Original Research Article

ASPECTS REGARDING THE MORPHOLOGY AND TOPOGRAPHY OF CAVITY LYMPH NODES IN PIGS

ABSTRACT

The lymphatic system, supported by the lymphatic vessels, is a vascular network in higher vertebrates, having essential roles, such as regulating tissue pressure, monitoring the immune system and absorbing fats from the diet. The lymphatic vessels constitute a unidirectional system that transports fluids and proteins, taking them from the interstitial space and returning them to the bloodstream. **The objectives** pursued in this study are the following: to identify the topography of the main cavity lymph nodes and the morphological and topographic variants that may occur; to identify the main interspecific histological characteristics of vessels and lymph nodes in pigs; to identify the best incidences of ultasonographic examination of lymph nodes in pigs. **Materials and methods.** The study was carried out on 20 animals weighing 25-30 kg, aged about 3.5 months, of both sexes. They came from private breeders. Ultasonographic investigations were also performed on half of them. The macro- and microscopic anatomical studies as well as the ultasonographic investigations were performed at the Faculty of Veterinary Medicine in Bucharest. For macroscopic and topographic analysis, lymph nodes in both the thoracic and abdominal cavities were examined "in situ". They were identified, from a terminological point of view, measured with the stool and photographed. For the ultrasound examination, the animal was examined in the supine position. The jejunal lymph nodes were followed in the jejunal meso, at the origin of the straight parallel branches of the jejunal arteries. For examination under the light microscope, samples were washed with distilled water, fixed with 11 % neutral formaldehyde solution, then dehydrated with a progressively increased concentration ethanol solution (70–100%), clarified in xylene and incorporated into Paraplast. 6 mm sections were then made and stained with hematoxylin-eosin and then analyzed.**Results.** Caudal mediastinal lymph nodes are always fewer in number (between one and three). They are associated with the esophagus, immediately behind the tracheobronchial and ventral lymph nodes of the aorta. The afferents originate from the pericardium, the caudal part of the mediastinum and the corresponding part of the esophagus. The efferents connect to the tracheobronchial lymph nodes or can also approach some thoraco-aortic lymph nodes. The lumbo-aortic lymph nodes are located on the lateral surfaces of the aorta, starting from the diaphragmatic orifice to the origin of the deep iliac circumflex artery. The iliac lymphocenters are represented by large lymph nodes that form a bundle at the origin of the celiac artery. Colic lymph nodes are located along the path of the right colonic artery. Splenic lymph nodes are placed on the path of the homonymous vessels. Their topography is between the aorta and the hilum of the spleen. In this sector there may be 2-4 lymph nodes, but there are others (2-5) located along the upper quarter of the spleen. The jejunal lymph nodes form a double chain in the middle of the jejuno-ileum meso, about 30 cm long. The caudal mesenteric lymph nodes are reduced, located dorsally by the descending colon on the path of the caudal mesenteric artery. **Conclusions.** The most important groups of visceral lymph nodes are jejunal and colic. It can be mentioned that the jejunal ones can be examined relatively easily by the ultrasound method. On the other hand, the colic ones are masked in the thickness of the mesocolon root and surrounded by the coils of the ascending colon, which is why they are difficult to spot by ultrasound. The most important parietal lymphocenter is the ileosacral one; In it, we were able to describe for the first time some individual variants, namely:

lateral iliac lymph nodes dominant in volume compared to the medial ones, the absence in some cases (10%) of anorectal lymph nodes in some specimens, in which, however, a compensation was observed by the development of a chain of small units on the path of the median sacral artery.

Key words:lymphatic system, thoracic lymphocenter, mediastinal lymphocenter, swine

1. INTRODUCTION

The lymphatic system has been mentioned in the history of medicine for many centuries. Hippocrates referred to "white blood in knots", and Aristotle pointed out the existence of fibers containing a colorless fluid between blood vessels and nerves. In 1627, Gasparo Aselli was the first to officially recognize the lymphatic system, which was constantly studied in the seventeenth and eighteenth centuries, a period in which medicine began to explore more deeply aspects related to lymph, lymphatic drainage and lymphatic anatomy. However, it is only in recent decades that we have witnessed an explosion of scientific research on this system, highlighting its involvement in numerous conditions, including cancer.

The lymphatic system, supported by the lymphatic vessels, is a vascular network in higher vertebrates, having essential roles, such as regulating tissue pressure, monitoring the immune system and absorbing fats from the diet. The lymphatic vessels constitute a unidirectional system that transports fluids and proteins, taking them from the interstitial space and returning them to the bloodstream.

The lymphatic system has several important functions; the first forms a link from the interstitial space to the venous system. This connection helps maintain interstitial fluid volume (Margaris and Black2012) and allows for the transport of proteins, peptides, and macromolecules (Randolph et al. 2017). The second well-known function of the lymphatic system is the transport of antigens and antigen-presenting cells to the lymph nodes, in order to mount targeted immune responses if needed (Padera et al. 2016).

The notion of "animal model" in medicine generally represents a non-human living animal in which a pathological process or lesion transmitted parentally, naturally acquired or induced will be investigated. The purpose of its use is to solve a research hypothesis of a similar condition in the target human species (Crisóstomo, et al., 2016; Dove and Alworth, 2015).

Over time, many species of animals have served as experimental models. It is known that rodents are species that have great advantages, this makes them some of the most favorable in biomedical research. Although cardiovascular biology has benefited from an immense amount of information, especially from the molecular and cellular segment of biology, the limitation of rodent use has been due to intrinsic differences between rodents and humans in terms of heart rate, adrenergic receptor ratio, oxygen consumption, reaction to loss, and other physiological processes such as the absence of the plateau phase and the expression of contractile protein critical for the coupling process excitation-contraction, as well as the spontaneous reversal of experimentally induced ventricular fibrillation in normal sinus rhythm, which make the use of rodents and the extrapolation of data derived from these models problematic (Lelovas et al., 2014). Over the past two decades, researchers have agreed that among the animal species that lend themselves to being used as experimental models, the closest in terms of anatomy and physiology of the cardiovascular system is the porcine model ((Lelovas et al., 2014; Ntonas et al., 2020, Nykonenko et al., 2017; Shah, 2022; Skjennald, 1982).

Both structurally and functionally, the body of this animal has many similarities with the

human one. In recent years, the species *Sus scrofa domesticus* has been intensively used as experimental material, especially in research carried out on various diseases of the circulatory system. In order to implement new surgical procedures and techniques, researchers first tried to know perfectly the morphological substrate on which, in the case of the above-mentioned field, vascular anatomy acts. Different procedures were used, such as injections of vessels with contrast agents, followed by dissections under a stereomicroscope or their follow-up by various paraclinical methods such as X-rays, computed tomography or MRI. Starting in 1930, when a study on the anatomy of the circulatory system of pigs appeared, in a classic reference work (Sisson et al. 1975), and until now, when morphology works based on more modern investigation procedures appeared, the creation of a database necessary for experimental medicine and veterinary practice has been constantly pursued.

