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Pathomorphological examination of dogs that died from gunshot wounds

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Abstract. The relevance of the study is due to the increase in the frequency of the use of firearms to kill animals during military conflicts. As evidenced by practice, most gunshot wounds are cases of animal cruelty. That is why a forensic veterinary expert must correctly assess not only the gunshot wound, but also the circumstances associated with the shooting. The purpose of this study was to identify and clarify the pathomorphological changes that occur in the organs and tissues of dogs in the area of a gunshot wound when shot with a firearm. As part of the forensic veterinary examination, a pathoanatomical autopsy was performed on two stray dogs that died from gunshot wounds. The first domestic dog received a penetrating wound to the abdominal organs during life, the cause of death of the second dog was a blind wound to the head. It was found that dystrophic and necrotic changes, and haemodynamic disorders, prevailed in the tissues of the gunshot wound. Focal and diffuse haemorrhages were recorded in skeletal muscle tissue, which were localised between stratified muscle fibres. Along with this, foci of

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haemorrhagic infiltration were noted. Massive thrombosis was detected in the lumen of large-calibre vessels, but the main changes were observed in the microcirculatory bed. Injuries that were recorded on the bodies of dead dogs were classified as serious bodily harm. They lead to pathological processes that are dangerous to the body and result in the death of the animal. The results obtained provide an opportunity to deepen the knowledge of forensic veterinary experts on the issues of animal damage by firearms, and the identified changes can serve to differentiate wounds caused by the action of such weapons from wounds of other origins

Keywords: forensic veterinary examination; entrance wound; exit wound; firearm; autopsy

Introduction

The spread of firearms, combat injuries, and uncontrolled shooting in the context of armed aggression and military operations on the territory of Ukraine has led to an increase in the number of wounded and killed domestic and stray animals, including dogs. Such cases often have signs of deliberate cruelty to animals, which requires a proper forensic veterinary assessment and evidence base for law enforcement agencies.

In contemporary scientific publications, considerable attention is paid to the development of forensic veterinary expertise of traumatic injuries in animals, especially in the context of countering ill-treatment and illegal use of weapons (Lemishevsky, 2024). The researcher emphasised the key role of pathomorphological research in establishing the mechanism of trauma, causes of death, and forming an evidence base for law enforcement agencies. The need for a systematic approach to the interpretation of injuries, considering morphological changes in tissues and the circumstances of the wound, which is of particular importance in armed conflicts, was highlighted. However, the available review works are mostly generalising in nature and do not always detail the pathomorphological features of gunshot wounds in dogs. Pathomorphological examination of gunshot injuries allows objectively establishing the mechanism of injury, the nature of the wound, the direction and distance of the shot, and the cause of death, which is key for documenting war crimes and countering animal cruelty in war conditions.

In the vast majority of cases, when animals are hit by firearms, soft tissues are primarily damaged, less often – parenchymal organs and the brain. However, the immediate cause of death is internal bleeding and pain shock. Visually, the damage will be accompanied by an entrance hole, which is a rounded defect up to 3 mm in size. The characteristics of the wound canal will depend on the morphological structure of the damaged tissue, on the degree of innervation and blood supply. If a parenchymal organ is affected, the entrance wound will have a star-shaped structure; if soft tissues are affected, haemorrhages will be present.

Clinical cases associated with injuries from the use of shells have a similar course to injuries from other types of weapons, so experts need certain markers for differential diagnosis. N. Bradley-Siemens & A.I. Brower (2016) described common types of shell injuries found in the United States of America, including firearms and ammunition associated with this form of injury. Three stages of ballistics exposure were discussed – internal, external, and terminal wounding.

R. Shrestha *et al*. (2023) detailed morphological features of gunshot wounds that are of

key importance for pathomorphological and forensic veterinary interpretation. Special attention was paid to the characteristics of the wound channel, which can be straight or tortuous, with zones of primary destruction, contusion, and distant tissue damage caused by the transfer of kinetic energy of the bullet. Secondary morphological changes were also described – bone fractures with radial cracks, ruptures of blood vessels and internal organs, massive haemorrhages, and with high-speed wounds – the phenomena of a temporary pulsating cavity. These signs are fundamentally important for pathomorphological examination of dog corpses, since they allow establishing the mechanism and direction of the shot, the approximate distance of the wound, and the immediate cause of death, which is important both for veterinary expertise and for the investigation of cases of animal cruelty.

J. Linder *et al.* (2023) devoted their research to the analysis of ballistic (firearm) injuries to the axial skeleton in 13 animals, mainly dogs. The researchers described the localisation of spinal and cranial injuries, neurological and ophthalmic manifestations, treatment approaches, and short-term clinical outcomes. T.H. Edwards *et al.* (2021) found that firearm injuries, as opposed to mechanical injuries, differ in terms of their mechanism of occurrence, clinical course, and various morphological manifestations. This fact is conditioned by the fact that gunshot injuries are a component of gunshot wounds and they will always complicate the pathogenetic situation.

