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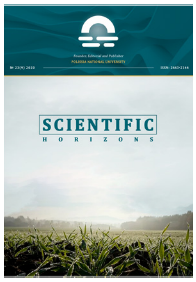

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Morphology, organo- and histometric features of the heart and lungs of a sexually mature domestic dog (*Canis Lupus Familiaris* L., 1758)

Leonid Horalskyi
Doctor of Veterinary Sciences, Professor
Zhytomyr Ivan Franko State University
10008, 40 V. Berdychivska Str., Zhytomyr, Ukraine
https://orcid.org/0000-0002-4251-614X

Ihor Sokulskyi*
PhD in Veterinary Sciences, Associate Professor
Polissia National University
10008, 7 Staryi Blvd., Zhytomyr, Ukraine
https://orcid.org/0000-0002-6237-0328

Maksym Ragulya
Postgraduate Student
Polissia National University
10008, 7 Staryi Blvd., Zhytomyr, Ukraine
https://orcid.org/0000-0003-2945-9651

Nataliia Kolesnik
PhD in Veterinary Sciences, Associate Professor
Polissia National University
10008, 7 Staryi Blvd., Zhytomyr, Ukraine
https://orcid.org/0000-0001-7741-8753

Yuriy Ordin
PhD in Veterinary Sciences, Associate Professor
Bila Tserkva National Agrarian University
09117, 8/1 Soborna Sq., Bila Tserkva, Ukraine
https://orcid.org/0000-0002-8547-5608

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Abstract. The cardiovascular system and respiratory organs in animals are interconnected, they perform extremely important functions for the vital activity of the organism, the main of which is gas exchange. Therefore, the study of the cardiovascular system and respiratory organs is an urgent issue of the present. The aim of the study was to morphologically evaluate the macro- and histological structures of the heart and lungs of the domestic dog. Comprehensive morphological methods of research were used: histological, anatomical, organ, histo-, cytometric, and statistical, which provided new

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**Corresponding author*

data on the peculiarities of macro-, histo-, and cytomorphometric characteristics of the morphological structures of the heart and lungs. The dog heart has a rounded shape, its absolute weight is 167.58±9.46 g (without epicardial fat – 154.22±8.04 g), relative weight – 0.72±0.005%. It was found that cardiomyocytes of the left ventricle had the largest volume, the right ventricle – the smallest, and atrial cardiomyocytes – the smallest. At the same time, the nuclear-cytoplasmic ratio of cardiomyocytes of the left ventricle is 0.0224±0.0076, the cardiomyocytes of the right ventricle have a greater value – 0.0275±0.0081 and the atrial cardiomyocytes have the highest value – 0.0367±0.0105. Such ambiguous cytometric parameters of cardiomyocytes are associated with the morphological and functional activity of the myocardial ventricular muscle tissue and its functional features inherent in spontaneous and rhythmic contractions, which result in blood flow through a closed system of vessels. The absolute weight of the domestic dog's lungs is 201.3±18.4 g, the relative weight is 1.21±0.14%, the ratio of the absolute weight of the left to the right lung is 1:1.33. According to the asymmetry coefficient (1.37:1), the lungs of dogs are of the narrowed-elongated type. The connective tissue stroma of the lungs occupies 59.62±3.4%, the respiratory part – 40.38±2.6%. The data on the morphology of the heart and lungs of the domestic dog, including the results of the study of the macro- and microscopic structure of the organs under investigation, which are presented in the publication, are of great importance for histology and comparative anatomy, and also make a significant contribution to clinical veterinary medicine

Keywords: comparative anatomy; histostructure of organs; cytometric parameters; cardiomyocytes; myofibrils; bronchial tree; alveolar tree

INTRODUCTION

The cardiovascular system and respiratory apparatus in mammals perform vital functions, ensuring the vital activity of the animal and human body. They are among the first to respond to various natural and anthropogenic environmental factors and to physical activity. These are phylogenetically interconnected organs whose morphological and functional activities are closely interconnected with the environment, thus forming a single "morphological and functional complex": organism (organ system) ↔ environment) (Sarah *et al.,* 2020). The main function of such a complex, multifunctional "complex" is to ensure gas exchange in the human and animal body through the process of inhaling air from the environment and excretion of CO_2 already formed in the body. At the same time, the response of the mammalian body to environmental factors occurs during the normal functioning of all its organs and systems, including the cardiovascular system, respiratory system and nervous system, which transforms them into a single whole. Therefore, an important priority area in veterinary medicine to prevent the emergence and spread of diseases of various geneses is the prevention of contagious and non-contagious pathologies, which, along with organizational and preventive measures, requires in-depth fundamental morphological studies of the animal body, its macro- and microscopic structure, including the cardiovascular system and respiratory organs.

The assessment of the functional state of the respiratory and cardiovascular systems is of great importance in clinical practice. Knowledge of respiratory and cardiac function is important for making a diagnosis, determining the severity of the disease, and choosing an effective treatment. According to B. Bi & G. Zhang (2021), in the process of mammalian phylogenetic development, a morphological and functional pattern of continuous combination and interdependence of all anatomical structures and their functions has historically been formed, especially between the respiratory system and the cardiovascular system, which exchanges gases between the environment and the blood of the animal body. It is this close relationship, formed in mammals in the course of their evolutionary development, between the structure and functions of the cardiovascular system (its closed system of large and small blood vessels) and the respiratory organs (their unique structure of the aerogeometric barrier of the lung alveoli), which are coordinated by the nervous system, that ensures the joint vital function of gas exchange (respiration) in the animal body with the external environment, as evidenced by the work of O. Voloshyn *et al.* (2020). At the same time, despite the implementation of preventive measures against diseases of the cardiovascular and respiratory systems in animals, according to S. Manickavel (2021), there is a significant increase in the number of diseases of these organ systems of various aetiologies. According to M. Günthel *et al.* (2018), prevention, diagnosis, surgery, and treatment of these pathologies are impossible without knowledge of the morphological and functional parameters of anatomy, histology, and physiology.

According to N. Cesarovic *et al.* (2020), the cardiovascular system, with the heart as its central organ, is extremely important in the physiological regulation of all body systems. Thus, according to studies by G. Liu & R. Summer (2019), it is the dominant system in providing respiratory, trophic and excretory functions, which ensures metabolism. Due to this structure of the cardiovascular system, it forms an important and basic link in the large (somatic) and small (pulmonary) circulation. According to I. Vyshnyvetskyy *et al.* (2017), oxygen, hormones, and nutrients are delivered to the tissues of the body throughout the body, and metabolic products are removed from the body. From the point of view of mechanics, according to the research of O. Shemla *et al.* (2021), the heart can be considered as a mechanism consisting of two discharge pumps formed into a closed system of tubes through which fluid (blood) circulates. In this case, the pumps serve to create a directed flow of blood in the appropriate direction. The heart itself, according to R. Storlund *et al.* (2021), is a muscular hollow organ and is topographically and functionally the central organ of the cardiovascular system, ensuring blood circulation.

