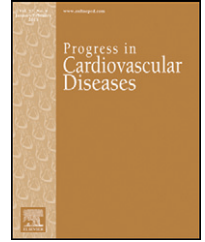


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Structure and Anatomy of the Human Pericardium

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ABSTRACT

The normal gross anatomy and light microscopy of the human pericardium are presented in detail that allows easy correlation with current cardiac imaging modalities. The anatomical structures of the parietal pericardium are shown from its mediastinal surface, including its ligaments to the sternum, diaphragm and vertebral column. The attachments of the parietal pericardium to the great vessels showing the intrapericardial location of the root of the aorta and pulmonary artery are documented. Also the attachments of the parietal pericardium to the venae cavae and the pulmonary veins are illustrated in detail. The internal anatomy of the parietal pericardium emphasizing the oblique and transverse sinuses is explained. The microscopic differences between the structures of the parietal pericardium and visceral pericardium (epicardium) are shown as the basis that allows understanding the spectrum of adaptation of the pericardium to diverse pathologic processes. However, the pathology of the pericardium is not discussed in this review.

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The pericardium is a roughly flask-shaped sac that contains the heart and proximal portions of the great vessels (Fig 1). The pericardium exerts mechanical effects by stabilizing the heart in its anatomic position and by maintaining cardiac geometry and pressure–volume relationships of the cardiac chambers.^{1,2} The pericardial sac serves as a physical barrier

that protects against the contiguous spread of infection or neoplasm within the mediastinum and also allows for potential targeted drug delivery that limits the concentration and action of the drug to the heart.³ The pericardial cavity normally contains <50 mL of serous fluid which lubricates the surface of the heart. The pericardial fluid contains prosta-

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Abbreviations and Acronyms

Ao = Aorta
AV = Aortic valve
H&E = hematoxylin and eosin
IAS = Interatrial septum
IVC = Inferior vena cava
LA = Left atrium
LAA = Left atrial appendage
LAD = Left anterior descending coronary artery
LH = Left hemidiaphragm
LIPV = Left inferior pulmonary vein
LJV = Left jugular vein
LPA = Left pulmonary artery
LPV = Left pulmonary vein
LPVR = Left pulmonary venous recess
LSPV = Left superior pulmonary vein
LV = Left ventricle
OS = Oblique sinus
PA = Trunk of the pulmonary artery
RA = Right atrium
RAA = Right atrial appendage
RIPV = Right inferior pulmonary vein
RPA = Right pulmonary artery
RPV = Right pulmonary vein
RPVR = Right pulmonary venous recess
RSPV = Right superior pulmonary vein
RV = Right ventricle
SVC = Superior vena cava

glandins secreted by mesothelial and endothelial cells that modulate autonomic cardiac reflexes, myocardial contractile function, and epicardial coronary tone.^{4–6}

In this article, we present the gross and microscopic structure of the pericardium in detail as a frame of reference that can be correlated with current cardiac imaging techniques and interventions. The limited repertoire of responses of the pericardium to diverse pathologic stimuli is briefly illustrated in the context of its normal structure.

Gross structure of the parietal and visceral pericardium

The pericardium is conventionally divided into parietal and visceral pericardium (Fig 2). The parietal pericardium consists of an outer fibrous connective tissue layer (fibrosa) lined by serosa (Fig 3). The serosal component consists of a single continuous layer of mesothelium that invests the fibrosa layer of the pericardium and extends over the root of the great ves-

sels to completely cover the external surface of the heart. The layer of mesothelium investing the outer surface of the heart is referred to as the visceral pericardium or epicardium (Fig 4). The serosal component also covers the anterior and lateral sides of the venae cavae and the anterior portion of the pulmonary veins.

The fibrous parietal pericardium is anchored in the mediastinum through several connections as follows. 1. The fibrous envelope is continuous with the adventitia of the great vessels

superiorly (Fig 5). 2. Anteriorly, it is attached to the dorsal aspect of the sternum through the sterno-pericardial ligaments which run in cephalocaudal direction from the sternal manubrium to the sterno-xyphoid junction (Fig 1). In the anterocaudal portion, the pericardium may come in direct contact with the costal cartilages of the left fourth to sixth ribs. 3. The next anchoring point is the attachment of the pericardial fibrosa to the central tendon of the diaphragm inferiorly through the pericardiophrenic ligaments (Fig 5). 4. Dorsally, the pericardial fibrosa is in contact with the major bronchi just caudal to the carina and for a short segment is in continuity with the fibrous fasciae of the esophagus and descending thoracic aorta. In this area, the fibrous tissue of the pericardium is also anchored to the vertebral column (Fig 6). 5. The lateral surfaces are invested by the mediastinal part of the parietal pleura, thus the mediastinal surface of the pericardium is also invested by mesothelial cells of the parietal pleura except in those areas where ligaments anchor the pericardium to the vertebral column, the sternum, and the diaphragm. The phrenic nerves and pericardiophrenic vessels travel in a cephalocaudal direction and are contained in two bundles flanking the lateral contours of the heart. These bundles lie between the fibrous pericardium and the mediastinal pleura anterior to the pulmonary hilum (Fig 7).