Currently, in order to understand the topography and distribution of the main cavity lymph nodes in pigs, those interested generally turn to the descriptions in anatomy treatises by established authors such as Barone, König, Sisson or Dyce (Sisson et al. 1975; König & Bragulla, 2007; Barone, 2012; Dyce et al., 2018;). However, they do not always provide the necessary details and we have found, as well as other authors (Yanina et al. 2024 Hsu and Itkin, 2016), that in the recent literature there are not enough morphometric studies of the lymph nodes of the thoracic and abdominal cavities. For this reason, problems arise especially in experimental surgery, in the case of using devices (probes, implants) incorrectly calibrated to the dimensions of the animal used. In order to determine morphometric details, the authors used both paraclinical methods, such as high-frequency ultrasonography (UHFUS) (Damian et al., 2015, Storkholm et al., 1997) or radiological examinations with contrast agents, but also classic dissection methods with the use of contrast agents injected into the arterial bed (Chirilean et al., 2010; Predoi et al., 2002).

Since the middle of the last century, anatomists who have been studying the lymphatic system in mammals have found an interesting thing, namely that in pigs they are structurally different from those in other domestic animals. On the one hand, it has been observed that in the central part of the lymph node the cortical is arranged (Trautmann and Fiebiger 1952, Spalding and Heath 1986, Anderson 2019) and on the other hand functionally, the passage of lymphocytes from the lymph to the blood takes place inside the lymph node (Drexhage et al. 1973, Bennell and Husband 1981). It has also been observed that the hilum, present in other species, is not well defined on the surface of the lymph node in pigs. (Semeraro and DAVIES 1986, Drexhage et al. 1973).

With the advent of new imaging techniques for investigation, it was possible to describe in detail not only the lymph nodes but also the lymphatic vessels in this species. Moreover, by using microinjection techniques, it was possible to define the lymphatic drainage territories by drawing up the so-called lymphosomes (Suami and Scaglioni 2018, Suami et al. 2017). The authors concluded that this species could be used as a large animal model for research of the lymphatic system due to the anatomical structure of lymphosomes and the considerable caliber of lymphatic vessels.

Since we found on the one hand that in the literature there are some small inconsistencies related to the topography of the abdominal lymph nodes in this species and on the other hand, that we did not find any source in which these structures are examined by the ultrasound method in this species, we tried to approach in this study a detailed description of the morphology and topography of these lymph nodes as well as the possibility of identifying the clusters by the ultrasound method.

The objectives pursued in this study are the following: to identify the topography of the main cavity lymph nodes and the morphological and topographic variants that may occur; to identify the main interspecific histological characteristics of vessels and lymph nodes in pigs; to

identify the best incidences of ultasonographic examination of lymph nodes in pigs.

2. MATERIALS AND METHODS

The study was carried out on 20 animals weighing 25-30 kg, aged about 3.5 months, of both sexes. They came from private breeders. Ultasonographic investigations were also performed on half of them. The macro- and microscopic anatomical studies as well as the ultasonographic investigations were performed at the Faculty of Veterinary Medicine in Bucharest.

For macroscopic and topographic analysis, lymph nodes in both the thoracic and abdominal cavities were examined "in situ". They were identified, from a terminological point of view, measured with the stool and photographed.

For the ultrasound examination, the animal was examined in the supine position. The jejunal lymph nodes were followed in the jejunal meso, at the origin of the straight parallel branches of the jejunal arteries. Although the colic lymph node chain in animals weighing 25-30 kg is approximately the same size, they are more difficult to identify by this workmanship, due to their deep topography in the colic meso, intimately surrounded by the loops of the ascending colon. The lymph nodes belonging to the ileosacral lymphocenter were analyzed with the animal in lateral decubitus, near the origin of the iliac arteries.

For the histological examinations after the euthanasia stage, tissue fragments were taken (thoracic aortic segment, pulmonary trunk, caudal vena cava, mesenteric vessels at the level of the jejunal insertion, mesenteric lymph node, tracheobronchial lymph node, superficial inguinal lymph node, thymus, artery and caudal mesenteric vein), segments with a longitudinal axis length of about 1.0 cm that were later immersed to fix, in a buffered solution of formaldehyde, with a concentration of 10%, for 24 hours.

After partial fixation, the tissue samples obtained reached the modeling stage, each piece being sectioned into several fragments with a thickness of about 2-3 mm, which were placed in cassettes with large or small meshes and put in another 10% formaldehyde solution, and then remained to be fixed for another 12 hours.

The next step is the introduction of samples into the histoprocessor for dehydration and pre-inclusion in paraffin. This technique consists of carrying out standard steps: fixation of the samples in 10% formaldehyde buffered solution for 24 hours, followed by washing, dehydration in successive baths of 70%, 96% and absolute alcohol, followed by inclusion in paraffin. Processing and paraffin inclusion were done automatically in the Thermo Scientific STP 120-3 tissue processor, and paraffin inclusion was done using the Thermo Scientific Microm EC 350-1 station. The formation of the paraffin blocks was carried out by using the "Tissue-Tek Tec Sakura" embedding station, and the sectioning of the parts to the size of 4-5 μm was done with the "Thermo Scientific HM 340E" microtome. The sections thus obtained were spread on histological slides, stained and then fixed with Canada balm. For the histopathological study, the preparations were usually stained with Hematoxylin-Eosin (HE).

Table 1.

Hematoxylin-Eosin (HE) staining stages

Etape	***Reactivi***	***Durata***
Color	Hematoxylin	8 min
Washing	Water	10 min

Color	Eosin	1 min
Washing	Water	-
Dehydration	4 successive baths in alcohol of different concentrations.	-

After inclusion, the blocks were sectioned to 4 µm using the Leica RM 125RTS microtome and spread on histological slides. The slides were colored using the Thermo Scientific Microm HMS 70 automatic slide coloring machine. Hematoxylin-eosin (HE) staining was used, which allows a good differentiation of cell types (Table 1).

Analysis of microscopic images - The microscopic examination of histopathological preparations was performed using the Olympus CX23 microscope, equipped with a digital camera for capturing images, model Olympus SC50. The complete and detailed examination of the preparations was carried out by successively using the x4, x10, x20 and x40 lenses.

4. RESULTS AND DISCUSSIONS

4.1. Morphology and topography of lymph nodes from thoracic and abdominal

4.1.1. Lymphnodes

In pigs, lymph nodes have an apparently different organization from that found in other species. The numerous nodules that make up their composition have a deep location and the medullary is slightly distinct (Fig. 1. Fig. 2). For this reason, their structure seems inverted, the cortex being deeply organized, surrounded by the medullary, which has become a peripheral part. This particular type of lymph node is considered an inverted lymph node (*Nodus lymphaticus inversus*).

The grouping of nodules on the inside and medullary sinuses pushed towards the periphery are observed.

As with other domestic mammals, the capsule is approached by a series of related lymphatic vessels. They will open into very narrow capsular sinuses under which the lymph nodes are located. Much more numerous are the afferents that directly penetrate the trabeculae, then follow a rectilinear path to the depth. They will open into irregular and relatively wide trabecular sinuses. In the immediate vicinity of these, most of the nodules develop. Their crown is very thick at the opposite pole of the sinus, where it forms a kind of cap (Fig. 2). Grouped around the nodules and in a middle area, there are clusters of cells that clearly equate to a paracortex. The assembly is integrated into a lax, unorganized connective tissue, where macrophages and plasma cells mix with lymphocytes. In general, there is no distinct hilum, but only an area of emergence of multiple efferent lymphatic vessels. At the level of this area, the peripheral tissue is organized into several medullary cords in the middle of a discrete network of medullary sinuses (Fig. 1).