Scientists R. Berg *et al.* (2022) noted that the functioning of the respiratory system is assessed through two homeostatic mechanisms: metabolic and conditioning. The first mechanism of regulation depends on the ambient temperature and is provided through the neuroendocrine apparatus of the body. Cutaneous and tracheobronchial receptors activate the adrenal glands and thyroid gland, and contribute to the synthesis of biologically active substances. This leads to changes in haemodynamics involving the large vascular field of the tracheobronchial tree, which results in changes in the haemodynamics of the small circulation.

Thus, according to A.F. Butkiewicz *et al.* (2022), the respiratory organs, which include the lungs, perform the main vital functions in the mammalian body, the most important of which is pulmonary respiration, which is characteristic of almost all terrestrial vertebrates, especially animals of the Mammalia class. Such respiration is the most perfect way of gas exchange between the animal organism and the environment, in contrast to diffuse, gill, and tracheal respiration, which are characteristic of poikilothermic organisms in most cases. In the respiratory department of the lungs, which includes respiratory bronchi, alveolar passages, alveolar sacs – structures containing alveoli, according to L. Cadiz & M. Jonz (2020), gases are exchanged between air and blood through the wall of the alveoli and the wall of capillaries.

Therefore, the purpose of the study was to determine the morphological structure of the heart and lungs at the macro- and microscopic levels, which will serve as markers and criteria for the morphological diagnosis of animal diseases associated with disorders of the cardiovascular and respiratory systems.

MATERIALS AND METHODS

Scientific research was carried out on the basis of the Laboratory of Pathomorphology at the Department of Normal and Pathological Morphology, Hygiene and Forensics, Polissya National University, Zhytomyr, during 2019-2023. The scientific work is a fragment of the department's development: "Development, morphology and histochemistry of animal organs in normal and pathological conditions" under the registration number 0113V000900.

Morphological, morphometric and statistical methods were used in the study. The object of the study was the heart and lungs of mature dogs (n=5), class – Mammalia, species – wolf (*Canis lupus*), subspecies – domestic dog (*Canis familiaris*). The lungs and hearts of experimental animals were used for anatomical dissection. For the morphological study, their absolute and relative weights were determined. The absolute mass (AM) of the heart and lungs was determined by weighing them on a laboratory balance (RADWAG PS 6000/C/2, Poland). Relative mass (RM) was determined by the formula:

$$\mathrm{BM} = \frac{\mathrm{AM}}{\mathrm{MA}} * 100, \quad (1)$$

where, AM is the absolute mass of organs; MA is the mass of the animal.

Determination of linear parameters of the studied organs (height, width, thickness, and circumference) was carried out by direct measurement. The development index (DI) of organs was determined by the ratio of their total height to width using the following formula:

$$\mathrm{DI} = \frac{\mathrm{HO}}{\mathrm{WO}} * 100, \quad (2)$$

where HO is the height of the organ; WO is the width of the organ.

For microscopic examination of the heart and lungs, the pieces of material made from them were fixed in a 10-12% chilled aqueous formalin solution for 24 hours or more. After fixation, the pieces of material were embedded in paraffin according to the schemes proposed in the methods of Manual L. Horalskyi *et al.* (2015). Sections, 10-12 μm thick, were made on a microtome, type MS-2.

To study the cyto- and histoarchitectonics of the heart and lungs, histological sections (after deparaffinisation) were stained with haematoxylin (Diapath, Italy, 2021) and eosin (Leica Geosystems, Germany, 2020). In addition, for microscopic examination (visualization of elements) of transverse striated myocardial muscle tissue, detection of cardiomyocyte cytostructure, staining of histological specimens by the Heidenhain method was used. The prepared histopreparations were used to study the main structures that make up the lungs and heart and for histological and cytometric studies.

Histometric characteristics: determination of the respiratory part and connective tissue base of the lungs (per unit area equal to 5.0 mm2); average alveolar volume; length and width (diameter) of cardiomyocytes; volume of cardiomyocyte nuclei, was performed by light microscopy using Micros microscopes (Micros, Austria, 2012) with an imaging system and MBS-10 (Micromed, China, 1998), according to the recommendations provided in the manual (Horalskyi *et al.,* 2015).

The volume of myocardial cells (cardiomyocytes) was determined by the following calculations:

$$V = \pi * \left(\frac{B}{2}\right)^2 * \mathrm{A}, \quad (3)$$

where *V* is the volume of the cardiomyocyte; π – 3.14; A – cardiomyocyte length; B is the width of the cardiomyocyte.

To determine the volume of nuclei cardiomyocytes, the following formula was used:

$$V = \frac{\pi}{6} * \mathrm{A} * \mathrm{B}^2, \quad (4)$$

where V is the volume of the cardiomyocyte; π – 3.14; A is the length of the nuclei cardiomyocyte; B is the width of the nuclei cardiomyocyte. The nuclear-cytoplasmic ratio (NCR) was determined by the formula:

$$NCR = \frac{The\ volume\ of\ the\ nuclei}{The\ volume\ of\ cells - The\ volume\ of\ the\ nuclei}. \quad (5)$$

Photographs of histological specimens were taken using a CAM V-200 video camera (Inter Med, China, 2017). Anatomical and histological terms of the heart and lung structures are given in accordance with the International Veterinary Histological and Anatomical Nomenclature (Terminology Dictionary) (Khomych, 2019). The statistical data of the results of quantitative studies were performed using the Statistica 7.0 software package (StatSoft, Tulsa, USA). The difference between the digital data of the studied indicators was carried out using ANOVA, where the difference was considered statistically significant at p<0.05.

All experimental studies were conducted in accordance with modern methodological approaches and in compliance with relevant requirements and standards, in particular, they meet the requirements of DSTU ISO/IEC 17025:2005 (2006). The study animals were kept and all manipulations (methods of morphological studies) were carried out in accordance with the provisions of the "Procedure for conducting experiments and experiments on animals by scientific institutions" (Law of Ukraine No. 249, 2012), the "European Convention for the Protection of Vertebrate Animals Used for Experimental and Other Scientific Purposes" (1986).

RESULTS AND DISCUSSION

The heart in dogs is located in the thoracic cavity between the lungs and occupies the space from the 3rd to the 7th rib and is slightly displaced to the left. The base of the heart is located in the plane of the middle of the first rib of the thorax, and its apex has a projection at the level of the 6th-7th ribs. The aorta comes out of the left ventricle of the heart, behind the pulmonary trunk. As it travels dorsally to the spine, it makes an arc at the level of the 11th thoracic vertebra.

