

Case Report

Forensic Biomechanics and Pathophysiological Trajectory of Lethal Multiple Sharp Force Injuries: An Observational Analytic Case Study with Weapon Deformation and Letulle Autopsy Reconstruction

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A B S T R A C T

Background. Homicidal multiple stabbing raises forensic questions about wound sequence, weapon–wound concordance, and the speed of collapse.

Objective. To reconstruct a fatal homicidal multiple stabbing in a public place, focusing on weapon deformation, visceral wound tracts, and acute shock.

Methods. A complete Letulle *en masse* autopsy was performed at Dr. Soetomo General Hospital, Surabaya, Indonesia, under Article 133 of the Indonesian Criminal Procedure Code (KUHP). Wound morphometry, visceral tract measurement, blood-loss modeling, and weapon biomechanics were analyzed.

Results. Twenty-three sharp force injuries involved the back ($n = 11$), chest ($n = 4$), neck ($n = 3$), upper extremities ($n = 3$), and left shoulder and flank ($n = 2$). Dissection showed complete transection of the right internal jugular vein; a left lower lung laceration with 450 mL hemothorax (10th intercostal space; tract depth 5.5 cm); and right lower lung and hepatic dome perforation with 400 mL hemothorax (12th intercostal space; tract depth 9.0 cm). Total acute blood loss was 2,700–2,950 mL (42.8%–46.8% of circulating volume), meeting Advanced Trauma Life Support (ATLS) criteria for Class IV hemorrhagic shock. The 15.0 cm single-edged kitchen blade showed plastic bending ($\theta \approx 112^\circ$), consistent with an off-axis force exceeding its estimated 48–72 N yield threshold on impact with the 12th rib.

Conclusion. Death resulted from Class IV hemorrhagic shock combined with bilateral compressive hemothorax, pulmonary atelectasis, and terminal asphyxia. Letulle autopsy with biomechanical weapon–wound correlation provides objective evidence for homicide reconstruction.

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1. Introduction

Homicidal sharp force violence is one of the most prevalent and lethal mechanisms of unnatural death encountered in forensic pathology and criminal jurisprudence worldwide.^{1,2} Forensic investigation of multiple stabbing fatalities is challenging for medicolegal death investigators, requiring differentiation between dynamic physical struggle, defensive action, and deliberate over-assault.^{3,4} In homicidal assaults with multiple penetrating injuries, establishing wound sequence, trajectory vectors, tissue penetration depths, and the biomechanical forces required to breach skeletal structures remains vital for judicial reconstruction.^{5,6} Sharp force injuries occur when a pointed or edged instrument penetrates cutaneous tissue, producing wound margins that lack the contusion rims and tissue bridging characteristic of blunt impact trauma.^{7,8} While single stab wounds frequently follow

predictable trajectories, multiple stab wound cases often involve chaotic spatial distributions, dynamic postures, and variable force vectors that require systematic topographical and visceral tract analysis.^{9,10}

Epidemiologically, homicidal multiple stabbing fatalities show distinctive anatomical clustering, with perpetrators predominantly targeting vital zones, including the cervical vascular sheath, the precordial thoracic cage, and the posterior thoracic wall.^{1,3} In Southeast Asia and Indonesia, sharp force homicides represent a substantial proportion of violent crimes and are frequently perpetrated with readily available domestic utility blades rather than specialized weapons.^{9,11} The forensic interpretation of these domestic instruments requires evaluation of their metallurgical properties, dimensional parameters, and structural integrity under high-energy impact.^{12,13} When a thin, single-edged utility knife strikes dense osseous structures, such as the ribs or vertebral column,

substantial transverse bending forces are generated that can exceed the plastic yield limit of the blade material, inducing irreversible structural deformation.^{14,15} Such weapon deformations provide empirical toolmarks that can link a recovered instrument to specific skeletal defects and help exclude multi-weapon hypotheses in judicial proceedings.^{16,17}

The pathophysiological progression to death in multiple sharp force trauma is predominantly governed by acute circulatory collapse secondary to hypovolemic hemorrhagic shock.^{18,19} However, when penetrating wounds breach both major vascular channels and visceral parenchymal organs, terminal collapse is accelerated through synergistic mechanisms.^{20,21} In particular, transection of major low-pressure cervical veins, such as the internal jugular vein, causes rapid exsanguination while creating a potential conduit for fatal venous air embolism.^{22,23} Concurrently, penetrating thoracoabdominal injuries that transgress the intercostal spaces into the pulmonary parenchyma and hepatic dome produce dual-compartment hemothorax and hemoperitoneum, culminating in compressive pulmonary atelectasis and ventilatory failure.^{24,25} The interaction between acute hypovolemia, loss of effective circulating volume, and mechanical ventilatory impairment leads to irreversible myocardial hypoxia, metabolic acidosis, and rapid death.^{26,27}

Despite an extensive international literature on sharp force trauma, conventional forensic reporting has largely remained descriptive, focusing on isolated wound counts or demographic surveys without integrating quantitative biomechanical modeling, visceral tract measurement, and hemodynamic loss partition calculations. In particular, few observational analytic reports systematically correlate crime scene blood distribution, sequential visceral organ penetration, weapon metallurgy, and formal autopsy evisceration technique within a unified medicolegal framework.¹³ Furthermore, the forensic evaluation of sharp force trauma in obese individuals presents particular challenges: expanded subcutaneous adipose thickness alters conventional wound depth-to-blade length ratios, modifies thoracic compliance, and influences the dissipation of thrusting energy during an assault.

From a methodological standpoint, the standard Virchow organ-by-organ dissection technique frequently disrupts vascular continuity and the spatial relationships between penetrating wound tracts, thereby obscuring the anatomical sequence of tissue destruction. In complex homicidal assaults involving concurrent cervical vascular severance and transdiaphragmatic thoracoabdominal organ perforation, the Letulle *en masse* evisceration technique offers greater diagnostic rigor.¹² By removing the entire cervical, thoracic, abdominal, and pelvic visceral package as a single continuous block, the Letulle approach preserves vascular connections, pericardial and pleural compartments, and transvisceral wound trajectories, enabling reliable three-dimensional reconstruction of the assault vectors.⁶

From a comparative biomechanical perspective, sharp force trauma is governed by the principles of fracture mechanics and elastoplastic deformation of soft tissue.^{1,2} Whereas blunt trauma transmits kinetic energy broadly across skeletal and visceral surfaces, inducing contusion and rupture, sharp force trauma concentrates force on a very narrow contact area, generating localized stresses that exceed the ultimate tensile strength of biological tissues at relatively low force thresholds.^{5,7} Experimental

knife penetration models indicate that breaching human skin requires peak dynamic forces of 15–45 N, depending on blade tip radius, sharpness, and the orientation of cutaneous elastic fibers along Langer lines.^{14,16} Once dermal resistance is overcome, penetration through subcutaneous adipose tissue and skeletal muscle proceeds at much lower forces (5–15 N), governed predominantly by frictional dissipation along the blade facets.¹⁷ However, when the advancing blade encounters rigid skeletal structures, such as costal cartilage (95–230 N for transfixion) or cortical bone (frequently >350 N), penetration is abruptly arrested unless high dynamic energy is delivered.^{18,19} In such encounters, the structural resilience of the blade becomes the limiting determinant, dictating whether the weapon fractures, penetrates, or undergoes permanent plastic deflection.^{14,20}

