**Western European Journal of Medicine and Medical Science**
Volume 2, Issue 11, November 2024
https://westerneuropeanstudies.com/index.php/3
ISSN (E): 2942-1918 Open Access| Peer Reviewed


# MODERN IDEAS IN THE THEORY OF HEART FUNCTION AND STRUCTURE (REVIEW OF LITERATURE)

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**Abstract.** The article reveals the processes and mechanisms of the diastolic function of the pericardium - the heart sac. It was found that the pericardium is not only a sac that surrounds the heart, but also ensures the stabilization of the diaphragmatic dome during systole of the heart chambers and ventricles, during breathing processes, and determines the constancy of the heart volume. The relationship between the heart's activity and the "legs of the diaphragm" muscles, which connect the ligament centers of the diaphragm with the vertebral column and are located in the abdominal cavity under the diaphragm, is revealed. It was found that the "legs of the diaphragm" muscles control the height of the ligament centers of the diaphragm. During diastole of the heart ventricles, these powerful muscles contract, pulling the diaphragmatic center downward, ensuring more efficient and faster filling of the heart ventricles with blood, increasing the vacuum in the pericardial cavity. A strong connection is formed between the heart and the vertebral column: myocardium↔epicardium↔pericardial cavity↔pericardium↔tendinous center↔diaphragmatic pedicle↔vertebral column (lumbar vertebrae L3-5).
**Keywords:** heart, diastole, myocardium, epicardium, pericardium, diaphragm, pedicles of the diaphragm.

As is known, the heart is a pumping organ and is located in the pericardial cavity with a volume of 700-140 ml [1]. The pericardium consists of two layers: the epicardium, which is attached to the myocardium, and the parietal (outer) layer, both of which are 1-2 mm thick. The epicardium passes into the parietal layer at the origin of the aorta, in the pulmonary girdle, and in the region of the vena cava, forming a hermetic space that contains 15-35 ml of pericardial fluid. The pericardium is attached to the diaphragm from the bottom [2,3]. When the heart is at rest, the pericardial cavity (the fifth chamber of the heart) is in a virtual state, since the epicardium is tightly attached to the pericardium, but during systole of the heart ventricles, the pericardial cavity expands and a vacuum condition is created in it. During diastole, the heart fills with blood [4]. The work of the heart consists of two main phases - diastole and systole. During systole, the myocardium contracts and ejects blood from the ventricles into the aorta for nutrition of the body and oxygenation of the blood in the lungs. Between the processes of systole and diastole, a complex process occurs, which ends with a new systole of the heart ventricles [5,6,7,8]. The main property of the myocardium is contraction and relaxation (return to its original state), "relaxation" is also an important property of muscle tissue. Muscles act in only one direction. "Antagonist - this is the main muscle (head), which acts opposite to the action of the agonist. Therefore, antagonist muscles are usually located opposite each other - on the opposite side, for example, biceps and triceps in the arms; quadriceps and triceps in the thighs; back muscles and chest muscles" [9]. Therefore, the heart myocardium performs only systolic function, that is, it pumps blood from the ventricles to the ventricles, and from the

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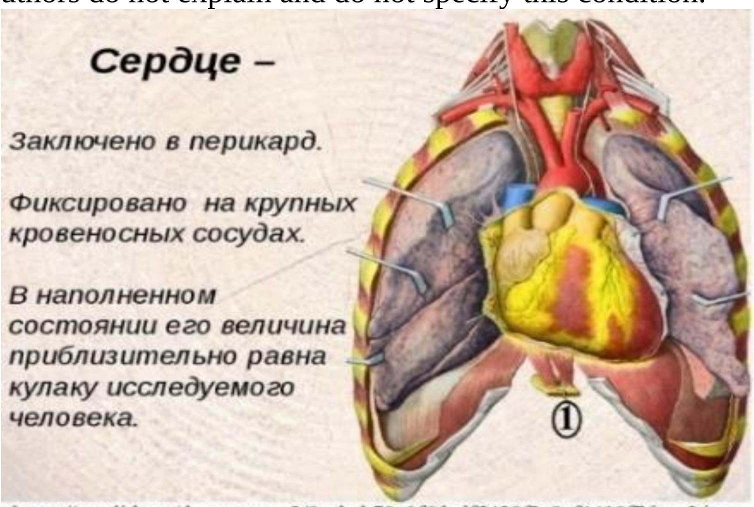
ventricles to the aorta and pulmonary trunk. For the efficient functioning of the myocardium, muscles and mechanisms or antagonistic muscle mechanisms are required as a synergistically powerful combination to fill and stretch the ventricles with blood during diastole. Without taking into account the pericardium and its fifth sealed chamber of the heart (antagonistic mechanism) [11], modern science and scientists cannot explain the mechanism of filling the ventricles of the heart. Biologists, together with medical professionals and physiologists, believe that the pericardium performs only a protective and limiting function [12,13].

