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Injury as a silent witness: forensic medicine's role in the legal qualification of an explosive case☆

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ABSTRACT

In forensic practice, the reconstruction of criminal behavior and charge determination are often entrusted solely to law enforcement, with forensic medicine playing a marginal, confirmatory role. Nonetheless, accurate injury analysis remains fundamental and, in specific contexts, may be decisive.

The authors present a case that underscores the crucial role of interdisciplinary forensic collaboration – particularly between forensic pathologist and ballistics expert – in the reconstruction of the event dynamics and in supporting judicial decision-making aimed at the accurate charge determination of the event. On the shutter of a bookstore a ticking object wrapped in white cloth was discovered. A bomb disposal technician intervened to neutralize the device. During the operation, the device exploded, causing the amputation of the left hand, loss of the right eye and bilateral thigh lacerations with retained foreign bodies. The technician claimed the explosion occurred spontaneously. Based on this, charges included mass murder, considering the alleged explosive power. A multidisciplinary forensic analysis integrating crime scene investigation, injury pattern review, radiological imaging and explosive residue testing was conducted. A detailed injury analysis and technical assessment of the device disproved this version, redefining the victim's position at the time of detonation and substantially reducing the inferred explosive capacity. This led to the reclassification of some criminal charges.

1. Introduction

Injury interpretation and dynamic reconstruction are two key pillars of forensic pathology. They provide the scientific foundation for reconstructing traumatic events and assessing their coherence with alleged causes and mechanisms. Wound morphology, anatomical distribution and tissue response are essential tools for inferring causative instruments and bullets or shrapnel trajectories causing trauma, particularly in blast injuries, where complex lesion patterns often emerge [1,2].

In post-mortem investigations, forensic pathologists often work within a multidisciplinary framework – particularly in complex cases such as decomposition, carbonisation or complex trauma – where the integration of different forensic competencies is necessary [3].

Conversely, the evaluation of injuries in living individuals, especially when delayed, presents unique challenges. The clinical forensic examination of survivors often occurs days or weeks after the traumatic event, by which time the morphology of the lesions may have changed significantly due to healing processes such as re-epithelialization, scar formation or resorption of hematomas. This can obscure the original features and compromise accurate dynamic reconstruction [4].

In these scenarios, a "back-to-the-origin" approach to accurate injury analysis, grounded in objective morphology and distribution, supported by technical findings (photographic documentation, radiological imaging or ballistic reconstructions) when available, becomes essential to reconstruct the event reliably and support legal decision-making.

In this article, the authors present the case of an Improvised Explosive Device (IED) specialist who survived after the exposure of a rudimentary IED, suffering severe injuries. The case report draws specific conclusions regarding body position, proximity to the blast and actual injury potential from an integrated assessment of injury morphology and distribution, radiological findings, scene observations and chemical analyses, recognising the inherent uncertainty of reconstruction based on expert opinion when direct measurements are unavailable.

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The case highlights the role of interdisciplinary forensic collaboration – particularly between the pathologist and ballistics expert – in clarifying the mechanism of injury and contributing to the charge determination of the event; specifically, to distinguish mass murder [5] from very grievous bodily harm [6]. Mass murder refers to art. 422 of the Italian Penal Code, i.e., conduct capable of endangering public safety and targeting an indeterminate number of victims, punishable by imprisonment of not less than fifteen years if it does not invlove death; very grievous bodily harm refers to art. 583 of the Italian Penal Code, punishable by imprisonment between six and twelve years.

2. Case report

2.1. Case description

On New Year's Eve, a suspicious object was identified, positioned inside the rolling shutter of a commercial establishment. Law enforcement personnel promptly intervened to assess the nature of the object; during the preliminary inspection, it was accidentally displaced by a foot, causing it to fall onto the sidewalk in front of the entrance.

Specialized personnel was subsequently requested. The IED specialist arrived, ordered the evacuation of the area and proceeded to initiate the disarmament protocol without wearing personal protective equipment. During this operation, the device exploded. In the immediate aftermath of the explosion two physicians, who happened to be nearby, provided first aid, followed shortly by emergency medical services, who transported the injured operator to the nearest emergency department.

