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RESEARCH ARTICLE

Computed Tomographic, Echocardiographic, Radiographic, and Morphological Anatomy of the Heart in Goats (*Capra Hircus*).

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Abstract

The heart is the most important organ in the cardiovascular system. It pumps oxygen-rich blood all over the body. The imaging techniques are vital to get details for the best description of the structures of the cardiovascular system. Hence, it is considered an important means for diagnosis and clinical application. The current study was performed on five healthy goats of both sexes from native breeds, weighing about 30–35 kg and aging from one to three years. These goats were used as follows: topographical examination, gum milk injection (Latex 60%), computed tomography followed by frozen cross-section technique, thoracic radiograph, and echocardiography respectively. Ten hearts of apparent healthy goats were dissected for describing the heart morphology. The heart of the goat was situated between the 3rd and the 6th ribs in the thoracic cavity. It was hollow muscular cone-shaped with a slightly pointed apex. It had two surfaces, two borders, a base, and an apex. It was divided into four chambers through coronary and longitudinal grooves. The Computed Tomography sections result was compared with the anatomical images. Radiography and echocardiography were figured, identified, and labeled to create a comprehensive guide for experts in anatomy, surgery, and veterinary education. In conclusion, heart dissection generates anatomical knowledge and description. Besides, the modern imaging modalities such as Computed Tomography, echocardiography, and radiograph, provided non-invasive means for the animal anatomy in living animals.

Keywords: Goats, Heart, Computed Tomography, Thoracic radiograph, Echocardiograph.

Introduction

Goats are considered a valuable model for teaching, biomedical research, and surgical training because they are small-sized, can be kept in small areas, and managed with ease [1]. Therefore, goats are considered as a suitable animal model for the study of human cardiovascular disease and its management [2]. They were reported in the development and assessment of artificial heart valves [3], skeletal muscle ventricles development [4], studies of chronic heart failure [5], the treatment of atrial fibrillation and pathophysiology [6], and the study of total artificial hearts [7].

Computed tomography (CT), Thoracic radiography, and Echocardiography are non-invasive imaging techniques and are commonly used for the diagnosis of diseases [8]. They are also available in the veterinary career, in animals for understanding the normal anatomy [9-11].

The anatomy and physiology of the heart are wide, exciting for a thorough recognizing of their changes to help in the expectation of disease, as well as appreciating the signs and symptoms [12].

The heart is a hollow, muscular organ and located in the thorax and is cone shaped. In goat, it extends from the third to the sixth rib and contacts the diaphragm at its caudal end, which resembles the other ruminants. It is enclosed within a double-walled fibro-serous pericardial sac, which is oriented into the fibrous pericardium, and serous pericardium. The fibrous pericardium is attached to the great vessels and encircled the heart [2].

The hearts of domestic animals are elongated and had a pointed apex, except for dogs which have an ovoid heart with a blunt apex, sheep and pigs have a blunt apex. However, the apices of a normal dog, pig, and sheep hearts are all formed entirely by the left ventricles [13].

The heart is divided into four different chambers with a distinct thickness of muscular walls. The left atrium and right atrium are small, thin-walled chambers and are located just above the left ventricle and right ventricle, respectively [12]. The ventricles are larger thick-walled chambers that perform most of the function. The atria receive blood from the venous system and lungs and eject the blood into the ventricles. The two atria were separated from the two ventricles by a circular coronary groove that filled with fat in well-nourished animals [14]. The heart valves are two atrioventricular valves and two semilunar valves [15-17].

The right ventricle had a greater number of chordae tendinae than the left ventricle in the horse [18] and pigs, sheep, and cow [19].

In domestic animals, the aorta originates from the left ventricle and the pulmonary artery from the right ventricle. The cranial and caudal vena cavae drain into the right atrium, and the pulmonary veins into the left atrium [20, 21].

Thorough knowledge of the normal heart and great blood vessels anatomy is important for a better understanding of cardiac disfunction in goats. Therefore, the current study aims to investigate, describe the morphological features of the heart of the goat, and contribute to the fields of clinical cardiology and cardiovascular imaging through the aids of computed tomography, thoracic radiograph, and echocardiography in living goats which create a comprehensive guide for experts in anatomy, surgery, and veterinary education.

Material and methods

Animals

The present study was performed on five healthy goats of both sexes from native breeds, weighing about 30–35 kg and aging from one to three years. The goats were obtained from the farm at the Faculty of Veterinary Medicine, Zagazig. Ten hearts specimens of apparent healthy goats were collected from different abattoirs in Sharkia Governorate. Egypt. The heart specimens were used for examination of the external and internal morphology and cross-sections of the heart. The goats were sedated with xylazine hydrochloride 0.05 – 0.1mg/kg intravenously (Xyla-Ject 2%®, ADWIA, Egypt) [22]. They were humanely euthanized and handled according to the guideline of the Zagazig University Research Center Institutional Animal Care and Use Committee (IACUC) under number ZU-IACUC/2/F/123/2021.

Macroscopical examination

One goat was carefully dissected for studying the topography and position of the heart. Another one was infused with normal saline through the right and left common carotid arteries. Then injected gently with gum milk (Latex 60%) mixed red and blue colored scib paints (Scib Paints Shop, Zagazig, Egypt) via the common carotid artery and lingofacial vein respectively for the demonstration of the arteries and veins. Then it was preserved in 10%formalin, 3% glycerine, and 1% thymol fixative solution to be carefully dissected later. The dissection of these goats was guided as previously described [23-25].

Computed tomography (CT)

The Computed Tomography was performed for one goat using CT Optima 680, 16 Multislices scanners (Third-generation equipment, General Electric Company, USA) at AL-Bayan center in Belbeis at El-Sharkia Governorate, Egypt. The goat was positioned in sternal recumbency with the head and neck was extended and supported on a sandbag. The thorax was scanned with a layer thickness of one mm and 2.5 mm interval with an

exposure of 120 KV and 270 MA imaging time of 2.2 sec. The computed tomography scanner was capable of acquiring up to 32 slices per second with a fast whole-body scan time of 0.5 seconds. The computed tomography images were taken without contrast material and the soft structures were inspected only at soft-tissue window level to detect the homogeneity, location, and shape of the heart. The procedure followed previously published protocol according to Computed tomography and cross-sectional anatomy of the thorax of goat [26].