The fibrosa layer of the parietal pericardium exhibits a slight variation in thickness from region to region and is between 0.8 and 1 mm thick but may appear slightly thicker on imaging.⁷ The pericardial sac is covered by variable amount of adipose tissue in its mediastinal surface (Fig 8). There is usually an abundance of epipericardial fat at the anterior cardiophrenic angles, where the fat collection could be mistaken for a mass lesion on chest radiograph. Rarely, necrosis of epipericardial fat occurs to be a cause of acute pleuritic chest pain. The parietal pericardium can be easily visualized on imaging where it is delineated by epipericardial and epicardial fat. In the newborn, the epicardial adipose tissue is almost absent. As a function of age, the epicardial fat becomes most abundant along the atrioventricular and interventricular grooves and over the right ventricle, especially at the acute border. The epicardial adipose tissue surrounds the coronary arteries and veins, lymphatics, and nerve tissue supplying the heart.

A vestigial triangular fold of the visceral pericardium, the ligament of Marshall, passes obliquely from the left pulmonary artery to descend between the left atrial appendage and the left superior pulmonary vein (Fig 9). This visceral pericardial fold contains the fibrous remnants of the embryonic left common cardinal vein (also called left duct of Cuvier) which is continuous with the oblique vein of Marshall that drains into the coronary sinus. In addition, myocardial and nerve tissue surrounded by fat has been identified within the ligament of Marshall.⁸ Dissections on adult cadavers revealed absence of the vestigial fold of Marshall in 7% of the bodies while a patent oblique vein could be identified in about 13% of cases.⁹

Pericardial sinuses and recesses

As stated above, the serosal membrane lining the fibrous parietal pericardium is continuous with the visceral

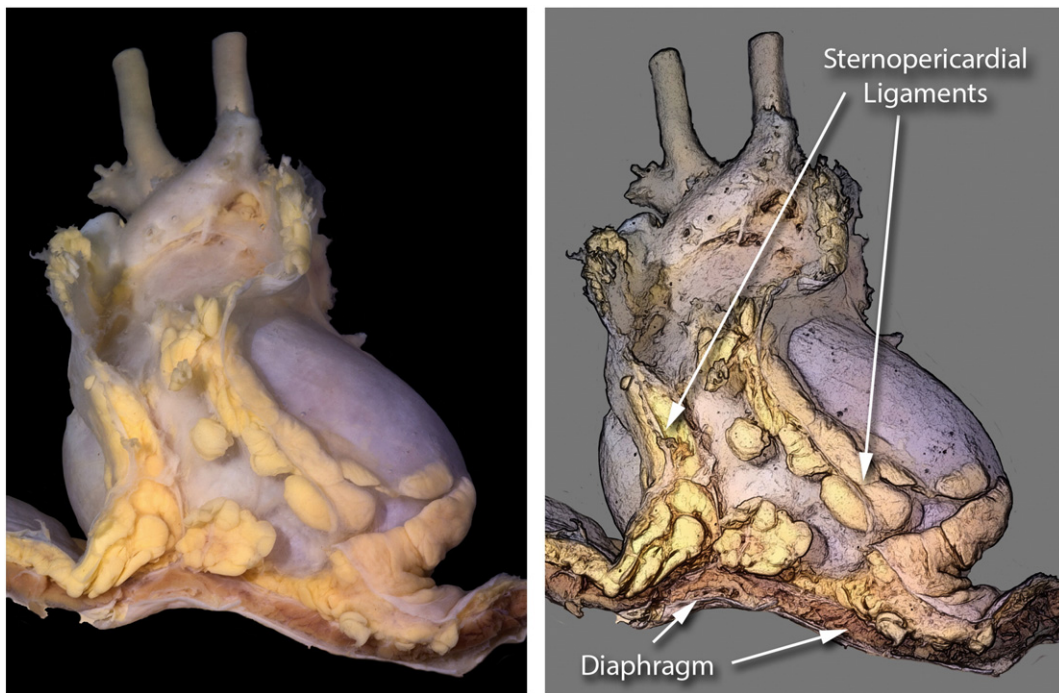


Fig 1 – Intact pericardium. Gross specimen from a 7-year-old child showing the heart covered by the pericardial sac. There are two longitudinal structures running in a cephalad-to-caudal direction on the mediastinal surface of the pericardial sac. These correspond to the right and left borders of the sternopericardial ligament. The pericardiophrenic ligaments are barely visible on the left and right margins of the pericardial sac.