According to the injured technician's statement, at the time of detonation, the device was on the ground in front of him. He reported that he was kneeling while holding pliers in his right hand, with his left leg on the ground and his right leg bent at the thigh; his right upper limb was slightly extended from his torso and stretched forward, with his hand reaching for the device without touching it. The event was described as a "spontaneous explosion", a sudden and unexpected detonation that occurred without any direct manipulation at that moment (i.e. not triggered by contact with the device) during the initial phase of the defusing procedure.

Crime scene investigation carried out on January 1st reported no damage to the glass door and the shop window immediately behind the rolling shutter, despite their close proximity to the device.

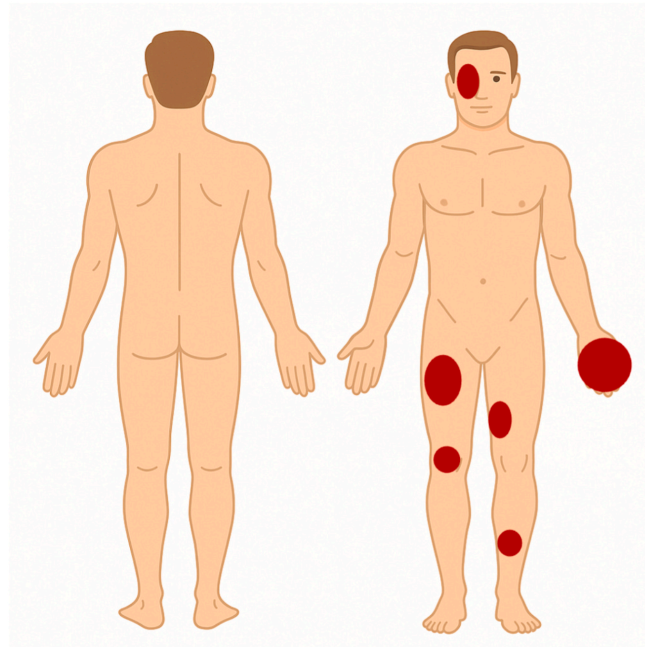

Fig. 1. Localization on the body of injuries.

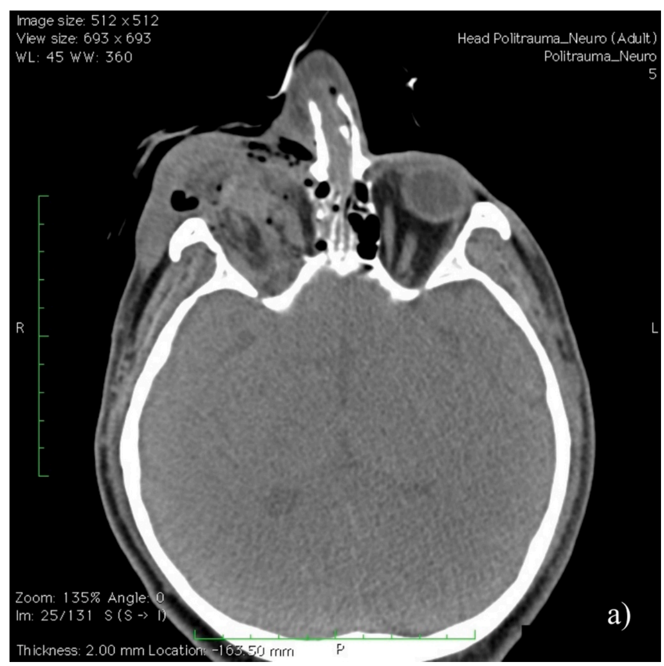

Fig. 2. Cranial CT scan **(a)** performed immediately after the explosion, showing multifragmentary fractures of the orbital walls, bone fragments dislocated intracranially and complete destruction of the right eyeball.

2.2. Injuries characteristics

Initial clinical evaluation documented severe blast-related trauma with traumatic amputation of the left hand, major right orbital-ocular injury with complete loss of the right eye, and multiple lower-limb lacerations with retained foreign bodies (Fig. 1).