The same goat was used for the **frozen cross-section** technique. The goat's forelimbs were removed, then was put in a deep freezer (-20°C) in a sternal or lateral recumbency position. After complete freezing of the goat (3 days or more), using an electrical band saw it was transversely sectioned into transverse sections at the level of the 4th thoracic vertebra and perpendicular to the longitudinal axis of the goat's trunk.

Thoracic Radiography

For the radiographical examination, one goat was imaged in the Department of Surgery, Anesthesiology, and Radiology, Faculty of Veterinary Medicine, Zagazig University. Left lateral radiographic views were taken at 45KV and 100 mAs included the standard diagnostic procedure [11].

Echocardiography

One goat was used for the echocardiographic examination. The procedures and precautions were carried out according to Hallowell *et al.*, [10]. An ultrasound unit (Sonoscape), with of a 2-6 MHz transducer were used By utilizing a manual restraint, the position of animals was set on the left and right lateral recumbency.

The left parasternal short-axis view was obtained at the level of the papillary muscle. M-mode dimensional measurements were obtained from the right parasternal long-axis view with the simultaneous display of two-dimensional echocardiographic images.

Results

Topography of the heart

The heart (Cor) of the goat was a hollow muscular cone-shaped with a slightly pointed apex which lied between the 3rd and the 6th ribs in the thoracic cavity occupied craniocaudal direction, in the middle mediastinum space between the right and left lungs. The right atrium and ventricle were directed cranially to the right side while the left atrium and ventricle were oriented caudally to the left side (Figure 1).

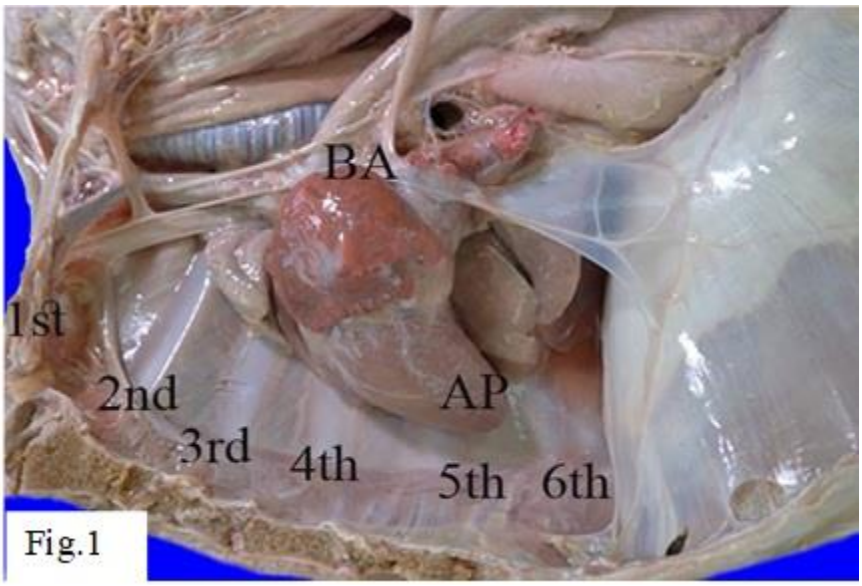

Figure 1: A photomacrograph of the topography of the thoracic cavity after removal of the left lateral thoracic wall of goat (left lateral view) showing: the heart base (BA); apex (AP); and ribs (1st, 2nd, 3rd, 4th, 5th, 6th).

External morphology of the heart

The heart had two surfaces; the left auricular surface (Facies auricularis) and the right atrial surface (Facies atrialis). They faced the left and right thoracic walls respectively. It had two borders; the cranial or right ventricular border (Margo ventricularis dexter) and caudal or the left ventricular one (Margo ventricularis sinister). The cranial border was convex and long while the caudal one was straight and short. The heart had a base (Basis cordis) that was oriented craniodorsally, and an apex faced caudoventrally in the thoracic cavity. The apex (Apex cordis) was slightly pointed and conical in appearance (Figures 1, 2, and 3).

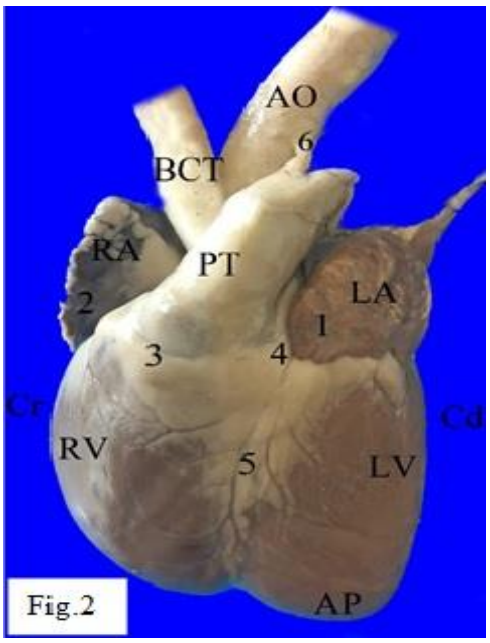

Fig. 2: A photomacrograph of the right auricular surface of the heart of the goat showing: the right ventricle (RV); left ventricle (LV); right atrium (RA); left atrium (LA); apex (AP); pulmonary trunk (PT); aorta (AO); brachiocephalic trunk (BCT); 1- left auricle; 2- right auricle; 3- conus arteriosus; 4- coronary groove; and 5- left interventricular paraconal groove.

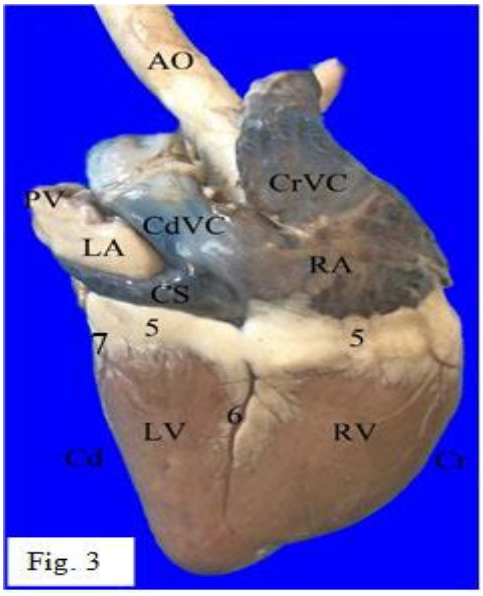

Fig.e 3: A photomacrograph of the right atrial surface of the heart of the goat showing: the right ventricle (RV); left ventricle (LV); right atrium (RA); left atrium (LA); aorta (Ao); pulmonary veins (PV); cranial vena cava (CrVC); (CdVC) caudal vena cava; coronary sinus (CS); 5- coronary groove; 6- right interventricular subsinosal groove; 7- intermediate groove.