[10] N.V. Kovalenko and N.I. Yabluchansky emphasize that "the diastole process is the main process in the biomechanics of the heart, it is it that forms the systole and through it the entire cycle of blood circulation. The energetic "boiler" of heart contractions is present in diastole" and at the same time openly admit that "the mechanisms of diastole processes still remain a mystery" [14, 5]. In this work, visual examination of the anatomical image of the heart and analysis of literature data help to understand the essence of these processes. Visual inspection methods, including image study [15], were used as the oldest method and until the creation of human images, such as "images on rocks", were studied. Based on the analysis of blood circulation in humans, it should be noted that during systole of the heart, a vacuum is created in the hermetic pericardial cavity, which narrows the dimensions of the heart, and the vacuum after systole pulls the myocardium (as an antagonist) to allow blood to pass (fill) from the ventricles [4]. However, it should also be added that the heart is connected to the diaphragm by the pericardium. The diaphragm is a thin, dome-shaped muscular band that separates the chest and abdominal cavities. As noted above, in the middle of the diaphragmatic fold there is a zone of fusion of the diaphragm and the pericardium. Here, the diaphragm thickens downwards. The area is 1.5 to 2 cm wide in front and above, firmly attached to the pericardium, and along the entire length of the remaining part there is a loose connective tissue between the diaphragm and the pericardium. In most anatomical drawings, the heart is depicted without the pericardium ("naked", one might say, cleaned), but sometimes the heart is depicted as shown in Figure 1. In addition to the "state of the heart in the pericardium", it is depicted as an "imitation" of the muscles, which are located in the abdominal cavity under the diaphragm, but the authors do not explain and do not specify this condition.




[11] https://myslide.ru/documents_3/8aabeb78a0f6dadf5438f2c9ef4418f7/img2.jpg

Fig. 1 "Location of the heart in the pericardium; posterior view. (lungs pushed to the side, pericardium hidden)" [17]

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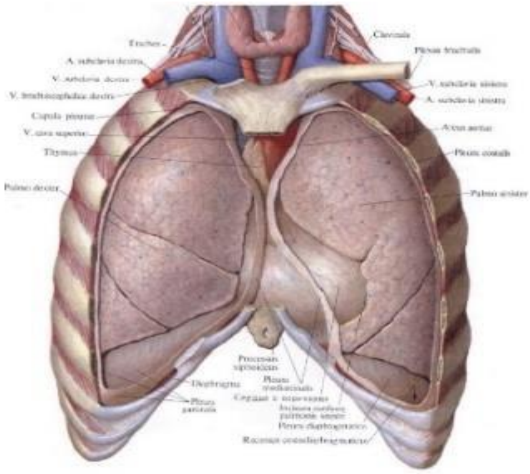

Figure 2 "The state of the organs in the chest; front view. (The anterior wall of the xiphoid process of the sternum (Processus xiphoideus) and the corresponding parts of the parietal pleura have been removed)" [16,14].

The search for the essence of such images led us to the "anatomical atlas" of R.D. Sinelnikov, Y.R. Sinelnikov [16]. Initially, the authors presented the image of the xiphoid process of the sternum (processus xiphoideus) under the diaphragm in the abdominal cavity, along with the image of the "state of the thoracic cavities" located on page 14 of the third volume of the atlas (Fig. 2). The xiphoid tumor has various forms (Fig. 3), but it is not known how the "position of the chest organs" can affect the heart function if it is not located in the abdominal cavity. Therefore, it is not advisable and incorrect to depict the sternum xiphoid tumor in relation to the chest. However, the authors continued to study the images. Figure 3 presents the forms of the xiphoid tumor, and one of them (case 4) corresponds to the tumor in Figure 2. Comparisons of the sternum, ribs, xiphoid tumor and cardiac shadow showed that the xiphoid tumor has no relation to the heart. The xiphoid tumor is located below the heart and there is no communication between the heart and the tumor (Fig. 4).


Figure 3. Xyloarthrosis of the sternum: 1-Xyloarthrosis; 2-Body of the sternum; 3-Xyloarthrosis, iliac view; 4-Xyloarthrosis with foramen.