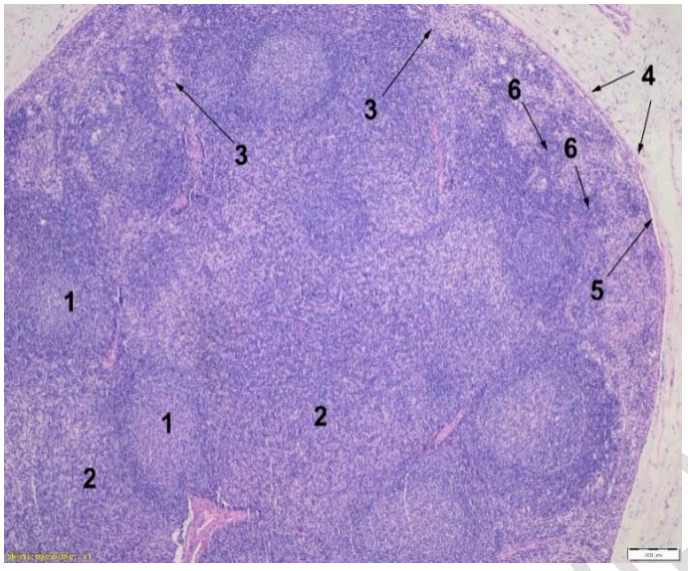

Fig. 1 Section through mesenteric lymph node, ob x4, col. HE (original)
1-lymphoid nodules with evident germinal centers; 2-diffuse lymphoid tissue; 3-medullary sinuses; 4-capsule; 5-subcapsular sinus; 6-medullary cords.

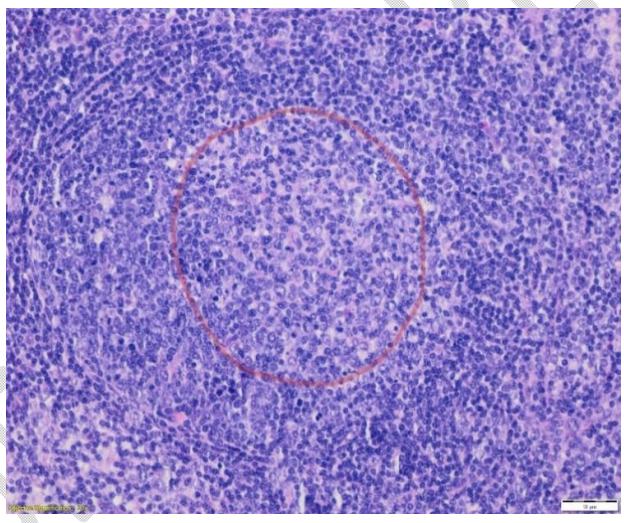

Fig. 2 Section through mesenteric lymph node, ob x20, col. HE (original).
Surrounded by red color is a lymphoid node (white pulp), the cortical area can be seen around it.

We can appreciate that the direction of lymph circulation does not differ in the case of these lymph nodes compared to those of other species. The lymph initially reaches the trabecular and subcapsular sinuses, coming into contact with the nodules before diffusing into the parenchyma, medullary sinuses and efferent vessels.

The blood vessels approach the periphery of the lymph node and accompany the trabeculae before feeding the capillary network. A few veins leave the lymph node along with the efferent lymphatic vessels.

4.1.2. Lymph nodes of the thoracic cavity

In the thoracic cavity there are four lymphocenters:

1. Dorsal thoracic lymphocenter. The thoraco-aortic lymph nodes are the only representatives of this lymphocenter. From the level of the sixth thoracic vertebra, it occupies the space between the aorta and the spine, up to the level of the last vertebra of this region. Slightly lateral to the aorta, they are somewhat irregularly arranged, both on the left and on the right. Their number is variable, observing 2-10 lymph nodes. Lymph is collected from the dorsal half of the chest wall, basically from all its layers, but also from the mediastinal septum and diaphragm. It also receives some efferents of the caudal mediastinal lymph nodes. The efferent vessels, through successive junctions, reach the thoracic canal and some reach the cranial mediastinal lymph nodes.

2. Ventral thoracic lymphocenter. Only the group of cranial sternal lymph nodes are present, relatively well represented. Their topography is dorsal to the first sternum, between it and the internal thoracic vessels (Fig. 3). It collects lymph from the ventral part of the chest wall, from the pectoral muscles but also from the most anterior part of the ventral abdominal muscles, including the regional breasts. Apart from these structures, lymph is also taken from the mediastinum, diaphragm, thymus, trachea and the thoracic portion of the esophagus. The destination of the efferent vessels is different: the thoracic duct, the right lymphatic duct, the external jugular vein and the brachiocephalic vein. A few efferents are tributary to the caudal deep cervical lymph nodes.

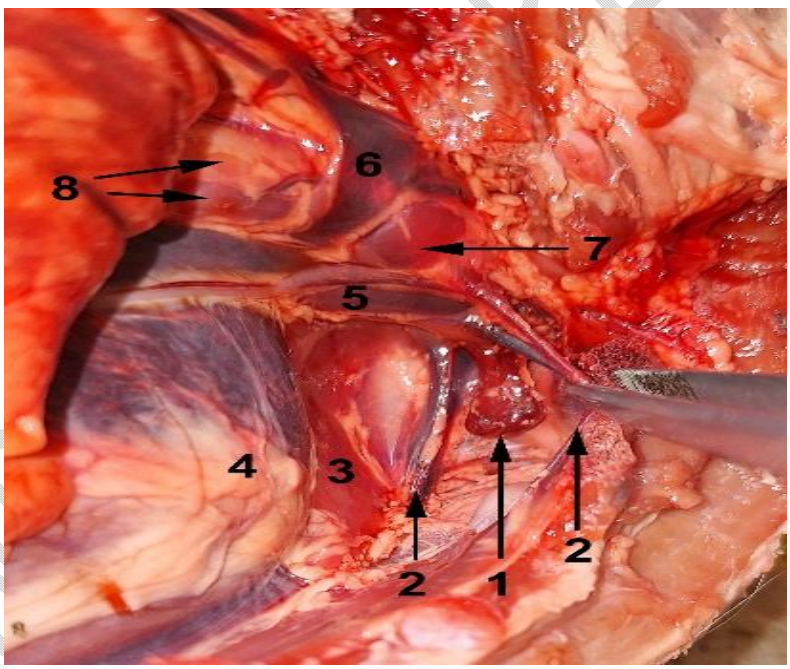

Fig. 3 Topography of lymph nodes in the cranial mediastinum (original)

1 - group of cranial sternal lymph nodes; **2** - internal thoracic arteries and veins; **3** - thymus; **4** - cord covered by pericardium; **5** - cranial vena cava; **6** - costocervical venous trunk; **7** - cranial mediastinal lymph nodes; **8** - cranial tracheobronchial lymph nodes (eparterial).

3. Mediastinal lymphocenter. It includes cranial and caudal mediastinal lymph nodes.

Cranial mediastinal lymph nodes have a lower topographic constancy. Even their number is variable (1-10). They accompany the trachea, the esophagus but also the large vessels especially on the right side. The ones in the anterior part border the cranial sternal ones and the most caudal ones are close to the tracheobronchial ones. The areas they serve are: the structures in the caudal

areas of the neck, those in the cranial parts of the walls of the thoracic cavity, the scapular regions, the cranial mediastinum, the trachea, the esophagus, the thymus and the pericardium. They also receive the efferents of the thoraco-aortic and tracheo-bronchial lymph nodes. The efferent vessels have different destinations, those on the right side reach the right lymphatic duct and those on the left side reach the thoracic duct. Some reach the cranial sternal lymph nodes.