K. Schrock *et al.* (2021) conducted a study of 97 animals with 137 acute fractures that were caused by gunshot wounds. Of these, 21 animals (15.3%) had fractures of the maxillofacial bone, 16 animals (11.7%) had spinal fractures, 8 animals (5.8%) had rib fractures, 56 animals (40.9%) had fractures of the distal long bones (below the knee and elbow joints), and 36 animals (26.3%) had fractures of the proximal long bones. Gunshot fractures generally have a high probability of poor outcome, which is associated with complications from soft tissue damage.

H. Baruah *et al.* (2021) found that with a gunshot wound, there will necessarily be an anatomical defect and functional disorders in the surrounding tissues, possibly bacterial contamination of the wound edges. The degree of damage to the tissue elements will depend on the ballistic characteristics of the projectiles: on the calibre, on the speed, on the shape and size, on the angle at which it enters the target, and on the anatomical structure and condition of the tissues at the wound site. However, the amount of energy transferred to the tissues will be crucial.

Given the small amount of literature data on the use of radiological imaging techniques in forensic veterinary medicine, M. Grela *et al.* (2021) attempted to evaluate the benefits of radiography and computed tomography (CT) in post-mortem diagnosis of gunshot wounds compared to classical autopsy. The experiment consisted of the following: 13 corpses of dogs were examined, in which the injuries were inflicted from different distances (1.5 and 12 metres) and one animal had a contact shot to the head. In each case, different types of ammunition were used, followed by X-rays and CT scans to investigate injuries sustained as a result of the shot. Post-traumatic bone damage and the presence of metallic foreign objects were successfully imaged in the study material using both X-ray and CT. GSW analysis using CT scans provided much better data quality and some additional information. Based on the results of experiments, the following general conclusions can be drawn. Firstly, the damage caused by a firearm correlates with the calibre, kinetic energy of the bullet, and the distance from the muzzle to the object of the shot is also very important. Secondly, radiological examination is useful for preparing forensic veterinary reports. They are

used as an adjunct to classical autopsies, and X-rays and CT scans increase the possibility of a more accurate post-mortem diagnosis.

The studied literature does not sufficiently cover the injuries that can occur under certain circumstances as a result of the use of firearms. In a few papers devoted to this problem, only macroscopic manifestations of the action of damaging factors of shots were studied and, as a rule, only the possibility of mechanical injuries (bruises, abrasions, wounds, bone fractures, damage to internal organs, and other anatomical structures) was stated. The available data were often unsystematic and were based solely on visual observations.

Each case of injury should be considered as individual and unique. Each gunshot wound is an injury that requires an individual approach – the same weapon and ammunition can cause completely different injuries, and different types of weapons and ammunition can cause the same or similar injuries. A veterinary physician acting as a forensic expert in the assessment of gunshot wounds in animals should have broad, unbiased knowledge and be able to analyse each case individually, without resorting to generalisations. Therefore, the purpose of this study was to determine the characteristic pathomorphological changes in the area of a gunshot wound in dogs injured by firearms.

Materials and Methods

The research was conducted from January 2024 to June 2025 at the scientific laboratory of the Department of Vertebrate Biomorphology named after Academician V.G. Kasianenko at the National University of Life and Environmental Sciences of Ukraine and at the Department of Normal and Pathological Morphology and Forensic Veterinary Medicine of Odesa State Agrarian University, within the framework of the interdepartmental research topic "Pathogenesis and Pathomorphology of Violent Death in the Context of Forensic Veterinary Examination", state registration No. 0123U102492. Live animals did not participate in the study. The authors considered the recommendations of ARRIVE (n.d.), however, since the present study was post mortem, it was based on OIE/WOAH standards (n.d.).

The study was conducted as part of a pre-trial investigation of criminal proceedings entered in the Unified Register of Pre-trial Investigations on the grounds of a criminal offence under Part 1 of Article 299 of the Criminal Code of Ukraine. The study material was the corpses of two mixed-breed dogs aged 4 and 5 years, who died as a result of gunshot wounds. Pathoanatomical examination of corpses was carried out in accordance with generally accepted forensic veterinary methods in compliance with the principles of completeness and objectivity of the examination. The autopsy was performed in the dorsal position using the complete evisceration method. Before starting the autopsy, a visual examination of animal corpses was performed, the general condition of the body, the presence of injuries, fatness were assessed, and attention was paid to the condition of the skin and mucous membranes of the respiratory tract, oral cavity, and eyes. After the autopsy, a sequential study of the subcutaneous base, muscles, bone system, thoracic and abdominal organs, central nervous system, and vascular bed was performed. Special attention was paid to the identification, localisation, and morphological characteristics of entrance and exit gunshot wounds, the direction and features of the wound canal, the presence of concomitant injuries and secondary pathological changes. Macroscopic assessment of injuries was performed taking into consideration the shape, size, condition of the wound edges, the presence of haemorrhages, tissue detritus, deformation of organs and bones. Signs of lifetime trauma were recorded, in particular, tissue reactions, vascular changes, haemorrhagic events, and manifestations of aspiration complications. All significant

morphological changes were documented by photographing. All data was carefully described and recorded in the protocol.