Cranial CT showed multifragmentary fractures of the right orbital walls and of the posterior wall of the right frontal sinus, with bone fragments displaced intracranially above the orbital roof, associated pneumoencephalus, and a small right frontobasal contusive hypodensity. The right globe was completely disrupted, with hemorrhagic involvement of the surrounding orbital fat; fractures of the right maxillary sinus walls and right nasal bones were also documented (Fig. 2).

Radiographs of the lower limbs revealed subcutaneously retained fragments (Fig. 4).

The patient subsequently underwent surgical revision of the left forearm stump, enucleation of the right ocular globe and bilateral extraction of embedded foreign material from the thighs.

The medico-legal evaluation carried out approximately two years after the explosion documented multiple post-surgical outcomes and residual injuries, predominantly in the form of scarring, reflecting the severity and anatomical distribution of the original trauma.

In the craniofacial region, the right eye had been avulsed and replaced with a cosmetic prosthesis; a small pearly scar was visible at the medial canthus. The nasal profile showed a sinusoidal deformity and palpation revealed tenderness over the nasal bones. The left upper limb showed a distal radioulnar amputation with a well-formed stump, fitted with a myoelectric prosthesis; joint mobility was preserved (Fig. 3). On the lower limbs, multiple scars were noted: punctate and hyperpigmented on the medial left thigh, linear and pale on the anterior leg and larger polygonal, sunken scars on the anterior and medial right thigh. Quadriceps hypertrophy and normal muscle tone were observed bilaterally (Figs. 4 and 5). The morphology and distribution of the lesions

Fig. 3. Comparison of injuries to the left hand. b) X-ray taken immediately after the explosion, showing multiple fractures. c) Late anatomical outcome with surgically revised stump following amputation.

Fig. 4. Comparison of injuries to the right thigh. **d)** X-ray taken immediately after the explosion, showing subcutaneous foreign bodies consistent with blast-related fragments. **e)** Scar tissue corresponding to the sites of fragments penetration.

were consistent with localized blast and fragment injuries sustained near the explosive device.

Overall, the injury pattern was limited to three anatomical regions: the left hand, the right eye and both thighs. No additional traumatic findings were reported in the remaining body districts examined.

2.3. Device characteristics

During the crime scene investigation one swab wetted with distilled water and one wetted with acetone were used to collect explosive traces. The materials collected and sent to the laboratory for further examination and analysis included partially burned pieces of white and black canvas fabric, five of the six internal cells of a 9 V battery, pieces of various types of adhesive tape, portions of deformed metal sheet with a thickness of approximately 0,5 mm, on which partial inscriptions are present, a spiral-shaped spring, a toothed metal wheel, a circular metal chassis, a metal clock hand, a damaged metal screw cap with a diameter of 70 mm, other metal elements, plastic fragments (one with the number "50" stamped on it), electrical wires (Fig. 6).

The swabs and other items collected during crime scene investigation were treated in laboratory to obtain organic and water solutions of traces. Analysis by gas chromatography – mass spectrometry (GC–MS) of the organic solutions did not detect any trace of organic explosives but only traces of sulphur. Analysis by ion chromatography (IC) found mainly chloride and potassium ions. Fluoride, nitrate, perchlorate, sulphate, calcium, magnesium and sodium ions were also found.

Based on the pieces of white and black canvas fabric it was possible to infer that the IED was concealed and transported to the explosion site using a canvas bag or sack.

