



Case report

Self-contained crash or run-over by a vehicle? Integrating post-mortem CT and kinematic analysis to reconstruct motorcycle accident dynamics



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ABSTRACT

Differentiating between primary impact injuries and those caused by a run-over event in motorcycle accidents can be challenging due to the complexity of trauma mechanisms and the lack of standardized diagnostic criteria. This report presents the case of a 57-year-old motorcyclist found deceased following a collision, with initial suspicions raised by surveillance footage suggesting the possibility of a run-over by a passing car. A comprehensive forensic investigation was conducted, including autopsy, post-mortem computed tomography (PMCT), and kinematic analysis, to determine the cause of death and reconstruct the accident dynamics.

The PMCT played a pivotal role in accurately documenting complex injury patterns, such as bilateral anterior-posterior fractures of the skull, ribs, and pelvis, which initially suggested a crushing mechanism. However, integration with kinematic findings and circumstantial evidence excluded the involvement of the suspected car. Instead, it was determined that the injuries resulted from compression between the overturned motorcycle and a tree during the collision.

This case highlights the indispensable value of PMCT in forensic investigations, particularly in identifying subtle fracture patterns and enhancing injury interpretation. Despite the sensitivity and applicability of PMCT in traffic accidents, there is limited data regarding the interpretation of differential diagnoses between crush injuries and blunt-force impacts in motorcyclists. The systematic use of PMCT, combined with interdisciplinary collaboration between forensic pathologists, radiologists, and kinematic experts, represents a significant advancement in reconstructing complex traffic accidents and reducing uncertainty in medico-legal evaluations.

Introduction

Motorcycle accidents, characterized by complex dynamics and the rider's vulnerability, significantly contribute to road fatalities. Due to the high vulnerability of motorcyclists, even low-speed collisions can result in severe or fatal injuries [1]. The head is the most injured body region in fatal motorcycle accidents, often due to direct impact with vehicles, road surfaces, or other obstacles. Traumatic brain injuries, including skull fractures, cerebral contusions, and intracranial hemorrhages, are frequently observed in post-mortem examinations. Following head trauma, injuries to the thorax and abdomen represent other significant contributors to mortality: rib fractures, pulmonary contusions, cardiac lacerations, and abdominal organ damage are

frequently reported, often resulting from direct blunt force trauma [2,3].

In fatal road traffic accidents involving motorcyclists, differentiating between crush injuries and high-energy impacts poses a significant challenge for forensic pathologists. This distinction is crucial in determining whether a victim succumbed to primary impact forces or was subsequently run over by another vehicle. Post-mortem Computed Tomography (PMCT), when utilized as an adjunct to forensic autopsy, enhances the detection of trauma in anatomically critical regions during investigations of motorcycle accident fatalities [4,5]. However, limited studies systematically correlate autopsy and radiological findings to differentiate between high-energy impact trauma and crush injuries, underscoring a gap in evidence-based diagnostic criteria for such cases. For this reason, besides the assessment of injury distribution, accident

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reconstruction plays a fundamental role in forensic investigations. By integrating post-mortem findings with kinematic principles, experts analyze vehicle damage, tire marks, and physical evidence to estimate vehicle speeds and reconstruct the sequence of events leading to the fatal crash.

This report presents a case involving a 57-year-old motorcyclist found deceased on a city street, with initial concerns arising from camera footage suggesting a possible run-over. A comprehensive forensic investigation was performed, including autopsy, PMCT, and kinematic analysis, to determine the precise cause of death and reconstruct the accident dynamics. The integration of multiple investigative techniques provided critical insights into whether the victim sustained fatal injuries upon initial impact or suffered additional trauma due to a secondary run-over event.

Case report

The body of a 57-year-old motorcyclist was discovered at night on a city street. He was lying on his back, positioned perpendicular to the traffic lane. According to rescuers testimonies, the motorcycle was covering his lower limbs, and his helmet was correctly worn and intact. Before the police arrived, the motorcycle had been moved, and the helmet removed to perform rescue maneuvers. A pooled bloodstain was observed near the body (Fig. 1a), and skid marks led to a plane tree on the adjacent right sidewalk, where plastic fragments were embedded in the tree bark, also showing signs of damages (Fig. 1b).

