FORENSIC MEDICAL ASSESSMENT OF INJURIES RESULTING FROM ROAD TRAFFIC ACCIDENTS.

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Abstract. Road traffic accidents (RTAs) represent one of the leading causes of traumatic injuries worldwide and pose complex medico-legal challenges. Forensic assessment focuses on the mechanism of trauma, biomechanical correlations, injury severity, and determination of causal relationships. Modern imaging, reconstruction methods, and standardized injury scoring systems have significantly improved the accuracy of forensic conclusions. This article reviews current approaches to the forensic medical evaluation of RTA-related injuries, highlighting diagnostic difficulties, methodological errors, and the role of multidisciplinary analysis.

Keywords: forensic medicine, road traffic accident, trauma mechanism, injury severity, medico-legal assessment, biomechanics.

Introduction. Road traffic accidents constitute a major global public health and forensic concern. According to the WHO (2023), more than 1.2 million people die annually due to RTAs, with tens of millions sustaining injuries of varying severity. Forensic medical assessment plays a critical role in determining:

- the mechanism and direction of traumatic impact,
- the sequence of injuries,
- the severity of bodily harm,
- the compatibility of injuries with reported accident circumstances,

- the presence of premortal or postmortem trauma,
- medico-legal liability of involved parties.

RTA-related injuries are often polystructural, combined, and involve multiple biomechanical vectors, making their forensic interpretation highly complex. Multidisciplinary analysis—including biomechanics, radiology, toxicology, and accident reconstruction—is now considered a gold standard in forensic practice [Smith, 2020; Madea, 2017].

Materials and Methods. The article is based on an analytical review of forensic cases involving RTA injuries, international guidelines (WHO, UNODC, ENFSI), and current scientific literature from 2010–2024. Key methods include: **Morphological analysis of injuries**. Morphological analysis included a detailed external and internal examination of injuries with description of their localization, shape, size, boundaries, color, depth and relationship to surrounding tissues. Special attention was paid to the differentiation of contusions, abrasions, lacerations, fractures and internal organ damage, as well as to the presence of patterned injuries corresponding to vehicle structures (e.g. bumper, dashboard, steering wheel). The morphological characteristics were systematically documented through standardized protocols and photographic recording, which provided the basis for subsequent biomechanical and medico-legal interpretation. **Biomechanical interpretation of trauma mechanisms.** Biomechanical interpretation was performed by correlating the observed injury patterns with the direction, magnitude and duration of external forces acting on the body during the road traffic accident. The position of the victim (driver, passenger, pedestrian, motorcyclist) and the presumed kinematics of the event were taken into account to explain primary and secondary impacts, acceleration–deceleration effects and compression phenomena. This approach allowed differentiation between contact and non-contact injuries, identification of the most probable mechanism of trauma, and evaluation of consistency between the injuries and the reported circumstances of the accident. **Radiological diagnostics (X-ray, CT, MRI).**

Radiological diagnostics included conventional radiography, computed tomography (CT) and, where indicated, magnetic resonance imaging (MRI). X-ray studies were used primarily for detection of skeletal injuries, including fractures of the skull, spine, ribs and extremities. CT provided high-resolution visualization of complex fractures, cranio-cerebral and thoracoabdominal injuries, as well as three-dimensional reconstructions for detailed topographical assessment. MRI was applied mainly for evaluation of soft-tissue, ligamentous, spinal cord and brain injuries, particularly in cases with suspected acceleration–deceleration trauma or subtle parenchymal damage. Radiological findings were systematically compared with morphological examination data. **Assessment of injury severity using standardized criteria** The severity of injuries was assessed using nationally accepted medico-legal criteria and, where appropriate, standardized scoring systems (e.g. Abbreviated Injury Scale, Injury Severity Score). Evaluation included the analysis of life-threatening conditions, duration of health impairment, need for surgical interventions, risk of long-term complications and development of permanent disability. The results of this assessment were used to classify the degree of bodily harm and to provide a clear medico-legal justification of the severity level in accordance with current legal regulations. **Correlation of clinical and scene findings.** Correlation of clinical and scene findings was performed by comparing injury patterns, medical records and radiological data with information obtained from the accident scene (police reports, photographs, sketches, vehicle damage). Particular attention was paid to the compatibility between the localization and morphology of injuries and the documented position of the victim, safety device use (seatbelts, airbags, helmets) and type of collision. This integrative approach enhanced the reliability of conclusions regarding the mechanism of trauma, sequence of events and causal relationships.

Evaluation of medical documentation. Evaluation of medical documentation included a thorough review of emergency department records, hospital charts, operative reports, imaging reports and discharge summaries. The timing and adequacy of diagnostic and therapeutic interventions were analyzed, as well as the dynamics of the victim's clinical condition. In cases involving alleged medical malpractice or delayed treatment, special attention was given to identifying possible diagnostic or therapeutic errors and their potential contribution to the outcome. This assessment provided an important basis for determining the role of medical care in the overall injury process. **Reconstruction of accident circumstances**. Reconstruction of accident circumstances was carried out by integrating forensic, clinical, radiological and technical data. Information on vehicle speed, direction of movement, point of impact, deformation of vehicle structures and final positions of the participants was analyzed in conjunction with the injury profiles. When available, eyewitness statements, video recordings and expert technical reports were also taken into account. This comprehensive reconstruction allowed the expert to determine the most probable mechanism of the accident, to verify or refute the versions presented by the involved parties and to substantiate medico-legal conclusions concerning causation and responsibility. Particular attention is paid to methodological errors and limitations that affect the accuracy of forensic conclusions.

