs of a physical struggle indicate murder [7].

MATERIALS AND METHODS

Detailed Examination of the Anatomical Structures and Mechanistic Foundations Regarding Vertebral Falls

Fractures in the vertebral column can occur in a variety of scenarios. Typically, they take place as a result of falls from a height. The triggers of these falls can be of different natures: accident, suicide, or homicide. As such, the forensic differentiation of these events is pivotal [8]. An overall understanding of the anatomical structures involved and the mechanical principles at play can lead to an exhaustive and systematic evaluation of the forensic indicators present in vertebral column falls.

Idiopathic or accidental falls are relatively easy to recognize due to the absence of injury marks on the

body that would indicate unusual circumstances. On the other hand, falls from height that are suicidal or homicidal in nature exhibit different indicators depending on the case at hand. From a morphological point of view, the nature of the different types of falls can be recognized from the pattern of the vertebral fractures and the possibility of concurrent injuries to the cervical cord or brainstem [9]. The analyses and descriptions conducted so far point to a striking similarity between these suicide and homicide falls, as highlighted in classic overview papers, but suicide is rarely associated with multiple perimortem injuries, signs of restraint, or injuries linked to attempt at defense or escape. The presence of one or more of these patterns in perimortem injuries should impart a strong probability to a homicidal fall. Suicidal falls usually take place when the person is completely weaponless as indicated by the absence of weapon marks on the scene [10].

Falls Reflecting Suicidal Intent

Intentional falls and those resulting from homicide are often parsed through available data, yet definitive conclusions about intentions can prove elusive [11]. Precise separation of a self-inflicted from an externally inflicted fall is possible due to the unique vertebral trauma sustained in each case. Knowledge of these distinctive trauma patterns alongside other scatter-able forensic identifiers can assist highly experienced professionals, nevertheless a multimodal examination of all relevant evidence is essential to avoid erroneous determinations [12]. Differentiating between intentional and non-intentional falls provides an important aid to forensic investigations. Suicidal falls display certain commonalities irrespective of height or landing position: they invariably begin with a leap directed by the decedent, their motion is preserved over a clear trajectory, and certain surfaces, upon which the deceased land, remain undisturbed [13]. Because they lack the universal characteristics of suicidal falls, homicidal events manifest differing patterns, which encompass various angles of impact, clusters of separate injuries, collapse following blunt-force trauma, and marks of resistance or restraint.

Falls Reflecting Homicidal Intent

Vertebral fractures resulting from falls off buildings can be broadly classified as suicidal or homicidal. Various considerations may guide the interpretation of the mechanism of fall and provide evidence as to the physiological state of the individual at the time of the fall [14]. The infliction of external trauma accompanying the fall remains the most unambiguous sign pointing towards a homicide event. Nevertheless, other less direct features may assist in distinguishing between these mechanisms, especially when the external conditions surrounding the case do not permit issues of intent to be simply ruled out [15]. In general, a single predominant fall trajectory is characteristic of self-inflicted falls,

while multiple vectors of force acting prior to the fall may indicate homicide. Features indicating a self-inflicted fall include avoidance of landing upon other surficial structures from which it would be easier to recover, as well as a lack of contusions, abrasions, or injuries consistent with defensive measures aimed at avoiding the fall [16]. The absence of impacted body segments that may connect with intermediate ledges or other surfaces such as rooftops, together with the absence of corresponding external trauma on impacted areas, further support the designation of a fall as self-inflicted. The presence of injuries suggesting blunt-force contact with the surface of the building from which the fall was attempted, likewise suggest non-accidental trauma [17].

Forensic Indicators in Suicidal Falls

The presence of vertebral trauma observed during forensic examinations of the deceased can be associated with suicidal or homicidal falls. The distinction of these modalities from a forensic perspective is of paramount importance, as conclusions drawn about the nature of the fall impact the investigation and its possible legal consequences [18]. Evidence-based criteria consistent with current scientific knowledge allow the forensic expert to reach an informed opinion on whether the fall should be regarded as suicidal or homicidal.