Surveillance footage from a nearby commercial establishment recorded the motorcycle approaching one hundred meters before the site of the crash but did not capture the impact. However, it showed a car passing by the street several seconds later, raising investigators' concerns about whether the car might have contributed to the motorcyclist's death. Therefore, it was crucial to determine if there were any evidence that the car, recorded by the camera and subsequently identified by investigators, had run over the motorcyclist, or if the death could be exclusively attributed to the collision with the tree. A comprehensive examination was conducted, including an autopsy, a post-mortem CT scan, and a kinematic analysis of the scene and vehicles.

The autopsy (Fig. 2) revealed multiple anterior and posterior ecchymoses and abrasions on the face, chest and back, several fractures to skull, ribs and pelvic bones fractures, subarachnoid hemorrhage, and lacerations of the pericardium, right atrium and liver. No typical tire marks were observed on the body [6], but the victim was dressed in full motorcycle gear, which was discarded before the suspicion of a crushing injury emerged from the surveillance cameras. However, there are cases in literature that demonstrate that tire tracks do not uniquely identify a

run-over, as they may also be present in collisions involving tire impact [7].

Based on the autopsy results, a PMCT was conducted to accurately detail the bone fracture patterns. For this purpose, the autopsy examination was conducted by attempting to preserve the anatomical relationships between the edges of the fractured bone fragments. Although not common, the value of performing a CT scan after the autopsy has been discussed in the literature [8], especially in cases where a timely radiological examination was not feasible, as occurred in the present case. The post-mortem CT confirmed multiple fractures involving the skull and facial bones (Fig. 3a-b), fractures of the left clavicle, rib fractures (anterior fractures from the 2nd to the 8th on the left and from the 4th to the 6th on the right, and posterior fractures of the 4th and from the 6th to the 11th on the right) (Fig. 3c-d) and a diastasis of the pubic symphysis and the right sacroiliac joint (Fig. 4). The cause of death was identified fatal traumatic brain injury, complicated by hemorrhagic shock due to thoraco-abdominal organ injury. The post-mortem findings are not among those typically described in motorcyclists involved in frontal collisions [9]. In particular, the bilateral anterior-posterior fractures of the skull, pelvis, and ribs supported the hypothesis of a crush injury, typically seen in run-over incidents, even in absence of organ herniation [10,11], suggesting the possible involvement of the identified car.

The kinematic analysis demonstrated that the vehicle speed at impact was estimated to be 50 km/h, as indicated by the speedometer that remained frozen. This data was consistent with the damage observed on the vehicle caused by the direct collision with the tree. The undisturbed speed maintained by the driver was determined by combining this data with the energy dissipated during the uniform decelerated motion over a total distance of 17.3 meters, as evidenced by the skid mark left on the asphalt. This resulted in an initial motorcycle speed of 75 km/h.

The kinematic reconstruction of the impact was based on the motorcycle damages, showing dents on the front left side of the motorcycle, and on findings from the on-site inspection: an intact helmet near the body and skid marks leading toward the tree. These factors suggested a collision between the motorcycle and the plane tree, followed by compression of the body between the tree and the overturned motorcycle, with a final projection onto the asphalt (Fig. 5a). For the assessment of the involvement of the car, the kinematic evaluation was based on: (i) the intactness of the helmet worn by the victim (Fig. 1a); (ii) the presence of blood traces near the corpse indicating stasis and excluding subsequent alterations (Fig. 1a); (iii) post-impact static position of the victim reconstructed from witness testimonies (Fig. 5b), according to which the motorcycle was found on top of the victim; and (iv)



Fig. 1. Position of the motorcyclist's body and the motorcycle after the arrival of the rescue team, where it is observed that the motorcycle has been lifted and placed against the tree, and the helmet has been removed (a). Skid mark indicating the trajectory followed by the motorcycle before the impact (b).