Results and Analysis. Classification of RTA-related injuries. For forensic purposes, injuries are classified according to:

a) Mechanism of trauma

- **Impact injuries** (frontal, lateral, rear, rotational impact)
- **Compression injuries**
- **Acceleration–deceleration injuries**

- **Shearing and tangential injuries**
- **Combined polymechanical trauma**

b) Position of the victim

- Driver of the vehicle
- Front-seat passenger
- Rear-seat passenger
- Pedestrian
- Motorcyclist / bicyclist

Each position generates characteristic injury patterns—e.g., dashboard injuries, windshield imprints, bumper fractures of the tibia in pedestrians, helmet-related impact injuries in motorcyclists.

Forensic significance of biomechanical analysis. Understanding the vector and magnitude of forces is crucial for:

- differentiating primary and secondary injuries;
- identifying the position of the victim at the moment of impact;
- distinguishing between self-inflicted and accident-related injuries;
- establishing speed, direction, and rotational dynamics of the vehicle.

Biomechanical reconstruction is particularly important in controversial cases, including hit-and-run and disputes between driver and passenger.

Modern imaging as a tool for forensic assessment. CT, MRI, and 3D reconstruction significantly enhance injury visualization.

Key forensic advantages:

- detection of occult fractures (orbital floor, skull base, rib fractures);

- precise mapping of polystructural trauma;
- visualization of internal hemorrhages and organ ruptures;
- assessment of soft-tissue injuries (contusions, hematomas, lacerations);
- identification of seatbelt marks and airbag-related lesions.

3D imaging data are increasingly used in court to demonstrate injury patterns.

Determination of injury severity

The forensic evaluation of injury severity relies on:

- degree of functional impairment,
- duration of health disturbance,
- risk of life-threatening complications,
- presence of permanent disability.

Courts require clear forensic justification referencing national legal standards.

Establishing causal relationships. One of the central medico-legal tasks is determining whether the injuries:

- correspond to the described mechanism of the accident,
- were the direct result of the RTA,
- could have occurred prior to or after the accident,
- were aggravated by inadequate medical care.

A scientifically grounded causal link is mandatory for legal decision-making.

Frequent forensic errors. Typical expert mistakes include:

1. Misinterpretation of injury mechanisms without biomechanical correlation
2. Incorrect assessment of victim's position

3. Failure to analyze seatbelt and airbag evidence
4. Underestimation of combined acceleration–deceleration injuries
5. Lack of radiological correlation
6. Insufficient scene investigation data

These errors may lead to incorrect conclusions and judicial disputes.

Discussion. The forensic assessment of injuries sustained in road traffic accidents requires the application of advanced technological and analytical approaches that exceed the capabilities of traditional morphological examination. Although classical morphological analysis remains a foundational component of forensic practice, it is increasingly evident that external and internal injury patterns alone cannot provide a complete understanding of the dynamics of high-energy traumatic events. The complexity of RTA mechanisms—characterized by rapid acceleration–deceleration forces, multiple impact vectors, and combined polymechanical loading—necessitates the use of complementary methods capable of revealing hidden, subtle, or deeply situated structural damage.

The integration of modern radiological techniques, including high-resolution computed tomography, magnetic resonance imaging, and three-dimensional reconstructions, enables precise visualization of skeletal and soft-tissue injuries that may be overlooked during conventional examination. Biomechanical modeling further enhances interpretative accuracy by allowing experts to correlate injury morphology with the magnitude, direction, and temporal sequence of traumatic forces. Moreover, computational simulations and digital accident reconstruction technologies contribute to a more objective and reproducible interpretation of trauma mechanisms, helping to resolve discrepancies between witness statements, technical evidence, and clinical findings. Together, these interdisciplinary tools significantly increase the scientific validity, evidentiary reliability, and medico-legal robustness of forensic conclusions.

Modern trends include:

- use of **machine learning** to predict injury patterns;
- **AI-assisted image interpretation**;
- **digital scene reconstruction** based on photogrammetry;
- **probabilistic modelling** of trauma mechanisms.

Interdisciplinary cooperation between forensic experts, radiologists, engineers, and legal professionals is essential to minimize uncertainty and expert discrepancies.

Conclusion. Forensic medical evaluation of RTA-related injuries represents a complex, multi-stage analytical process that demands strict methodological rigor, comprehensive documentation, and a high level of multidisciplinary expertise. The reliability of expert conclusions largely depends on the accurate identification of trauma mechanisms, precise biomechanical interpretation of the injury patterns, and objective assessment of injury severity in accordance with standardized medico-legal criteria. Such a systematic approach minimizes diagnostic uncertainty, enhances the reproducibility of expert findings, and contributes to the formation of well-substantiated medico-legal judgments. Furthermore, the integration of advanced imaging modalities, digital reconstruction technologies, and biomechanical modelling has substantially increased the evidentiary value of forensic assessments, allowing experts to visualize trauma dynamics with unprecedented precision. These developments not only strengthen judicial decision-making, but also promote transparency, scientific validity, and consistency across forensic medical practice.

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