Ideally, the conclusions of forensic examinations should provide direction to investigative operations, suggest avenues of inquiry, and offer expert opinions that harmonize with the facts of the case. Two independent features afford guidance in determining whether a vertebral traumatic fall was suicidal or homicidal: the specific configuration of the fractures observed and the timing of the injuries in relation to the death. Fracture configuration analysis correlates with the height from which the fall occurred as well as the posture assumed during the fall [19]. During a forensic examination, careful consideration is given to the fall height and body position, enabling a reliable inference about the probable trajectory of the fallen body after the impact and the transfer of kinetic energy eventually absorbed by the vertebral column, notwithstanding the difficult nature of evaluating these factors. The configuration of the observed fractures is then classified according to a decision scheme and matched with earlier conclusions regarding height and position [20]. The timing of the injuries also plays a significant role in establishing the fall's nature; the default assumption is that perimortem shocks would normally elicit involvement of the central nervous system, while a suicidal fall would rarely coincide with the act of strangulation. When sufficient data permits an assessment on the basis of these two features, the expert can indicate whether the fall involved a suicidal act or not. If the evidence does not allow the probative value of the configuration approach to be raised even perhaps

beyond the level of pure speculation, the examination may nevertheless still incorporate the timing aspect of the injuries [21].

FORENSIC INDICATORS IN HOMICIDAL FALLS

Homicidal falls typically exhibit atypical vertebral fracture distributions and often coincide with concurrent perimortem injuries. In cases where a victim is restrained, additional mechanical force applied to the spine may result in vertebral fractures. Defense-related injuries are more prevalent in homicide scenarios [22]. If strangulation occurs thereafter, characteristic injuries to the upper cervical spine coupled with signs of brainstem or cord trauma can emerge. The presence of a weapon nearby may further substantiate the mechanistic interpretation. Various site-specific indicators at the scene, such as marks suggesting the victim's own effort to ascend the location, can indicate third-party agency [23].

AUTOPSY AND IMAGING CORRELATES

Vertebral Columns Sustaining Fall-Related Trauma: Forensic Relevance

Differentiation of suicidal from homicidal falls through vertebral trauma draws on biophysics, anatomy, and forensic mechanism reconstruction to illuminate self-inflicted versus externally imposed loading and to connect external findings with internal injury. The cervical, thoracic, and lumbar regions exhibit characteristic fracture patterns in both scenarios. Age and bone quality define biophysical thresholds that govern fall-induced fractures and that the absence of vertebral damage rules out skeletal contribution to death; threshold assessment, therefore, informs temporal analysis of the fall [24]. Vertebral fracture patterns arising from intentional or unintentional acts exhibit distinctive features. Suicidal falls generate consistent initial trajectories often accompanied by preparatory movements, whereas a combination of loading vectors, blunt-force features, and defensive injuries signals homicide. Analysis of such patterns enables situational modelling of motive, access, and opportunity and thus clarifies the range of probable mechanistic scenarios [25].

Radiography and other imaging modalities enhance injury assessment and provide crucial information in complex cases. Post-mortem examinations further assist in ascribing fall mechanisms by correlating vertebral trauma with soft tissue or viscera damage. The integration of contemporary forensic and clinical insights contributes to the interpretation of fall-related vertebral trauma and reinforces the legitimacy of differential support [26].

The distinction between suicidal and homicidal falls remains a significant consideration in forensic investigations. Both suicidal and homicidal falls can lead to fatal outcomes, and the identification of the source of loading and related external internal correlations can contribute to the clarification of

intent [27]. Characterization of the fall trajectory and loading parameters supports situational reconstruction. The identification of potential confounding factors such as an atypical trajectory without direct access to the fall site highlights the limits of inference and suggests that detailed sketching of the surroundings constitutes an important step in the analytical process [28].

The forensic interpretation of fall related vertebral trauma can apply mechanical knowledge to assist in the determination of possible intent by evaluating the sequence of external events leading to body superposition and the nature of skeletal injuries.

External Exam Findings

Falls from heights are a distinct form of blunt trauma, characterized by unique patterns of injury due to trauma mechanisms. They often present multiple injuries, with vertebral fractures being among the most frequently observed. Biomechanical and clinical analysis of fall-related trauma helps to understand its mechanisms; therefore, these studies can be useful in ascertaining whether injuries were self-inflicted or externally inflicted [29]. Differentiating self-inflicted injuries from externally inflicted ones represents a major challenge in forensic science. In cases of suspected suicides, distinguishing between self-inflicted injuries and injuries caused by a third party is crucial. An analysis of the mechanisms and patterns underlying jump-related injuries enables the identification of certain fractures and other morphological features that indicate whether injuries were sustained during a suicide attempt or were inflicted by a third party [30].