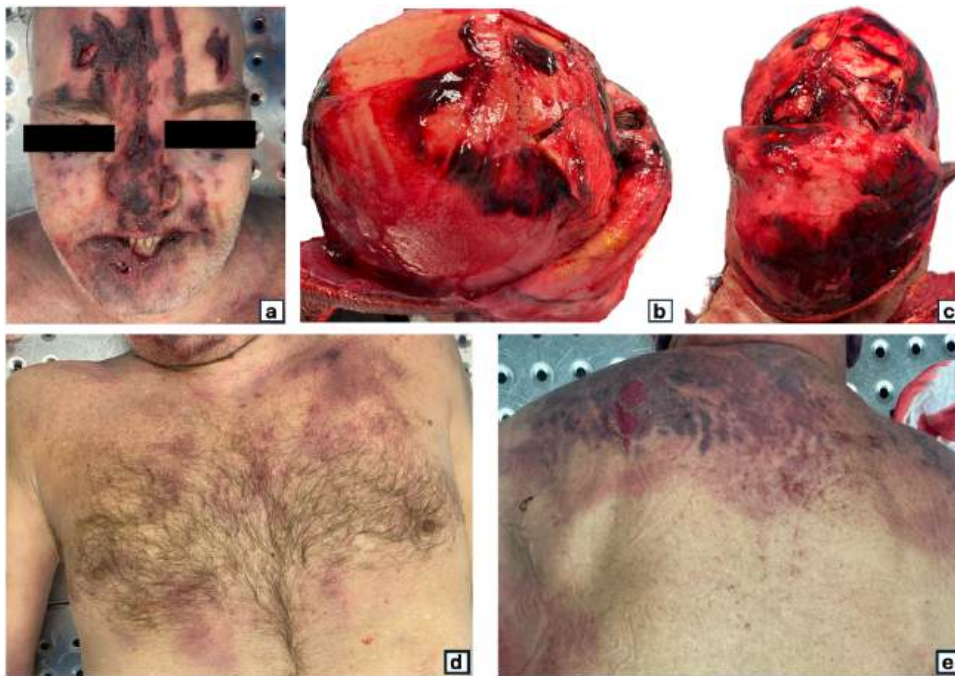


Fig. 2. Extensive abrasions and facial crushing (a), with hemorrhagic infiltration of both anterior and posterior soft tissues (b and c). Extensive ecchymosis on both sides of the chest (d). Extensive ecchymosis on the upper part of the back, bilaterally (e).