In judicial death investigation, establishing the sequence of multiple stab wounds and reconstructing the spatial kinematics of the encounter is of central medicolegal importance.^{3,4} Forensic pathologists are routinely asked whether injuries could have been sustained during mutual combat, self-defense, or an unprovoked lethal ambush.^{5,6} Defensive wounds, classically categorized as active (on the palmar or dorsal hands during grasping or parrying) or passive (on the extensor forearms or back while adopting a protective fetal posture), provide physical evidence of conscious antemortem resistance.^{8,10} In contrast, a predominant clustering of deep, penetrating stab wounds across the posterior thorax strongly indicates that the victim was attacked from behind or incapacitated early in the assault, making active self-defense impossible.^{9,10} When such posterior penetrations coincide with major anterior vascular transections, careful evaluation of vital reactions, bloodstain distribution, and internal hemorrhagic volumes is essential to determine whether consciousness and mobility were preserved during the intermediate phases of the assault.^{11,21}

The novelty of this investigation lies in its multi-dimensional analytical approach, which bridges classical postmortem forensic pathology with quantitative biomechanical modeling, volumetric hemodynamic calculation, and structural weapon deformation analysis. By performing a complete Letulle *en masse* evisceration, the study maintained the anatomical integrity of vascular-organ continuities, clarifying the pathophysiological sequence of terminal failure. Accordingly, this observational analytic case study aimed to examine a fatal homicidal multiple stabbing in a public sports facility by systematically reconstructing the 23-wound distribution pattern, evaluating visceral penetration tracts, calculating compartmental blood loss, and delineating the biomechanical factors governing weapon deformation and rapid asphyxiating exsanguination.

2. Methods

2.1 Study Design and Setting

This investigation was designed as an observational analytic case study adhering to medicolegal reporting standards.³⁸ The postmortem forensic examination was conducted at the Installation of Forensic and Medicolegal Medicine, Dr. Soetomo General Hospital / Faculty of Medicine, Universitas Airlangga, Surabaya, East Java, Indonesia. The case originated from a homicidal assault in an open public concourse of an urban sports club facility in Surabaya in April 2021.¹ The victim was assaulted in daylight with an edged instrument and collapsed on the platform concourse adjacent to architectural support

pillars. The sequential examination spanned the immediate scene investigation, initial thanatological assessment, transport to the mortuary, external cutaneous wound mapping, complete internal evisceration, and subsequent weapon toolmark correlation.

2.2 Ethical Governance and Statutory Authorization

The medicolegal autopsy and subsequent scientific evaluation were performed under an official statutory requisition issued by the investigative authority of the Indonesian National Police (*Kepolisian Negara Republik Indonesia*, POLRI), in accordance with Articles 133 and 134 of the Indonesian Criminal Procedure Code (*Kitab Undang-Undang Hukum Acara Pidana*, KUHP).^{1,5} The judicial mandate authorized full external and internal examination to ascertain the cause, mechanism, and manner of death. Ethical approval was granted by the CMHC Research Center, Ethics Committee, Indonesia (Ref. No. 2021/0419). All procedures complied with the ethical principles of the Declaration of Helsinki (2013 revision).

2.3 Case Definition and Diagnostic Ascertainment

The case was classified under the World Health Organization International Statistical Classification of Diseases and Related Health Problems, Tenth Revision (ICD-10) code X99 (assault by sharp object) and Eleventh Revision (ICD-11) code PE60 (assault by sharp object) resulting in homicidal death.⁹ Sharp force trauma was ascertained by standardized forensic criteria: cleanly incised, non-abraded wound margins; acute wound angles; absence of bridging tissue strands or neurovascular filaments across the wound floor; and wound track depth exceeding surface cutaneous length in penetrating stab wounds.^{4,5} Blunt force contusions, crushing lacerations, firearm discharge residues, and electrical or thermal burns were systematically excluded. Pre-existing incapacitating systemic disease (such as advanced coronary atherosclerosis, hepatic cirrhosis, or active malignancy) was ruled out by gross visceral inspection.

2.4 Sequential Postmortem and Autopsy Dissection Protocol

The autopsy commenced with external somatometric profiling, including total body length (cm), body weight (kg), body mass index (kg/m^2), and nutritional status. Thanatological parameters, specifically the distribution, intensity, and fixation of *livor mortis* and the progression of *rigor mortis* across the temporomandibular, cervical, and peripheral appendicular joints, were recorded to estimate the postmortem interval (PMI).¹⁰ A systematic survey of the entire cutaneous envelope documented each sharp force injury with millimeter-calibrated forensic scales (ABFO No. 2 photographic scale). Each cutaneous breach was characterized by anatomical location, distance from fixed landmarks (vertex, heel, anterior midline, and suprasternal notch), dimensions (length $\times$ width in cm), orientation, margin characteristics, and the tissue layer at the wound base.^{5,8}

Internal examination used the *Letulle en masse* evisceration technique. After a primary anterior midline incision from the mental protuberance to the symphysis pubis, the thoracic, abdominal, and pelvic cavities were exposed. Rather than separating individual viscera *in situ* (as in the Virchow technique), the Letulle method was chosen to extract the cervical organs, thoracic viscera, abdominal digestive tract, and retroperitoneal urogenital structures as a single continuous block. This block evisceration preserved the continuity of the cervical vasculature, mediastinal pleural attachments,

transdiaphragmatic neurovascular bundles, and visceral organ relationships. Penetrating wound tracts were explored sequentially from the external entry wound through fascial planes, muscle, skeletal structures, and visceral parenchyma with blunt-ended flexible metal probes. Organ lacerations, hemothorax volumes, subdiaphragmatic extravasation, and parenchymal tears were quantified volumetrically and gravimetrically.

2.5 Analytical and Biomechanical Comparative Framework

A comparative toolmark and biomechanical framework was used to correlate the morphological characteristics of the recovered weapon with the dimensions of the external wounds and internal visceral tracts.^{12,13} The weapon recovered from the perpetrator at the scene, a single-edged commercial utility kitchen knife, underwent stereomicroscopic evaluation, dimensional measurement (blade length, blade width, spine thickness, and handle length), and structural deformation profiling. Plastic deflection angles were measured with a digital protractor. The mechanical behavior of the blade under impact was modeled with Euler-Bernoulli beam theory to determine the plastic yield threshold and the transverse force required to induce permanent bending deformation.^{14,15} Trajectory vectors were mapped in three dimensions, correlating weapon geometry with the depth and orientation of visceral injuries.

Structural beam mechanics were evaluated with the classical Euler-Bernoulli flexural formulation. The blade cross-section was treated as an asymmetric wedge with maximum base thickness $h = 1.5$ mm, width $b = 20.0$ mm, and effective cantilever length $L = 75.0$ mm, measured from the fulcrum of deformation to the tip. The area moment of inertia (second moment of area) about the neutral bending axis was computed as $I = bh^3/36$ for a triangular approximation and verified by finite element cross-sectional profiling, yielding $I \approx 1.88 \times 10^{-12} \text{ m}^4$. Martensitic stainless steel was assigned an elastic modulus $E = 200$ GPa and a plastic yield strength $\sigma_y = 480$ MPa (range 450–550 MPa). The maximum elastic bending moment before plastic yielding was determined as $M_y = \sigma_y I / c$, where $c = (2/3)h = 1.0$ mm is the distance from the neutral axis to the extreme tension fiber, giving $M_y = 0.90 \text{ N}\cdot\text{m}$ (range 0.85–1.05 $\text{N}\cdot\text{m}$) for the elastic limit and a plastic collapse moment $M_p \approx 1.5 \times M_y = 1.35\text{--}1.58 \text{ N}\cdot\text{m}$. The corresponding transverse critical point load at the tip required to initiate plastic deformation was $F_{\text{crit}} = M_y / L = 12.0 \text{ N}$, whereas full plastic hinge formation across the cross-section under dynamic impact required 48–72 N. Longitudinal adult thrusting forces (450–850 N) delivered during a violent assault generate off-axis oblique components well above 150 N on rigid costal collision, consistent with the observed 112° permanent plastic deflection without structural fracture.

