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Forensic-medical characteristics of penetrating wounds as manifestations of explosive trauma in the case of decomposed bodies examination

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ABSTRACT

The Russian invasion of Ukraine in 2022 caused a significant spike in the number of deaths from blast injury. The impossibility of evacuating the bodies of dead servicemen or civilians from the battlefield for a long time leads to the fact that forensic experts often have to deal with the examination of bodies in a state of decomposed changes. At the same time, the material and technical support of forensic medical institutions in different parts of Ukraine is heterogeneous: most experts do not have access to laboratory or instrumental research methods and can only rely on macroscopic research data. This article provides an overview of the cases of expert examination of cases of explosive trauma of decomposed bodies using macroscopic, microscopic, chemical and instrumental research, which indicates the high efficiency of their use for the purpose of solving expert questions of various nature. At the same time, the identified morphological characteristics of the damage are not purely specific and indicate the action of a blunt solid object with a limited contact surface, which had high kinetic energy and significant penetrating capacity.

1. Introduction

Since World War II, humanity has practically not had to deal with large-scale military conflicts between different countries, where both sides had all kinds of heavy weapons (tanks, planes, artillery, missile weapons, etc.), significant human resources and battles fought on a significant length of the front line, covering major cities. One of the characteristic types of trauma that accompanies military conflicts is explosive trauma, which is a consequence of the action of explosive objects (grenades, rockets, etc.). An example of this kind of military conflicts until 2022 were the wars in Iraq and Afghanistan. Thus, from 2005 to 2009, among almost 2 million servicemen stationed there, 5,862 cases of explosive injuries were recorded, which accounted for 74 % of all injuries [1].

Terrorist attacks, the frequency of which is steadily increasing in the world, are also an equally significant source of explosive trauma [2].

However, Russia's invasion of Ukraine in February 2022 became the new conflict, which in terms of scale became the largest since the Second World War. This conflict in 1 year resulted in more than 7,000 deaths and almost 12,000 injuries among the civilian population [3]. As of December 2022, the number of casualties among Ukrainian servicemen was about 13,000 [4].

The Forensic Medical Service of Ukraine had almost no experience with cases of mass gunshot or explosive injuries until 2014, when the fighting on Maidan Nezalezhnosti began [5]. Subsequent battles in the east of Ukraine revealed the unpreparedness of the forensic medical service in terms of organization and logistics for the examination of this type of injuries.

And although the morphological features of explosive trauma are well described in the literature [6], the issue of examination of explosive trauma in the case of decomposition is still poorly studied. This problem became widespread during the war in Ukraine due to the impossibility of evacuating the bodies of the dead, the lack of refrigeration facilities, and the long-term exchange of bodies with the other side of the conflict [7].

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2. Materials and methods

The material of the study was 12 biological objects (skin samples) taken from various parts of the trunk and head of persons who died in the combat zone (archives of the "Conclusions of Expert Research" of the Kyiv Regional and Kyiv City Clinical Bureau of Forensic Medical Examination). In the vast majority of cases, the skin samples had pronounced putrid changes and were subsequently restored in an alcohol-vinegar solution according to the method of A.N. Ratnevsky. As a result, they acquired elasticity and the morphological properties of the damage on it were restored. Before the start of the study, the skin flaps were stored in the freezer of the refrigerator at a temperature of −18 °C. Before the start of the study, they were thawed and dried at room temperature for 2 h.

Damage was examined visually and stereomicroscopically using a digital stereomicroscope "Carl Zeiss stereo Discovery. V12 (EMS3/SyCoP3; with PlanApo S0.63 optics and Eyepiece: 16x/16, with an Axiocam 305 digital camera, at a magnification of 5.0 × to 63 ×), and also using a stereomicroscope MBS-9 and MBS-10 (magnification 4.8–56 ×). To identify the nature and topography of the distribution of metallization in the areas of damage on skin flaps and establish the elemental composition, the following were used: 1) contact-diffusion chromatography and 2) micro-X-ray fluorescence spectral analysis, which was carried out using the "M4 TORNADO" micro-X-ray fluorescence spectrometer of Bruker (Germany) according to standard analytical methods. Small inclusions of the remnants of the destroyed striking element were studied by micro-X-ray fluorescence analysis on the M4 TORNADO spectrometer to establish their elemental composition.