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Figure 4. Contours of the heart shadow under the sternum and ribs in the chest.

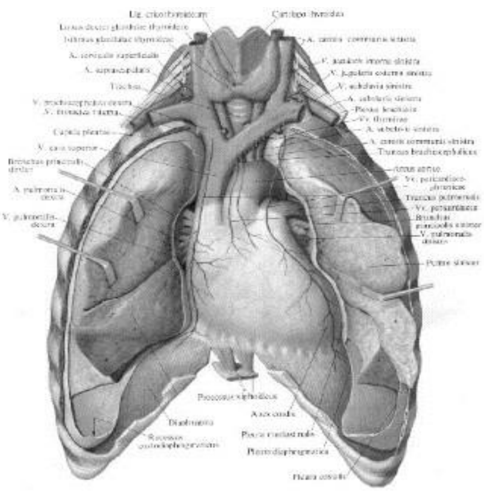

Figure 5. "Heart condition; front view" [16]. Below the diaphragm is a "xiphoid process", but this is not a true xiphoid process.

In Figure 5, this "tumor" of the "xiphoid process" is unusual; instead of a tumor, the muscles in the abdominal cavity that connect the diaphragm with some area are "imitated". The authors may have depicted some non-standard situation in the figure, perhaps known only to them. If these are imitations of muscles, then we should look for the muscles schematically depicted in Figure 5, which go from the abdominal cavity below the dome of the diaphragm. It turned out that these are the "legs of the diaphragm" (Figure 6) [19]. These are strong muscles in the abdominal cavity that connect the L4-5 lumbar vertebrae with the tendon center of the spinal column. Here, another thing that seems strange is that in Figure 6, the authors have depicted the "diaphragm legs" well and reliably, but the "legs" are not marked in the figure.

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Figure 6. Diaphragm from bottom to top [19]. The figure is supplemented: the diaphragm legs and their connection to the lumbar vertebrae L4 and L5 of the spinal column are marked by the right (1) and left (2) muscles.

When anatomists know the function of a particular muscle, they also specify its function after describing it: for example, the transverse thoracic muscles "participate in exhalation and lower the ribs." Unfortunately, this is not the case for the "diaphragm legs" muscles. According to some authors [15], the function of the "legs of the diaphragm" is to "not oppose" the processes of blood circulation and digestion. In our opinion, these functions are incorrect, and the task of further studying the issues of the purposeful use of these powerful muscles arises. According to [18], another function of the diaphragm is to ensure the passage of certain structures from the chest into the abdominal cavity (inferior vena cava, esophagus and aorta) [14,20,21]. The thoracic-abdominal barrier (diaphragm) muscle section is divided into lumbar, costal and thoracic parts. The lumbar section forms two strong muscle legs - right and left. The pericardium of the heart is firmly attached to the center of the rib cage in the upper part and rises from this center upwards, following the "legs of the diaphragm" the abdominal cavity They connect with each other in front of the aortic opening from the side of the cavity and then move slightly to the left and up, moving away from it and forming a hole here, through which the esophagus passes (Fig. 6) [20].

In Fig. 7a, the "legs of the diaphragm" are depicted slightly differently (but here too, the connection of the lumbar vertebrae of the spinal column with the muscles of the intercostal space in the abdominal cavity is clearly visible).

In Fig. 7a, the connection of the L4 lumbar vertebra with the intercostal space from the side is depicted, and the diagram of the left legs of the diaphragm is shown. Fig. 7b shows that the Th12 vertebra of the Th12 spinal column has a curvature facing forward. Due to this curvature, the directional movement of the "legs" takes a straight vertical position under the direction of the diaphragm, without levers and angular bends..

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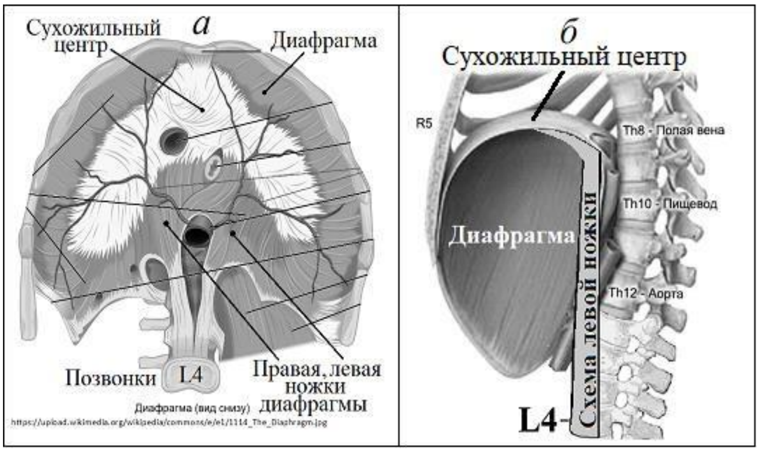


Fig. 7. Diaphragm (top view): a-muscular "legs" of the diaphragm in the abdominal cavity [20]; b-scheme of the lateral aspect of the vertebral column and the left leg of the diaphragm, left side view.