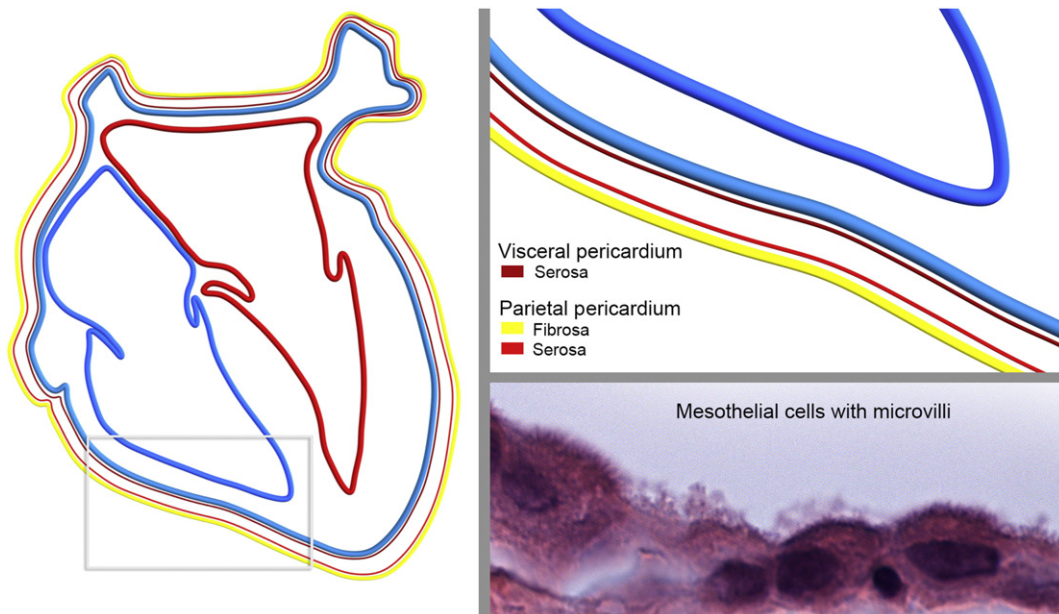


Fig 2 – Parietal vs. visceral pericardium. These diagrams show that the pericardium has, as several other serosal surfaces, a parietal and a visceral component. The parietal pericardium is composed of two layers: a serosal lining (thin red line) and a fibrous sac (thicker yellow line). The visceral pericardium or epicardium is composed of a single layer of serosal investment covering the entire heart (thin red line overlying the myocardium in blue). Note that the serosal lining of the parietal and visceral pericardium is a continuous layer of mesothelial cells. The potential space lined by the apposing layers of parietal and visceral pericardium is the pericardial cavity. The light micrograph shows a high magnification close up of mesothelial cells with distinct microvilli facing the pericardial cavity. These microvilli increase the surface area for production and reabsorption of normal pericardial fluid (×800, H&E).