The heart was divided into four chambers by grooves; the atrioventricular or coronary groove (sulcus coronarius) and the interventricular grooves. The former was circular and revealed the division between the two upper atria and lower ventricles at which the coronary blood vessels were crossing. The interventricular grooves were longitudinal and present between the two ventricles, which continued toward the apex. They were two; left paraconal (Sulcus interventricularis paraconalis), and right subsinosal grooves (Sulcus interventricularis subsinuosus). In addition to the intermediate groove (Sulcus intermedius) present on the left caudal border (Figures 2 and 3).

Internal morphology of the heart chambers

The right atrium (Atrium dexter) was the right upper chamber of the heart. It consisted of two parts; Sinus venarum cavarum and an auricle (Auricula atrii). The former was a smooth cavity in which all the venous blood was drained. It was separated by a ridge termed the terminal crest (Crista terminalis) from the rest of the atrium. The main openings of the right atrium were four; the cranial vena cava (Ostium venae caveae cranialis), caudal vena cava (Ostium venae caveae caudalis), the right atrioventricular opening (Ostium atrioventriculare dextrum), and the coronary sinus (sinus coronarius). The intervenous tubercle (Tuberculum intervenosum) was a ridge present between the two openings of the caval veins (Figures 3, 4 and 5).

The right ventricle (Ventriculus dexter) extended from the interventricular paraconal groove to the interventricular subsinosal one. It represented the cranial border of the heart and did not reach the apex and appeared crescentic in cross-section. It had a small cavity with a thin wall and was separated from the left ventricle by the interventricular septum (Septum interventriculare). The right atrioventricular orifice was guarded by a tricuspid valve attached to three papillary muscles (Musculi papillares). The latter was connected through thread-like structures termed the Chordea Tendinea which are short and numerous. M. Papillares Magnus was the largest and measured 2cm in average length and the average width was 1cm. M. Papillares Subarteriosus faced proximally to the pulmonary trunk, measuring 0.5 cm in the average length and the average width was 0.5cm. M. Papillares Parvi measured 1cm mean length and the mean width was 0.5cm. Trabeculae carnae was present in the wall of the right ventricle which bears muscular ridges which were prominent than in the left ventricle. The moderator band (trabecula septomarginalis) extended from the interventricular septum to the opposite outer wall of the right ventricle (Figures 2, 3,4, 6, and 7).

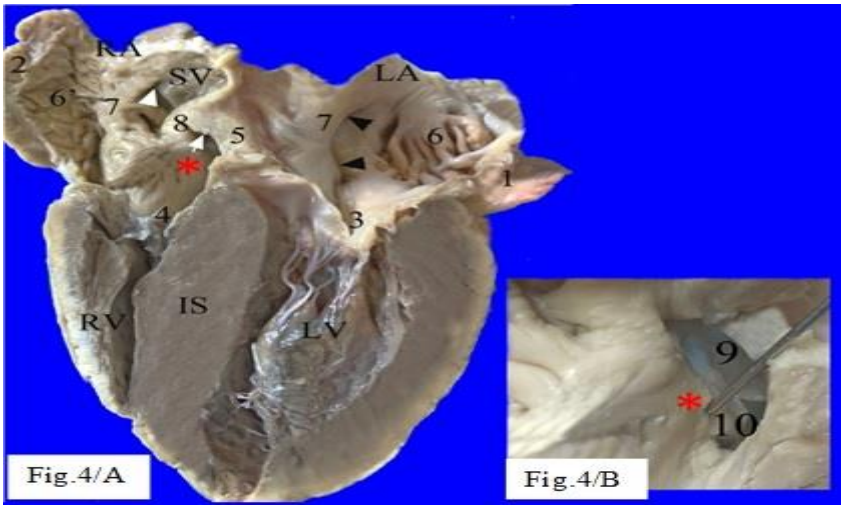

Fig. 4: A. A photomacrograph of a longitudinal section of the heart of the goat (cut at right angles to the interventricular septum) showing: the right ventricle (RV); the left ventricle (LV); the right atrium (RA); the left atrium (LA); the interventricular septum (IS); sinus venarum cavarum (SV); 1- left auricle; 2 - right auricle ; 3- the left atrioventricular opening; 4- the right atrioventricular opening; 5- the membranous interatrial septum; 6- the left pectinate muscles; 6'- the right pectinate muscles; 7- terminal crest; 8- the intervenous tubercle. The black arrows refer to the openings of pulmonary veins. The white arrow refers to the opening of the coronary sinus while the pinhead arrow to the opening of the caudal vena cava. **B.** A magnified photomacrograph of the asterisk in fig. 4/A of the longitudinal section of the heart of the goat (A) showing: 9- the opening of the caudal vena cava; 10- the opening of the coronary sinus.

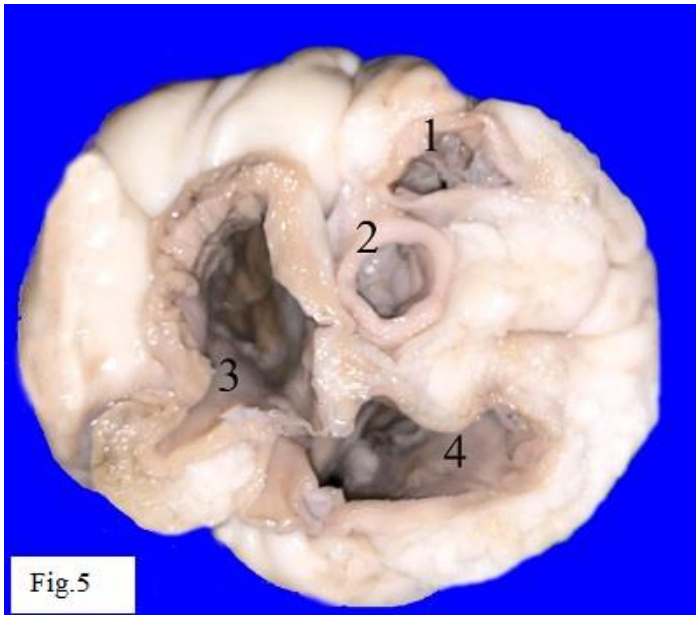

Fig. 5: A photomacrograph of cross-section from the base of the heart of the goat showing: 1- pulmonary trunk opening; 2- aortic opening; 3- left atrioventricular opening; 4- right atrioventricular opening.