Caudal mediastinal lymph nodes are always fewer in number (between one and three). They are associated with the esophagus, immediately behind the tracheobronchial and ventral lymph nodes of the aorta. The afferents originate from the pericardium, the caudal part of the mediastinum and the corresponding part of the esophagus. The efferents connect to the tracheobronchial lymph nodes or can also approach some thoraco-aortic lymph nodes.

4. Bronchial lymphocenter

The right tracheobronchial lymph nodes, up to three in number, are positioned in contact with the trachea, before the origin of the right main bronchus (Fig. 4). They drain the right lung and the terminal portion of the trachea. The efferents reach the left tracheo-bronchial lymph nodes and cranial or cranial mediastinal lymph nodes.

The left tracheobronchial lymph nodes (2-7) are found in contact with the trachea, cranially by the left main bronchus, dorsally masked by the left azygose vein. The afferent vessels come from the left lung but also from the heart, trachea and esophagus and for some to the caudal mediastinal and right tracheobronchial lymph nodes. The efferent vessels reach the thoracic duct or the caudal mediastinal lymph nodes.

The middle tracheobronchial lymph nodes, 2-5 in number, are placed dorsally by the angle of separation of the main bronchi (Fig. 5). The afferent vessels come from the lungs, pericardium, trachea, esophagus and mediastinum. The efferent vessels reach the left tracheobronchial and cranial lymphodes as well as the cranial mediastinal lymph nodes.

The cranial tracheobronchial lymph nodes (1-5) are placed ventrocranially from the origin of the tracheal bronchus or slightly cranially from it, at the ventral part of the trachea (Fig. 4, 5 and 6). In specimens in which there is only one lymph node, it is bulky. The afferent vessels come from the lungs, heart and pericardium, but also from other tracheobronchial lymphodes. The efferent vessels are directed to the cranial mediastinal lymph nodes.

4.1.3. Lymph nodes of the abdominal cavity

In the abdominal and pelvic cavities there are five lymphocenters:

1. Lumbar lymphocenter. It is represented by five groups of lymph nodes: lumbo-aortic, renal, fernic-abdominal and testicular.

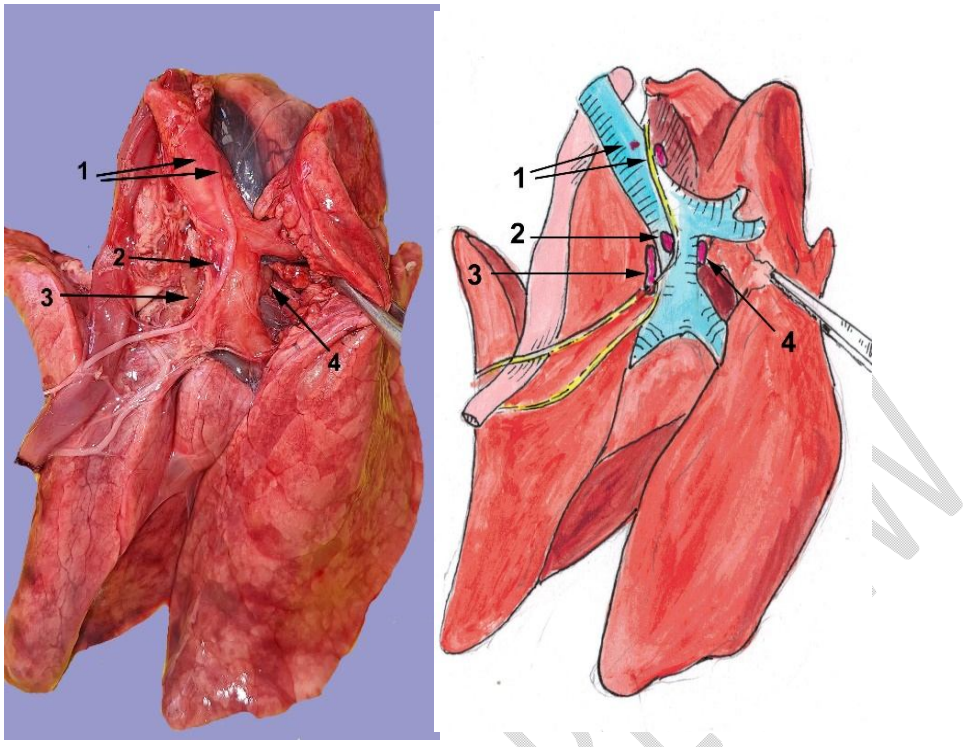

Fig. 4 Topography of lymph nodes belonging to the tracheobronchial lymph center, photograph (A) and schematic representation (B) (original)

1 - cranial tracheobronchial lymph nodes; **2** - intermediate tracheobronchial lymph nodes; **3** - left tracheobronchial lymph nodes; **4** - right tracheobronchial lymph nodes.

The lumbo-aortic lymph nodes form an elongated group of about 10-15 relatively small formations, placed between the origins of the renal arteries and the terminal portion of the aortic artery, the latter close to the group of medial iliac lymph nodes. They have relations with the lateral but especially dorsal parts of the aortic artery and vena cava. The afferent vessels drain the dorsal and lateral walls of the abdomen, the peritoneum, the kidneys and adrenal glands, the gonads and the tubular part of the genital tract. These lymph nodes are reached by part of the efferents of the medial and lateral iliac lymph nodes, caudal mesenteric lymphodes and other lymph nodes belonging to the lumbar lymphocenter. The efferent vessels associate with each other and finally approach the lumbar trunks or the cistern of the chyl.

Renal lymph nodes are variable in number (1-4), placed on the path of the homonymous vessels, between the aorta or caudal vena cava and the kidney on that side (Fig. 7). It performs lymphatic drainage of the kidneys and adrenal glands, but also of the peritoneum and regional muscles. They receive the efferents of the phrenic-abdominal lymph node and some lumbo-aortic lymph nodes in the vicinity. The efferent vessels reach the lumbar trunks or the chyle cistern.

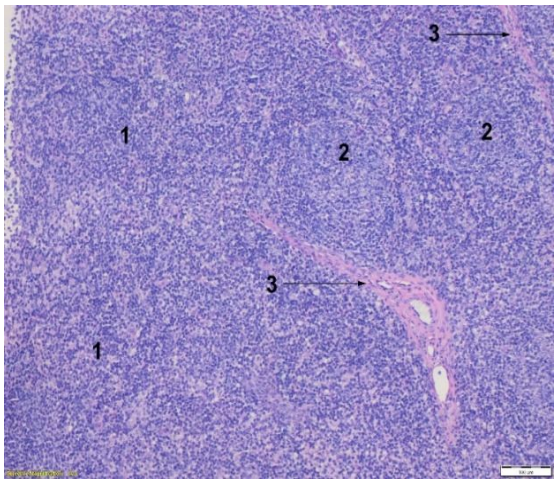

Fig. 5 Section through cranial tracheobronchial lymph node, ob x10, col. HE (original)
1-diffuse lymphoid tissue; 2-lymphoid nodules; 3-conjunctive-muscular trabecula.