Based on the partial inscriptions present on the portions of deformed metal sheet with a thickness of approximately 0,5 mm it was possible to infer that the explosive charge was in a spray can of the type used by the

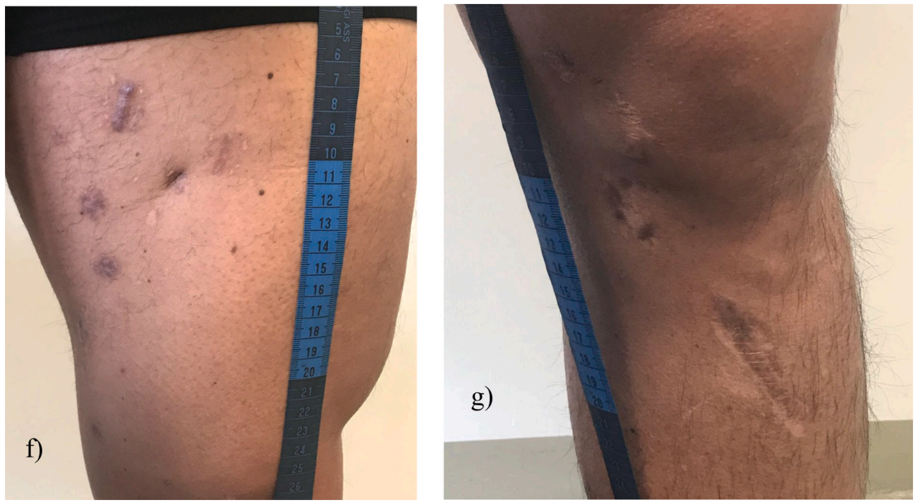

Fig. 5. Scar tissue on the left thigh **(f)** and on the left knee and leg **(g)** in the sites of fragmenst penetration.

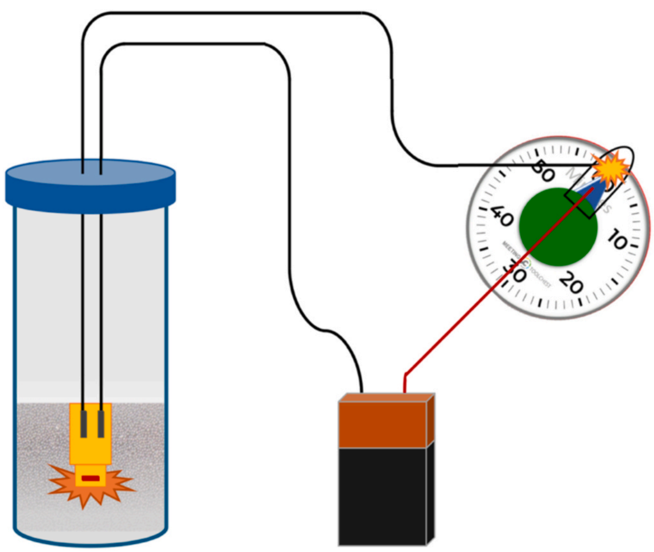

Fig. 6. Reconstructed improvised explosive device (IED) based on recovered components: a spray paint can, a 9-volt battery and a timer, assembled into a rudimentary circuit capable of triggering a handmade ignition system and a pyrotechnic charge.

company "BOSTON" as container for gloss acrylic spray paint.

Based on analytical results it was possible to infer that the explosive charge was made with a pyrotechnical mixture, classified as Category 1 (powders and similar products in explosive effects) according to Italian legislation.

Some items collected during crime scene investigation allowed to reconstruct most of a 9 Volt battery "DURACELL ULTRA POWER" model "DURALOK" and a mechanical kitchen timer, easily transformed into a trigger mechanism included in the basic IED circuit, where the clock hand was the switch.

3. Discussion

In the context of forensic medicine applied to explosion-related events a clear distinction between the various types of explosive devices is essential, as the physicochemical properties of the explosive charge involved and the wounding mechanisms significantly influence both the injury potential and the clinical manifestations observed.

From a regulatory perspective, Italian legislation classifies explosives into five main categories [7,8]: powders, dynamites, detonating explosives, pyrotechnic articles and safety ammunition. Explosive substances can also be divided into two groups: detonating and deflagrating.

Detonating explosives are characterized by high-velocity chemical reactions that produce a supersonic reaction front and a very rapid increase in pressure and temperature. Commonly employed substances in this category include trinitrotoluene (TNT), cyclotrimethylenetrinitramine (RDX or T4), pentaerythritol tetranitrate (PETN) and binary mixtures such as ammonium nitrate and fuel oil (ANFO) [9].