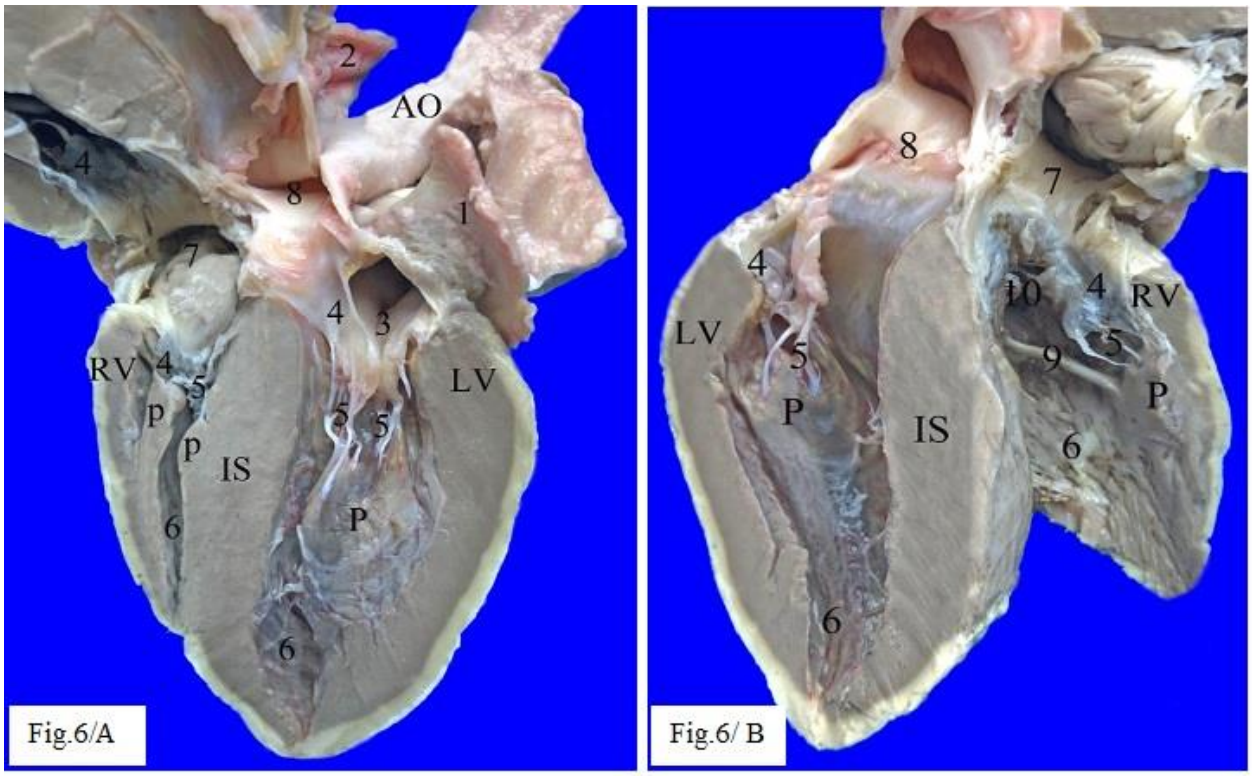

Fig. 6: A and **B.** A photomacrograph of a longitudinal section of the heart of the goat (cut at right angles to the interventricular septum) showing: the right ventricle (RV); left ventricle (LV); interventricular septum (IS); papillary muscles (P); 1- left auricle; 2 - right auricle; 3- left atrioventricular opening; 4- cusps of the valves; 5- chordae tendinae; 6- trabeculae carnae; 7- right atrioventricular opening; 8- aortic opening; 9- moderator band; 10- pulmonary trunk opening.

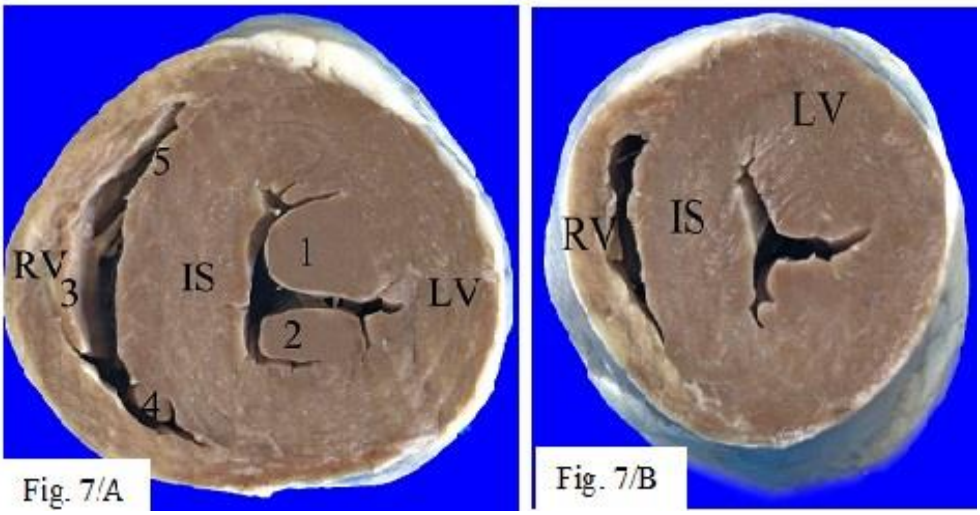

Fig. 7: A and **B.** Photomacrographs of cross-sections from the apex of the heart of the goat showing: the right ventricle (RV); left ventricle (LV); interventricular septum (IS);1- M. papillares subatrialis 2- M. papillares subauricularis; 3- M. Papillares Magnus; 4- M. Papillares Subarteriosus; 5- M. Papillares Parvi.

The left atrium was the left upper chamber of the heart. It was composed of a smooth surface and a left auricle. The latter had pectinate muscles and a terminal crest. The left atrium was separated from the right atrium by the interatrial septum (Septum interatriale). It had two openings; pulmonary veins about 4 to 5 and the left atrioventricular orifice (Figure 4).