To investigate the morphological picture of injuries that occur during the use of firearms, histological examination of tissue micro-preparations from the sites of incoming gunshot wounds was performed. A key role in forensic veterinary examination was played by histomorphological changes that occur in the tissues that form the wound channel after a firearm shot. The study of these changes is important because it helps to clearly distinguish injuries caused by firearms from injuries of other origin (for example, caused by blunt or sharp objects, or shots from gas weapons), thus increasing the objectivity of the expert opinion.

For histological examination, tissue samples were taken from the areas of incoming and outgoing gunshot wounds, wound canal, adjacent soft tissues, and internal organs that were damaged. Subsequently, the selected material was fixed in a 10% solution of neutral formalin (pH 72-74). Haematoxylin and eosin were used for staining histological sections. Microstructural changes and histological structure in the preparations were studied under an MC 100 LED light microscope (Micros Austria). During the histological assessment, the nature of alterative, necrodystrophic and vascular changes, the presence of haemorrhages, thrombosis, destruction of muscle fibres, and the localisation and distribution of powder combustion products (soot, microparticles) in the structures of the skin and subcutaneous base were analysed. Interpretation of the obtained morphological data was carried out based on literature sources on forensic veterinary medicine, pathomorphology, and clinical traumatology. Based on the combination of macro- and microscopic signs, the mechanism of injury, the damage during lifetime, the features of thanatogenesis and the causal relationship between a gunshot wound and the onset of animal death were established.

Results and Discussion

Examination of the corpse of the first dog showed that it was a male (neutered) under 4 years of age, well-fed, body length 88 cm to the base of the tail. The body structure was proportionate and correct, the coat colour was pale brown, and there was an ear tag on the left ear. The hair cover was short and firmly attached to the hair follicles. The skin was grey and white. The coat was locally stained with blood behind the last rib, on the left side of the body (ventrally from the vertebrae), and on the right side of the body (lateral abdominal area) – behind the last rib, at the level of ½ of its length. One gunshot wound with a diameter of approximately 0.4 cm was observed in the skin of the above-mentioned areas, on the left and right sides of the body (Fig. 1).

A B

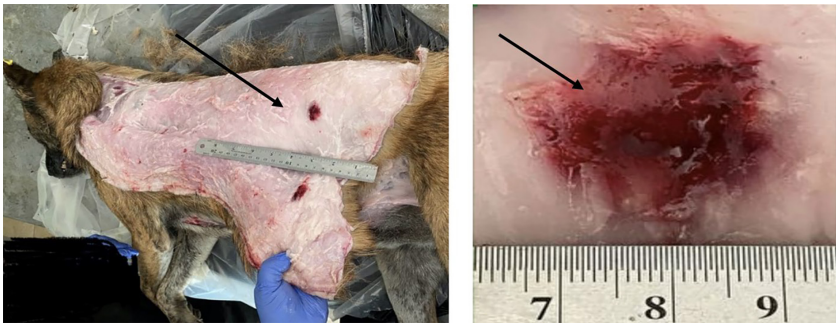
Figure 1. Entrance gunshot wound on the left side of the dog's body
***Note**: A – the black arrow shows the entrance hole from a gunshot wound; B – the size of the wound*
***Source**: photo taken by the authors*

The cornea, sclera, and conjunctiva of the eyes were light red in colour. The oral fissure was closed, vomit masses of white colour of doughy consistency were observed in the lumen of the oral cavity. The skin around the mouth slit was contaminated with vomit. The mucous membrane of the gums and oral cavity was moderately moistened, without damage, with natural pigmentation. The teeth were firmly held in their sockets. In the lumen of the nasal cavity, separate fragments of doughy masses (identical to the contents of the oral cavity), the mucous membrane of diffuse, light red colour was observed. The anal opening was clean, without pathological changes and damage. The integrity of bones and joints was not compromised. Algor mortis was clearly evident, with the lower jaw locked in place. There were no cadaveric spots or signs of decomposition of the corpse.

The results of a pathoanatomical autopsy of the first dog showed that during his lifetime he received a through gunshot wound with the establishment of a direct wound channel. Entrance gunshot wound on the left side of the body – area of the ventral edge of the first lumbar vertebrae; the wound channel ran from the cranial edge of the spleen dorsoventrally, in the wall of the duodenum (loops located at the level of the caudal edge of the pancreas); in the connective tissue of the cranial mesenteric lymphatic centre, in the wall of the jejunum; the exit gunshot wound was located on the right side of the body, at the level of ½ the length of the last rib.

C.S. Bartlett (2013), H. Capak *et al.* (2016) and B.B. Putra *et al.* (2017) based on morphological and functional changes in gunshot wounds, identified three zones within the wound channel: primary wound channel, contusion, and concussion. According to current research, the primary wound channel was caused by crushing, separation, and fragmentation of tissues along the axis the projectile trajectory. The diameter and contour of the same channel varied throughout its entire length. This is conditioned by the behaviour of the projectile and the anatomical characteristics of damaged tissues. Sometimes, with gunshot wounds, the resulting tissue defect is filled with wound detritus, crushed tissues, and blood. The contusion zone, or the zone of direct traumatic, primary necrosis, occurs when a projectile comes into contact with living tissues that are located in the immediate vicinity of the wound canal. As a result of the physical impact of the projectile on the tissues, they are the first to undergo necrosis at the time of injury or immediately, in the next few hours after it. A concussion zone is a zone of lateral impact that is directly adjacent to tissues that have completely lost their viability at the time of injury or in the next few hours after it. This was discovered during the resection of the dog's skin: on the left side of the body behind the last rib, in its dorsal part (the area of the ventral edge of the first lumbar vertebrae), the subcutaneous base and muscles (the psoas major muscle) around the wound channel were damaged and saturated with blood (diameter up to 2.5 cm) (Fig. 2).