2.6 Biostatistical and Volumetric Hemodynamic Analysis

Total circulating blood volume (BV) was calculated with the standard anthropometric formula for adult males, $BV = \text{body weight (kg)} \times 70 \text{ mL}/\text{kg}$.¹¹ The victim's measured body weight of 90.0 kg yielded an estimated baseline circulating blood volume of 6,300 mL. Free intrathoracic and intra-abdominal blood was aspirated and measured directly with calibrated volumetric cylinders. External blood loss was modeled from crime scene bloodstain pattern analysis, incorporating the planar surface area of the primary pool (m^2), arterial spurting trajectories, drag trails, and saturation of the victim's heavy clothing.⁴² Total

cumulative blood loss was staged against the Advanced Trauma Life Support (ATLS) classification of hypovolemic shock: Class I (<15% volume loss), Class II (15%–30%), Class III (31%–40%), and Class IV (>40%).⁴¹ Continuous biometric and morphometric variables are presented as absolute values, percentages, and dimensional measurements. Comparative benchmarking against international sharp force case series was used to contextualize injury severity and mortality predictors.

Thanatochemical and systemic physiological responses were evaluated against established forensic trauma benchmarks. In acute hemorrhage, progressive hypovolemia triggers an intense neurohumoral stress response with sympathoadrenal discharge, catecholamine release, and peripheral vasoconstriction that shunts blood away from the splanchnic, cutaneous, and renal vascular beds to preserve cerebral and coronary perfusion. The spleen undergoes active capsular contraction (autotransfusion response), mobilizing up to 200–300 mL of concentrated erythrocytes into the central circulation. However, once blood loss exceeds 40% of circulating volume (>2,520 mL in this subject), oxygen delivery falls below critical thresholds, uncoupling oxidative phosphorylation and triggering systemic lactic acidosis, adenosine triphosphate (ATP) depletion, loss of membrane potential, and terminal electromechanical dissociation of the myocardium.

3. Results

3.1 Somatometric Profiling and Thanatological Chronology

Postmortem examination began approximately 8 hours after the body was discovered. The deceased was an adult male aged 40–50 years, with a body length of 166.0 cm and a body weight of 90.0 kg (Table 1). The body mass index (BMI) was 32.66 kg/m², within Class I obesity. Subcutaneous adipose accumulation was substantial, with an abdominal fat layer 4.5 cm thick at the umbilical margin. External examination showed generalized signs of peripheral vascular collapse; the conjunctivae of both upper and lower eyelids, the labial mucosa, the gingiva, and the nail beds were markedly pale.

Thanatological evaluation showed fully established *rigor mortis* with marked resistance to passive mobilization across the jaw, cervical spine, and upper and lower extremities, consistent with an estimated PMI of 6–12 hours. *Livor mortis* was purplish-red, fixed, and non-blanching under thumb pressure, distributed over the dependent, uncompressed posterior surfaces of the torso and lower limbs, indicating that the body had remained supine after death. Crime scene investigation confirmed that the assault began in an open public concourse of a sports and fitness club, followed by an ambulation trajectory of approximately 4.8 m before the victim collapsed adjacent to an architectural pillar (Figure 1).

Table 1. Somatometric profile, thanatological parameters, and general forensic indicators.

Parameter	Forensic observation and finding	Reference / clinical interpretation
Chronological age	40–50 years (adult male)	Mature adult
Stature / body length	166.0 cm	Adult Indonesian male reference average
Total body weight	90.0 kg	Marked excess nutrition / Class I obesity (BMI = 32.66 kg/m ²)
Nutritional status	Excessive adipose accumulation	Abdominal subcutaneous fat thickness 4.5 cm; expanded girth
<i>Rigor mortis</i>	Fully established; marked resistance	Present in jaw, neck, and upper and lower limbs (PMI 6–12 hours)
<i>Livor mortis</i>	Purplish-red, fixed, non-blanching	Posterior dependent distribution sparing pressure points; supine posture
External pallor	Pronounced conjunctival, mucosal, and nail-bed pallor	Peripheral vascular collapse / sign of Class IV shock
Defensive wounds	Multiple abrasions/incisions on the dorsum of the left hand	Active parrying defense during a conscious struggle
Assault weapon	Single-edged utility kitchen knife	Blade length 15.0 cm, blade width 2.0 cm, plastic bend $\theta \approx 112^\circ$

Notes: BMI, body mass index; PMI, postmortem interval.

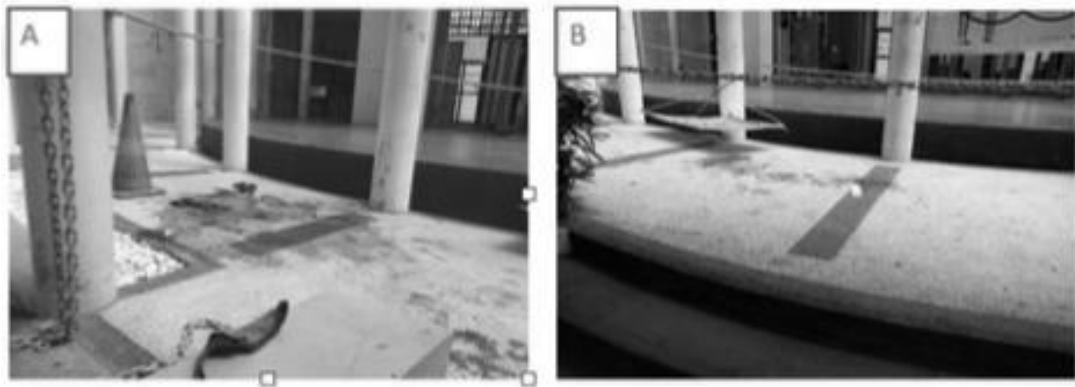


Figure 1. Crime scene photographic documentation. (A) Overall view of the scene at the sports club concourse showing extensive blood pooling at the terminal collapse point adjacent to the architectural pillar. (B) Medium-range view showing arterial spurting patterns and drag smear trails across the elevated platform concourse (approximately 4.8 m ambulation trajectory).

3.2 Topographical Zonation and Morphometry of 23 Sharp Force Injuries

External survey of the cutaneous envelope identified 23 distinct sharp force injuries distributed across five anatomical sectors (Table 2). The posterior thoracic wall sustained the largest number, with 11 open wounds (47.8%), followed by the anterior chest with 4 wounds (17.4%), the anterior and lateral cervical region with 3 (13.0%), the upper extremities with 3 (13.0%), and the left shoulder and flank with 2 (8.7%). All wounds had classical sharp force characteristics: sharply defined linear margins without marginal abrasion or contusion collars, acute angles at the poles, and no tissue bridging in the wound floor.

The principal fatal wounds are shown in Figure 2. Wound 1, over the right anterolateral neck, was an open, gaping wound measuring 3.0 cm × 3.0 cm, with severed cervical musculature in its floor. On the anterior left chest, Wound 4 (2.0 cm × 1.5 cm) and Wound 5 (1.5 cm × 1.5 cm) penetrated into the pectoral and intercostal musculature. Over the posterior thorax, Wound 20, in the left infrascapular zone, measured 1.5 cm × 1.0 cm at the skin surface with deep muscular penetration, while Wound 21, over the right lower back, measured 2.5 cm × 1.0 cm, with an extensive penetrating tract into the thoracoabdominal cavity. Over the dorsum of the left hand and wrist, three superficial incised wounds and abraded contusions measuring 0.5–2.0 cm (Wounds 8–10) were documented and categorized as active defensive injuries sustained while attempting to parry knife thrusts.