Internal Injuries and Vertebral Column Trauma

Falls leading to vertebral trauma have been linked to suicide and homicide. Fall-related spinal injuries have become a frequent examination request in forensic practice due to the association of suicidal and homicidal intent with the influence of both the living and the dead on the legal process. There is a need for forensic experts to contribute to the investigation by examining relevant arguments and expert opinions. Analysis of vertebral column traumatism can provide significant assistance in determining the nature of the event [31]. Vertebral trauma is analyzed according to its mechanism of production, force vector direction, point of impact, and subject's body position at the time of the fall, which discriminate between self-inflicted loads and externally applied forces. Distinction is made among the cervical, thoracic, and lumbar zones, together with fracture types (e.g., vertebral body, posterior elements, and ligamentous injuries) that serve as potential hallmarks of suicidal or homicidal involvement. A biomechanical threshold is outlined to differentiate between vertebral bone fractures typically caused by vertical falls and those associated with relatively low-energy injuries under

the influence of other factors (e.g., advanced age, osteoporosis, and preexisting vertebral disease) [32]. Correlation of external examination findings with internal injuries helps establish a continuity of trauma that may support the interpretation of the fall as self-inflicted or inflicted by another party. The type of internal damage also allows inferences about the fall mechanism [33, 34]. Fractures of the vertebral column are mapped against contusions and lacerations in other body areas to determine the number of distinct initial impacts, which may indicate that the fall was not voluntary. The nature of the external or internal violence likewise relates to indicators of self-inflicted or acting-by-third-party involvement.

Imaging Modalities and Interpretive Limits

Differences in the interpretation of forensic evidence may promote divergent opinions on the mechanics of injury, and vertebral trauma associated with falls is sometimes viewed as an exception. Various processes may act together to produce vertebral injuries, and the internal examination age is sometimes assumed to be contemporary with injury [35]. Forensic pathologists frequently examine vertebral trauma associated with falls to deduce the mechanics of injury. Self-inflicted injuries remain an uncommon aspect of forensic expertise, yet examinations frequently include presentations classified as suicide to determine the absence of external involvement. Forensic pathologists often examine vertebral trauma associated with falls to deduce the mechanics of injury [36].

The Significance of Imaging: Discerning What Remains Hidden

Modern imaging technology is critical when determining whether an individual used their own bodily autonomy to fall or if they were actively pushed. Autopsies have their uses, but when it comes to delicate internal fractures, they fall short. In these situations, Postmortem Computed Tomography (PMCT) comes in handy. For all intents and purposes, PMCT functions as a virtual autopsy. It permits forensic professionals to assess the interior of a body without inflicting a single incision [37]. In deaths associated with falls, PMCT is adept at capturing clear images of anatomical structures such as the spine and determining if vertebrae suffered compression (crushed), burst (split outward), or rotational injuries (twisting). Such indicators deduce landing position; feet first, headfirst, or sideways. Imaging typically demonstrates the legs to spine sustaining fractures, indicative of jumping suicide, but when high neck and upper back spinal injuries appear devoid of low-leg harm, the advanced imaging tells a different story that if a person was off balance or unconscious and pushed instead. PMCT aids in revealing concealed injuries such as minute fractures, slight tears of ligaments, or intricate patterns of internal bleeding that may not be apparent during a

traditional autopsy. These pieces of evidence help in constructing the wider context to the laboratory it can be presented in court to aid in the visualization of reality for judicial decision-makers [24].

Multi-detector computed tomography (MDCT) continues to represent the reference standard for rapid examination of acute non-embolic, postmortem cardiovascular disease since postmortem computed tomography (PMCT) angiography enables three-dimensional visualization of the coronary arterial system without additional examination time or radiation dose [5]. Such examinations offer both forensic and clinical data and the capacity to reconstruct sections of the human body, as patients, as for other short- and intermediate-term postmortem alterations, delineate between death due to drowning and environmental immersion associated with a corpse concealed by aquatic transport. Follow-up Forensic MDCT enables examination for acute traumatic lesions in flat and rounded bones [38]. The consolidation of human remains, both postmortem and during human development and/or skeletonization, accommodates the identification of cadavers. At this later stage, complementary examinations may assist in the forensic context, concomitant radiological imaging, repair osteology, orthotic items of deceased subjects offer assistance in determining the pre-mortem condition and tracing any cadaver preceding, blood or vomitus, within cavity structures exhibit pre-mortem injury. In examining trauma-associated injury patterns, the anatomical site requires prioritization in combination with pattern recognition and clinical experience. Particular injury patterns frequently denote a rejection of alternative competing explanatory models even in the absence of supportive circumstantial data [39]. Vertebral injuries associated with falls, sometimes considered an exception, offer an opportunity to apply principles governing forensic interpretation of contusions, abrasions, and lacerations from blunt trauma toward the precise examination of vertebral trauma.