The phrenic-abdominal lymph node is reduced, and may be present only unilaterally or even absent. When it exists, it is placed on the path of the caudal branch of the phrenic-abdominal vessels, near the lateral edge of the major psoas muscle. It drains the peritoneum and zonal muscles and can receive some efferents of the lateral iliac lymph nodes. The efferent vessels reach the lumbo-aortic or renal lymph nodes, even directly into the lumbar trunks.

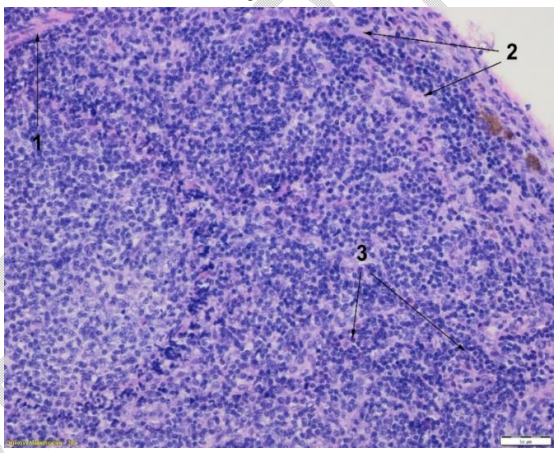

Fig. 6 Section through cranial tracheobronchial lymph node, ob x20, col. HE (original)
1-trabeculae with smooth muscle tissue; 2-medullary sinuses; 3-diffuse lymphoid tissue.

The testicular lymph node is located subperitoneally, on the path of the testicular vessels. Sometimes it occurs near the origin of these vessels, but most commonly in the vicinity of the inguinal region. There are cases in which it appears in duplicate but also cases in which it may be missing. It drains the testicle and epididymis and sends the efferents to the lumbo-aortic lymph nodes.

Uterine lymph nodes, classified by some authors as belonging to the ileosacral lymphocenter, by their topography and the relationships they have with the lumbo-aortic lymph nodes, can rather be considered as belonging to the group in which the latter fall. There are one or two lymph nodes, which may be bilaterally or unilaterally absent.

It drains the ovary, fallopian tubes and the corresponding horn of the uterus. The efferent vessels are destined for the lumbo-aortic or medial iliac lymph nodes.

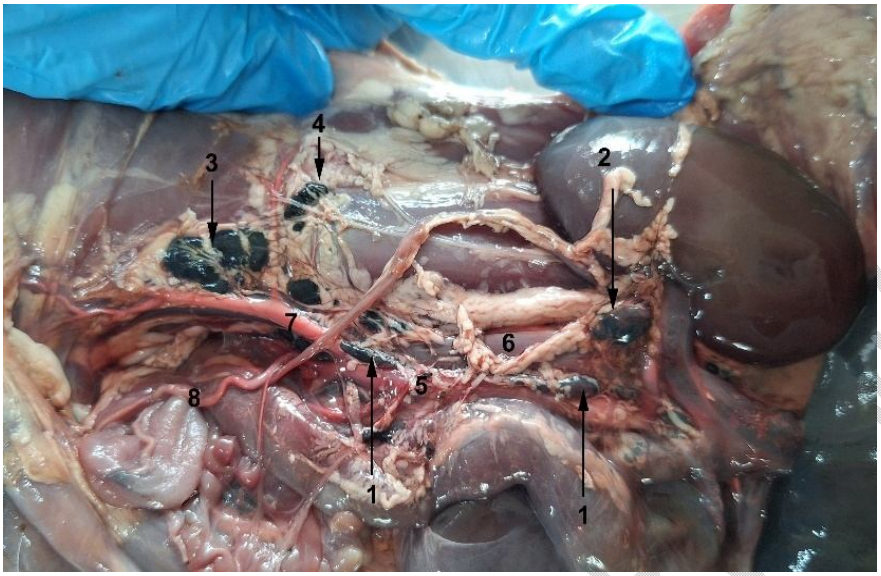

Fig. 7 Topography of lymph nodes on the roof of the abdominal cavity in pig (original)

1-lumbo-aortic lymph nodes; 2-renal lymph nodes; 3- medial iliac lymph nodes; 4-lateral iliac lymph nodes, 5-abdominal aorta; 6-caudal cava vein; 7-external iliac artery; 8-umbilical artery.

4.1.4. Celiac lymphocenter

Celiac lymph nodes (3-4) are placed around the celiac artery, often difficult to isolate from splenic or gastric lymph nodes. They receive afferent vessels from the lung, mediastinum, diaphragm, liver, spleen, adrenal glands, adjacent muscles, as well as the efferents of all the other lymph nodes belonging to this lymphocenter. The efferent vessels come together to form the celiac lymphatic trunk.

The hepatic (portal) lymph nodes (2-7) are located along the portal vein and in the area of the hepatic hilum (Fig. 9). The afferent vessels come from the liver, gallbladder and pancreas. The efferents of the pancreaticoduodenal lymph nodes are also collected. The efferent vessels reach the celiac lymph nodes or the celiac trunk.

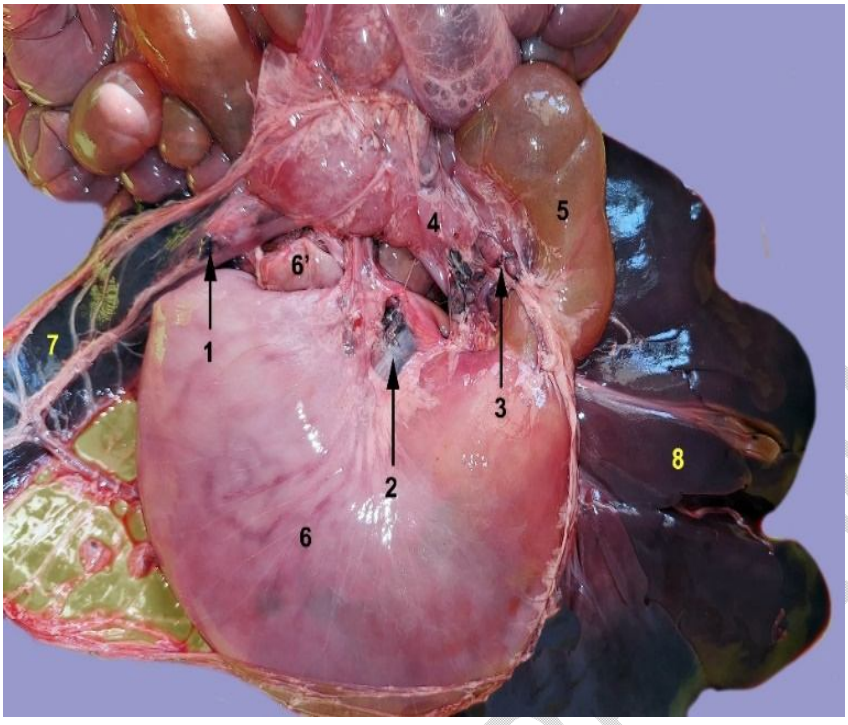

Fig. 8 Topography of the lymph nodes belonging to the celiac lymph center (original)

1- splenic lymph nodes; **2** - gastric lymph nodes; **3** - pancreaticoduodenal lymph nodes; **4** - pancreas; **5** - duodenum; **6** - stomach; **6'** - ventricular diverticulum; **7** - spleen; **8** - liver

Splenic lymph nodes are placed on the path of the homonymous vessels. Their topography is between the aorta and the hilum of the spleen (Fig. 8). In this sector there may be 2-4 lymph nodes, but there are others (2-5) located along the upper quarter of the spleen. They receive the efferent vessels from the spleen, from the great epiplon, from the left portions of the stomach and pancreas. The efferent vessels are directed to the celiac lymph nodes or the celiac trunk.