Externally, the epicardium of the heart is smooth, moist, shiny, white-grey in colour, transparent, without any layers, and a small amount of white-grey fat is noted. The heart myocardium is of elastic consistency, pale red on the surface and in the section, the fibre pattern is well-defined. It should be noted that the heart has different shapes in mammals (Emam & Abugherin, 2020). In predators, the dominant shape is spherical or cone-ellipsoidal. According to the literature, dogs, depending on their breed characteristics, have different heart shapes: spherical (7%), ellipse-elliptic (26%), cone-elliptic (24%), and most often ellipsoidal (43%) (Gómez-Torres *et al.,* 2021). The heart of mammals, including dogs, is divided into four chambers by partitions: the left and right atria, left and right ventricles. According to the results of research, the right ventricle has a thicker wall than the atrium, but less thin than the left ventricle. The difference in wall thickness between the right and left ventricles is approximately 2.4 times.

The canine heart has a dilated base directed dorsocranially and a narrowed apex directed ventrocaudally (Figs. 1, 2). The heart cavity is divided into left and right halves by an internal septum. The latter are divided into atria and ventricles. Each right and left atrium with their respective ventricles are connected to each other by the atrial-ventricular opening. The atria are located at the base of the heart. They are separated from the ventricles of the heart by a transverse coronary groove. The atria at the base of the heart are formed by the right and left heart ears (sac-like protrusions), which are cranial in direction and located on the right and left, relative to the trunk of the pulmonary arteries and aorta. The right and left ventricles of the heart occupy the main part of the organ. Externally, they are separated by interventricular grooves — the near-cone groove, which is located more cranially, and the sub-axillary groove, which is located caudally. These furrows are interconnected on the anterior (cranial) part of the heart, not reaching the apex, and separate the left ventricle from the right ventricle, respectively.

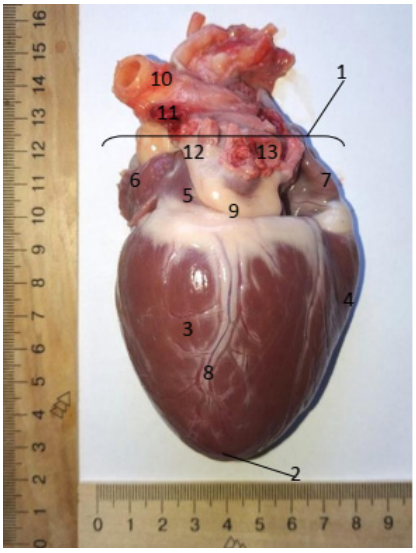

Figure 1. *Macroscopic structure of the heart of a sexually mature dog (right side)*
Notes: *1 – heart base; 2 – apex of the heart; 3 – right ventricle; 4 – left ventricle; 5 – right atrium; 6 – right auricle; 7 – left atrium; 8 – axillary interventricular groove; 9 – subepicardial fat; 10 – aorta; 11 – trunk of pulmonary arteries; 12 – cranial vena cava; 13 – caudal vena cava. Photo from macropreparation*
Source: *photo of the authors*

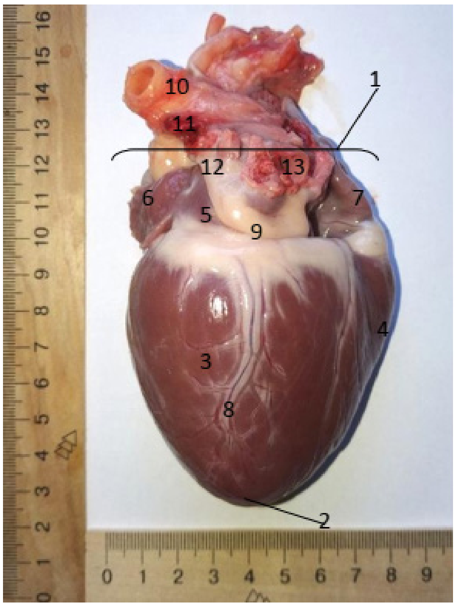

Figure 2. *Macroscopic structure of the heart of a sexually mature dog (left side)*
Notes: *1 – heart base; 2 – apex of the heart; 3 – right ventricle; 4 – left ventricle; 5 – left atrium; 6 – left auricle; 7 – right auricle; 8 – semi-conical interventricular groove; 9 – subepicardial fat; 10 – blood vessels; 11 – pulmonary veins; 12 — aorta. Photo from macropreparation*
Source: *photo of the authors*

Studies have been published that show that the absolute heart weight depends on the breed and age of dogs, and in relation to body weight ranges from 0.76 to 1.2% (Brambilla *et al.*, 2020). According to the results of the studies, the absolute heart weight is 167.58±9.46 g, and the RM is 0.72±0.005%. According to L. Queiroz *et al.* (2018), the relative heart weight in dogs ranges from 0.6 to 1.1% of the animal's body weight. Perhaps such ambiguous parameters are due to the breed properties of animals. The ratio of muscle thickness of the left and right ventricles was not the same, the left ventricle was 1.6 times thicker than the right, which is almost the same as in our studies.

The net weight of the heart (without epicardial fat) in the dog is 154.22±8.04 g. The height of the heart is 11.09±0.04 cm, the width is 7.6±0.02 cm, and the circumference is 17.7±0.08 cm. Comparing the morphometric data of A. Best *et al.* (2022) and the analysis of morphological measurements, the heart of the studied mature dogs is more often rounded (ellipsoidal) in shape (Figs. 1, 2).

According to the results of morphometric studies, the weight of the dog's LV heart is 76.24±1.02 g, the weight of the right ventricle is 43.59±0.62 g. The average weight of the right and left ventricles is 120.26±1.98 g, and the weight of the atria is 33.77±0.48 g. At the same time, the ratio of the mass of the ventricles (right and left) of the heart to the net mass is 1:0.78, respectively, the ratio of the mass of the atria (right and left) to the net mass of the heart is 1:0.22, and the ratio of the mass of the atria to the mass of the ventricles is 1:0.28. The wall thickness of the heart ventricles, depending on their morphological and functional activity, is different: the wall thickness of the left ventricle (15.92±0.34 mm) is 1.52 times ($p \leq 0.01$) greater (10.47±0.11 mm) than that of the right ventricle. Atrial wall thickness was 4.01±0.02 mm.