Deflagrating explosives, generally called "low explosives", produce a subsonic reaction front, which results in a slower and more localized release of free energy. This group includes black powder, pyrotechnics and smokeless powders, which are frequently used in civilian settings and often improperly repurposed in the construction of improvised explosive devices. Deflagrating charges can still cause significant traumatic effects, particularly when combined with metallic casings or other components capable of fragmentation and producing shrapnel. Pyrotechnic articles [10] contain pyrotechnics and are designed to produce visual, auditory or mechanical effects through controlled exothermic reactions. A common composition is the black powder, containing potassium nitrate mixed with carbon and sulphur. Other pyrotechnic compositions include mixtures of potassium chlorates or perchlorates with aluminium in variable proportions. Despite the reduced power of the charge in devices containing low explosive potential, their tampering or improper use can nonetheless result in serious injuries.

The typology of explosive devices is associated with specific or characteristic injury profiles, defined by the mechanism of energy release – overpressure, fragmentation, heat – and body displacement. In the forensic evaluation of explosion-related trauma, accurate characterization of lesion patterns according to the type of explosive device and the victim's proximity to the blast source is essential for reconstructing the event dynamics and determining the appropriate charge determination.

Detonating devices, such as hand grenades or improvised explosive devices (IEDs) containing detonating charges, produce high-velocity chemical reactions that generate supersonic shock waves. These result in complex polytrauma, commonly categorized into four injury types: primary (barotrauma), secondary (penetrating trauma from projectiles), tertiary (displacement-related injuries) and quaternary (burns and gas toxicity) [2,11–13]. Primary blast injuries typically affect air-filled organs, such as lungs (*blast lung*), gastrointestinal tract, eyes (*blast eye*), auditory structures (*blast ear*) and brain (*blast brain*), even in absence of external wounds and can occur even at moderate distances from the position of the exploded charge. Secondary blast injuries arise from high-velocity projectiles (e.g. shrapnel), leading to penetrating wounds, traumatic amputations and skeletal fractures. Additional trauma may occur due to the body being propelled into surrounding objects (tertiary injuries). Civilian cases involving hand grenades have been shown to produce multiple penetrating injuries with anterior predominance and irregular trajectories, suggesting a frontal orientation of the victim at the moment of detonation in a case reported by Karger et al. [14]. When the explosion occurs near the body, the destructive force markedly increases. Kujirai et al. [15] reported a case in which an IED explosion near the victim caused extensive facial and upper limb fractures, ocular trauma, traumatic amputations and deep burns, emphasizing the critical role of proximity in injury severity. Even low-power, improvised devices can mimic the destructive effects of military-grade explosives when detonated close to the body. A case reported by Kunz et al. [16] described a cranial explosion resulting from a modified firework device held near the face. These findings align with those of Galante et al. [17], who emphasized that lesion distribution, particularly when blast and ballistic injuries coexist, offers crucial clues about the victim's position and distance relative to the device at the time of the explosion.

In contrast, deflagrating devices, such as consumer-grade fireworks and pyrotechnics, operate via subsonic combustion and typically produce localized thermal and mechanical injuries. They do not generate a true shock wave, but individuals may sustain deep burns and lacerations resulting from the explosion of the device's casing. Despite their classification as low-energy explosives, these devices can cause severe trauma, particularly when manipulated improperly or detonated in close contact with the body.

The hands represent the most frequently affected anatomical region. In a clinical series of 58 cases, Matheron et al. [18] found that all patients suffered from hand injuries, often requiring digital amputation or complex reconstructive surgery. Al-Qattan and Al-Tamimi [19] reported palmar and digital lesions characterized by the coexistence of localized burns and deep tissue disruption caused by explosive force. Beyond the hands, ocular trauma is also a significant concern. Liu et al. [20] demonstrated that severe firework-related eye injuries frequently involve open-globe lacerations, intraocular foreign bodies and retinal detachment, often necessitating emergency surgery and resulting in long-term visual impairment. As Kunz et al.[7] further illustrated, self-made fireworks used near the face may cause fatal head injuries, underscoring their potential lethality despite being classified as pyrotechnic devices.