All studies were performed in accordance with current Ukrainian legislation, in particular Order No. 6 of the Ministry of Health from 1995 [8].

3. Cases presentation

Below is a case of an explosive injury, which was characterized by multiple shrapnel injuries of the body of the deceased as a result of a rocket hitting a non-residential premise in 2023. The object of the study was a flap of skin with a wound, removed from the back surface of the chest (Fig. 1a).

During direct stereomicroscopy in the area of the edges and walls of the damage on the skin flap, no extraneous layering and inclusions were found, except for layerings of a homogeneous substance of a dark red color covering the entire flap (resembling blood) and small foreign inclusions (flats of uncertain shape, dark -golden color), the removal of which is impossible due to their size. In its upper part, there is a through-and-through damage of a three-ray shape, the rays of a tortuous shape and have a length of 10, 11, 13 mm (Fig. 1 b.).

The edges of the injury had an uneven, tortuous appearance, without abrasion and bruising. They are compared with each other with the formation of a tissue defect of an irregular triangular shape, the size of 0.5x1x2 mm, at the place of their joint departure. The walls of the injury are beveled from left to right and somewhat from the bottom up, bumpy, with weak bruising, not demarcated; all the ends of the damage rays are close to acute angles in shape, the end of the second ray branches into two segments 3 mm and 4 mm long with a distance of 2 mm between them, which end with ends similar to acute angles. In addition, the damage is located on the background of a bruise of purple color, which covers almost the entire area of the flap and does not have clear borders and contours.

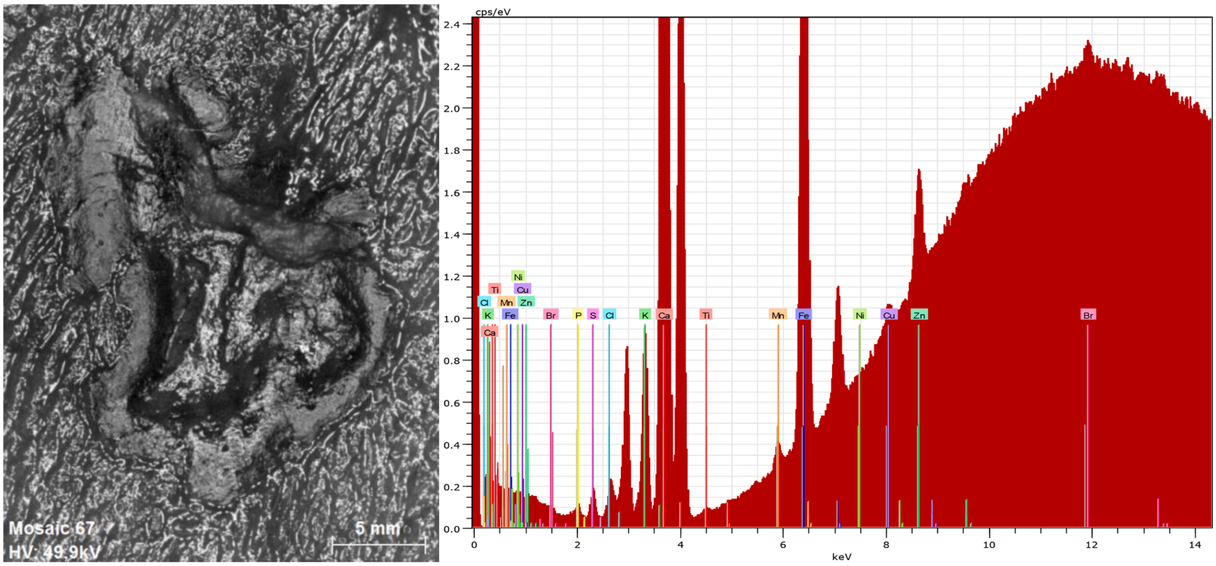
Using micro-X-ray fluorescence spectral analysis of a skin flap (Fig. 2 a), spectra of the following elements were obtained from the scanning plane in the area of damage: P, S, Ca, Cl, K, Mn, Ti, Br, Ni, Fe, Cu, Zn (Fig. 2 b.).