On the right side of the dog's body, at the level of ½ the length of the last rib, the subcutaneous base and muscle tissue (oblique abdominal muscle) around the wound channel were saturated with blood. The above-mentioned injuries of the domestic dog were life-threatening injuries, which at the time of inflicting caused a threat to the animal's life. The injury caused pain that activated the gag reflex, which led to the ingress of vomit into the respiratory tract and their blockage. As the autopsy showed, the oesophagus and trachea contained vomit masses resembling a pasty mass (milky in colour with a light green tint) (Fig. 3). The mucous membrane of the oesophagus has acquired a greyish pink colour, the trachea – light red.



A B

Figure 2. General view of the entrance gunshot wound after resection of the skin on the left side of the dog's body

***Note**: A – the arrow shows the area of skin resection around the wound site; B – the area of soft tissue damage and blood impregnation*

***Source**: photo taken by the authors*

A B

Figure 3. Aspiration of the respiratory tract with vomit

***Note**: A – the arrows show the oesophageal mucosa with vomit of a domestic dog; B – the arrows show the presence of vomit in the lumen of the trachea, large and medium bronchi*

***Source**: photo taken by the authors*

The lumen of the trachea, large and medium bronchi was up to 80% clogged with pasty greyish white vomit with a light green tint. Light uneven colour, from light pink to dark red, darker red clearly defined areas that sunk above the general surface. Areas without clear contours of various shades of red were observed. Up to 30% of small bronchi contained vomit. Parenchyma had no content.

O.F. Pirgo (2024) pointed out that very often with gunshot wounds, animals experienced a state of shock. There are several mechanisms in its pathogenesis. This condition cannot be considered only hypovolemic. An important role is played by a pronounced pain syndrome and significant tissue damage, in which tissue mediators are released. Research by I.S. Zozulia *et al*. (2021) demonstrated

that central and peripheral pain receptors are involved in the perception of pain. Visceral pain occurs when the receptors located in the peritoneum are irritated and respond to damage. It does not have a clear localisation, and is often combined with signs of irritation of the autonomic nervous system: nausea, pallor of the skin, vomiting, palpitations, and sweating. At first, vomiting has a reflex character (due to irritation of the peritoneum), and then shock, hypoxia and intoxication of the body develop, the frequency of vomiting increases and becomes of central origin.

During the examination of the heart, no blood was observed in the atria, there was a moderate expansion of the lumen of the ventricles of the heart (right more) with a wall ratio of 1:4. No pathological changes were detected in the membranes of the heart. The blood was semi-liquid, dark red. The abdominal cavity contained liquid blood of dark red colour with admixtures of clots in a volume of up to 0.5 litres. On the surface of the serous membranes – blood clots. The visceral peritoneum and omentum contained moderate amounts of adipose tissue. Blood vessels had lower than average blood filling. Serous membrane of the abdominal wall, stomach, and intestines had a diffuse light red colour. In the abdominal wall on the left side of the body, an entrance gunshot wound with a diameter of up to 0.5 cm, oval in shape, was observed (Fig. 4).

A B

Figure 4. General view of the entrance gunshot wound from the serous membrane of the abdominal wall of a domestic dog

***Note**: A – the arrows indicate changes on the side of the serous membrane in the area of the entrance hole; B – the place of the entrance hole in the area of the abdominal wall on the left side of the animal*

***Source**: photo taken by the authors*

The wound channel passed through the dorsoventral surface of the spleen along the cranial edge of the organ, continuing into the wall of the small intestine loops and the connective tissue of the cranial mesenteric lymphatic centre. The exit gunshot wound was located in the abdominal wall on the right side of the body, oval in shape with a specific tissue deformity (Fig. 5). On the right side of the dog's body, at the level of ½ the length of the last rib, the subcutaneous base and muscle tissue (oblique abdominal muscle) around the wound channel were saturated with blood.

The stomach was then examined and found to be of normal shape, with no obstruction of the cardia or pyloric regions. The organ was half-empty, the mucous membrane of the bottom of the stomach was covered with contents identical to vomit found in the respiratory tract. Pronounced folding and light red colouration of the gastric mucosa were observed.

A B

Figure 5. General view of the initial gunshot wound after skin resection on the right side of the body of domestic dog

***Note**: A – the arrows in the figures indicate the location of the exit hole of the gunshot wound; B – the specific deformation of tissues in the area of the exit hole*

***Source**: photo taken by the authors*

The intestine (small part) was empty, the serous membrane had a light red colour, with the exception of two areas of rich dark red colour (at the level of the caudal edge of the pancreas), where through holes pass, which were a continuation of the wound channel. Damage to the integrity of the wall of the jejunum was established, the loop of which was located on the right side of the body. The edges of the holes were soaked in blood. Large intestine had no damage, light red colour.