Gastric lymph nodes, which vary in number (1-5), are placed especially in the first part of the left gastric artery to near the cardia. It receives the efferent vessels of the mediastinum, the caudal portion of the esophagus, the stomach and pancreas. The efferent vessels are directed to the celiac lymph nodes or the celiac trunk.

The more numerous pancreatico-duodenal lymph nodes (5-10) are located along the cranial pancreatico-duodenal artery, between the descending portion of the duodenum and the right lobe of the pancreas. They receive related vessels from these organs, from the right side of the stomach and the great epiplon. The efferent vessels approach the celiac lymph nodes and some can reach the colic lymph nodes.

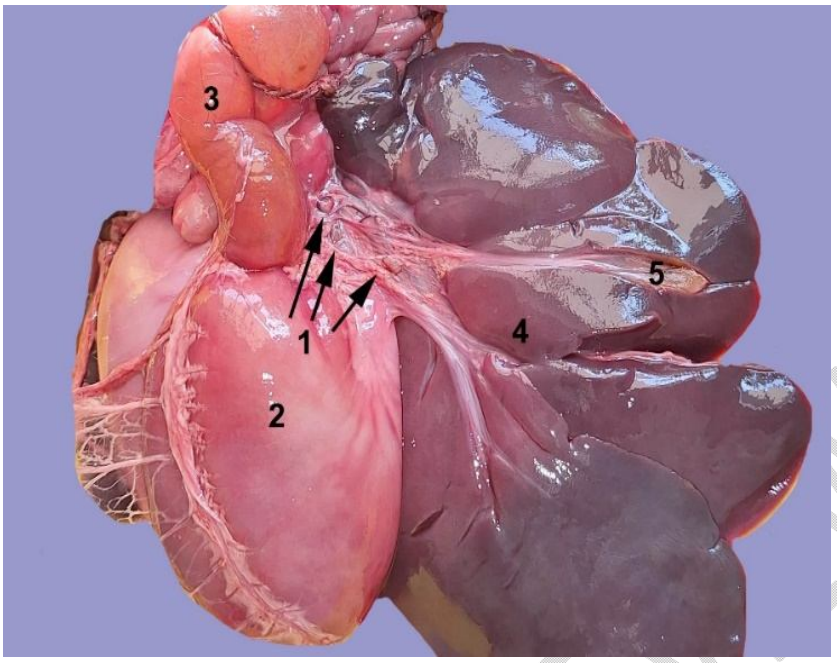

Fig. 9 Portal lymph node topography (original)
1 - portal lymph nodes; **2** - stomach; **3** - duodenum; **4** - liver; **5** - gallbladder

4.1.5. Cranial mesenteric lymphocenter

Cranial mesenteric lymph nodes are located around the origin of the cranial mesenteric artery. They can be confused with some of the pancreatico-duodenal and celiac lymph nodes. It receives the afferent vessels from the colon and some efferent vessels from the jejunal and colic lymph nodes. The efferent vessels reach the visceral trunk and intestinal trunk.

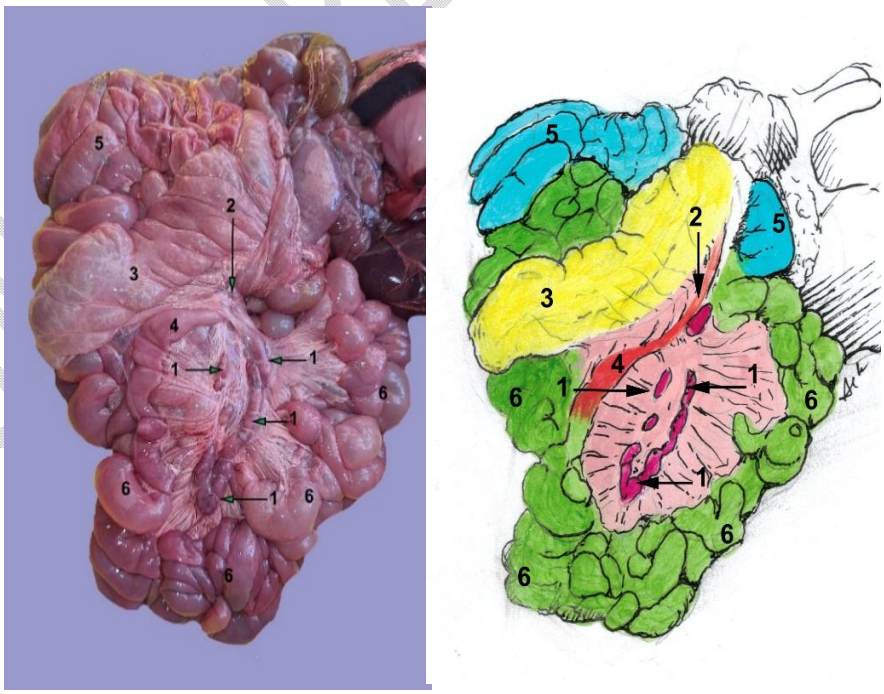

Fig. 10 Topography of lymph nodes belonging to the cranial mesenteric lymph center, photograph (A) and schematic representation (B) (original)

1 - jejunal lymph nodes; **2** - ileocecal lymph nodes; **3** - cecum; **4** - ileum; **5** - ascending colon; **6** - jejunal loops

The jejunal lymph nodes form a double chain in the middle of the jejuno-ileum meso, about 30 cm long (Fig. 10, Fig. 11). The two portions of this chain, each in contact with the peritoneum of one side of the meso, are separated by a layer of adipose tissue, crossed by the jejunal vessels. In the area corresponding to the ileum, the jejunal lymph nodes are more dispersed.

The afferent vessels drain the ascending portion of the duodenum, the jejunum and the ileum. The efferent vessels converge in the mesum to form the roots of the intestinal triuncle. The vessels that come from the lymph nodes close to the duodenum reach this trunk directly. On the other hand, those close to the ileum will address the ileocolic lymph nodes.

The ileocolic lymph nodes (5-10) form a group less well defined by the jejunal and colic lymph nodes in the vicinity. They are arranged on either side of the terminal portion of the ileum, both in the ileonic mesoum and in the ileocecal fold. The afferent vessels come from the cecum, the ileum and the terminal portion of the jejunum. Some come from the last jejunal lymph nodes. The efferent vessels reach the intestinal trunk.