Epidemiological studies [21,22] confirm that young age, direct handling and lack of protective measures are key risk factors for traumatic injuries, including multiple burns, blast wounds and traumatic amputations, particularly during celebratory events (above all during the night of December 31st December to January 1st).

In the presented case, the injuries sustained by the IED specialist were initially attributed to the explosion of a rudimentary improvised device, reportedly placed on the ground and detonated unexpectedly without direct contact during the initial phase of the disarming procedure. At the time of the explosion, he recalls holding the pliers in his right hand while kneeling, with his left leg positioned on the ground and his right leg flexed at the thigh. His upper limb was somewhat distanced from the torso yet extended and his hand was reaching out without touching the device.

Based on this reconstruction, the criminal charges initially included mass murder and attempted multiple homicide, also in consideration of the alleged explosive potential of the device.

To assess the plausibility of the declared dynamics and the effective lethality of the device, a multidisciplinary forensic approach was undertaken, integrating injury pattern analysis with the technical evaluation of the device itself.

The ballistic investigation, based on the reconstruction of the device and the analysis of all recovered fragments, identified chemical residues consistent with the composition of low-order explosive materials. Specifically, nitrates, chlorides, perchlorates, sulfur, potassium and sodium were found, typically found in inorganic explosive powders commonly used for loading consumer-grade fireworks. The absence of damage to the glass door and to the window of the bookstore located immediately behind the rolling shutter and in close proximity to the explosion site further supports a limited blast radius.

Particular attention was paid to the morphological and topographical analysis of the injuries. These involved three anatomically distant regions: the left hand, the right orbit and both thighs, with sparing of other areas such as the chest, abdomen, right hand, left hemiface and lower limbs.

In disagreement with the reported dynamic, the distribution was highly suggestive of a specific posture at the time of the explosion: a kneeling position with the right knee on the ground, the left leg elevated, and the device held in the left hand, which was positioned near the right side of the face. The proximity of the most severely injured areas supports the hypothesis that the explosive energy and shrapnel dispersion were confined to a very limited radius, likely just a few centimeters, ruling out a large-scale detonation.

The pattern of trauma – characterized by blast injuries and penetrative wounds consistent with ballistic effects from device fragments – demonstrated a highly localized destructive force, reflective of low-order explosive characteristics and insufficient to support the scenario of a high-yield detonation. These findings are in accordance with literature describing the trauma mechanisms associated with low-power IEDs, which may produce devastating localized injuries but lack the capability necessary to cause widespread damage to people and objects if they are not close enough to the charge.

As a result, the forensic evidence contradicted the initial narrative and led to a substantial re-evaluation of the device's actual explosive power, ultimately contributing to a reclassification of the legal charges in grievous bodily harm, with the exclusion of the most serious indictments.

The reconstruction proposed herein is based on converging medico-legal, radiological, chemical and scene findings, and remains inherently interpretive and case-specific.

4. Conclusion

This case highlights the importance of integrated forensic approach, where crime scene investigation, trauma analysis, imaging and technical expertise contribute to clarifying the reconstruction of past events, seeking to uncover the material truth. A detailed evaluation of injury patterns, combined with ballistic assessment and device analysis, enabled a critical review of the declared version of events and supported the correct charge determination of the event. In this context, injuries served as a *"silent witness"*, providing objective evidence capable of challenging initial criminal charges in court. The case also reaffirms the central role of forensic traumatology as one of the cornerstones of contemporary forensic medicine, advocating for a return to its methodological foundations. Modern forensic pathologist, while rooted in traditional morphological analysis, is increasingly supported by advanced tools such as imaging and the contributions of specialists in related fields, including ballistics, toxicology, anthropology and entomology. Such a multidisciplinary approach enhances diagnostic precision and affirms the indispensable role of forensic medicine not only in establishing cause of death or injury but also in reconstructing the dynamics and legal implications of criminal acts.

Ethics approval

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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