The wall of the dog's heart, as in other domestic mammals, is formed by 3 membranes: endocardium, myocardium and epicardium, of which the muscular membrane is the most developed. The atrial myocardium consists of two layers – outer (common to both atria) and deep. The middle shell of the ventricles (myocardium) is formed by 5 layers: the outer and inner layers, in which the muscle fibres are located in an oblique longitudinal direction, then deeper layers — the outer and inner layers and the deepest layer, whose muscle fibres have a direction similar to the letter "eight". Due to this structure of the myocardial ventricles and their functional activity, their walls are much thicker than the atrial walls.

The histoarchitecture of the myocardium is built by transversely striated muscle fibres, which form unicellular cells – cardiomyocytes. When histological sections are stained using the Heidenhain method, their cytostructure looks like dark transverse, rectangular stripes (Figs. 3, 4). The sarcolemma, myofibrils, and nuclei located in the centre of cardiomyocytes are differentiated.

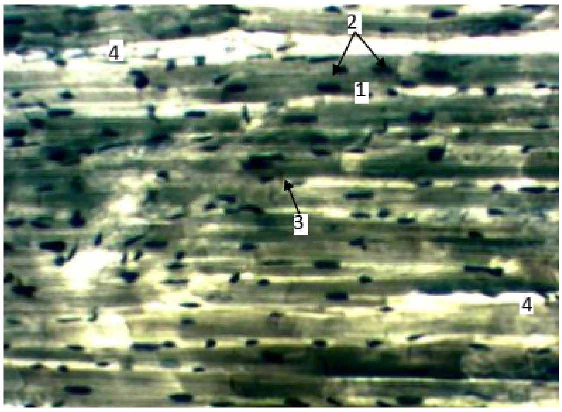

Figure 3. *Histological section of the myocardium of the left ventricle of the heart of a sexually mature dog*
Notes: *1 – cardiomyocyte cells; 2 – nuclei of cardiomyocyte cells; 3 – insert disk; 4 – intermuscular connective tissue; Dyeing according to the Heidenhain method. ×280*
Source: *photo of the authors*

The assessment of changes in the quantitative morphometric parameters of each organ in any of its pathologies should start from a certain point of reference. This starting point is the concept of "normal". However, there are various quantitative variants of the parameters of an unchanged heart, depending on genetic, constitutional factors, physical activity, etc. Therefore, the concept of "normal heart" is rather conditional. According to S.M. Bilash *et al.* (2019), morphologists should use their own quantitative parameters of the heart, taking into account age-related changes. Mathematical analysis of the structures of morphological objects, which has gained recognition as a method that is distinguished by objectivity and reliability, is of great importance in morphology to determine the structure, shape, size of organs and systems, the ratio of their specific structural features (Hryhorieva & Cherniavskyi, 2018).

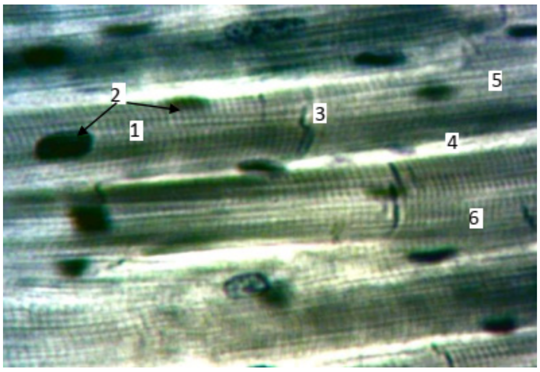

Figure 4. *Histological section of the myocardium of the left ventricle of the heart of a sexually mature dog:*
Notes: *1 – cardiomyocyte cells; 2 – nuclei of cardiomyocyte cells; 3 – insert disk; 4 – intermuscular connective tissue; 5 – longitudinal striation; 6 – transverse striation; Dyeing according to the Heidenhain method. ×600*
Source: *photo of the authors*

According to the results of morphometric studies, cardiomyocytes of the left (LV) and right ventricles (RV), atrial cardiomyocytes, depending on their morphotopography, and hence on their functional load, have ambiguous cytometric parameters. Morphometric analysis shows that the quantitative parameters of cardiomyocytes of the left ventricle of the dog heart are significantly higher than those of the right ventricle. Thus, the length and width of LV cardiomyocytes are 1.1 times greater than those of the right ventricle and are equal to 46.06±1.12 μm (length) and 9.02±0.39 μm (width), respectively.

Similar changes were found in the morphometric study of cardiomyocyte volumes: the largest volume of cardiomyocytes was determined in the LV (2941.76±127.44 μm^3), in the right ventricle this indicator was significantly ($p \leqslant 0.05$) less by 1.31 times and was equal to 2237.24±103.02 μm^3. Similar results of morphometric parameters were found when determining the volume of cardiomyocyte nuclei: the average volume of the nucleus of cardiomyocytes of the left ventricle was 64.58±5.09 μm^3, of the right ventricle – 59.97±5.83 μm^3. According to such ambiguous quantitative cytometric characteristics of cardiomyocytes for the ventricles of the dog heart, they formed different NCR: the lowest such indicator was characteristic of LV cardiomyocytes (0.0224±0.0076), the highest for RV cardiomyocytes (0.0275±0.0081), which indicated their morphological and functional load. According to S.C. Orozco *et al.* (2019) and the results of our own studies, this is an objective reality, since the LV functions mainly as a pump, and the RV functions as a volume pump.

Therefore, an increase in the morphometric parameters of cardiomyocytes of the left ventricle myocardium, compared to the right ventricle, correlates with the morphological and functional load of myocardial muscle tissue, namely, the consequence of rhythmic contractions of cardiomyocytes of the heart, promoting blood flow through a closed circle of vessels. At the same time, LV cardiomyocytes perform a higher load, contributing to the movement of blood through a large circle of blood circulation; RV cardiomyocytes perform a lower load, contributing to the movement of blood through the vessels of a small circle of blood circulation.

Significantly lower cytometric parameters (length and width), cardiomyocyte volume, and nuclei volume were characteristic of atrial cardiomyocytes, and thus, such cardiomyocytes had the highest nuclear-cytoplasmic ratio (0.0367±0.0105) (Table 1). The results indicate that such an increase in the nuclear-cytoplasmic index of atrial cardiomyocytes, relative to the ventricles, indicated a lower morphological and functional load, since more functionally mature and active cells are those characterized by a low nuclear-cytoplasmic ratio and, conversely, cells with a high nuclear-cytoplasmic ratio are less functionally active (Horalskyi *et al.*, 2022). Such ambiguous morphometric parameters of cardiomyocytes of the left and right ventricles and atria are associated with morphological and functional features of the heart. In this case, the right and left atria receive blood that returns to the heart from the body, performing a lower load, and the ventricles (left and right) pump blood from the heart to the body of animals, performing a much higher load.