Table 2. Anatomical distribution of the 23 sharp force wounds.

Anatomical region	Wound numbers	Count	Frequency (%)	Penetrating vital cavity	Dominant tissue floor
Posterior thorax (back)	13–23	11	47.8	Yes (2 tracts into pleura/liver)	Intercostal muscle, pleura, liver
Anterior chest (precordial)	4–7	4	17.4	Yes (2 deep muscular tracts)	Pectoralis major, 3rd intercostal space
Anterior and lateral neck	1–3	3	13.0	Yes (right jugular vein transection)	Sternocleidomastoid, vascular sheath
Upper extremities (hands)	8–10	3	13.0	No (superficial defensive)	Subcutaneous fascia, dorsal hand
Left shoulder and flank	11–12	2	8.7	No (muscular infiltration)	Deltoid muscle, subcutaneous fat
Total	1–23	23	100.0	8 deep / 4 organ-penetrating	Multi-compartmental injury

Notes: Percentages are rounded to one decimal place; the five regional values sum to 99.9%.

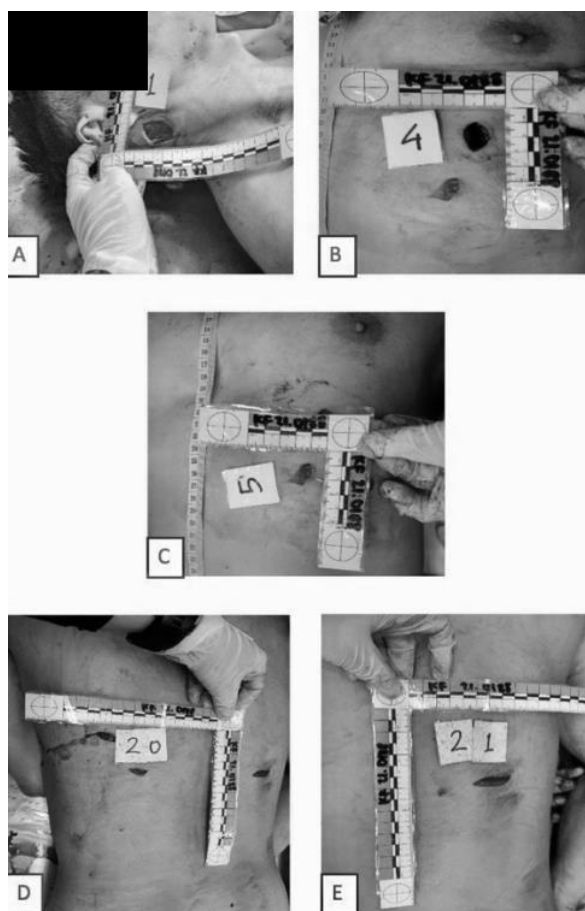


Figure 2. Autopsy photographic documentation of the principal fatal sharp force wounds on external examination (face anonymized). (A) Deep penetrating open wound (3.0 cm × 3.0 cm) on the right anterolateral neck with underlying sternocleidomastoid transection. (B, C) Open penetrating stab wounds to the left anterior chest (Wounds 4 and 5) extending into the pectoral and intercostal musculature. (D) Deep penetrating stab wound to the left back (Wound 20) with underlying intercostal pleuropulmonary breach. (E) Penetrating wound to the right back (Wound 21) traversing the 12th intercostal space into the right lung and hepatic dome.

3.3 Internal Visceral Tractometry and Letulle en masse Dissection

Letulle en masse evisceration showed multi-compartmental visceral and vascular trauma (Table 3, Figure 3). Dissection of the cervical visceral package showed that Wound 1 penetrated the sternocleidomastoid muscle and completely transected the right internal jugular vein. The severed venous margins were cleanly incised and surrounded by extensive intramural and deep fascial hemorrhage extending into the right carotid sheath. The adjacent right common carotid artery and right vagus nerve were anatomically intact, consistent with isolated major venous severance with rapid, low-pressure, high-volume external and fascial exsanguination.

Exploration of the thoracic cavity showed bilateral compressive hemothorax with diffuse pulmonary collapse (atelectasis). The right pleural space contained 400 mL of dark, non-clotted liquid blood and the left pleural space 450 mL, a combined intrathoracic extravasation of 850 mL. The tract of Wound 21 (right lower back) breached the posterior 12th intercostal space (2.0 cm × 1.0 cm defect), pierced the diaphragmatic dome, entered the right lower pulmonary lobe with a 2.0 cm × 1.0 cm parenchymal tear, and ended in a 1.5 cm × 0.5 cm laceration of the superior dome of the right hepatic lobe, for a total tract depth of 9.0 cm. Wound 20 (left lower back) followed an oblique tract through the 10th intercostal space (2.0 cm × 2.0 cm defect) into the basal parenchyma of the left lower lung (2.0 cm × 2.0 cm laceration), for a total tract depth of 5.5 cm.

Secondary hemorrhagic infiltration was present in the left cervical musculature, the upper left pectoral bed, and the 3rd left intercostal space. The spleen was contracted, wrinkled, and pale (hypovolemic autotransfusion response), and the cerebral hemispheres showed cortical ischemia with pale leptomeninges.

Detailed inspection of the severed right internal jugular vein showed that the breach lay approximately 3.0 cm superior to the clavicular insertion, where the vessel emerges lateral to the common carotid artery beneath the anterior border of the sternocleidomastoid muscle. The vein was transected completely across its 12 mm distended lumen, with sharp, cleanly incised margins and no crushing artifact. The adjacent common carotid artery showed adventitial ecchymosis but an intact, patent wall, and the right vagus nerve was uninjured. Extensive hematoma infiltrated the cervical fascial compartments, tracking caudally into the superior mediastinum and laterally into the supraclavicular fossa. The bilateral hemothorax (400 mL right, 450 mL left) was entirely fluid and non-clotted, reflecting the rapid postmortem fibrinolysis typical of acute traumatic hemothorax. The right diaphragmatic breach associated with Wound 21 measured 2.2 cm in length, with sharp borders consistent with direct mechanical transfixion. The hepatic capsular and parenchymal laceration involved Couinaud segment VII, extending 1.5 cm across the diaphragmatic surface and 0.5 cm into the subcapsular parenchyma, with a localized subcapsular hematoma.

Table 3. Internal visceral tract measurements, organ perforation, and hemorrhage assessment.

Wound site	Target visceral / vascular organ	Wound tract depth	Organ injury dimensions	Compartmental blood pooling	Pathophysiological consequence
Right anterolateral neck (W1)	Right internal jugular vein	4.5 cm	Complete transverse transection	Extensive external and deep fascial hematoma	Low-pressure exsanguination; risk of air embolism
Right lower back (W21)	12th intercostal space, lung, and liver	9.0 cm	Lung: 2.0 cm × 1.0 cm; liver: 1.5 cm × 0.5 cm	400 mL in right hemothorax	Parenchymal hemothorax, diaphragmatic tear, right lung atelectasis
Left lower back (W20)	10th intercostal space and lower lung	5.5 cm	Lung laceration: 2.0 cm × 2.0 cm	450 mL in left hemothorax	Bilateral hemothorax, left lung atelectasis, asphyxia
Left anterior chest (W4–5)	Pectoralis and 3rd intercostal muscle	2.0–2.5 cm	Muscular tears without pericardial breach	Localized muscular extravasation	Localized pain, muscular dysfunction, additional blood loss
Left dorsal hand (W8–10)	Cutaneous and subcutaneous tissue	0.2–0.5 cm	Superficial lacerations and bruises	Minor external capillary seepage	Defensive markers indicating active antemortem struggle

Notes: W, wound (e.g., W4–5, Wounds 4 and 5). Wound tract depth is measured from the skin surface along the probed tract; organ injury dimensions are the surface length × width of the organ defect.