On the obtained maps of the distribution of elements in the damaged area, the following was noted: an increase in the concentration of calcium and iron and a slight increase in the concentration of titanium, chromium and zinc (Fig. 3). Subsequently, targeted studies were conducted from the edge of the injury, from the area of intact skin (control point) and from the surface of foreign inclusions (flats of uncertain shape, dark golden color), detected during scanning using standard methods.

As a result, several foreign inclusions were found in the damage walls, which mainly contained iron compounds (80.34 %) and a small amount of zinc (12.32 %) and aluminum (3.98 %). Therefore, a wound

a b

Fig. 1. The general view of the skin fragment after its restoration (a) and the microscopic view of the damage (b).



a b

Fig. 2. Video image of the research object (a) and spectrum from the scanning surface (b).

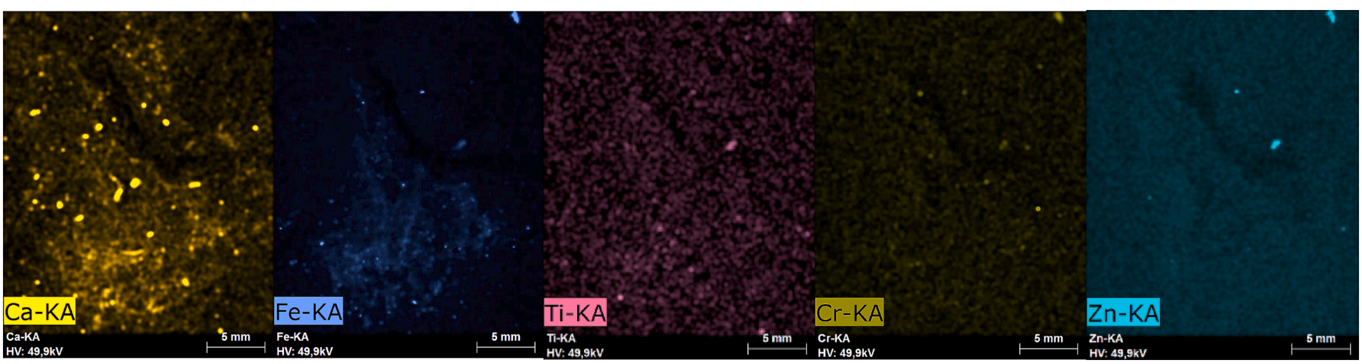


Fig. 3. Distribution maps of calcium (Ca-KA) and iron (Fe-KA), titanium (Ti-KA), chromium (Cr-KA) and zinc (Zn-KA).

on a flap of skin from the back surface of the chest is a fragmental wound, characteristic of an explosive injury, which was formed by the action of a blunt solid object with a limited contact surface (fragment/element of an explosive device or a secondary projectile) that acted with high kinetic energy, having at the same time a significant penetrating ability and contained iron, zinc and aluminum compounds in its composition.

In another case, thanks to the use of micro-X-ray fluorescence spectral analysis, it became possible to determine the direction of the traumatic effect of a fragment of an explosive device. In Fig. 4 a, a flap of skin with a laceration-fatigue wound is shown, which was formed by the action of a blunt object with a limited contact surface - a fragment/element of an explosive device (Fig. 4 b).