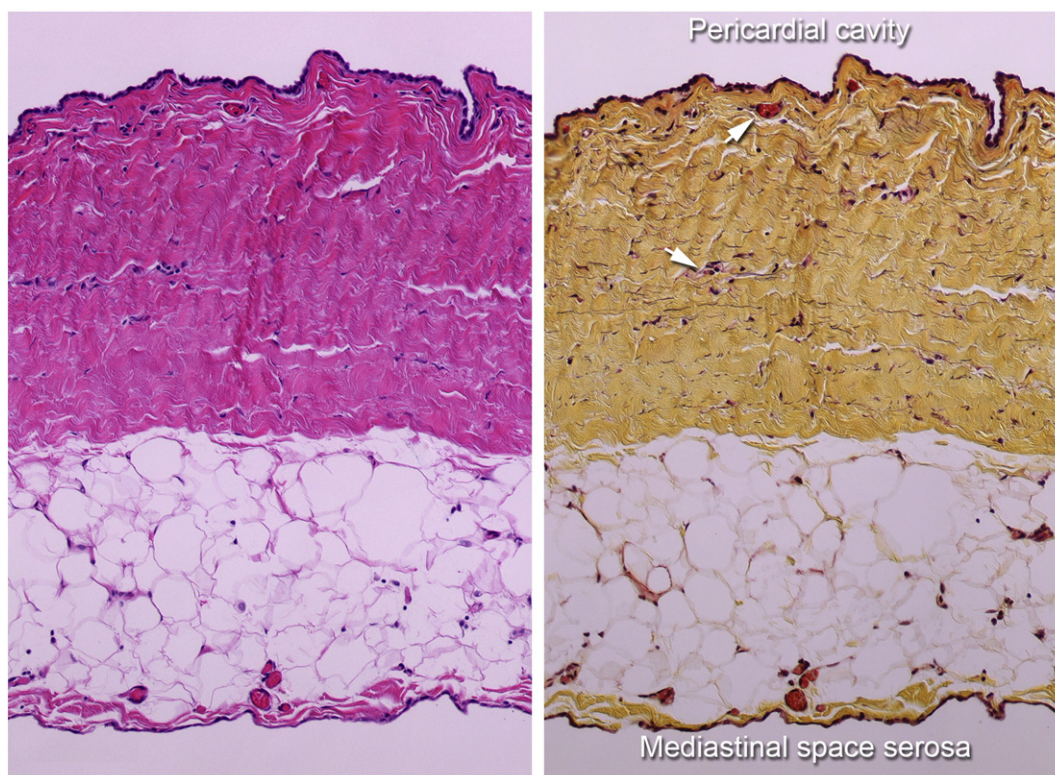


Fig 3 – Parietal pericardium. These microscopic images of the lateral wall of the parietal pericardium shows a serosal layer of pericardial mesothelial cells lining the pericardial cavity and the fibrosa layer. The fibrosa layer is the thick eosinophilic layer (left image) or yellow layer (right image) made up of dense wavy collagen fibers. Faint black lines represent a minimal amount of elastic lamellae in the fibrosa. The parietal pericardium contains a few small blood vessels (arrows). Between the fibrosa of the parietal pericardium and the mediastinal parietal pleura is a layer of epipericardial fat. Note the serosal layer of the pleura is also made up of a layer of mesothelial cells. ($\times 50$, H&E and Movat pentachrome).

pericardium that invests the heart and the proximal segments of the great vessels that enter and leave the heart. The reflections of the serosa around the arteries and the veins form the pericardial sinuses and recesses. Pericardial fluid can collect within these pericardial spaces that can be detected on imaging. Moreover, fluid in the pericardial recesses must be differentiated from mass lesions in the contiguous structures including the bronchi, esophagus, and mediastinal and tracheobronchial lymph nodes.¹⁰

The ascending aorta and main pulmonary artery together are completely ensheathed by an investment of the visceral pericardium. This investment creates a potential space, the transverse sinus, which separates the great arteries from the atria and veins (Figs 10 and 11). The ascending aorta and main pulmonary artery are anterior while the superior vena cava and superior pulmonary veins are posterior to the transverse sinus. The floor of the transverse sinus is formed by the roof of the left atrium. This passage behind the great arteries also allows access between the right and left sides of the pericardial cavity. The transverse sinus is continuous with the superior aortic recess between the aorta and the superior vena cava (Figs 10 and 12). This cephalad extension of the pericardial reflection reaches the proximal aortic arch superiorly and the left pulmonary artery laterally (Figs 11-13). The transverse sinus also extends downward to the level of the

root of the aorta. The space between the right lateral wall of the ascending aorta and the right atrium is the inferior aortic recess (Fig 12). The lateral extensions of the transverse sinus are called the right and left pulmonary recesses. The right pulmonary recess is a shallow recess bounded by the inferior wall of the proximal right pulmonary artery and the superior vena cava. The left pulmonary recess is the space between the left pulmonary artery and left superior pulmonary vein bounded by the ligament of Marshall on the medial aspect (Figs 11 and 13).¹¹

A second investment of visceral pericardium separately covers the venae cavae and pulmonary veins (Fig 13). The postcaval recess lies on the right lateral aspect and behind the superior vena cava. Its boundaries are the right pulmonary artery superiorly and right superior pulmonary vein inferiorly. The right and left pulmonary venous recesses are formed by the pericardial reflection between the respective superior and inferior pulmonary veins (Fig 14). The depth of the pulmonary venous recesses varies between individual hearts depending on the extent of invagination of the visceral pericardium around the superior and inferior pulmonary veins. The cul-de-sac located behind the posterior wall of the left atrium is the oblique sinus (Figs 13 and 14). It is delimited by the pericardial reflection along inferior pulmonary veins and the inferior vena cava. It directly abuts the carina and the esophagus posteriorly. The oblique sinus can vary from a