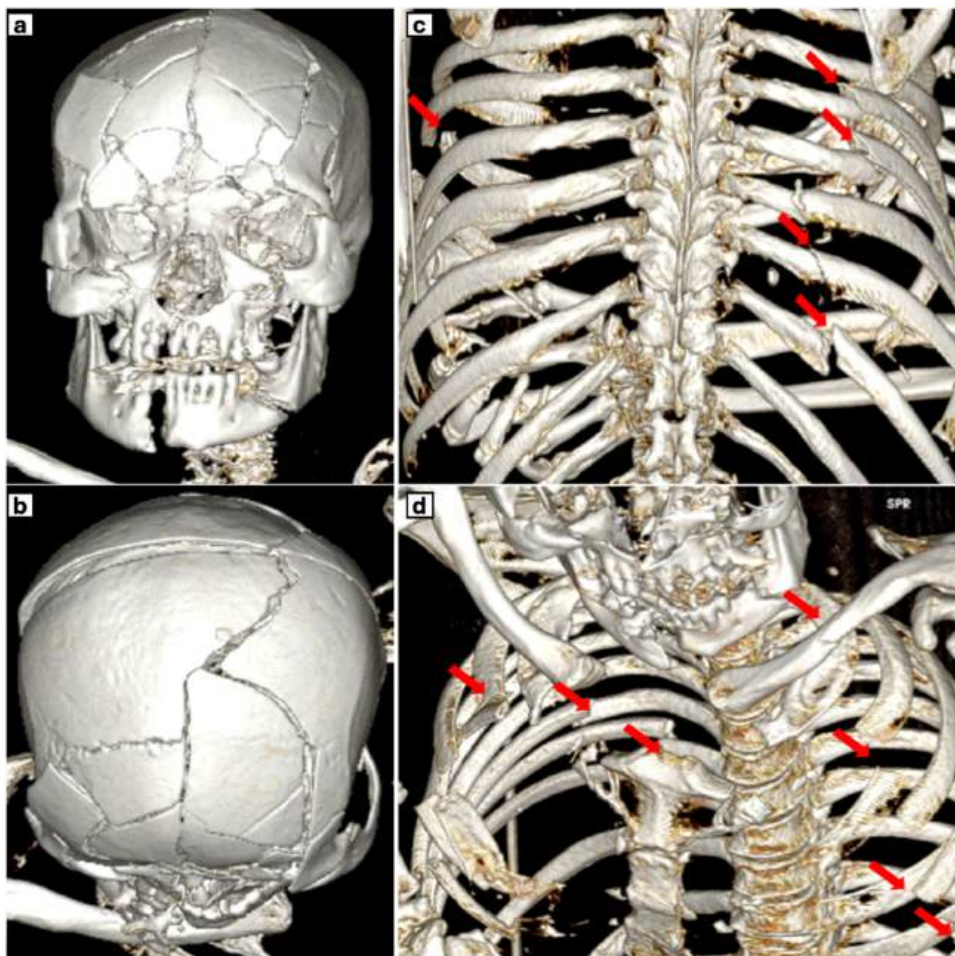


Fig. 3. 3d reconstructions of post-mortem CT showing multiple fractures (arrows) of the anterior and posterior cranial rims, with anterior cranial compression (a, b), clavicular fractures, and multiple bilateral rib fractures, both anterior (c) and posterior (d).



Fig. 4. 3d reconstructions of post-mortem CT showing diastasis of the pubic symphysis and the right sacroiliac joint (arrows).

the analysis of photographs of the suspected car, which showed no signs of frontal impact. These factors ruled out the possibility of a run-over. Therefore, the anterior and posterior injuries, as well as the anteroposterior crushing of the head and chest, could be attributed to the compression of the driver's body between the tree and the motorcycle.

Discussion

This case illustrates how the interpretation of evidence obtained by autopsy and PMCT can be improved with the introduction of new elements of investigation, highlighting the central role of interdisciplinary collaboration between forensic specialists and kinematic experts in the reconstruction of complex accidents, especially in the differential diagnosis between high-energy impacts and run-over accidents.

In fact, run-over accidents are relatively rare and typically involve pedestrians who are initially struck by a vehicle and subsequently thrown to the ground. Motorcyclists, although less frequently reported in literature, can also be run over by vehicle wheels, generally after falling from their motorcycles [9–11]. Multiple skull fractures, as observed in the present case, are a common finding in run-over accidents [12]; these fractures are related not only to the magnitude of force but also to the location of impact, duration of the force, area of contact between the object causing injury, and other factors. Fractures can occur on both the tire side and the ground side, with the ground side fracture generally being more severe. Beside skull fractures, PMCT provided critical insights into the precise pattern of injuries, including anterior

and posterior ribs fractures and pelvis fractures - findings that are consistent with those generally observed in victims who have been run over by a vehicle [13–15]. Other findings typically observed of a run-over, such as tire marks on the skin and clothing, burn injuries from hot metal, and deposits of lubricant oil, were not observed [9,16]. However, the victim was dressed in full motorcycle gear, which was discarded before the suspicion of a crushing injury emerged from the surveillance cameras.

On the other hand, in case of collision with fixed objects, injuries typically affect the upper extremities [17,18], not found during post-mortem investigation. However, in this case the collision involved a large roadside structure, for which literature suggests that serious thoracic injuries, particularly rib fractures, are frequently observed, especially in high-speed crashes [19,20]. Additionally, in frontal collisions with large surfaces, ejected motorcyclists can sustain injuries such as facial soft tissue injuries, depressed skull fractures, and cerebral contusions [17], like those observed in run-over incidents. Nevertheless, pelvic injuries are often attributed to impacts with the fuel tank or the handlebar, as abrupt stops create high peak loads between the rider's pelvis and the tank [21].

Therefore, even though initially indicative of a run-over incident, the post-mortem findings, considering the complex dynamics, cannot be used to support either hypothesis. The integration of radiological data with circumstantial evidence and kinematic reconstruction clarified that these injuries resulted from compression forces exerted by the overturned motorcycle against the tree, rather than by a secondary vehicle impact, excluding a run over.