The analysis of maps of the distribution of iron (Fe), copper (Cu), zinc (Zn) and nickel (Ni) in the composition of layers in the wound area showed that iron elements are scattered along the edges of the wound and around them, and the layering of compounds of copper, nickel and zinc are located on the upper right edge of the wound and above its upper edge in the form of one large speck of an irregular oblong shape (Fig. 5). It is this topography of trace elements of iron, copper, zinc and nickel that indicates that the traumatic force acted at an angle.

The next objects of our research were skin flaps removed from different parts of the body and head of victims who died in the war zone as a result of being hit by a fragment/element or fragment of an explosive device or a secondary projectile of an explosive device (possibly mines, shells, etc.) (Figs. 6-8). All of them had mainly atypical morphological features of the injuries. Namely: their shape was tortuous, irregularly rectangular, rounded, often with a fabric defect (“minus fabric”). They were characterized by signs of bruising - their ends were sharp-angled or indistinct, smoothed, with connective tissue membranes; the edges are uneven, sharply bruised, patchy in some places, due to numerous small marginal tears of the skin; the walls are bumpy, softened, bruising, etc.). The sizes of the injuries were different.

During the study using contact-diffusion chromatography obtained from the outer and inner surfaces of the above-mentioned skin flaps, including from the head (where there were small particles of silver-colored metal), speckled deposits of blue-green color were found, which are characteristic of the presence iron compounds that could correspond to the elemental chemical composition of the material of the traumatic projectiles.

4. Discussion

Penetrating and superficial shrapnel injuries of the skin are the most common (95 %) type of injury in explosive trauma, according to data from the analysis of forensic medical records of those who died from explosive trauma in Ukraine since February 2022 [4].

The data of Ukrainian forensic medical experts during the examination of explosive injuries caused by AGS-17 projectiles and F-1 grenades revealed morphological characteristics of skin damage similar to