Table 1. *Histometry cardiomyocytes of the heart of a sexually mature dog, (M±m, n=5)*

Indexes	Length cardiomyocytes (μm)	Width of cardiomyocytes (μm)	Volume cardiomyocytes (μm^3)	Volume nuclei cardiomyocytes (μm^3)	Nuclear-cytoplasmic relationship
Left ventricle	46.06±1.12	9.02±0.39	2941.7 ±127.44	64.58±5.09	0.0224±0.0076
Right ventricle	41.47±1.24	8.29±0.42	2237.24±103.02*	59.97±5.83	0.0275±0.0081*
Auricle	39.06±1.35*	7.19±0.49*	1496.92±98.02**	53.06± 6.02*	0.0367±0.0105**

Note: ** $p \leqslant 0.05$; ** $p \leqslant 0.01$; *** $p \leqslant 0.001$ in relation to the left*
Source: *developed by the authors*

The lungs of mature dogs have a similar structure and morphotopography to those of domestic mammals (Zamorska & Grushanska, 2022). Thus, the left and right lungs of dogs are divided into lobes (cranial, middle, caudal) by deep notches on the ventral side. The right lung has an additional lobe. At the same time, in comparison with other domestic animals, the lobes of the lungs of the dog have distinct deep interlobar notches that pass through the dorsal margin and reach almost to the main bronchus. The pattern on the lung surface is smoothed (Fig. 5).

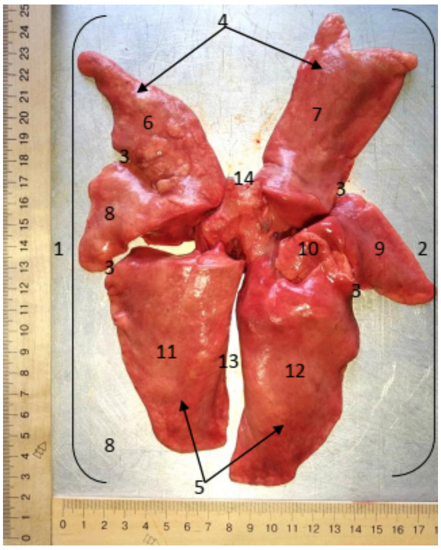

Figure 5. *Anatomical structure of the lungs of a sexually mature dog (costal surface)*
Notes: *1 – left lung; 2 – right lung; 3 – deep cuts; 4 – top of the lung; 5 – the base of the lung; 6 – left cranial lobe; 7 – right cranial lobe; 8 – left middle (cardiac) lobe; 9 – right middle (cardiac) lobe; 10 – additional share; 11 – left caudal lobe; 12 – right caudal lobe; 13 – interlobular slits; 14 fragment of tracheal bifurcation; Photo from macropreparation*
Source: *photo of the authors*

The middle lobe of the left lung in dogs caudally overlaps the cranial lobe, and at the blunt (dorsal) edge, these parts merge with each other (there is no separation between the lobes). The caudal lobe of the left lung in dogs is compact and has an irregular pyramidal shape. The cranial lobe of the right lung in dogs is almost completely separated from the other lobes by the cranial interlaminar gap. The cranial contour of the cranial lobe is rounded. The middle lobe is located between the cranial and caudal lobes, not reaching the dorsal edge of the lung. The ventral end of this lobe is pointed. The directed cranial margin of the middle lobe forms the cardiac notch together with the directed caudal sharp margin of the cranial lobe. The caudal lobe of the right lung is similar in shape to the caudal lobe of the left lung. On its surface, which borders on the diaphragm, an uneven depression is found medially due to the adjacent accessory lobe. The accessory lobe of the right lung is different in shape from the other lobes: its middle part is relatively thicker and has three processes directed dorsally, ventrally and laterally. The accessory lobe of the right lung of dogs is fused to the medial surface of the caudal lobe.

The peculiarity of the anatomical structure of the canine lung is that the interlobular gaps dividing the lung into lobes are deep and reach the main bronchus. Lung lobes are not connected to each other by parenchyma, except for the cranial and middle lobes of the left lung, where they are connected to each other in the dorsal part (Fig. 5). Morphometric studies of organs and systems in clinically healthy humans and animals are important for their assessment at the cellular, tissue and organ levels, which are criteria for the diagnosis of diseases of contagious and non-contagious pathology (Hosapatna *et al.*, 2022).

According to the results of morphometric studies, the total length of the dog's lungs is 23.0±2.42 cm, width 16.7±1.34, and thickness 1.9±0.36 cm. The right lung was 22.9±2.18 cm long, 8.1±0.62 cm wide, and 1.8±0.11 cm thick. The left lung was 20.2±2.44 cm long, 7.6±0.54 cm wide, and 1.5±0.09 cm thick. The ratio of the average lung length to lung width in dogs is 1.37:1, so the lungs in dogs are of the narrowed-elongated type. The AM of the lungs of dogs is 201.3±18.4 g, the relative weight is 1.21±0.14%. At the same time, the absolute weight of the left lung in dogs is 86.26±8.01 g, and the right 115.04±10.14 g, their ratio in mature clinically healthy dogs, according to the results of organometry, is 1:1.33 (Table 2).

Table 2. *Absolute and relative mass of lung lobes of a sexually mature dog, (M±m, n=5)*

Particles lungs	Left lung		Right lung		Both lungs	
	AM (g)	RM (%)	AM (g)	RM (%)	AM (g)	RM (%)
Cranial	22.09±3.01	10.97±0.96	27.29±3.21*	13.56±0.92	49.38±6.34	24.52±1.52
average	19.91±2.84	9.89±0.64	23.65±2.96	11.75±1.14	43.56±5.87	21.64±2.03
Caudal	44.26±6.02	21.98±1.82	47.96±6.38	23.83±1.82	92.22±8.76	45.81±5.38
Additional	–	–	16.14±2.08	8.02±0.48	16.14±2.08	8.02±0.48
Total:	86.26±8.01	42.84±6.04	115.04±10.14*	57.16±8.02	201.3±18.4	100

Note: ** p⩽0.05; ** p⩽0.01; *** p⩽0.001 in relation to the left lobe*
Source: *developed by the authors*

At the same time, the absolute weight of the cranial lobe of the left lung is on average 22.09±3.01 g, and the cranial lobe of the right lung is 27.29±3.21 g. The absolute weight of the middle lobe of the left lung averaged 19.91±2.84 g, and the right lobe – 23.65±2.96 g. The absolute weight of the left lung caudal lobe is 44.26±6.02 g, and the absolute weight of the right lung caudal lobe is 47.96±6.38 g. The absolute weight of the additional lobe of the right lung was 16.14±2.08 g (Table 2). Thus, the results of organometric studies indicate that in dogs, the most developed are the caudal lobes of the right and left lungs, followed by the cranial and middle lobes (Table 2).