Fig. 11 The mesenteric ganglion group - (B mode - longitudinal section) - It is identified as ovoid structures (arrows), with reduced echogenicity (inferior to intestinal loops and similar to regional vascular structures), the contour is regular, the echostructure is homogeneous

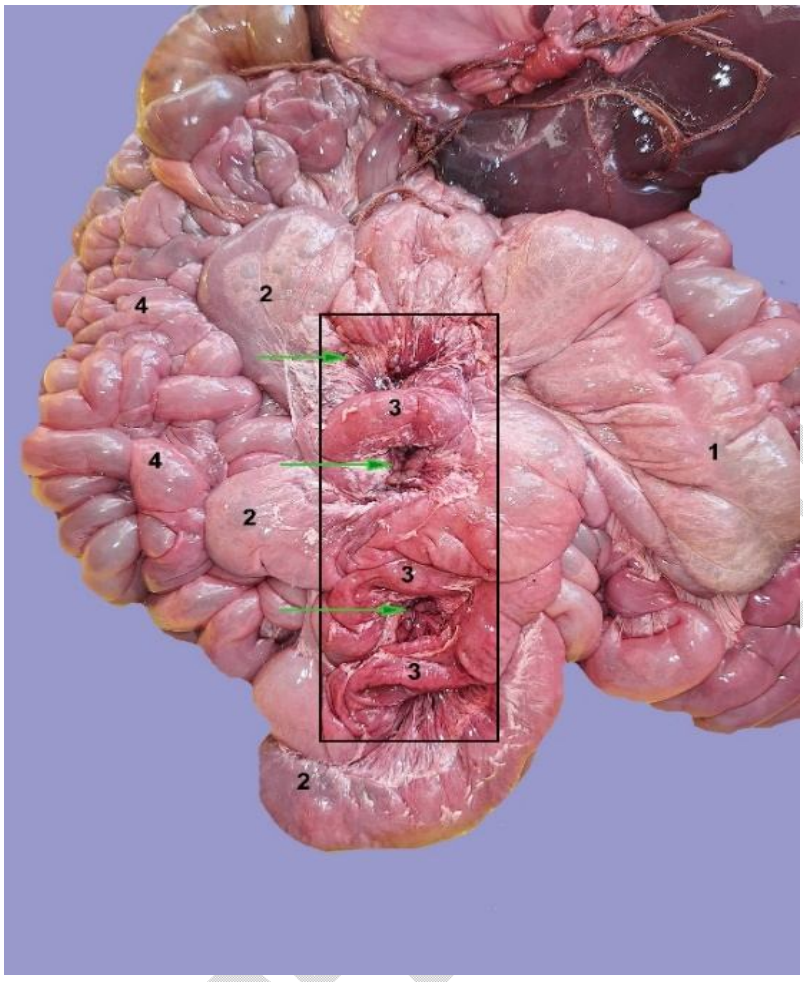

Fig. 12 Colic lymph nodes arranged in the connective axis of the helical colon indicated by green arrows (original)

1- caecum; **2** - centripetal turns of the helical colon; **3** - centrifugal turns of the helical colon; **4** - jejunal convolutions.

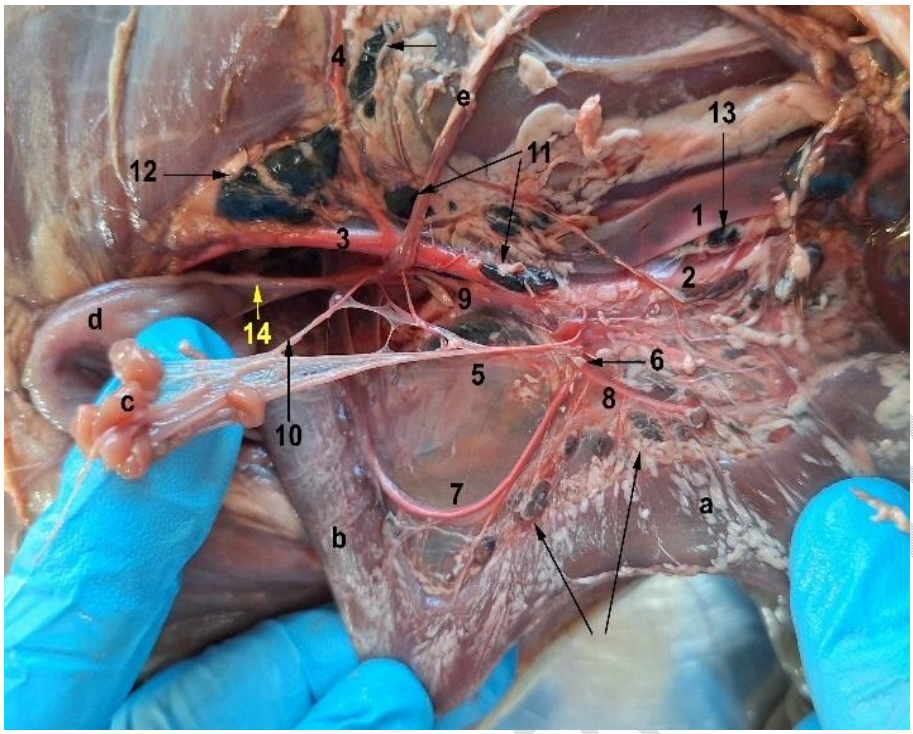

Fig. 13 Caudal mesenteric artery and lymph nodes in the pelvic cavity in pigs (original)
1-caudal vena cava; 2-abdominal aorta; 3-external iliac artery; 4-deep iliac circumflex artery; 5-descending mesocolon (small mesentery); 6-caudal mesenteric artery; 7-cranial rectal artery; 8-left colic artery; 9-the origin of the internal iliac artery; 10-uterine artery; 11-medial lymph nodes; 12-ileofemoral lymph nodes; 13-lumbo-aortic lymph nodes; 14-umbilical artery; a descending colon; b-rect; c-uterine horn; d-bladder, e-ureter.

Colic lymph nodes are very numerous, and can even reach 50. It forms a chain associated with the right colic artery in the thickness of the connective axis that supports the coils of the ascending colon (Fig. 12). The afferent vessels drain the adjacent portion of the cecum, the ascending colon and the transverse colon. Some efferents of the pancreaticoduodenal lymph nodes can also reach the colic ones. The efferent vessels form the roots of the colic trunk; some reach directly into the intestinal trunk.

Caudal mesenteric lymphocenter. The caudal mesenteric lymph nodes form a not very compact chain of about ten nodular structures, which accompany the descending colon.

Ileosacral lymphocenter. This lymphocenter is represented by the medial iliac, lateral iliac, sacral and anorectal lymph nodes (Fig. 7, Fig. 13).

The medial iliac **lymph nodes** are a group of lymph nodes located at the origin of the deep iliac circumflex artery. At this level, three or four lymph nodes have been observed in 80% of cases, the most voluminous not exceeding 1.2 mm. The more rostral ones are not well delimited by the lumbo-aortic lymphodes.

The lateral iliac **lymph nodes**, generally two in number, are found at the cranial edge of the terminal bifurcation of the deep iliac circumflex artery, in the superitoneal adipose tissue organized on the lateral side of the psoas major muscle. In 10% of cases, they may be absent unilaterally or bilaterally.

The sacral **lymph nodes** are located at the origin of the median sacral artery, between the initial portions of the two internal iliac arteries. At this level, 2-3 lymph nodes have been observed, but on the path of the first half of the median sacral artery, accessory lymph nodular clusters are frequently found (75% of cases).

The anorectal **lymph nodes**, numerically variable (2-10 units), are located on the dorsal side of the retroperitoneal portion of the rectum. In about 10% of cases they are not present.

Ileofemoral lymphocenter. In pigs, this lymphocenter is represented only by **ileofemoral** lymph nodes. They are positioned along the external iliac vessels, from the origin of the deep iliac circumflex artery to the vicinity of the deep inguinal ring. In general, there are 3-4 lymph nodes, but less often (about 10-15% of cases, only one large lymph node appears).