Thus, the "legs of the diaphragm" are directly connected to the costal center and the L3-5 lumbar vertebrae. When these muscles contract, the heart and pericardium sink into the chest above the diaphragm, acting on the costal center, as a result of which the costal center is pulled down, the "legs of the diaphragm" received their "artistic" name due to insufficient knowledge of their intended function. The heart muscle (myocardium) performs circular contractions, like the muscle rings of a snake. The contraction of the muscles in a circular direction allows the development of a large compressive force to squeeze blood out of the ventricles of the heart. The working muscle fibers of the myocardium of the ventricles and chambers make up the main mass of the heart and ensure its function of pumping blood. According to N.V. and O.V. Fatinkov (17,21), "the increase in the internal volume of the ventricles occurs faster than the phase of rapid filling with blood and the volume of blood passing through it. As a result, a paradox arises in the form of the development of the blood-sucking function of the ventricles [23]. This is also confirmed by other sources [24]. It follows that blood from the dilated chambers of the heart is expelled into the ventricles not only due to the "catapult", but also due to the strong contraction of the "diaphragmatic legs", which have antagonistic and synergistic functions, which at the same time pull down the diaphragm's iliac crest and, together with the pericardium, increase the vacuum in the pericardial cavity [4,12]. According to Y.V. Devaykin, the catapult effect on the filling of the ventricles with blood is called: "rapid filling phase: blood is pumped from the ventricles to the ventricles," notes [25]. The pericardium is firmly attached to the chest wall and is very firmly connected to the center of the diaphragmatic ligament (Fig. 8). The parietal layer of the pericardium is attached to the large blood vessels of the heart from the upper side and from the back by connective tissue flaps. Anteriorly, the pericardium is attached to the sternum by two ligaments. These ligaments are located medially, free from the anterior part of the pericardium, the pleura. The superior pericardial ligament is attached to the first costal cartilages and the posterior surface of the sternum handle. The inferior sternopericardial ligament is attached to the xiphoid process. On the lateral surfaces of the thoracic vertebrae, the vertebral-pericardial ligaments pass to the lateral layers of the pericardium, which form the intrathoracic fascia [26]. In addition, the pericardium is connected by soft connective tissue to all structures in the thoracic cavity (breastbone, vertebral column,

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large aorta entering and leaving the heart, pulmonary girdle, lungs). This tissue and all organs surrounding the sternum are a single whole, containing collagen and elastic fibers..

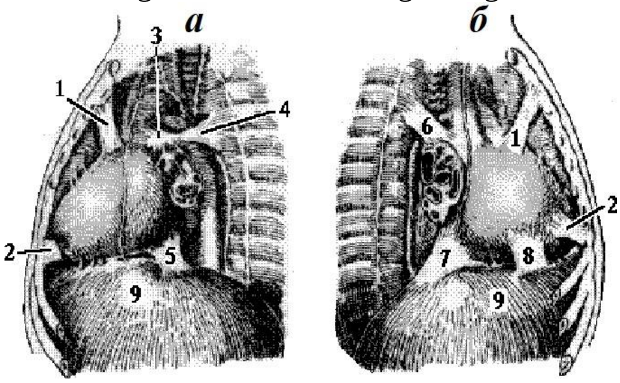


Figure 8. Attachment of the pericardium to the thorax [26]: 1-superior sternal pericardial ligament; 2-inferior sternal pericardial ligament; 3-parietal layer of the pericardium attached to the great vessels of the heart; 4,6-connective tissue folds; 5,7,8-attachment to the diaphragm; 9-center of the pericardium.