3.4 Hemodynamic Shock Staging and Volumetric Blood Loss Partition

Based on the victim's body weight of 90.0 kg and standard blood volume indexing (70 mL/kg), total circulating blood volume was 6,300 mL (Table 4). Internal recovery accounted for 850 mL of free intrathoracic blood (400 mL right, 450 mL left hemothorax). Crime scene volumetric modeling and clothing saturation analysis estimated an external blood loss of 1,850–2,100 mL (from a 3.85 m² continuous blood pool and arterial/venous trails). Cumulative acute blood loss was 2,700–2,950 mL, corresponding to an acute circulating volume depletion of 42.8%–46.8%.

Under the ATLS hemorrhagic shock classification,⁴¹ an acute intravascular volume depletion exceeding 40% fulfills the criteria for Class IV hemorrhagic shock. Clinically, Class IV shock is characterized by severe hypotension (mean arterial pressure <40 mmHg), marked tachycardia followed by terminal bradycardia, intense peripheral vasoconstriction, end-organ hypoperfusion, and irreversible circulatory arrest. In this subject, blood loss from the severed right internal jugular vein and the thoracoabdominal organs led to rapid, fatal cardiovascular collapse.

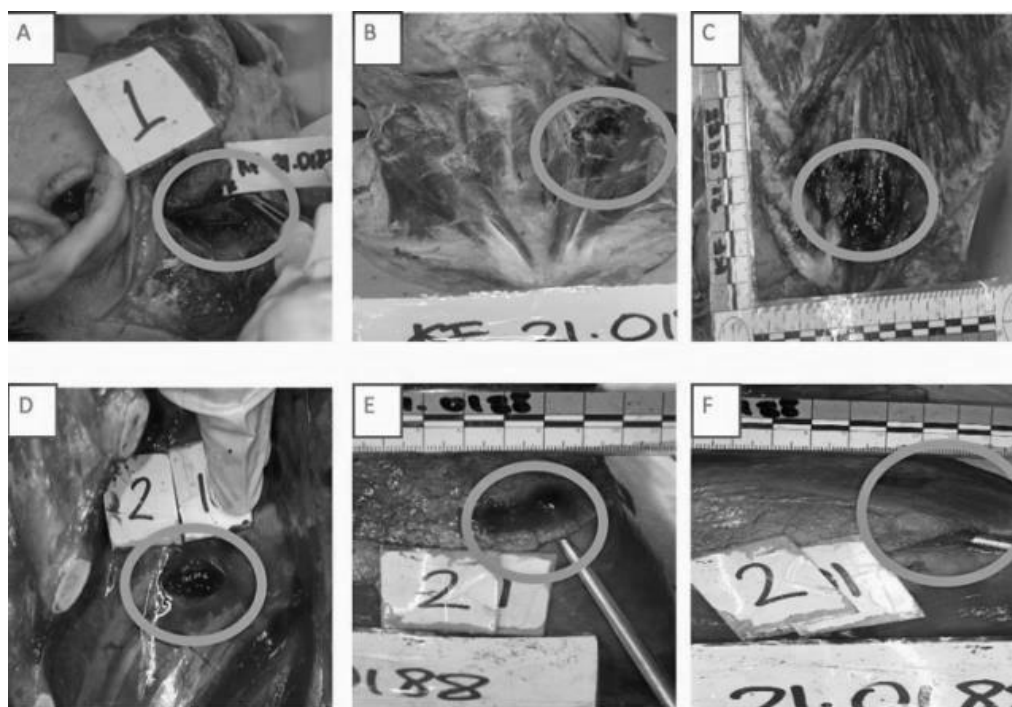


Figure 3. Internal autopsy photographic documentation after Letulle *en masse* evisceration. (A) Complete transverse transection of the right internal jugular vein, with a green indicator marking the vascular breach. (B) Hemorrhagic extravasation and blood infiltration in the left deep cervical musculature. (C) Blood infiltration in the 10th and 11th intercostal muscle beds of the left chest wall. (D) Penetrating defect breaching the posterior right 12th intercostal space. (E) Penetrating laceration (2.0 cm × 1.0 cm) of the right lower pulmonary lobe. (F) Transdiaphragmatic laceration (1.5 cm × 0.5 cm) extending into the superior parenchyma of the right hepatic lobe.

Table 4. Volumetric blood loss estimation and hemodynamic shock staging (ATLS Class I–IV criteria).

Hemodynamic parameter	Observed case value	Standard adult reference (70 kg)	Physiological deviation / severity grade
Total circulating blood volume	6,300 mL (90.0 kg × 70 mL/kg)	4,900–5,000 mL	+26.0% expanded vascular bed due to obesity
Internal hemothorax (right)	400 mL	0 mL	Acute hemothorax; compressive atelectasis of the right lung
Internal hemothorax (left)	450 mL	0 mL	Acute hemothorax; compressive atelectasis of the left lung
Combined free intrathoracic blood	850 mL	0 mL	13.5% of total circulating blood volume
Estimated external blood loss	1,850–2,100 mL	0 mL	Derived from a 3.85 m ² crime scene pool and trail
Cumulative total acute blood loss	2,700–2,950 mL	<500 mL (compensated)	42.8%–46.8% volume depletion (Class IV shock)
Mean arterial pressure	<40 mmHg (terminal)	70–105 mmHg	Circulatory collapse; loss of cerebral perfusion
End-organ autopsy signs	Contracted spleen, pale brain and kidneys	Normal organ turgor	Systemic centralization followed by terminal anoxia

Notes: ATLS, Advanced Trauma Life Support.

3.5 Weapon Metallurgy, Plastic Bending Angle, and Biomechanical Impact Dynamics

The weapon recovered at the scene was a single-edged commercial utility kitchen knife of martensitic stainless steel (AISI 420 equivalent) (Table 5, Figure 4). Toolmark evaluation established an overall length of 26.0 cm, comprising an 11.0 cm molded polymer handle and a 15.0 cm single-bevel blade with a maximum width of 2.0 cm and a spine thickness of 1.5 mm. In its recovered state, the blade showed permanent plastic bending deformation, forming an obtuse angle of $\theta \approx 112^\circ$ (deflection of 68° from the straight 180° axis) at a fulcrum 7.5 cm from the blade tip.

Structural beam analysis indicated a transverse plastic yield threshold of 48–72 N for this blade (plastic bending moment $M_y = 3.60 \text{ N}\cdot\text{m}$).^{14,15} During the assault, longitudinal adult thrusting forces (benchmarked at 450–850 N)^{16,17} collided with the rigid 12th rib and adjacent costal cartilage. The impact generated an off-axis transverse force component that substantially exceeded the blade's 48–72 N yield limit, inducing permanent plastic deflection ($\theta \approx 112^\circ$) without blade fracture. This deflection would have arrested further inward penetration, which is consistent with the maximum internal depth of Wound 21 (9.0 cm) being substantially shorter than the 15.0 cm blade. The structural toolmark deformation is consistent with the recovered knife having produced the costal bone marks observed at autopsy.

Stereomicroscopic examination of the deformed blade surface showed microscopic striations and toolmark transfer marks along the lateral bevel, corresponding to frictional sliding across costal cortical bone. No micro-chipping, notch embrittlement, or transverse fatigue cracks were detected along the concave or convex margins of the bend, indicating the high ductility characteristic of properly tempered martensitic stainless steel. The plastic

hinge formed 7.5 cm from the blade apex, corresponding to the mid-blade zone of maximum bending moment during levering against the inferior margin of the 12th rib. The permanent deflection of $\theta \approx 112^\circ$ altered the effective reach of the weapon, reducing its straight projected length from 15.0 cm to 11.2 cm and mechanically preventing visceral penetration beyond the 9.0 cm tract depth of Wound 21.