The left ventricle (Ventriculus sinister) was conical in shape with a thick wall and formed the apex of the heart. It appeared as T-shaped in cross-section. The left atrioventricular opening was guarded by a bicuspid valve that connected to the papillary muscles. The latter was two in number were situated in the wall of the ventricle. M. papillares subauricularis was measured 3.5cm in average length and the average width was 2cm. M. papillares subatrialis was measured with an average 4cm length and average width was 2.5cm. The chordae tendinea were thread-like structures that were long and few in numbers. Trabeculae carneae were muscular ridges and bands on the wall of the left ventricle near the apex (Figures 6 and 7).

Major blood vessels

The aorta was the main systemic arterial, large, unpaired trunk that arose from the base of the left ventricle, medial to the pulmonary vessel. It ascended craniodorsally to give off the ascending aorta (Aorta Ascendens), the aortic arch (Arcus Aortae), and curved back over the heart to become the descending aorta (Aorta Descendens). The descending aorta continued downward through the thorax called the thoracic aorta (Figure 8).

The pulmonary trunk (truncus pulmonalis) began as a conus arteriosus at the base of the right ventricle. The cranial vena cava (Vena Cava Cranialis) carried blood from the cranial part of the body and drained it into the right atrium. The caudal vena cava (Vena Cava Caudalis) received the blood from the caudal part of the body and returned it into the right atrium. The left vena azygos drained the blood into the coronary sinus (Figure 8).

The ascending aorta gave off the left coronary (Coronaria Sinistra) and right coronary (Coronaria dextra) arteries nourishing the blood to the heart. The aortic arch (arcus aortae) gave off cranially the brachiocephalic trunk (Truncus Brachiocephalicus) at the level of the 3rd to the 4th ribs. The brachiocephalic trunk gave off the right, left subclavian arteries (Arteria Subclavia) and the bicarotid trunk (Truncus Bicarotidus). The left subclavian artery arose before the right one and each one gave rise to the costocervical trunk (truncus

costocervicalis), superficial cervical artery (A. cervicalis superficialis), internal thoracic artery (A. thoracica interna), and the axillary artery (Arteria Axillaris). The costocervical trunk spring supreme intercostal artery (A. intercostal suprema), dorsal scapular artery (A. scapularis dorsalis), deep cervical artery (A. cervicals profunda), and vertebral artery (a. vertebralis). The 1st, 2nd, and 3rd intercostal arteries arose from the supreme intercostal artery, while from the 4th to 12th intercostal arteries were originated from the thoracic aorta. In addition to bronchoesophageal artery (A. bronchoesophageal) arose at the level of the 6th thoracic vertebrae (Figure 9).

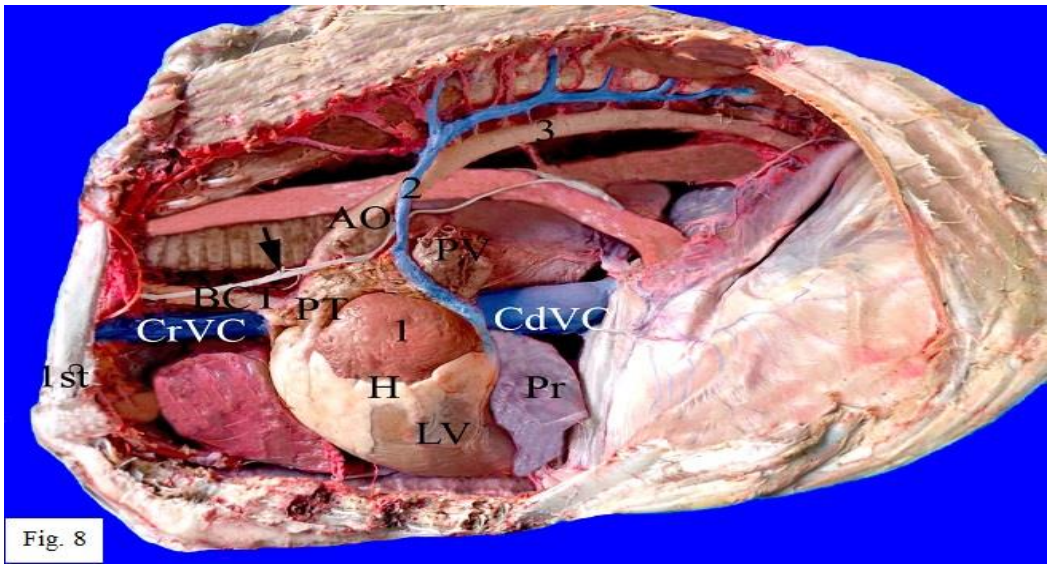

Fig. 8: A photomacrograph of the great blood vessels of the goat heart of the left thoracic cavity injected gently mixed gum milk (Latex 60%) colored red with scib paint through the common carotid artery and blue with scib paint through the lingofacial vein showing: the heart (H); left ventricle (LV); pulmonary trunk (PT); aorta (AO); caudal vena cava (CdVC); cranial vena cava (CrVC); pulmonary veins (PV); brachiocephalic trunk (BCT); pericardium (pr); first rib (1st); 1- left auricle; 2- left vena azygos ; 3- descending thoracic aorta. The vagus nerve (the black arrow).