The external dimensions of the pericardium vary individually and depend on the volume of the heart. The difference in heart volume is usually very large, reaching 700 ml in non-athletic men and 1400 ml in skiers [23]. The surface area of the pericardium is on average more than 400 cm2 in men, and in high-level skiers, for example, more than 500 cm2. The negative pressure in the sternum pulls the pericardial wall from the outside along its entire surface. This pulling state also causes the pericardial cavity to become stagnant in the chest. Thus, the pericardium is not only a "jacket" of the heart, it is a capsule, the function of which is to ensure the stability and self-supporting ability of the diaphragmatic dome, as well as the constancy of its volume during respiratory vibrations of the diaphragm and deformation of the heart volume during systole in the ventricles of the heart. The diaphragm is controlled by the right and left cusps of the diaphragm (Fig. 9).

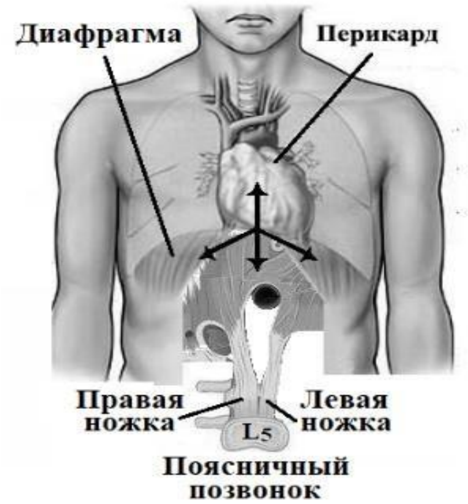


Fig. 9. Schematic diagram of the pericardium-diaphragm-diaphragmatic pedicles [22]. Note: the index indicates the direction of the force.

Conclusion. Thus, the diagram of the interaction of forces on the heart and vertebral column is: myocardium ↔ epicardium ↔ pericardial cavity ↔ pericardium ↔ tendon center ↔

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diaphragmatic pedicles ↔ vertebral column. The myocardium of the heart is covered from the outside (fused together) with the epicardium. The epicardium, 1-2 mm thick, surrounds a large area of up to 500 cm2, depending on the volume of the heart, and through the epicardium ↔ pericardial cavity vacuum ↔ pericardium, it is in contact with the air space formed by the outer parietal layer (pericardium), affecting the myocardium, and is held in place by numerous ligaments and soft connective tissue in the vertebral column, sternum and ribs. The pericardium has a tight connection with the tendon center of the diaphragm, contraction of the muscles of the "legs of the diaphragm" causes a decrease in the center, which increases the vacuum in the pericardial cavity. Acting on the epicardium, the "legs" stretch the myocardium, creating conditions for a forced increase in the volume of the ventricles for effective suction of blood from the filling of the chambers with blood. This mechanism leads to high efficiency of the heart (ventricular systole ≈ 1520 ml (21-29%), systolic volume of blood ≈ 70 ml) up to 71-79%.

Conclusion. The pericardium is connected to all the structures of the thoracic cavity (diaphragm, sternum, vertebral column, blood vessels entering and leaving the heart, lungs) by soft connective tissue and ligaments and is fused with connective tissue over large areas of up to 400-500 cm2. This connective tissue is the only whole unit in the thoracic cavity. It was found that the pericardium is a capsule, the function of which is to ensure the stability of the diaphragmatic dome and its retention, as well as to ensure the constancy of the volume of the heart during respiratory movements of the diaphragm and the deformation of the heart volume during systole of the ventricles and ventricles of the heart. There is a connection between the activity of the heart and the muscles of the "legs of the diaphragm", which connect the vertebral column at the level of the lumbar spine and the tendon centers of the diaphragm and are located in the abdominal cavity under the diaphragm. During systole, the dimensions of the heart decrease, creating a vacuum in the hermetic pericardial cavity, and the vacuum, filling the "catapult" of the ventricle, allows blood to be sucked (filled) from the ventricles and vena cava into the ventricles of the heart, and after systole, stretches the myocardium (like an antagonist) [7]. The diaphragm "legs" are directly connected to the sacral center and the L3-5 lumbar vertebrae of the spine. When these powerful muscles contract, the sacral center is directly affected by the diaphragmatic center, which has grown together with the pericardium of the heart, and is pushed down. The lumbar vertebrae of the spine have places for forward bending. Due to this bending, the "legs" under the direction of the diaphragm, without the help of levers and bending angles, take a straight vertical position. It was found that the muscles of the "legs of the diaphragm" control the height of the sacral center of the diaphragm. When the diaphragm contracts, these powerful muscles increase the vacuum in the pericardial cavity and pull the sacral center of the diaphragm down, which ensures more efficient and faster filling of the ventricles with blood during diastole.

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