Table 5. Weapon toolmark metallurgy, plastic deformation metrics, and impact force analysis.

Biomechanical parameter	Quantified value / observation	Comparative standard / benchmark	Forensic toolmark implication
Blade overall length	15.0 cm	Standard domestic utility knife	Exceeds all wound tract depths (maximum 9.0 cm)
Maximum blade width	2.0 cm	Commercial single-bevel blade	Concordant with entrance wound lengths (1.5–3.0 cm)
Blade thickness at spine	1.5 mm	Martensitic stainless steel	Relatively low bending resistance against rigid bone
Plastic deformation angle	112° (deflection 68°)	Straight blade baseline (180°)	Permanent deflection at fulcrum ($x = 7.5$ cm)
Yield strength (σ_y)	450–550 MPa	Standard cutlery steel (AISI 420)	Exceeded during impact with the costal framework
Dynamic impact force and yield mechanics	Transverse yield limit 48–72 N ($M_y = 3.60$ N·m); longitudinal thrust 450–850 N	Skin 15–45 N; cartilage 95–230 N; transverse force exceeds the 48–72 N limit	Plastic bending ($\theta \approx 112^\circ$) from off-axis impact exceeding the plastic limit
Wound–weapon concordance	All 23 wounds concordant with the recovered weapon	Single-weapon trajectory signature	Makes multi-weapon involvement unlikely

Notes: The comparative standard column gives either a reference value (with the tissue in question) or a descriptive benchmark. AISI, American Iron and Steel Institute; M_y , elastic bending moment; σ_y , plastic yield strength; θ , bend angle.

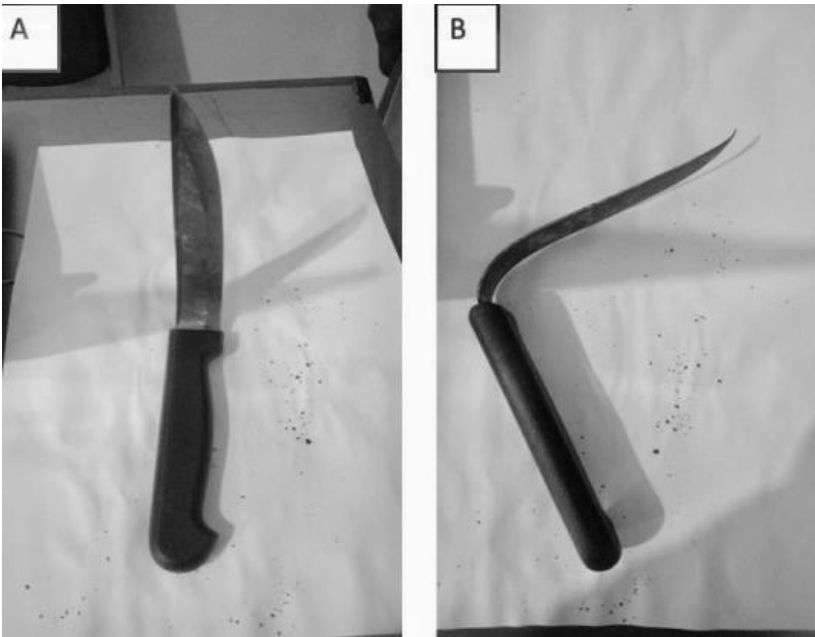


Figure 4. Toolmark photographic documentation of the recovered weapon. (A) Single-edged commercial utility knife straightened after recovery, showing a total length of 26.0 cm (15.0 cm blade, 11.0 cm handle) and a width of 2.0 cm. (B) Recovered state of the weapon at the scene, showing permanent plastic bending deformation with an obtuse angle of $\theta \approx 112^\circ$ located 7.5 cm from the blade tip.

3.6 Antemortem Vitality of the Wounds

All 23 sharp force wounds showed microscopic markers of antemortem vitality, including intense microvascular congestion, extensive perivascular erythrocyte pooling, and dense fibrin meshwork deposition within the wound beds.²¹

4. Discussion

4.1 Wound Distribution and Assault Dynamics

The findings of this case study delineate the multi-tiered biomechanical and pathophysiological mechanisms governing the fatal outcome of a homicidal multiple sharp force assault.^{1,2} Multiple sharp force fatalities are

distinguished by high injury counts, dynamic wound morphologies, and variable penetration vectors that reflect sustained physical interaction between perpetrator and victim.^{3,4} In the present case, topographical mapping identified 23 sharp force injuries concentrated over the posterior thoracic wall (47.8%), anterior chest (17.4%), and cervical region (13.0%), with active defensive wounds on the left upper extremity (13.0%). This distribution is characteristic of an intense, close-quarters assault in which the victim initially resisted before sustaining incapacitating vascular and thoracic trauma, culminating in collapse after an ambulation trajectory of approximately 4.8 m.^{5,6}

4.2 Weapon Deformation and Blade Biomechanics

A central biomechanical finding of this investigation is the plastic bending deformation of the recovered weapon ($\theta \approx 112^\circ$, deflection 68°). Forensic literature documents that domestic kitchen cutlery is engineered for slicing soft foodstuffs under modest axial and shear loads rather than for withstanding high-energy transverse impacts against dense human skeletal structures.^{12,13} Metallurgically, commercial utility blades of martensitic stainless steel (AISI 420 equivalent) have high hardness and tensile strength (yield strength $\sigma_y \approx 480$ MPa) but relatively modest lateral bending resistance when manufactured with a thin cross-section (spine thickness 1.5 mm, blade width 2.0 cm).^{14,15} Using Euler–Bernoulli beam theory, the transverse plastic yield limit for this blade geometry was calculated at 48–72 N (plastic bending moment $M_y = 3.60$ N·m; see the query in Section 3.5).¹⁴ During violent homicidal stabbing, thrusting forces exerted by an adult male perpetrator routinely reach 450–850 N.^{16,17} When the blade struck the rigid 12th costal arch obliquely during the infliction of Wound 21, the resulting transverse force component substantially exceeded the 72 N threshold, inducing permanent plastic deflection at a fulcrum 7.5 cm from the tip without fracturing the blade.^{18,19} This deflection altered the penetration geometry and would have arrested further visceral transit at 9.0 cm, substantially less than the 15.0 cm blade length.^{20,21}

The trajectory and force reconstruction also offers insight into weapon handling during homicidal violence.^{16,18} When an assailant delivers multiple forceful stab wounds to the posterior thorax while the victim is moving or attempting to flee, the interaction between forward thrusting velocity and evasive body movement introduces significant off-axis angular components.¹⁹ In this case, the blade met the inferior border of the 12th rib at an acute oblique angle. The bone offered immediate, rigid resistance, converting the kinetic energy of the forward thrust into a transverse bending moment acting on the cantilevered blade.¹⁴ The resulting plastic deflection ($\theta \approx 112^\circ$) locked the blade in a curved orientation, effectively turning the knife into an angled hook that precluded further linear penetration and altered the toolmark morphology of any subsequent strikes.¹⁵ This sequence illustrates the importance of evaluating weapon deformation as both a physical artifact and a chronological marker of assault progression.¹⁶