5. CONCLUSIONS

Although variable in number, thoraco-aortic lymph nodes are constant, but intercostal lymph nodes have been identified in any case. Similarly, the cranial sternal lymphocenter is represented by constant cranial lymph nodes and the caudal ones are absent.

In the case of mediastinal lymph nodes, the anterior ones are present, but their topography differs significantly from individual to individual. Caudal mediastinal lymph nodes are reduced and we consider their value in the anatomo-pathological examination to be insignificant.

The most important groups of visceral lymph nodes are jejunal and colic. It can be mentioned that the jejunal ones can be examined relatively easily by the ultrasound method. On the other hand, the colic ones are masked in the thickness of the mesocolon root and surrounded by the coils of the ascending colon, which is why they are difficult to spot by ultrasound.

The most important parietal lymphocenter is the ileosacral one; In it, we were able to describe for the first time some individual variants, namely: lateral iliac lymph nodes dominant in volume compared to the medial ones, the absence in some cases (10%) of anorectal lymph nodes in some specimens, in which, however, a compensation was observed by the development of a chain of small units on the path of the median sacral artery.

Disclaimer (Artificial intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

REFERENCES

1. ANDERSON, D.E., MULON, P.Y,. Anesthesia and surgical procedures in swine. In: Zimmerman JJ, Karriker LA, Ramirez A, Schwartz KJ, Stevenson GW, Zhang J, (2019) eds. *Diseases of Swine*. 11th ed. Wiley/Blackwell; 2019:171–196.

2. BARONE, R. (2012). Anatomie comparee des mammiferes domestiques. tome 5: angiologie 2eme ed. Vigot, Paris.

3. CHIRILEAN, I., DAMIAN, A., POPOVICI, N.C., STAN, F., DEZDROBITU, C. (2010), Specific Anatomical Aspects of the Aortic Opening (Ostium Aortae) and of the Left Cardiac Artery (A. coronaria sinistra) in Swine. Bulletin of University of Agricultural Sciences and Veterinary Medicine, Cluj-Napoca, Veterinary Medicine, Volume 67, Issue l/2010, pp. 28-33, Print ISSN

1843-5270, Electronic ISSN 1843-5378.
4. CRISÓSTOMO V, SUN F, MAYNAR M, ET AL. (2016) - Common swine models of cardiovascular disease for research and training. Lab Anim. 2016;45(2):67–74.
5. DAMIAN, A., TUNS, F., DEZDROBITU, C. PAPUC, I., MARTONOS, C., IRINA IRIMESCU, MELANIA CRIȘAN (2015) - Radiological Investigation with Contrast Agent of the Cardiovascular System in Swine, Agriculture and Agricultural Science Procedia 6, 309 – 315.
6.DONE, S.H., GOODY, P.C., EVANS, S.A., STICKLAND, N.C. (2006) – Color Atlas of Veterinary Anatomy, Vol III, Dog and cat, Mosby, ISBN 07234 2441 1.
7.DOVE, C.R., ALWORTH, L.C,. (2015), Blood collection from the orbital sinus of swine. Lab Anim (NY);44(10):383–384. doi:10.1038/laban.869
8.Drexhage, H.A., Mullink, H., de Groot, J. *et al.* A study of cells present in peripheral lymph of pigs with special reference to a type of cell resembling the langerhans cell. *Cell Tissue Res.* 202, 407–430 (1979). https://doi.org/10.1007/BF00220434
9. DYCE K.M., SACK, W.O., WENSING, C.J., (2018) Textbook of Veterinary Anatomy, 5 th ed., Elsevier, St. Louis ,Miss.)
10. Hsu MC, Itkin M. 2016. Lymphatic anatomy. *Tech Vasc Interv Radiol* **19**: 247–254.
11. KONIG H E, LIEBICH, H.-C. (2007), Veterinary anatomy of domestic mammals: textbook and colour atlas. Schattauer Verlag; . p. 351-352.
12.KÖNIG, H.E., (2014) Veterinary Anatomy of Domestic Mammals. Textbook and Colour Atlas. 6th Edition, Schattauer, Stuttgart.
13. Margaris KN, Black RA. 2012. Modelling the lymphatic system: challenges and opportunities. *J R Soc Interface* 9: 601–612

14 LELOVAS, P.P, KOSTOMITSOPOULOS G. N., XANTHOS, T, X. (2014), A Comparative Anatomic and Physiologic Overview of the Porcine Heart, J Am Assoc Lab Anim Sci.; 53(5): 432–438.
15. NTONAS, A., KATSOURAKIS, A., GALANIS, N., FILO, E., NOUSSIOS, G. (2020), Comparative Anatomical Study Between the Human and Swine Liver and Its Importance in Xenotransplantation, Cureus. 2020 Jul 27;12(7):e9411. doi: 10.7759/cureus.9411. PMID: 32864240; PMCID: PMC7449635.
16. NYKONENKO A., VARVRA P., ZONCA P., (2017), Anatomic Particularities of Human and Pig Liver. Experimental and Clinical Transplantation, 15(1):21-26.
17. Randolph GJ, Ivanov S, Zinselmeyer BH, Scallan JP. 2017. The lymphatic system: integral roles in immunity. *Annu Rev Immunol* 35: 31–52.
18. Padera TP, Meijer EF, Munn LL. 2016. The lymphatic system in disease processes and cancer progression. *Annu Rev Biomed Eng* 18: 125–158.
19. SEMERARO, D., DAVIES, J.D., (1986), The arterial blood supply of human inguinal and mesenteric lymph nodes, J Anat, 1986 Feb:144:221-33
20. Spalding HJ, Heath TJ. Blood vessels of lymph nodes in the pig. Res Vet Sci. 1986 Sep;41(2):196-9. PMID: 3775110.
21. Suami H , Scaglioni MF . 2017 . Lymphatic territories (lymphosomes) in rats: an anatomical study for future lymphatic research. *Plast Reconstr Surg* **140** : 945 – 951 .
22. Suami H, Scaglioni MF. 2018. Anatomy of the lymphatic system and the lymphosome concept with reference to lymphedema. *Semin Plast Surg* 32: 5–11.
23. SHAH, A.. (2022) Anatomical Differences Between Human and Pig Hearts and Their Relevance for Cardiac Xenotransplantation Surgical Technique, JACC Case Rep.; 4(16): 1049–

1052.
24. SKJENNALD A., (1982), Anatomy of the liver and pancreas in the domestic swine, with special reference to vascular structures. Scand J Gastroenterol. 1982;17:16–31.
25. SISSON, S, GROSSMAN, J. D. ROBERT GETTY, R., (1975), Sisson and Grossman's The anatomy of the domestic animals, 5th ed. Saunders, Philadelphia.
26. STORKHOLM, J.H., VILLADSEN, G.E., KROGH, K. ET AL. (1997), Dimensions and mechanical properties of porcine aortic segments determined by combined impedance planimetry and high-frequency ultrasound. Med. Biol. Eng. Comput. 35, 21–26.
27. Trautmann & Fiebiger (1952).Trautmann A, Fiebiger J. Fundamentals of the Histology of Domestic Animals. Ithaca: Cornell University Press; 1952.
28. YANINA, L. R., GRANKIN, D. S., PODOLSKAYA, K. S., ZHURAVLEVA. I., (2024), "Pigs as Models to Test Cardiovascular Devices Biomedicines 12, no. 6: 1245.