The relative weight of the cranial lobe to the absolute weight of both (right and left) lungs in dogs averages 10.97±0.96% in the left lung and 13.56±0.92% in the right lung. The relative weight of the middle lobe in relation to the absolute weight of the lungs in the left lung is 9.89±0.64%, in the right lung, respectively, 11.75±1.14%. The average volume of the caudal lobe in both lungs was 21.98±1.82% in the left lung and 23.83±1.82% in the right lung. The relative weight of the additional lobe, respectively, is 8.02±0.48% (Table 2).

The lungs are formed by branches of the bronchi (bronchial tree), which have different sizes and branches of the respiratory department (alveolar tree). Such branches of the alveolar tree are usually accompanied by blood vessels, nerves and delicate layers of loose connective tissue. Haematoxylin and eosin staining of histological specimens reveals a significant amount of collagen and elastic fibres in the connective tissue, which are red and clearly differentiated in the lung tissue section. The bronchi are divided into extrapulmonary (main and interlaminar) and pulmonary bronchi, which are part of the lungs, where they branch out to form the bronchial tree. The lobular bronchi are branched off by segmental bronchi of different sizes. They are divided into dorsal and ventral segmental bronchi depending on the direction.

To date, it has been proven that the structure of the bronchial tree in animals corresponds to the location of the lobes of the lungs. It is known that the lobular bronchi of the right and left lungs are not developed equally. In the studies of A.F. Butkiewicz *et al.* (2022), it was noted that the pig lungs have dorsal, ventral, medial, and lateral bronchiolar systems on both sides. In addition, the tracheal bronchiole (bronchus) arises from the right side of the trachea. According to the bronchial branching, the right lung consists of cranial, middle, caudal and accessory lobes, and the left lung consists of bilobed middle and caudal lobes. The branching of the lung bronchi in dogs is as follows: the trachea branches into two main bronchi at the bifurcation (Fig. 6). The main bronchi enter the lungs, giving rise to the lobar bronchi. The anatomical structure of the main and lobar bronchi is similar to that of the trachea. However, the right main bronchus has a larger diameter than the left one.

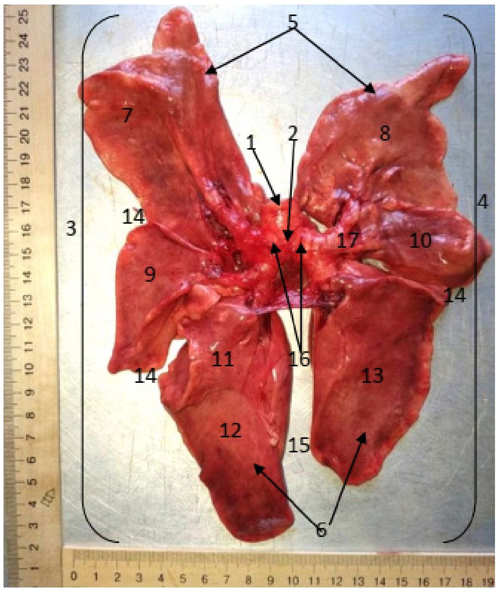

Figure 6. *Anatomical structure of the lungs of a sexually mature dog (mediastinal surface)*

Notes: *1 – trachea; 2 – bifurcations of the trachea; 3 – right lung; 4 – left lung; 5 – top of the lung; 6 – the base of the lung; 7 – right cranial lobe; 8 – left cranial lobe; 9 – right middle (cardiac) lobe; 10 – left middle (cardiac) lobe; 11 – additional share; 12 – right caudal lobe; 13 – left caudal lobe; 14 – deep cuts; 15 – interlobular gap; 16 – main right and left bronchus; 17 – branching of the bronchi of the left lung; Photo from macropreparation*

Source: *photo of the authors*

In the area where the trachea divides into two main bronchi (bifurcation), the latter form an angle of 65°-70°. At the same time, the left main bronchus deviates more strongly from the tracheal axis, forming an angle of 45°-50° with it (Fig. 6). Both main bronchi branch first cardio-laterally, then caudally and are directed to the caudal lobes, forming their bronchi. Branching in each lung of the main bronchus into large, then medium, small bronchi, terminal bronchioles, occurs at the base of their blunt edges, where they go caudally, forming a bronchial tree. At the same time, the largest branches of the main bronchus branch and, one branch at a time, go to the cranial, middle, caudal and additional lobes – only for the right lung. Thus, directly after the bifurcation, the right cranial lobar bronchus branches off from the right main bronchus at almost right angles. Immediately afterwards, the middle lobar bronchus extends ventro-laterally. The next branch is the ventro-medial bronchus of the accessory lobe.

From the left main bronchus, the left cranial bronchus for the cranial lobe branches cranially. After the branching of this bronchus, the left main bronchus continues as a bronchus (caudal bronchus) for the left caudal lobe of the lungs. The large bronchus of the caudal lobe gives eight (four dorsal and four ventral) branches to its parenchyma in each lung. The smallest intralobular bronchi enter the lung lobes, where they branch into terminal bronchioles, which branch into respiratory bronchioles, then alveolar ducts and alveolar sacs, thus forming the alveolar tree (Fig. 7).

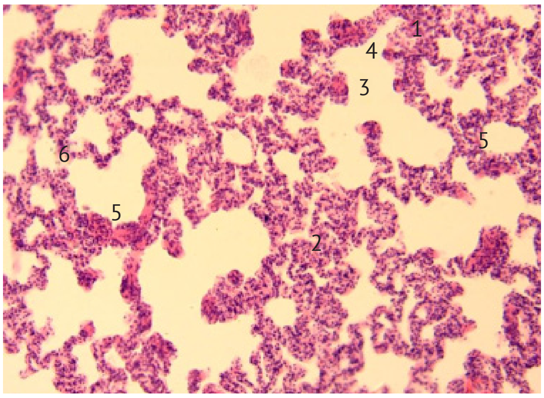

Figure 7. *Histological section of the lung tissue of a sexually mature dog*

Notes: *1 – respiratory part of lung tissue; 2 – connective tissue; 3 – alveolar course; 4 – alveolar sac; 5 – alveoli; 6 – interalveolar partitions; Haematoxylin and eosin staining. ×280*

Source: *photo of the authors*

The bronchial tree is the airways of the lungs, which are microscopically formed by bronchi of different calibre (main bronchi, large, medium, and small), which vary in diameter and structure along the direction of the bronchial tree. Thus, the histoarchitectonics of the wall of bronchi, especially large ones, is similar to the wall of the trachea, which is formed by the inner – mucous, middle – fibrous -cartilaginous, and outer – adventitia membranes (Fig. 8).