The spleen remained unchanged in volume, diffuse light red in colour, with a wound channel running dorsoventrally from its cranial edge, which had stellate tears (more pronounced on the dorsal side), the edges of the tears were concave in the dorsoventral direction and saturated with blood. The liver was not enlarged in volume, with sharp edges, the organ had a diffuse light brown colour, the parenchyma was moderately moistened, the vessels were below average blood filling, and the parenchyma was distinctly granular. The gallbladder had a medium filling, bile of greenish mustard colour. The mucous membrane of the gallbladder was velvety, yellow in colour. The pancreas had a diffuse grey-pink colour, the vessels had below average blood filling. In the kidneys, the border between the cortical and medulla was well expressed, the colour of the cortical substance was light brown, the cerebral substance was greyish white. Bladder was pear-shaped, hollow, serous membrane of light red colour, mucous membrane of pale pink colour.

Pathoanatomical examination showed that the bones of the skull were dense and immobile, the mobility of the spine was preserved, and the spinal column had a natural configuration without signs of deformities or mechanical damage. In general, maintaining bone integrity in gunshot wounds in dogs was considered a prognostically favourable factor associated with a higher chance of survival with timely veterinary care, as reported by R.J. Fullington & K.M. Otto (2017). However, the results of research by J.R. Lewis *et al*. (2008) and M. Grela *et al*. (2021) indicate that penetrating damage to internal organs or involvement of anatomically critical areas significantly impairs the prognosis regardless of bone condition, which was confirmed by the results obtained in the current study.

During histological examination of the entrance gunshot wound, it was found that the structure of the affected tissues was dominated by pronounced necrodystrophic changes and

significant haemodynamic disorders. In the parenchymal-stromal elements of soft tissues, an intense layering of powder combustion products was visualised: soot and small individual dust particles. Localisation of these elements had a specific character: the surface was characterised by the fact that the bulk of soot and microparticles of gunpowder ended up in the epidermis and surface layers of the dermis, and with deep localisation, due to the mechanical action of the shot, there was a delamination of the surface layers of the skin, which ensured the penetration of foreign particles into the dermis. They were infiltrative and concentrated perifollicularly (around the hair follicles). In addition, micro particles of gunpowder were found in the sebaceous glands. Morphological changes were recorded in the reticular layer of the dermis, which were manifested by pronounced oedema and destructive changes in the vascular bed. Uneven connective tissue oedema was noted. Disorganisation of collagen fibres was observed: their thick bundles were focally detached and lost contact with subcutaneous adipose tissue. The compression of fibres was also observed, leading to histoarchitectonic disruption. In the affected areas, the walls of blood vessels were homogenised, the endothelium was desquamated, and blood clots were present in small vessels.

When examining muscle tissue in the wound area, a combination of alterative changes, haemodynamic disorders, and mechanical stratification of muscle fibres was recorded. Diffuse and focal haemorrhages were also detected. In the areas of haemorrhagic infiltration, the structure of muscle fibres was sharply disrupted: there was a loss of sarcolema, infiltration of sarcoplasma by red blood cells, and the absence of nuclei. In relatively preserved fibres, the absence of transverse striation was noted, which is evidence of deep destructive changes in myofibrils. The established morphological features were sufficient to determine the mechanism of wound formation and its differentiation from other types of injuries.

Based on the conducted pathomorphological study of Case No. 1 (through gunshot wound of the abdominal organs of a domestic dog), the following key aspects were established: morphological parameters of the entrance and exit holes, and the nature of the wound channel, most likely indicate the use of small-calibre firearms using pellets with a diameter of approximately 0.5 cm. A direct causal relationship was also established between the gunshot wound caused and the death of the animal. The specified wound was classified as an injury that caused acute, life-threatening pathological phenomena at the time of infliction. The death of the animal occurred as a result of the combined action of traumatic factors. The leading pathological processes were: acute internal bleeding (haemoperitoneum) caused by multiple violations of the integrity of the parenchymal and hollow organs of the abdominal cavity (spleen, duodenum, jejunum) and obstructive asphyxia (mechanical obstruction of the airways by aspirated vomit), which led to obstructive atelectasis of the lungs. The detected signs (hyperaemia of the cornea and sclera, anaemia of internal organs, the presence of vomit in the respiratory tract) confirm that the injury was in vivo, accompanied by intense pain and activation of protective reflexes (vomiting) shortly before death. This case illustrates the need for a detailed sectional study to identify all links in thanatogenesis, which is key to an objective forensic veterinary assessment.

The results of previous research and studies by other scientists indicate the need for pathomorphological research to consider such signs as: damage to organs responsible for vital functions of the body, the area and severity of damage to various organs and tissues; the degree of blood filling of vessels of parenchymal

organs; the state of blood in the vessels. The development of a blood clot in the area of vessel damage (local haemostasis) helps to stop bleeding. However, during acute massive blood loss, damage to large-calibre vessels and traumatic injuries to a large volume of tissues, excessive blood hypercoagulation becomes an independent pathogenic factor and can lead to the development of disseminated intravascular coagulation (DIC) (Skrypka *et al.*, 2020; Yatsenko, 2023).