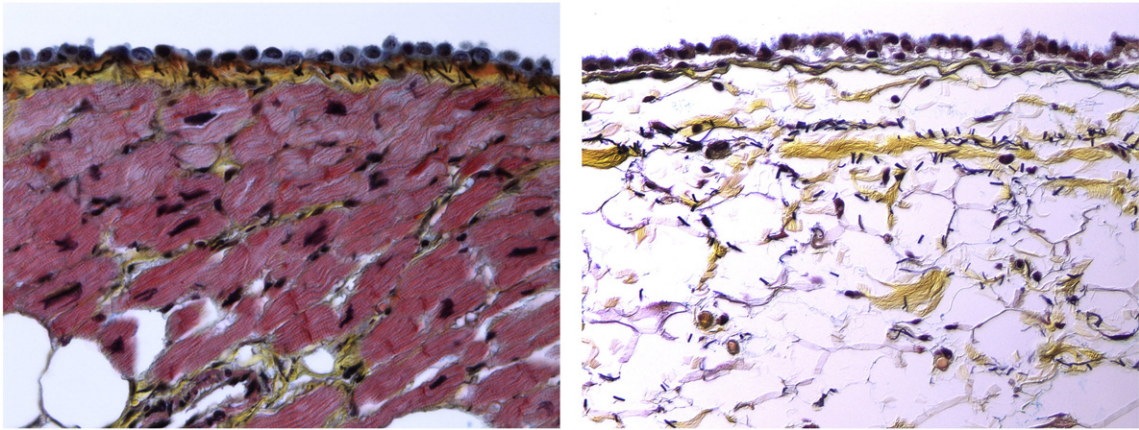


Fig 4 – Visceral pericardium. These two microscopic images show the serosal (mesothelial cell) component of the visceral pericardium that invests the heart. The image on the left represents an area where the visceral pericardium is in direct contact with the myocardium. Only a thin layer of fibrous tissue (yellow) separates the mesothelial cells (gray blue cytoplasm) from the cardiac myocytes (red sarcoplasm). Note the scant amount of elastic lamellae shown as black straight lines in the middle of the yellow fibrous tissue just underneath the mesothelium. ($\times 200$, Movat pentachrome). The image on the right shows the visceral pericardium as it covers an area of the heart with abundant adipose tissue in the epicardium (such as the interventricular and atrioventricular grooves or around the coronary vessels). There is a small amount of fibrous tissue (yellow) as well as scant elastic lamellae (black). The mesothelial cells forming the serosal layer play an important role in the production and reabsorption of fluid in the pericardial space ($\times 200$, Movat pentachrome).

triangular to square shape depending on the symmetry and depth of the pulmonary venous recesses.¹²

Lymphatic drainage, vascular supply, and innervation

The pericardial cavity is the closed potential space lined by the serosal membrane of the parietal and visceral

pericardium. It contains an average of 20 to 25 mL of fluid with range between 20 to 60 mL.¹ In the supine position, most of the pericardial fluid collects in the superior aortic recess and transverse sinus.¹⁰ The pericardial fluid is an ultrafiltrate of plasma that comes from epicardial and parietal pericardial capillaries. Pericardial fluid is drained by the lymphatic system on the epicardial surface of the heart and in the parietal pericardium. Additionally, the pericardial lymphatics also anastomose with the lymphatics in the epipericardial fat,