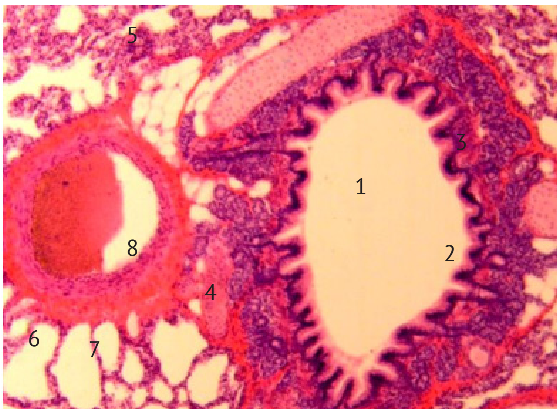

Figure 8. *Histological section of the lung tissue of a sexually mature dog*

Notes: *1 – lumen of a large bronchus; 2 – epithelial plate; 3 – muscle plate; 4 – cartilage plates; 5 – connective tissue stroma; 6 – alveoli; 7 – interalveolar septa; 8 – vessel; Haematoxylin and eosin staining. ×280*

Source: *photo of the authors*

In the large bronchi, the cartilage rings of the fibrous -cartilaginous membrane are represented by separate, clearly defined cartilage plates (Fig. 8), and the middle shell of the middle bronchi contains cartilage plates that occur in groups in the form of separate cartilage islands (Fig. 9). The wall of the small bronchi is formed only by the mucous membrane and adventitia. There are no cartilage plates in the wall of the small bronchi.

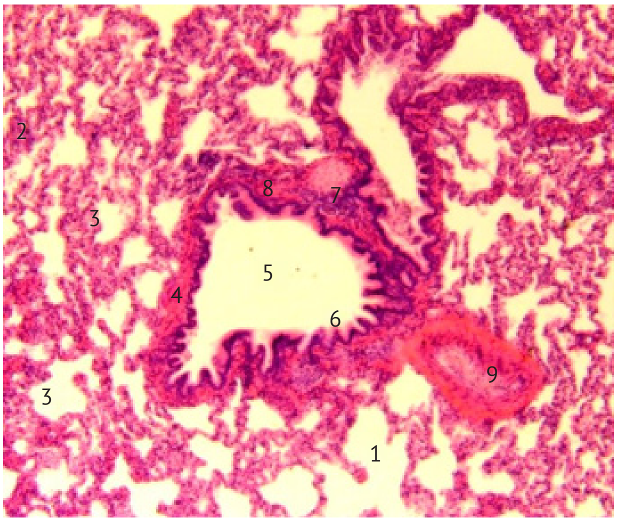

Figure 9. *Histological section of the lung tissue of a sexually mature dog*

Notes: *1 – respiratory part; 2 – connective tissue stroma; 3 – alveoli; 4 – middle bronchus; 5 – lumen of the middle bronchus; 6 – internal mucous membrane; 7 – cartilage plates in the form of cartilage islands; 8 – muscle plate; 9 – vessel; Haematoxylin and eosin staining. ×280*

Source: *photo of the authors*

The histoarchitectonics of dog lungs is formed by pulmonary lobules. The latter have a pyramidal or conical shape. The lobules include pulmonary acini, which are formed by respiratory bronchioles, alveolar ducts, alveolar sacs, and alveoli. In dogs, unlike other domestic animals, terminal bronchioles are generally poorly developed. Each terminal bronchiole is joined by several respiratory bronchioles, which are well-developed in dogs. Their wall is lined with a single-layer prismatic epithelium. The wall of the alveoli is lined with a single-layer flat epithelium (alveolocytes), which include respiratory and secretory cells and alveolar macrophages. Interalveolar membranes of alveoli are formed by layers of loose connective tissue. According to the results of histometry, the average volume of lung alveoli of sexually mature dogs is 58.9±6.26 thousand μm^3.

The respiratory part of the lungs in adult animals occupies 40.38±2.6%, the connective tissue base, respectively, 59.62±3.4% (Fig. 10).

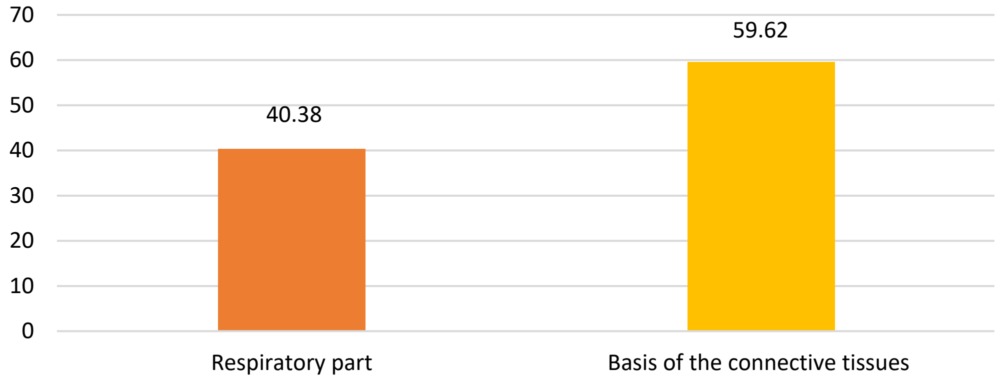

Figure 10. *The area of the histostructure of the lungs of a sexually mature dog*
Source: *developed by the authors*

Thus, the cardiovascular system and respiratory organs are interconnected and perform extremely important functions in the body for the vital activity of the organism. Their main function is gas exchange, through inhalation of air from the environment and excretion of carbon dioxide formed in the body of humans and animals. Gas exchange in the body directly occurs in the lungs, between air and blood by diffusion of O_2 and CO_2 through the walls of the pulmonary alveoli into the blood capillaries (Voloshyn *et al.,* 2020). Studies in this area have shown that the morphological structure of the heart and lungs in clinically healthy dogs has a similar morphoarchitectonics to that of other species of mammals, but differs in morphometric parameters.

Thus, depending on the morphofunctional load, the largest morphometric parameters (cardiomyocyte volume, volume of their nuclei) are characteristic of cardiomyocytes of the left and right ventricles, in which the NRC is the smallest (respectively, 0.0224±0.0076 and 0.0275±0.0081), compared to the NRC of atrial cardiomyocytes (0.0367±0.0105), indicating their morphological and functional activity (the most functionally mature cells are those with a low NRC index and, conversely, cells with a high NRC are less active). Depending on the type of respiration characteristic of dogs, their lungs are of the elongated type according to the developmental index (IDI = 137±2.84), and the lung asymmetry ratio is 1:1.33. The respiratory part of the lung parenchyma is 40.38±2.6%, the connective tissue base is 59.62±3.4%, and the average volume of the pulmonary alveoli is 58.9±6.26 thousand μm³. Such studies are of great importance for comparative morphology and are the basis for clinical veterinary medicine as criteria for the morphological diagnosis of diseases of various geneses.