4.3 Mechanism of Death

From a pathophysiological perspective, the victim died from a synergistic tripartite mechanism: hyperacute low-pressure venous exsanguination, bilateral compressive hemothorax with diffuse pulmonary atelectasis, and Class IV hypovolemic hemorrhagic shock, as summarized in the schematic diagram in Figure 5.^{22,23} Complete transverse severance of the right internal jugular vein (Wound 1) constituted a primary lethal breach. Although low-pressure venous hemorrhage lacks the pulsatile arterial spurting associated with carotid transection, the internal jugular vein has a large lumen and continuous, high-volume venous return from the intracranial sinuses.²² Transection of this vessel resulted in rapid extravasation into the deep cervical fascial spaces and heavy external blood loss onto the concourse floor.²³ Furthermore, because negative intrathoracic pressure during inspiration can draw air into severed cervical veins, internal jugular laceration carries a risk of fatal venous air embolism; however, the autopsy excluded intracardiac air entrapment, indicating that exsanguination was the primary fatal mechanism.^{24,25}

Simultaneously, the penetrating posterior thoracic wounds (Wounds 20 and 21) caused serious injury to the respiratory and hepatobiliary systems.²⁶ Wound 20 traversed the 10th intercostal space and penetrated the left lower pulmonary lobe (2.0 cm × 2.0 cm laceration), producing 450 mL of hemothorax, while Wound 21 penetrated the 12th intercostal space, the right lower pulmonary lobe (2.0 cm × 1.0 cm tear), and the dome of the right hepatic lobe (1.5 cm × 0.5 cm laceration), yielding 400 mL of hemothorax. The accumulation of 850 mL of free intrathoracic blood compressed the pulmonary parenchyma, inducing diffuse bilateral compressive atelectasis. This compromised gas exchange, producing hyperacute ventilation–perfusion mismatch, severe hypoxemia, and acute respiratory distress that compounded the systemic effects of rapid blood loss.²⁴

4.4 Hemodynamic Modeling and the Influence of Obesity

The volumetric hemodynamic modeling in this study provides objective quantification of the circulatory collapse.¹⁰ Based on standard adult male metrics (70 mL/kg), the victim's circulating blood volume was 6,300 mL for a body weight of 90.0 kg.¹¹ Internal hemorrhage accounted for 850 mL within the pleural spaces, while bloodstain pattern analysis and clothing saturation modeling estimated an external blood loss of 1,850–2,100 mL, giving a cumulative acute blood deficit of 2,700–2,950 mL. This represents an acute circulating volume depletion of 42.8%–46.8%. Under ATLS guidelines, an acute intravascular volume loss exceeding 40% fulfills the criteria for Class IV hemorrhagic shock. In Class IV shock, compensatory vasoconstrictive and neurohumoral mechanisms (sympathoadrenal discharge, tachycardia, and splenic autotransfusion) are overwhelmed, leading to systemic hypoperfusion, severe metabolic acidosis, myocardial ischemia, terminal ventricular dysrhythmia, and asystolic circulatory arrest.²⁶

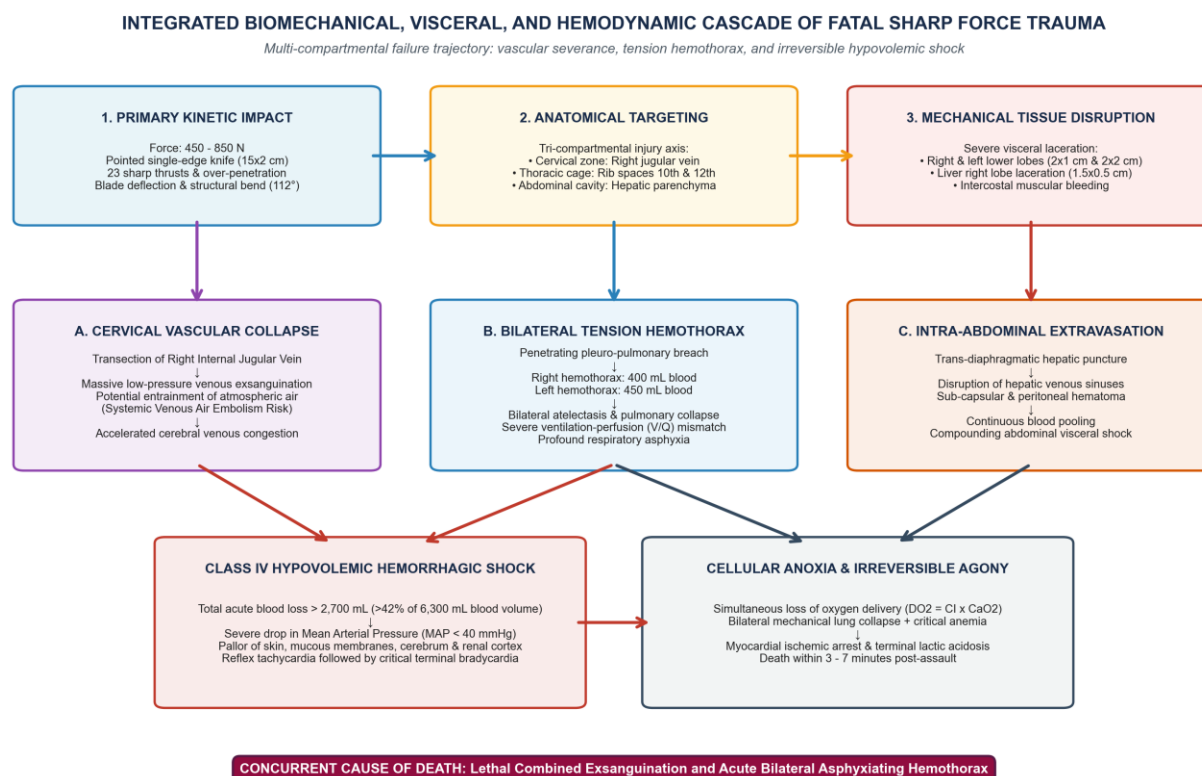


Figure 5. Schematic diagram of the biomechanical, visceral, and hemodynamic cascade of fatal multiple sharp force trauma: (Tier 1) high-energy thrusting and costal impact inducing plastic deformation of the weapon ($\theta \approx 112^\circ$); (Tier 2) multi-compartmental visceral injury comprising right internal jugular vein transection, bilateral pulmonary lacerations (Wounds 20 and 21), and transdiaphragmatic hepatic perforation; and (Tier 3) terminal collapse through acute Class IV hemorrhagic shock (42.8%–46.8% volume depletion) and bilateral compressive hemothorax (850 mL) producing pulmonary atelectasis and terminal asphyxia. CaO_2 , arterial oxygen content; CI, cardiac index; DO_2 , oxygen delivery; MAP, mean arterial pressure; V/Q, ventilation-perfusion ratio.

An important consideration is the influence of obesity on traumatic hemorrhage and weapon dynamics.²² In individuals with Class I obesity ($\text{BMI} = 32.66 \text{ kg/m}^2$), substantial subcutaneous adipose tissue (abdominal fat thickness 4.5 cm) increases the distance from the skin surface to the visceral and retroperitoneal organs.¹⁴ However, adipose tissue has low shear strength and minimal penetration resistance compared with skeletal muscle and dense fibrous fascia.¹ While the expanded fat layer absorbed part of the thrusting energy, it offered little structural protection against the point of the blade. Furthermore, the larger absolute blood volume associated with obesity (6,300 mL) meant that an absolute blood loss exceeding approximately 2,520 mL (40% of 6,300 mL) was required to reach Class IV decompensation, which may explain why the victim retained enough physical capacity to walk 4.8 m before terminal collapse.