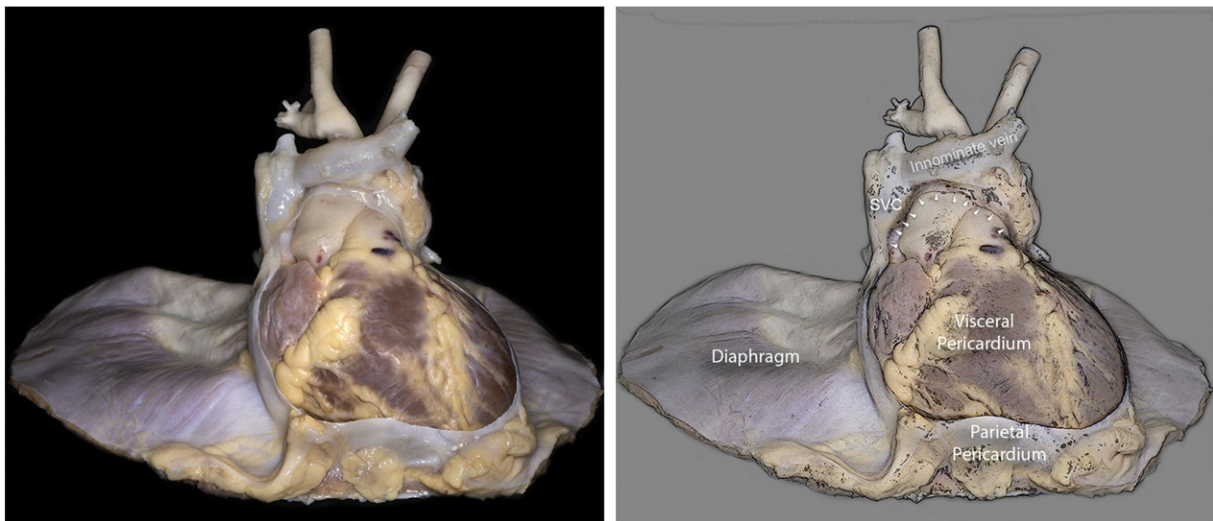


Fig 5 – Anterior-cephalad view of the heart and pericardial sac. The anterior portion of the pericardial sac has been cut to reveal the heart in situ. The pericardiophrenic ligament is clearly seen anchoring the base of the pericardial sac to the surface of the diaphragm where these two structures make contact. The insertion of the pericardial fibrosa around the great vessels is marked by the white arrowheads. The surface of the heart is glistening due to the presence of a moist surface visceral pericardium (serosa) which covers all the intrapericardial structures including the ventricles, atria and the roots of the great vessels. Abbreviation: SVC = Superior vena cava.

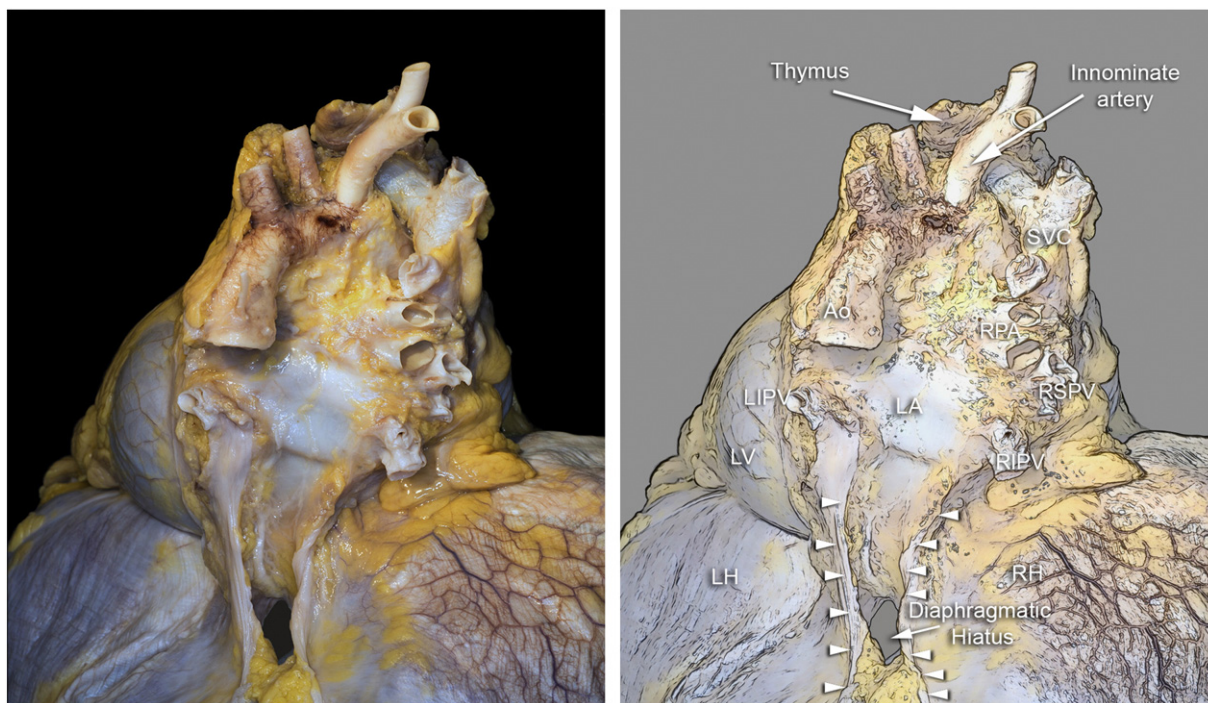


Fig 6 – Dorsal view of the pericardial sac containing the heart. The attachment of the pericardial sac to the diaphragm is shown in the posterior view (the anterior view is shown in Fig 1 and 5). There are two distinct ridges of connective tissue (white arrowheads) which represent the pericardiovertebral ligament. In the lower portion of these ligaments is an orifice which corresponds to the diaphragmatic hiatus (the thoracic portion of the aorta, the esophagus, trachea and right and left bronchi have been removed). The posterior central position of the left atrium flanked by the pulmonary veins is shown. The pericardial fibrosa merges with the adventitia of each of the pulmonary veins, just as it merges with the root of the great vessels anteriorly. Inside the pericardium, the space bounded by the posterior wall of the left atrium and the pulmonary veins corresponds to the oblique sinus of the pericardium. Abbreviation: Ao = Aortic arch. LH = Left hemidiaphragm. LIPV = Left inferior pulmonary vein. LV = Left ventricle. RPA = Right pulmonary artery. RIVP = Right inferior pulmonary vein. RSPV = Right superior pulmonary vein. SVC = Superior vena cava.