In the second case, a study was conducted on a domestic dog (female), 5 years old, mixed breed, average body condition. The body structure was proportionally correct; the coat was black and grey with a white colour of the ventral neck and underbelly (grizzle). Hairline was medium length, firmly attached to the hair follicles. The skin was grey and white. The integrity of the bones and joints was not compromised. There was no discharge from natural orifices. The anus was clean, without pathological changes and damage. The conjunctiva of the right eye was red with haemorrhages. The integrity of the membranes of the right eyeball within the anterior pole was damaged with a hole and a dark red (almost black) border along the edge, with blood in the form of a thin crust on the surface (Fig. 6A). The conjunctiva of the left eyeball was unevenly dull red in colour, with no damage to its integrity. The lumen of the nasal cavity was free, the mucous membrane was diffuse light red in colour (Fig. 6B). The oral cavity was closed.

A B

Figure 6. External pathomorphological changes in the head area of a domestic dog after a bullet wound

***Note**: A – the arrows in the figures indicate haemorrhagic impregnation of the right eyeball; B – hyperaemia of the nasal mucosa*

***Source**: photo taken by the authors*

The mucous membrane of the gums and oral cavity was moderately moistened, without damage and layers with the existing natural pigmentation. The root of the tongue and the pharyngeal mucosa were light red with haemorrhages. The teeth were firmly held in their sockets with moderate enamel wear and pronounced tartar build-up.

Algor mortis and rigour mortis were well expressed. However, there were no cadaveric spots or signs of decomposition of the corpse. During skin resection in the head area, dark red discolouration was observed in the subcutaneous tissue and muscles around the right eyeball, root area, and bridge of the nose. The periorbital, intra- and extraorbital fat bodies have become gelatinous in consistency, saturated with bloody fluid. The muscles under the eye (circular eye muscle) had a rich dark red colour, high humidity in the form of a triangle (Fig. 7).

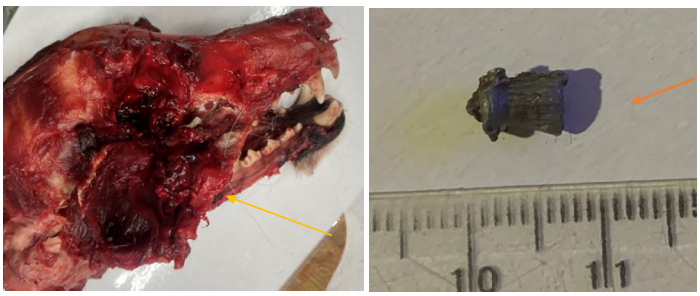
A B

Figure 7. Pathomorphological changes during skin resection in the head area of a domestic dog after a bullet wound

***Note**: A – the arrows indicate haemorrhagic impregnation of periorbites, intra- and extraperiorbital fat bodies; B –haemorrhagic impregnation and the entrance wound opening of the right eyeball*

***Source**: photo taken by the authors*

During the examination of the animal's masticatory muscles, diffuse haemorrhage with the formation of dark blood clots was observed (Fig. 8A). The same diffuse haemorrhage was found in the pterygoid muscle. A metal object resembling a shotgun pellet, up to 1 cm long, with signs of moderate deformation, was found and removed from the thickness of the latter (Fig. 8B).



A B

Figure 8. Pathomorphological changes in the masticatory muscle area caused by a foreign object

***Note**: A – the arrows indicate haemorrhages in the masticatory muscles; B – a metal object removed from the masticatory muscle tissue*

***Source**: photo taken by the authors*

The lungs were diffuse light red in colour, with vessels of moderate blood filling. Lumen of the trachea, bronchi and alveoli had no contents. When examining the heart, the expansion of the lumen of the right atrium (maximum) and ventricle was observed as a result of their blood filling, postmortem blood clotting was pronounced. No pathological changes were detected in the membranes.

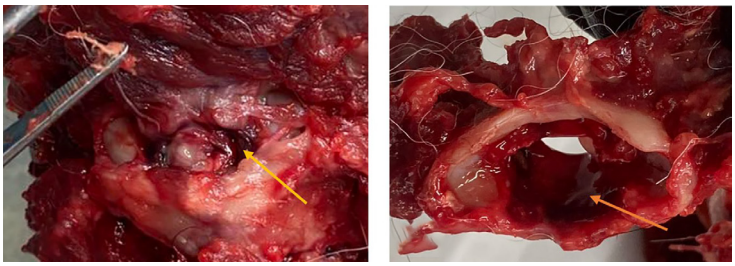
Abdominal cavity had no foreign contents. The placement of organs was anatomically correct. The serous membrane of the digestive tract and the greater and lesser omentum were diffusely light red in colour. The visceral peritoneum and omentum contained moderate amounts of adipose tissue. Blood vessels had moderate blood filling. Serous membranes were moderately moist and smooth. The stomach had a