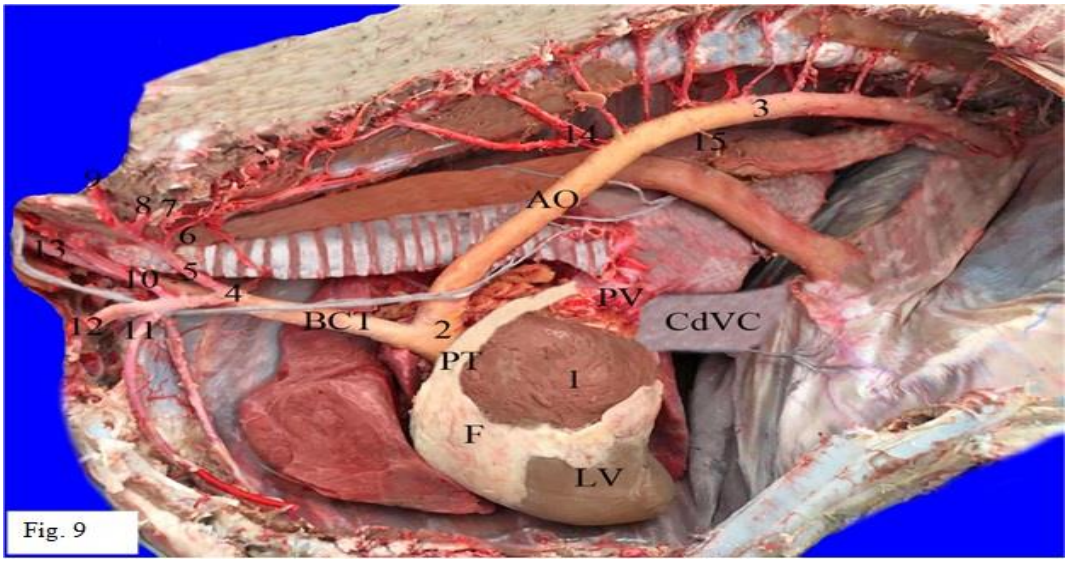

Fig. 9: A photomacrograph of the branches of the aorta of the left thoracic cavity of a goat showing branches of the aorta: 1- left auricle; 2- aortic arch ; 3- descending thoracic aorta; 4- left subclavian; 5- costocervical trunk; 6- supreme intercostal artery; 7- dorsal scapular artery; 8- deep cervical artery; 9- vertebral artery; 10- superficial cervical artery; 11- internal thoracic artery; 12- axillary artery; 13- bicarotid trunk; 14- dorsal intercostal arteries; 15- bronchoesophageal trunk; adipose tissue (F); left ventricle (LV); pulmonary trunk (PT); aorta (AO); caudal vena cava (CdVC); pulmonary veins (PV); brachiocephalic trunk (BCT).

Computed tomography of the thorax

The heart appeared from the level of the second to the level of the sixth thoracic vertebrae of the median plane. It was located between the two lungs dorsally, sternum ventrally, and shifted slightly to the left side. Its chambers appeared as hypodense grey structures. The aorta, pulmonary trunk, right and left pulmonary arteries, and caudal vena cava appeared as grey structures originating from the base of the heart (Figures 10/A, B, C).

The examined frozen section at the level of the fourth and thoracic vertebrae indicated that the heart was slightly shifted toward the left side of the median plane. This part of the heart was recognized by the left ventricular wall and the right ventricle. The latter filled with clotted blood. The heart was related closely to the two lungs and sternum (Figures 10/A, B, C, D).

Radiograph of the thorax

The cardiac silhouette on the left lateral view of the thoracic cavity X-ray was ovoid with the apex pointed toward the left side. The cranial border of the cardiac silhouette was situated at the level of the second rib whereas the caudal border of it was placed at the level of the fifth rib. On the left lateral view, the aorta and the brachiocephalic trunk were less distinct, the caudal vena cava, cranial vena cava, and the left vena azygos were clear and visible (Figure 11).

Echocardiography of the heart

The heart chambers were seen based on the anechoic blood in their lumens. Hypoechoic inter-ventricular septum and myocardium could be visualized in the same view as the heart chambers. The left ventricle, left atrium, right ventricle, and right atrium was seen hypoechoic in the right parasternal longitudinal axis as well as the myocardium (Figure 12/A), while in the right parasternal short-axis heart view showed the anechoic lumens of the right atrium, left atrium and the aortic lumen (Figure 12/B).

The right parasternal short axis at the level of papillary muscles revealed the right ventricle, the left ventricle, the myocardium, and the papillary Muscles in cross-section (Figure 12/C).

The distribution of echocardiographic diastolic and systolic parameters was obtained by the M-mode (Motion mode) and represented in a right parasternal short-axis view, at the level of papillary muscles in the left ventricle, the lumen appeared relaxed in the diastolic and was contracted in the systolic phases (Figure 12/D).

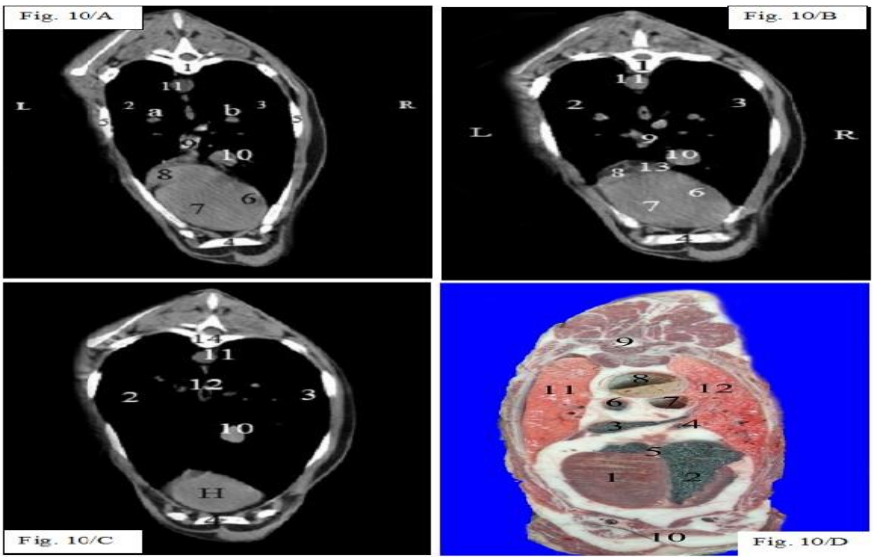

Fig. 10: A and **B.** Photomacrographs of CT image (2.5mm thickness interval) at the level of the fourth thoracic vertebra. **C.** A photomacrograph of CT image (2.5mm thickness interval) at the level of the fifth thoracic vertebra showing: 1. Fourth thoracic vertebrae; 2. Left lung; 3. Right lung; 4. Sternum; 5. Ribs; 6. Right ventricle; 7. Left ventricle; 8. Left atrium; 9. Pulmonary trunk; 10. Caudal vena cava; 11. Aorta; a. left pulmonary artery; b. Right pulmonary artery; 13. Right atrium; 14. fifth thoracic vertebrae; (H) Heart. **D.** A photomacrograph of the transverse anatomical section in the thorax of the goat at the level of the fourth thoracic vertebra (caudal view) showing: 1. Left ventricular wall; 2. Right ventricle; 3. left atrium; 4. Coronary sinus; 5. Interventricular septum; 6. Aorta; 7. Trachea; 8. Esophagus; 9. Fourth thoracic vertebrae; 10. Sternum; 11. Left lung; 12. Right lung.