mediastinal pleura and diaphragm to provide alternate flow routes of pericardial fluid.¹³ The lymphatic vessels of the anterior pericardium drain to the anterior mediastinal lymph nodes. The lymphatic networks of the lateral and posterior parietal pericardium run predominantly cephalad to the peribronchial and tracheobronchial lymph nodes and also to the posterior mediastinal lymph nodes.^{13,14}

The arterial supply of the pericardium comes from the pericardiophrenic and musculophrenic branches of the internal thoracic artery and the descending thoracic aorta. The pericardiophrenic veins provide venous drainage of the pericardium directly or via the superior intercostal veins and internal thoracic veins into the brachiocephalic veins.¹⁵ Connections with the inferior phrenic veins that drain into the inferior vena cava provide alternate pathways for the drainage of the pericardiophrenic veins.¹⁶

The phrenic nerve supplies sensory fibers to the pericardium. The parasympathetic nerve supply of the pericardium is from the vagus and left recurrent laryngeal nerves as well as branches from the esophageal plexus. Sympathetic innervation is derived from the first dorsal ganglion, stellate ganglion and the aortic, cardiac, and diaphragmatic plexuses.¹

Microscopic and ultrastructural organization of the pericardium

The microscopic structure of the pericardium is the basis to understand the narrow spectrum of adaptation and pathologic responses of the pericardium to various noxious stimuli. Three distinct layers can be defined in the pericardial sac: the serosa, the fibrosa, and an outer layer of epipericardial connective tissue which is the interface of the pericardium with surrounding mediastinal structures. The serosa is the innermost surface of the sac and is formed by mesothelial cells. There is a narrow submesothelial space (2 micrometers in thickness) which separates the mesothelium from the subjacent dense fibrosa. The mesothelial cells are rich in microvilli which are important for the formation and reabsorption of pericardial fluid. In the parietal pericardium, the fibrosa is composed of dense collagen bundles and scant elastic fibers (Fig 3). The fibrous tissue bundles subjacent to the mesothelium tend to have a cephalo-caudal orientation; whereas the more external bundles have a more weaved organization, which allows for some distensibility of the pericardial fibrosa. The fibrosa contains scant connective