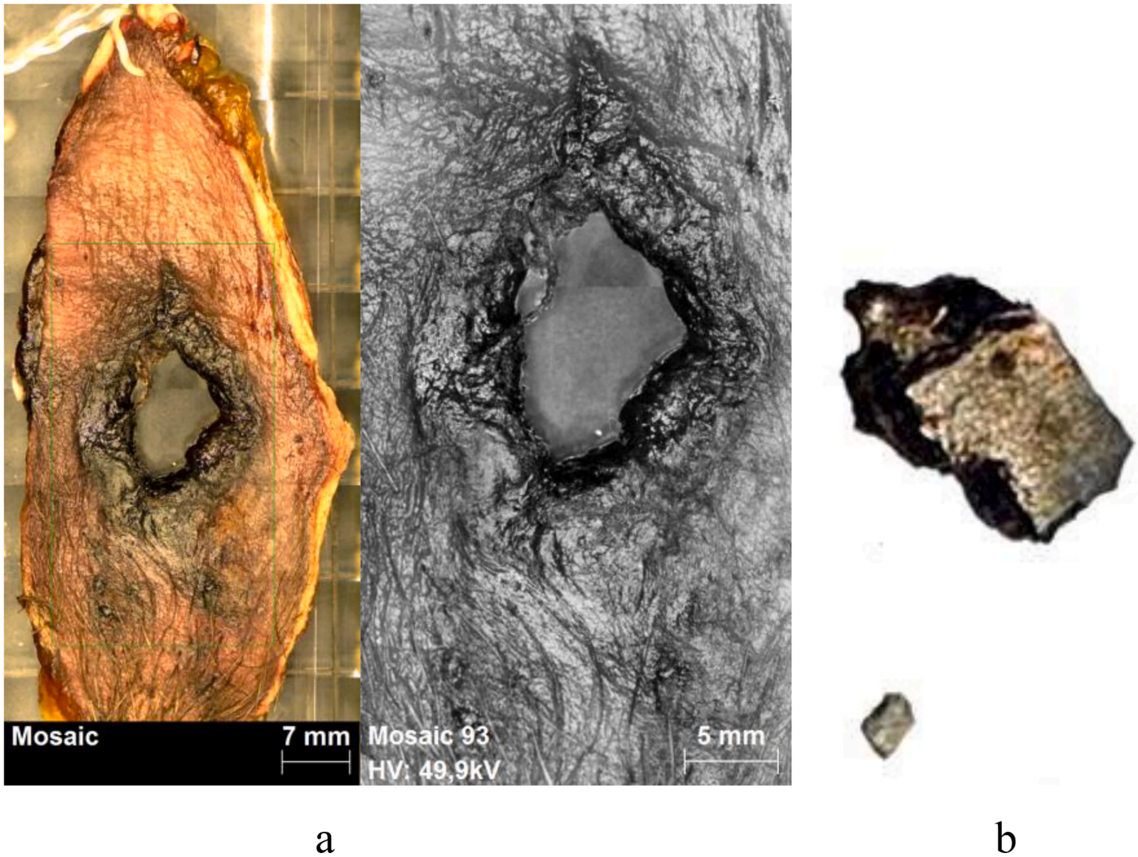


Fig. 4. A laceration wound caused by a blunt object with a limited contact surface (a) and a fragment/element of an explosive device (b). 4,8–56 ×.

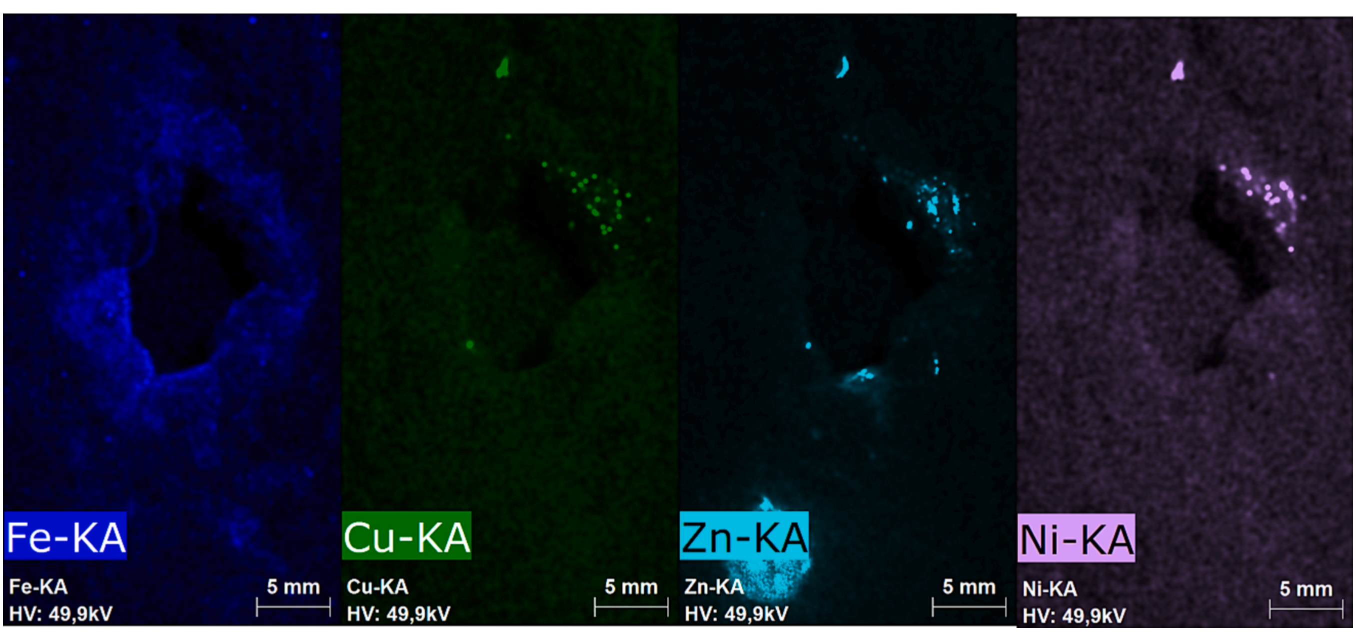


Fig. 5. Distribution maps of iron (Fe-KA), copper (Cu-KA), zinc (Zn-KA) and nickel (Ni-KA) in the wound area.

those presented by us - abrasion, on the background of which there were wounds of oblong and rounded shapes. The edges of rounded wounds with a “minus-tissue” defect are relatively even, in places; elongated wounds - uneven, distended, patchy [9,10].