CONCLUSIONS

The heart of most mature dogs has a rounded (ellipsoidal) shape. The absolute weight of the heart is 167.58±9.46 g (without epicardial fat – 154.22±8.04 g), the relative weight – 0.72±0.005%. Height was 11.09±0.04 cm, width – 7.6±0.02 cm, circumference – 17.7±0.08 cm. The ratio of the total mass of the right and left atria to the mass of the right and left ventricles is 1:0.28, the ratio of the mass of both ventricles to the net mass of the heart is 1:0.78, respectively, the mass of the atria is 1:0.22. The microscopic structure of the ventricles and atria of the dog heart has a similar histoarchitectonics, but differs in cytometric parameters, according to the functional load: the largest volumes are characteristic of cardiomyocytes of the left ventricle – 2941.76±127.44 μm³, smaller – of the right ventricle 2237.24±103.02 μm³ and the smallest – of atrial cardiomyocytes 1496.92±98.02 μm³. The volume of nuclei of cardiomyocytes of the left (64.58±5.09 μm³) and right (59.97±5.83 μm³) ventricles of the heart is almost the same, in atrial cardiomyocytes this index is much lower (53.06±6.02 μm³).

The nuclear-cytoplasmic ratio of cardiomyocytes of the left ventricle is 0.0224±0.0076, a slightly higher value is observed in cardiomyocytes of the right ventricle – 0.0275±0.0081 and the highest value is observed in atrial cardiomyocytes (0.0367±0.0105). The dog's lungs have a partial structure. The left lung is characterized by three lobes (cranial, middle, caudal), and the right lung by four lobes (cranial, middle, caudal and accessory). The absolute weight of the lungs of dogs is 201.3±18.4 g, the relative weight is 1.21±0.14%. The weight of the left lung is less (86.26±8.01 g) than the right (115.04±10.14 g), their ratio is 1:1.33.

The length of the lungs of dogs is 23.0±2.42 cm, width 16.7±1.34, thickness 1.9±0.36 cm. The ratio of their length to width (asymmetry ratio) is 1.37:1, so the lungs in dogs are of the narrowed-elongated type. The histoarchitecture of the lungs is formed by cone-shaped or pyramidal lobules separated by connective tissue septa, which form the connective tissue stroma (59.62±3.4%), formed by loose connective tissue and containing elastic fibres, blood and lymphatic vessels. The respiratory parenchyma of the lungs (40.38±2.6%) is formed by respiratory bronchioles, alveolar ducts and alveolar sacs, the walls of which contain alveoli (large, medium, small), which together form the alveolar tree. The average value of the alveolar volume is 58.9±6.26 thousand μm^3. Prospects for further research are to conduct a species-specific morphological study of the heart of domestic animals of the class Mammalia – Mammals.

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There is none.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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Морфологія, органо- та гістометричні особливості серця та легень статевозрілої свійської собаки (*Canis Lupus Familiaris* L., 1758)

Леонід Петрович Горальський

Доктор ветеринарних наук, професор
Житомирський державний університет імені Івана Франка
10008, вул. В. Бердичівська, 40, м. Житомир, Україна
https://orcid.org/0000-0002-4251-614X

Ігор Миколайович Сокульський

Кандидат ветеринарних наук, доцент
Поліський національний університет
10008, бульвар Старий, 7, м. Житомир, Україна
https://orcid.org/0000-0002-6237-0328

Максим Русланович Рагуля

Аспірант
Поліський національний університет
10008, бульвар Старий, 7, м. Житомир, Україна
https://orcid.org/0000-0003-2945-9651

Наталія Леонідівна Колеснік

Кандидат ветеринарних наук, доцент
Поліський національний університет
10008, бульвар Старий, 7, м. Житомир, Україна
https://orcid.org/0000-0001-7741-8753

Юрій Миколайович Ордін

Кандидат ветеринарних наук, доцент
Білоцерківський національний аграрний університет
09117, пл. Соборна, 8/1, м. Біла Церква, Україна
https://orcid.org/0000-0002-8547-5608

Анотація. Серцево-судинна система та органи дихання в організмі тварин взаємопов'язані між собою, вони виконують надзвичайно важливі функції для життєдіяльності організму, основною з яких газообмін. Тому, дослідження серцево-судинної системи та органів дихання є актуальним питанням сьогодення. Метою роботи була морфологічна оцінка макро- та гістоструктур серця і легень свійської собаки. Для роботи застосовували комплексні морфологічні методи досліджень: гістологічні, анатомічні, органо-, гісто та цитометричні, статистичні, завдяки яким представлено нові дані щодо особливостей макро-, гісто- та цитоморфометричної характеристики морфологічних структур серця та легень. Серце собаки має округлу форму, його абсолютна маса дорівнює 167,58±9,46 г (без епікардіального жиру – 154,22±8,04 г), відносна маса – 0,72±0,005 %. Встановлено, що найбільший об'єм мають кардіоміоцити лівого шлуночка, менший – правого та найменший – кардіоміоцити передсердь. При тім, ядерно-цитоплазматичне відношення кардіоміоцитів лівого шлуночка дорівнює 0,0224±0,0076, більше значення мають кардіоміоцити правого шлуночка – 0,0275±0,0081 і найбільше кардіоміоцити передсердь – 0,0367±0,0105. Такі неоднозначні цитометричні параметри кардіоміоцитів пов'язані з морфофункціональною діяльністю м'язової тканини шлуночків міокарду та функціональними її особливостями, властивими до спонтанних і ритмічних скорочень, внаслідок чого відбувається рух крові по замкнутій системі судин. Абсолютна маса легенів свійської собаки становить 201,3±18,4 г, відносна – 1,21±0,14 %, співвідношення абсолютної маси лівої до правої легені становить 1:1,33. Згідно коефіцієнту асиметрії (1,37:1), легені у собак звужено-витягнутого типу. Сполучнотканинна строма легень займає 59,62±3,4 %, респіраторна частина – 40,38±2,6 %. Відомості з морфології серця та легень свійської собаки, включаючи результати дослідження макро- та мікроскопічної будови досліджуваних органів, які представлені у публікації, мають велике значення для гістології та порівняльної анатомії, а також роблять вагомий внесок у клінічну ветеринарну медицину

Ключові слова: порівняльна анатомія; гістоструктура органів; цитометричні параметри; кардіоміоцити; міофібрили; бронхіальне дерево; альвеолярне дерево