regular shape. The patency of the cardiac and pyloric parts was not disturbed, the organ was below average filling, contained dirty-grey fluid, the gastric mucosa was light red, and greyish pink in other areas. The intestines were empty, the serous membrane was light red, the mucous membrane was pale pink, covered with a moderate amount of translucent mucus. The spleen was not enlarged in volume, pink with a brownish tinge, the edges were pointed, there was no scraping of the parenchyma, blood vessels of medium filling. The liver was not enlarged in volume, brownish red, the parenchyma was moderately moistened, the vessels are of medium blood filling, the parenchyma was distinctly granular, the edges were rounded. The gallbladder had a medium filling, bile had greenish mustard colour. The mucous membrane of the gallbladder was velvety, yellow in colour. The pancreas was characterised by a diffuse light red colour, and the vessels had below-average blood filling.

In the kidneys, the border between the cortical and medulla was not pronounced, the colour of the parenchyma was red brown. The bladder was pear-shaped, empty, the wall was thickened, the serous membrane was light red, the mucous membrane was uneven dull red, and barely noticeable haemorrhages were noted. The lymph nodes of the cranial mesenteric lymph centre were not enlarged, pink, and the parenchyma was moderately moist. The wall of the uterus, uterine horns and ovaries were diffusely red in colour. The animal was pregnant (up to 2 weeks of gestation, 8 foetuses were counted).

The bones of the skull were dense, connected to each other motionless. The periosteum was uneven from light pink to dark red. The membranes of the brain were uneven dark red in colour, in the area of the basal surface of the brain-blood clots, brain tissue of gelatinous consistency, vessels filled with blood. A focal subdural haematoma was found in the area of the visual intersection and the appearance of a diffuse subdural haematoma of the brain in the caudal direction, which went beyond the brain cavity, reaching the subdural space of the spinal canal (1-2 cervical vertebrae).

Spinal mobility remained within the normal range. Vertebral column had no deformations and damage, natural configuration. The integrity of the spinal cord was not compromised. The spinal canal of the atlas contained a blood clot, and the meninges of this area had an uneven red colour (imbibition) (Fig. 9).



A B

Figure 9. Changes in the spinal canal area of the atlas

***Note**: A – the arrows indicate the spinal canal in the atlas region containing blood clots; B – blood impregnation of the medial (inner) wall of the atlas*

***Source**: photo taken by the authors*

The pathomorphological study of the Case No. 2 of a blind gunshot wound to a domestic dog provided the following conclusions: the death of the animal occurred as a result of the

development of critical pathological processes threatening the body, namely: severe traumatic brain injury, which led to the formation of massive intracranial and spinal haematomas and secondary brain oedema. A direct causal relationship has been established between mechanical damage caused by the action of pellet weapons and the onset of animal death. Detected injuries (violation of the integrity of the eyeball, subdural haematomas of the brain and spinal cord, brain oedema) were classified as severe injuries. This case was an illustration of the application of objective morphological criteria to confirm the fact of animal cruelty. The degree of damage to the central nervous system indicates the presence of intense pain and irreversible changes, which is a sufficient basis for appropriate legal qualification of actions.

Analysis of the results of studies of two cases of gunshot wounds of animals showed that when classifying trauma as severe or fatal, massive blood loss or the development of disseminated intravascular coagulation syndrome (DIC) is not always the leading pathogenetic mechanism. The results obtained are consistent with the data by A.M. Perebetiuk & V.V. Biktimirov (2003), who noted that when fired at close range from a gas barrel weapon, blood vessels are the first to suffer. Changes in them depend on the area of attachment of vessels to the wound, massive thrombosis is noted in large blood vessels, and due to plasmorrhagia, the walls of these vessels are homogenised. C.S. Bartlett (2013) found that in more remote areas from the wound, in the vessels of the microcirculatory bed, there is a violation of the rheological properties of blood in the form of stasis and microthromb development. The permeability of the walls of blood vessels becomes high, which is confirmed by diapedetic haemorrhages. Changes that occur in the wound area when fired at point-blank range from a gas barrel weapon are also characteristic of injuries from a firearm.

M. Risselada (2017) emphasised that penetrating traumatic injuries in dogs, in particular gunshot wounds, can be accompanied by minimally pronounced external morphological changes in the presence of significant internal injuries, which complicates their initial visual assessment. L. Miller *et al*. (2018) showed that in service dogs that suffered combat and gunshot injuries, deaths were most often caused by damage to internal organs and the development of critical pathological conditions, and not by the nature of external wounds. From a forensic veterinary standpoint, this is of fundamental importance, since an objective assessment of the severity of gunshot damage is possible only based on the results of a full-fledged sectional study with an analysis of the wound canal and damage to internal organs. The results obtained in this paper confirmed the need for a comprehensive pathomorphological approach to establish the mechanism of injury, thanatogenesis, and causal relationship between damage and the onset of animal death.