4.5 Value of the Letulle *en masse* Technique

Methodologically, the Letulle *en masse* evisceration technique was essential for the objective reconstruction of this complex assault. In multiple stabbing cases involving adjacent cervical, thoracic, and abdominal penetrations, conventional Virchow organ-by-organ dissection unavoidably severs vascular bridges, diaphragmatic attachments, and intercostal tract trajectories, precluding accurate three-dimensional tract reconstruction.^{3,4} In contrast, Letulle block evisceration preserved the continuity between the cervical vascular sheath, the pleuropulmonary tree, the diaphragm, and the retroperitoneal hepatic bed. This intact preparation allowed the forensic team to confirm that Wound 21

transgressed the 12th intercostal space, traversed the diaphragm, breached the right lower pulmonary lobe, and ended in the liver parenchyma along a single continuous 9.0 cm trajectory, strongly indicating a single deep thrust rather than multiple superficial strikes.

4.6 Comparison with Published Series

When benchmarked against the international literature on sharp force homicide, the present case shows both convergences and distinctive features. International retrospective autopsy series, including studies from Southeast Asia, report that homicides involving multiple sharp force injuries average 8–18 stab wounds per victim, with over-assault (>20 wounds) documented in fewer than 15% of cases.^{1,3} In this case, the presence of 23 sharp injuries, nearly half (47.8%) over the posterior thorax, indicates sustained violence consistent with over-assault or an intense interpersonal altercation. Furthermore, while cardiac laceration is the leading single cause of death in thoracic stabbing fatalities (35%–55% of cases in published registries), this case highlights an equally lethal but less frequently recognized trajectory: simultaneous major venous exsanguination and bilateral compressive pulmonary atelectasis in the absence of cardiac or aortic injury.^{5,6}

4.7 Survival Interval and Functional Capacity

The survival time and functional capacity of the victim after the initial wounds are pivotal questions in forensic medicine and court testimony.²⁷ Classical forensic teaching indicates that complete transection of the internal jugular vein, although low-pressure, can lead to loss of

consciousness within 15–45 seconds if external extravasation is unimpeded.²² In the present case, however, the victim had an expanded circulating blood volume (6,300 mL at 90.0 kg body weight) and sustained defensive wounds to the left hand, indicating an initial conscious struggle.^{8,10} Crime scene bloodstain analysis documented an arterial and venous smear trail extending 4.8 m across the sports club platform and ending at the pillar where the victim collapsed. This physical evidence indicates that the victim remained mobile for an estimated 30–90 seconds after the initial neck and chest wounds, attempting to flee before the combined effects of 850 mL of bilateral hemothorax, diffuse lung collapse, and more than 2,700 mL of total blood loss produced fatal cerebral anoxia and cardiovascular collapse.

4.8 Antemortem Vitality

To confirm the antemortem vitality of the 23 sharp force injuries, histopathological and thanatochemical criteria were correlated with the macroscopic autopsy findings. True vital sharp injuries are characterized by active erythrocyte extravasation into the perivascular connective tissue, leukocyte margination and early neutrophilic infiltration along severed muscle bundles, and retraction of elastic dermal fibers creating gaping wound margins.^{8,10} In contrast, postmortem incised defects have collapsed, bloodless margins without active tissue infiltration or cellular edema. The microscopic findings reported in Section 3.6 therefore indicate that all injuries were sustained while the systemic circulation was active, consistent with a continuous, rapid assault before terminal cardiac arrest.

4.9 Medicolegal and Judicial Implications

From a medicolegal standpoint, the concordance between the recovered weapon, the costal toolmarks, and the internal visceral tracts provides forensic evidence for court proceedings under Indonesian criminal law (Articles 338 and 340 of the Indonesian Penal Code, *Kitab Undang-Undang Hukum Pidana*, KUHP).^{1,5} The documentation of 11 stab wounds on the posterior thorax, together with three defensive cuts on the left upper extremity, is consistent with an aggressive assault on an actively defending victim who was subsequently stabbed repeatedly in the back.³ The plastic deformation of the blade ($\theta \approx 112^\circ$) on impact with the 12th rib provides a physical marker within the wound sequence, indicating that Wound 21 was inflicted with high kinetic force during the confrontation.^{14,16} This reconstruction makes defense claims of accidental injury, mutual combat, or multi-assailant involvement unlikely and provides objective evidence for judicial adjudication.^{5,6}

This case also underscores the role of the forensic pathologist in reconstructing homicide mechanics for the courts under the KUHP (Articles 338 and 340) and the KUHP (Article 184).^{1,5} Quantification of wound tract trajectories, volumetric blood loss, and weapon deformation provides objective evidence against common defense strategies. In homicidal stabbing trials, defendants frequently claim that the fatal injury occurred accidentally during a mutual struggle or that the victim was attacked by several individuals with different weapons. Here, the dimensional and toolmark concordance between the deformed single-edged knife and all 23 cutaneous wounds supports a single-weapon etiology.^{12,16} Furthermore, the 11 posterior thoracic stab wounds and the plastic deformation of the blade on impact with the 12th rib are consistent with intentional, forceful, and repeated stabbing from behind, providing the court with strong scientific evidence of homicidal over-assault.^{3,5}

4.10 Strengths and Limitations

This case study has both strengths and limitations. A primary strength is the integration of quantitative biomechanical modeling, Euler–Bernoulli beam analysis, volumetric blood loss partition, and complete *Letulle en masse* evisceration within a single case study. Limitations include the lack of postmortem computed tomography (PMCT) before autopsy, which was unavailable at the municipal mortuary, and reliance on planar surface modeling for the estimation of external blood loss. Nonetheless, the macroscopic autopsy findings, direct volumetric fluid measurements, and weapon toolmark correlations provide an empirically grounded framework for understanding fatal multiple sharp force trauma.

5. Conclusion

This observational analytic case study indicates that death resulted from the combined effect of acute Class IV hypovolemic hemorrhagic shock, secondary to complete transection of the right internal jugular vein and transvisceral pulmonary-hepatic perforation, and bilateral compressive hemothorax (850 mL) producing diffuse pulmonary atelectasis and rapid terminal asphyxia.

The *Letulle en masse* evisceration technique was central to preserving multi-compartmental vascular and visceral continuity, enabling clear three-dimensional tract reconstruction across cervical, thoracic, and diaphragmatic structures. Structural beam modeling correlated the plastic bending deformation of the domestic utility knife ($\theta \approx 112^\circ$) with high-energy costal impact, providing a toolmark signature that links the weapon to the skeletal injuries. The integrated analytical approach described here offers a standardized, objective framework for medicolegal death investigation and homicide adjudication in complex multiple sharp force fatalities.

Declarations

Use of generative artificial intelligence. No generative artificial intelligence or AI-assisted tools were used in the design of this study, in the collection, analysis, or interpretation of the data, or in the drafting and revision of the manuscript. The authors are fully responsible for the content of this article.

Author contributions. SP: Conceptualization, Methodology, Investigation, Writing – original draft. PR: Investigation, Formal analysis, Data curation. ET: Methodology, Formal analysis, Investigation. AY: Supervision, Validation, Writing – review and editing. All authors have read and approved the final version of the manuscript and agree to be accountable for all aspects of the work.

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Conflict of interest. None. The authors declare no financial, personal, professional, or institutional competing interests.

Ethical approval. The autopsy was performed under an official requisition from the Indonesian National Police (POLRI) pursuant to Article 133 of the KUHP. Ethical approval was granted by the CMHC Research Center, Ethics Committee, Indonesia (Ref. No. 2021/0419). All procedures followed the Declaration of Helsinki. Written informed consent for the anonymized use of postmortem data, autopsy findings, and forensic photographs was obtained from the legal next of kin.

Consent for publication. Written informed consent for publication of this case study and the accompanying anonymized images was obtained from the legal next of kin. Facial features have been obscured with an anonymization bar in accordance with ICMJE and COPE guidance.

Data availability. All data supporting the conclusions of this article are included in the manuscript, tables, and figures. Additional non-identifiable forensic material may be made

available by the corresponding author on reasonable request and with institutional approval.

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