Yann Delannoy and co-authors [11], analyzing skin injuries during various terrorist attacks, confirm our data on the presence of a different morphological picture of explosive injuries, which does not allow us to use the data of macroscopic studies to identify the type of injury. In particular, they indicate their similarity to a gunshot injury.

At the same time, the majority of modern scientific literature in the field of forensic medicine related to the topic of explosive trauma is devoted to the analysis of bone fractures [12]. Issues related to the study

a b

Fig. 6. Fragmentary injuries of a tortuous shape from the lumbar region of the body (a) and chest (b). 4,8–56 ×.

a b

Fig. 7. Fragmental through injuries of the area of the left forearm (a) and with a tissue defect of an irregular rectangular shape from the iliac area (b)0.4,8–56 ×.

of skin damage caused by the healing elements of an explosive injury are rare.

Publications devoted to the study of explosive trauma under the conditions of decomposition of the body are even rarer. This trend can be explained by the fact that explosive trauma is mostly observed and is the subject of a forensic medical investigation in peaceful conditions, where nothing prevents rapid detection (populated areas), investigation at the scene and moving the body to a morgue or other structure with appropriate storage temperature conditions. Such incidents include suicide [13,14], terrorist attacks [15,16], accidents [17] or minor military conflicts [18].

The study of altered skin presented in the literature, conducted on an animal model with a gunshot wound, allows us to analyze its results to a certain extent. For example, mummification processes prevailed over

a b

Fig. 8. Damage to the skin of the head area with small tears and smoothed edges (a); on the walls of the damage there were small particles of silver-colored metal (b). 4,8–56 ×.

decay in bodies left in the air, which allowed preserving the contours of the damage. While the bodies of those left in the ground were dominated by decay processes that destroyed the macroscopic picture. The authors conclude that laboratory methods aimed at determining gunshot residue were most informative in the assessment of damage [19].

Modern instrumental and laboratory methods of analysis allow detecting the smallest particles of elements and therefore are a key component for identifying the nature of damage [20].

MicroCT analysis data of human skin with gunshot injuries with and without putrefactive changes showed the presence of gunshot residue in the first case both in the epidermis surface and in the dermis, while in the second case only in the dermis [21]. In the case of our observations, metal deposition could be observed on the surface of the skin. This nature of differences can be explained by different objects that caused the pollution. In our case, these were metal fragments that significantly outnumbered the microparticles of steam produced when a firearm was fired. In this way, much more contamination of the wound could occur. At the same time, research data show that pollution from the outside (both by air and when in the ground) by elements does not affect the assessment of gunshot or explosive injuries [22]. This once again emphasizes the significant relevance of the use of instrumental methods of identification of elements in and around the wound.

At the same time, neglecting a macroscopic study is not advisable, and it is correct to combine all the available research results in order to assess the nature of damage to the skin, which in essence, in cases of the use of explosive elements, are ballistic wounds produced by primary fragments and secondary fragments, which possess significant kinetic energy and significant penetrating capacity [23,24,25].

5. Conclusions

In the conditions of the emergence of new full-scale military conflicts, the assessment of explosive trauma becomes a new challenge for the forensic medical service. The data of our study showed that, despite its destructive nature, decomposition allows us to assess the damage to the skin with confirmation of the fact of the action of the striking elements of the explosive devices and the identification of the circumstances of the damage. A key role in this is played by research methods that allow detecting the layering of metal particles that remain on the skin even under conditions of severe decay.

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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