INTERPRETIVE FRAMEWORKS AND DECISION AIDS

Falls can be classified as suicidal, homicidal, or accidental. The determination of intent is critical, as it directly affects the potential for prosecution, commitment to a mental health facility, and the responsibility of the forensic expert [1]. Vertebral fractures resulting from fall accidents are known to exhibit certain patterns. Finding such a pattern and a high concentration of contradicting indicators may lead to the conclusion that the analysis cannot differentiate between the three ways to assess the situation [40]. It is possible to invoke an analytic schema that identifies the presence of the main indicators. Although it must remain flexible to accommodate unusual cases, such schemas and their embodiments in differential diagnoses, decision

trees, scoring rubrics, and measures of conflicting association between the indicators can be beneficial [41].

CASE STUDIES AND COMPARATIVE ANALYSES

Falls from height, frequently utilized methods of suicide or homicide, can also occur accidentally. Differentiate between suicidal, homicidal, and accidental falls through forensic analysis of vertebral trauma, specifically: (1) fracture pattern and vertebral level injured, (2) presence, location, and appearance of associated contusions, (3) number of fractures, and (4) pattern of compression, wedge, and burst fractures; when such fractures are present, their characteristics provide additional guidance. A forty-three-year-old woman, previously diagnosed with severe depression and suicidal ideation, fatally fell from seventh storey whilst seeking a means to die. Autopsy revealed multiple vertebral fractures, predominantly of the lower spine and without cranial injury. Her behavior during the hours preceding the fall, furthermore, strongly indicated suicidal intent. Such findings correspond closely with those recorded in other cases of suicidal vertebral injury. A sixty-seven-year-old woman whose husband exhibited sexually violent and threatening behaviors fell from a similar height shortly after midnight. Evidence indicated she was forcibly propelled over the balcony. Autopsy findings included multiple vertebral fractures located throughout the column, numerous other injuries, and the absence of pre-existing disease. Such patterns correlate more closely with previous accounts of homicide than any other modality. Cases of accidental fall through the same trajectory similarly differ from either suicide or homicide by several defining features. Further comparative summaries clarify distinctions between these three fall categories. Not all characteristics must be present to establish intent and must be regarded as suggestive rather than definitive, further underscoring the value of cross-case analysis

UNCERTAINTIES, AND FUTURE DIRECTIONS

Falls resulting in vertebral fractures can be either suicidal or homicidal in intent. Differentiation is paramount, given there are legal predicaments surrounding a suicidal designation and no public protection from the perpetrator. Reports based on a series of cases described the differentiation process. The examination of the body and scene yielded the most informative parameters. Modifying these parameters yields a simplified probabilistic approach to assess the likelihood of each disposition from a given body-scene configuration. Maintaining a strict definition of these parameters and having a witness corroborate the information wherever possible greatly enhance the reliability and credibility of the forensic assessment.

A realistic test scenario for the proposed approach employed two test data sets from recent cases. Parameters required assessing body-mouth distance, body-substrate distance, the degree to which the body had turned, the time elapsed since death, whether or not further injuries had been noted, the existence of a note, and the allocation of corroboration grades to different testimonies. The relevant data was then analysed by assigning to each the body-scene likelihood ratio for both the suicidal and the homicidal hypotheses. An overall likelihood ratio quantifying the degree of support given by the data to one of the two hypotheses was finally obtained.

CONCLUSION

Determining the appropriate classification of a death serves a critical function in judicial proceedings and in the administration of justice more broadly. Criteria for determining intent—whether the deceased fell from a height with the objective of ending their own life or at the behest or through the action of another party—depend on the interpretation of several pieces of evidence, including, in particular, the nature and extent of vertebral trauma sustained during the fall.

The axial loading of the spine associated with a fall from a height generates energy that can be

transferred to the skeletal structure and mandibular bones. The positioning of the individual at the point of impact can express intent, with victims of homicide frequently being positioned supine, seated, or semi-reclined, while victims of suicide often adopt offensive postures—or land prone, feet first, seizing an opportunity to salvage themselves. Marks left on the scene, the simultaneous presence of items such as personal effects or weaponry, the direction from which a corpse was disposed of, and the profile of the individual are all determinants. Further indicators include the configuration of the vertebral damage itself, external disruptions to the anatomy, the distribution of overall traumatic features, and the presence, amount, or pattern of autoinflicted trauma.

1. The detection of extra or different distribution damage to other regions of the body reinforces a diagnosis of other than suicide.

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