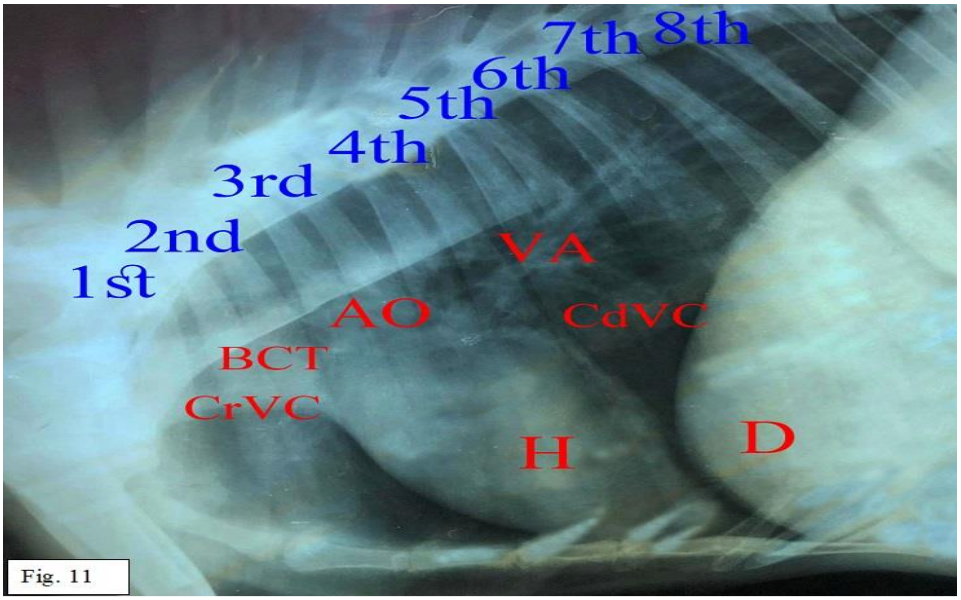

Fig.11: Radiographic images of the left lateral thoracic wall of goat showing: the heart (H); cranial vena cava (CrVC); caudal vena cava (CdCV); aorta (AO); brachiocephalic trunk (BCT); left vena azygos (VA); diaphragm (D), and the ribs from 1 to 8.

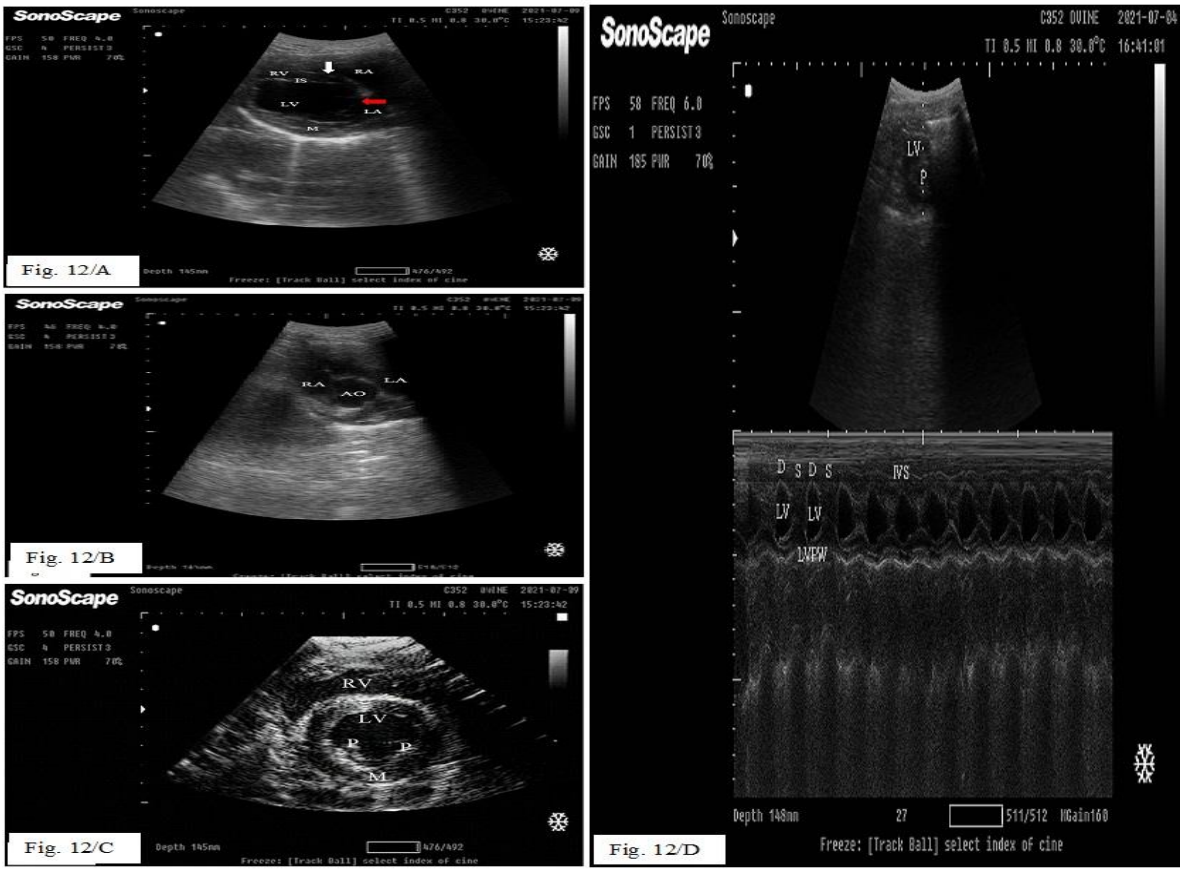

Fig. 12: A. Echocardiographic images of the right parasternal longitudinal axis four-chamber view (2D); LV: left ventricle; LA: left atrium; RV: right ventricle; RA: right atrium; M: myocardium. **B.** Echocardiographic images of the right parasternal short axis (2D): LA: left atrium; RA: right atrium; AO: Aorta. **C.** Echocardiographic images of the right parasternal short axis at the level of papillary muscles (2D); RV: right ventricle; LV: left ventricle; M: myocardium and P: papillary Muscles. **D.** Echocardiographic Motion-mode (M-mode) at the left ventricular papillary muscle (P) level showing LV: left ventricle; IVS: interventricular septum; LVPW: left ventricular posterior wall.

Discussion

The knowledge of heart anatomy provides the necessary means to perform and develop any medical, surgical, and educational processes in domestic animals. Moreover, it is the essential column for physiological and pathological studies. Generally, the hearts of mammals contribute many similarities, but they can vary considerably in size, shape, position, and vessel organization among species. The current paper explains the main aspects of the external and internal anatomy of the heart of goats.