Thus, the results of pathomorphological and histological examination of two cases of gunshot wounds in dogs demonstrated significant variability in the localisation of injuries, mechanisms of traumatic action, and morphological manifestations of tissue and organ damage. In both cases, the characteristic signs of gunshot trauma with the formation of wound channels, pronounced alterative and destructive changes in soft tissues, vascular disorders, and secondary pathological processes that were crucial in the development of fatal consequences were established. The obtained morphological data helped to objectively assess the severity of injuries, their lifetime nature, and the relationship between the localisation of trauma and the development of critical pathological conditions. The presented results expanded the available information on the pathomorphological features of gunshot wounds in dogs and can be used in veterinary

pathoanatomy, forensic veterinary practice, and in the preparation of expert opinions.

Conclusions

The study of two cases of death of domestic dogs due to gunshot wounds allowed systematising the key pathomorphological criteria necessary for an objective forensic veterinary assessment of animal cruelty. In both cases, the presence of multiple serious injuries caused by firearms was unquestioningly qualified as ill-treatment that led to the death of animals. Despite the different locations of the primary injury (abdominal cavity in Case No. 1; eyeball and central nervous system in Case No. 2), critical, life-threatening pathological processes developed in both situations. In particular, Case No. 1 illustrated the rapid development of haemorrhagic shock due to internal bleeding. Case No. 2 recorded neurological complications – fatal consequences of traumatic brain injury (haematomas, brain oedema), which caused irreversible changes in the central nervous system. The complex of detected histomorphological changes (pronounced necrodystrophic processes, haemodynamic disorders, and destruction of muscle fibres) indicated the presence of a gunshot wound. The characteristic localisation of gunpowder combustion products in the deep layers of the dermis and specific changes in the vascular bed were pathognomonic signs of the effects of concomitant factors of a firearm shot from close range (contact or near-contact shot). The identified criteria allowed differentiating this wound from injuries of other origin.

Based on a detailed pathoanatomical study in both cases, a direct causal relationship was clearly established between the action of the traumatic factor (shot) and the onset of death, which is a key criterion for qualifying a crime. Morphological features, such as ante-mortem tissue reactions, hyperaemia of the mucous membranes, organ anaemia, and obstruction of the respiratory tract by vomit, confirmed that the animals experienced intense pain and significant suffering shortly before death. The described cases emphasised the need for a comprehensive approach (including pathoanatomical and histological examination) to fix all injuries and determine the exact mechanism of death, which ensures the scientific validity of forensic veterinary examination. They demonstrated that a comprehensive approach is needed to objectively establish the truth in the forensic veterinary examination of gunshot wounds. A detailed study of all body systems allows not only stating the fact of injury, but also accurately establishing the pathophysiological chain of events that led to death, which is of key importance for forensic qualification of animal cruelty.

The prospects for further research are to expand the sample of forensic veterinary cases of gunshot wounds in domestic animals to clarify the spectrum of morphological variants of injuries and features of thanatogenesis, depending on the type of weapon, the distance of the shot, and the location of the injury. It is advisable to use in-depth histochemical, immunohistochemical, and molecular methods for objectifying the lifetime of injuries and temporal assessment of injuries, which will increase the evidentiary value of expert opinions in criminal proceedings related to animal cruelty.

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Conflict of Interest

None.

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Патоморфологічне дослідження трупів собак, які загинули внаслідок вогнепальних поранень

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Анотація. Актуальність дослідження зумовлена збільшенням частоти застосування вогнепальної зброї з ураженням тварин під час воєнних конфліктів. Як показує практика, більшість вогнепальних поранень – це випадки жорстокого поводження з тваринами. Саме тому, судово-ветеринарний експерт повинен правильно оцінити не лише вогнепальне поранення, але й обставини, пов'язані зі стрільбою. Метою цього дослідження було виявлення та з'ясування патоморфологічних змін, які виникають в органах і тканинах собак у зоні вогнепальної рани, при пострілі зі ствольової зброї. В рамках проведення судово-ветеринарної експертизи було здійснено патологоанатомічний розтин двох безпритульних собак, що загинули від вогнепальних поранень. Перший собака свійський за життя отримав наскрізне поранення органів черевної порожнини, причиною загибелі другого собаки стало сліпе поранення в голову. З'ясовано, що у тканинах вогнепальної рани переважали дистрофічні та некротичні зміни, а також розлади гемодинаміки. В скелетній м'язовій тканині реєстрували вогнищеві та дифузні крововиливи, які локалізувались між розшарованими м'язовими волокнами. Поряд із цим, відмічали вогнища геморагічної інфільтрації. В просвітах судин великого калібру виявляли масивне тромбоутворення, але основні зміни відмічали в мікроциркуляторному руслі. Патологічні зміни, які фіксували на тілах загиблих собак, відносилися до важких тілесних ушкоджень. Вони призводять до загрозливих для організму патологічних процесів і закінчуються загибеллю тварини. Отримані результати дають можливість поглибити знання судово-ветеринарних експертів із питань ураження тварин вогнепальною зброєю, а виявлені зміни можуть слугувати для диференціювання ран, спричинених дією такої зброї, від ран іншого генезу

Ключові слова: судово-ветеринарна експертиза; вхідне поранення; вихідне поранення; вогнепальна зброя; розтин