The present analysis is subject to certain limitations, primarily due to the loss of original scene integrity and the use of PMCT. The removal of clothing and the helmet, as well as the repositioning of the motorcycle, were necessary to perform emergency rescue procedures. While the inability to analyze the clothing represents a significant but unavoidable forensic limitation, the position of the vehicle and the proper use of the helmet were reconstructed as accurately as possible based on eyewitness accounts. A second major limitation is that the radiological examination was conducted after the autopsy. To mitigate the impact of this factor, particular care was taken during the dissection to preserve the anatomical relationships between bone fracture margins, thereby maintaining the diagnostic reliability of the subsequent radiological assessment. Although the fracture anatomy of the skull and pelvis was largely preserved, other anatomical regions—notably the ribcage—demonstrated alterations. Specifically, while the number and location of rib fractures remained consistent, the spatial relationships between rib fragments appeared modified in the CT scans, likely due to

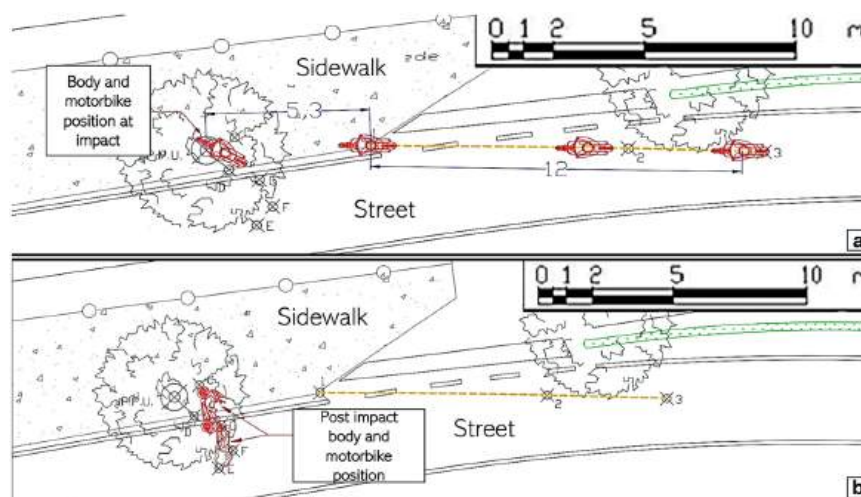


Fig. 5. Kinematic reconstruction of the event (CAD software), showing the direction followed by the motorcyclist before the impact with the tree and the point of impact between the motorcycle and the tree (a), and the position of stasis after the collision, reconstructed from witness testimonies (b).

post-mortem handling.

This report highlights that, given the scarcity of reported cases and the lack of injuries uniquely attributable to a run-over, forensic pathologists often face challenges in differentiating between crushing injuries and high-energy impacts in fatal road traffic accidents. This is particularly true in motorcycle fatalities, where the complex and multifaceted nature of autopsy data complicates interpretation [14]. For this reason, beside autopsic and radiological data, also physical evidence collected from traffic collision scenes, including vehicle damage, bloodstains, tire tracks, and fragmented vehicle parts, plays a crucial role in forensic reconstructions [14].

Despite the sensitivity and applicability of PMCT in traffic crashes, there is limited data regarding the differential diagnosis between crush injuries and impact injuries in motorcyclists, where crash dynamics can be highly complex and involve multiple body regions. Furthermore, particularly in high-energy trauma cases, the injury pattern of a frontal collision—observed both during autopsy and post-mortem radiological examination—can be challenging to distinguish from crush injuries. This information is pivotal, especially during the initial stages of investigations.

Conclusion

This case underscores the importance of adopting a multidisciplinary approach involving forensic pathologists, radiologists, and kinematic experts to ensure accurate accident reconstruction. The systematic use of PMCT in forensic investigations not only enhances diagnostic precision but also contributes to the broader understanding of motorcycle-related fatalities. Future studies and case reports integrating PMCT findings will further enrich scientific literature, providing valuable frameworks for reducing uncertainty in similar medico-legal scenarios.

Ethics approval and consent to participate

The current Italian legislation neither requires the family's consent or ethical approval for a single case, as long as the data are kept strictly anonymous. Because summoning the parents was not possible as it would badly interfere with the grieving process, parents' consent was waived, according to the Italian Authority of Privacy and Data Protection ("Garante della Privacy": GDPR nr 679/2016; 9/2016 and recent law addition number 424/ 19th of July 2018; <http://www.garanteprivacy.it>).

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CRediT authorship contribution statement

Elena Giovannini: Writing – original draft, Investigation. **Guido Pelletti:** Writing – original draft, Conceptualization. **Luigi Friio:** Investigation, Formal analysis. **Mattia Strangi:** Investigation, Formal analysis. **Paolo Fais:** Investigation, Conceptualization. **Susi Pelotti:** Supervision, Investigation.

Declaration of competing interest

The authors declare no conflict of interest.

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