The present work showed that the heart was placed opposite to the ribs from the 3rd to the 6th, however, it was stated that the heart extended between the 2nd and the 5th in sheep and goat, from the 3rd to 5th in ox, from the 3rd to 6th rib in pig, dog, and horse [27].

The present study revealed that the heart of the goat was hollow muscular cone-shaped and present in the middle mediastinum in the thoracic cavity space between the right and left lungs. These results simulated the findings of [2, 16]. Our finding showed that the heart in goat was organized into four chambers and the blood supply to and from the heart throughout the body was delivered via the same main arteries and veins. These results were similar in all mammalian species, in which the heart was composed of the upper two atria and lower two ventricles with the main large blood vessels originating from the base [9, 11].

The two pumps within the heart; the right, which collected and pumped the venous blood from the body to the pulmonary trunk, and the left, received the blood from the pulmonary veins and the aorta distributed it to the rest of the body. These features were like those described in domestic animals, where the right atrium received the cranial, caudal vena cava, and the coronary sinus, and then drain the blood into the right ventricle. Then after the pulmonary trunk divided into right and left pulmonary arteries which proceeded into the corresponding lung. While, the pulmonary veins opened into the left atrium and conveyed the blood into the left ventricle then into the aorta [28-30].

Our findings revealed that the hearts of goats were conical and had a pointed apex, unlike dogs, which had an ovoid heart with a blunt apex, sheep, and pig with a blunt apex as reported by [13]**.** However, the apices of goat hearts are all formed entirely by the left ventricles similar to the findings in the dog, pig, and sheep [13].

The exterior morphology of the goat heart was analogous to that of the domestic animals. Regarding the three grooves; the coronary, left and right longitudinal interventricular were similar in ruminant and equine. But the intermediate groove was present in ruminant animals only as described in the heart of goats. These results agree with domestic animals [16, 27, 29**]**. In camel, the intermediate groove was absent [31].

There were 3 papillary muscles were encountered in the right ventricle and two papillary muscles in the left ventricle. The different measurements and positions of each papillary muscle were important for proper functioning and maintaining the integrity of the right and left atrioventricular valves, any abnormalities could range from muscle rupture to muscle calcification. As well as the papillary muscle malformation, an increased number, and size might lead to left or right ventricular outflow tract block and valve regurgitation [32].

In the right ventricle of the heart of the goat, it presented one rounded septomarginal trabecula and carneae trabeculae that increased the cardiac contraction. These results were in a harmony with that described in domestic animals [27, 29]. The carneae trabeculae were not well-developed in both ventricles in the deer [33]. On the other hand, the presence of two septomarginal trabeculae was previously reported in goats [34].

The right ventricle of the goat had numerous chordae tendinae than the left ventricle. This finding was in agreement in horses [18], pigs, sheep, cows [19], and goats [34].

During CT scanning, the soft tissue appeared as hypodense of moderate density (grey) and gases visible as low density (black). CT scanning results revealed that the

heart extended from the level of the fourth to the level of the sixth thoracic vertebrae. It was located between the two lungs dorsally, sternum ventrally, and shifted slightly to the left side. Its chambers appeared as hypodense grey structures. The aorta, pulmonary trunk, right and left pulmonary arteries, and caudal vena cava appeared as grey structures originating from the base of the heart. These results simulated the findings of [26, 35].

The radiograph of this study revealed that the cardiac silhouette on the left lateral view of the thoracic cavity was ovoid with the apex pointed toward the left side. The aorta and the brachiocephalic trunk were less distinct, the caudal vena cava and cranial vena cava were clear and visible. It was consistent with what was reported in the previous literature [36]. The radiograph was recommended for thorax evaluation. The normal cardiac position and shape were assessed on the lateral radiograph. Abnormal cardiac shape caused by different changes in the contour of the cardiac silhoute. Assessment of the blood vessels anatomy including the aorta, vena cavae could change with the different diseases process [37].

Conclusion

The traditional animal anatomy is dependent on dissections with details to generate anatomical knowledge and description. Currently, the modern imaging modalities, such as CT, echocardiography, and radiograph, provide non-invasive means for the animal anatomy in living animals. Therefore, the integration of both cadaver dissections with using the imaging techniques is considered an interesting means of anatomical education. Further research on these imaging modalities can create three-dimensional models of considerable significance for anatomical studies.

Conflict of interest:

None of the authors have any conflict of interest to declare.

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الملخص العربي

التصوير المقطعي وتخطيط صدى القلب والتصوير الشعاعي وتشريح القلب في الماعز

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القلب هو أهم عضو في الجهاز القلبي الوعائي، يضخ الدم الغني بالأكسجين في جميع أنحاء الجسم. تعد تقنيات التصوير أمرًا حيويًا للحصول على تفاصيل أفضل لوصف تركيب القلب والأوعية الدموية. ومن ثم، تعتبر وسيلة مهمة للتشخيص والتطبيق السريري. تم أجراء الدراسة الحالية على خمسة ماعز سليمه من كلا الجنسين من سلالات محلية تزن حوالي 30-35 كيلوجرام ويتراوح عمرها من سنة إلى ثلاث سنوات. تم استخدام هذه الماعز عن النحو التالى: الفحص الطبوغرافي، حقن صمغ اللاتكس 60٪، التصوير المقطعي متبوعًا بتقنية المقطع العرضي المجمد، تصوير الصدر بالأشعة، وتخطيط صدى القلب. تم تشريح عشرة قلوب من الماعز السليمة الواضحة لوصف مورفولوجيا القلب. يقع قلب الماعز بين الضلع الثاني والسادس في التجويف الصدري. مخروطي الشكل مجوفًا مع قمة مدببة قليلاً. له سطحان، وحدان، وقاعدة، وقمة. القلب مقسم الى أربع غرف من خلال الأخاديد التاجية والطولية. تمت مقارنة نتائج التصوير المقطعي مع الصور التشريحية. تم تحديد التصوير الشعاعي وتخطيط صدى القلب وتصنيفهما لإنشاء دليل شامل للخبراء في علم التشريح والجراحة والتعليم البيطري. في الختام، يولد تشريح القلب معرفة ووصفا تشريحيا. إلى جانب ذلك، فإن طرق التصوير الحديثة مثل التصوير المقطعي وتخطيط صدى القلب، والتصوير الشعاعي، وفرت وسائل غير جراحية لتشريح الحيوان في الحيوانات الحية.