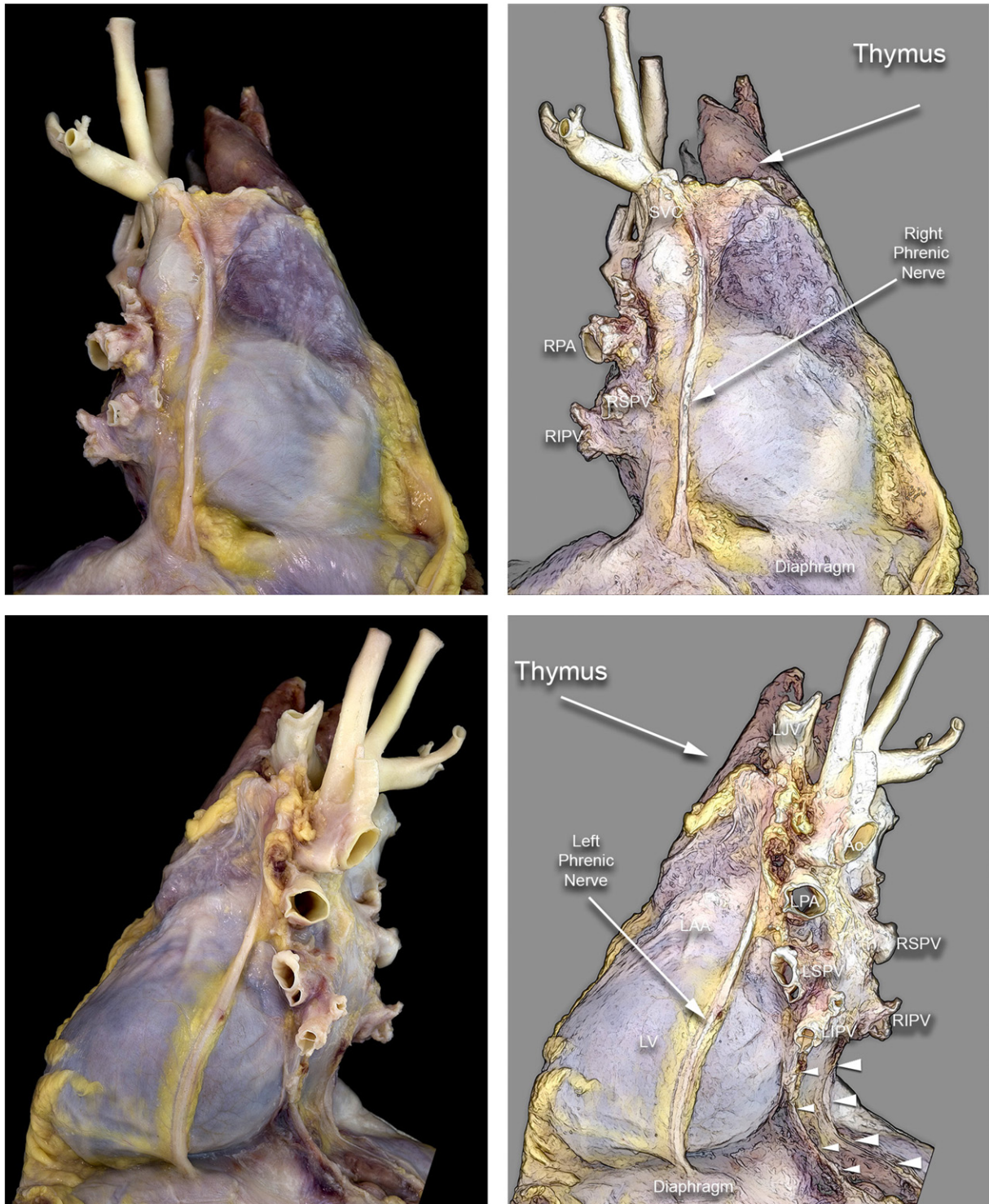


Fig 7 – Lateral views of the pericardium covering the heart. The top image is a right lateral view showing the brachiocephalic artery on the uppermost posterior position. Anterior to it the thymus is clearly visible, partially covered by a thin fascia of loose connective tissue. The right phrenic nerve is seen just anterior to the superior vena cava. It follows an almost vertical path on the right border of the heart until it reaches the diaphragm. The lower image shows the left lateral view of the heart and pericardium. The left phrenic nerve is seen emerging just behind the adipose tissue in front of the left pulmonary artery. It follows a roughly vertical direction and moves slightly anteriorly as it courses over the contour of the “obtuse margin” of the left lateral ventricular wall, and it moves slightly posterior as it reaches the diaphragm. The arrowheads delineate the pericardiovertebral ligaments in the posterior aspect of the pericardium. *Abbreviations:* Ao = Aorta. LJV = Left jugular vein. LPA = Left pulmonary artery. LSPV = Left superior pulmonary vein. LIPV = Left inferior pulmonary vein. RPA = Right pulmonary artery. RIPV = Right inferior pulmonary vein. RSPV = Right superior pulmonary vein.



Fig 8 – Anterior view of the pericardial sac from an adult elderly man. This specimen shows abundant adipose tissue in the anterior mediastinal surfaces of the pericardial sac (asterisks). The pericardial sac extends and includes the root of the aorta, the ascending aorta and the trunk of the pulmonary artery. The dotted line shows distinctly the continuity of the pericardial sac over these areas. The pericardial surfaces are glistening throughout as these surfaces are lined by mesothelial cells of the mediastinal pleura.

tissue cells and small vessels. The vessels tend to penetrate in an oblique plane and extend for about $8\ \mu\text{m}$. The outer epiperical layer shows somewhat more abundant elastic fibers, adipose tissue, neural elements, and blood vessels. Rare mast cells and mononuclear cells have been described in this layer.¹⁷

The ultrastructure of the mesothelial cells shows abundant microvilli and rare cilia. The microvilli measure up to $3\ \mu\text{m}$ in length and $0.1\ \mu\text{m}$ in width. Pinocytic vesicles are present in the surface facing the pericardial cavity but not in the base of the mesothelial cells. The lateral surfaces of the mesothelial cells are highly interdigitated and show cell junctions and desmosomes. Irregular invaginations of the plasma membrane, multivesicular bodies, and coated and uncoated vesicles are present which play a role in the transport of fluid and proteins. Overlapping cell cytoplasm is present. In the parietal pericardium, there are virtually no anchoring cell junctions such as hemidesmosomes between the mesothelial cell and the basal lamina.

In contrast, the visceral pericardium (Fig 15) is formed by a thin layer of loose fibrous tissue overlying the myocardium invested by mesothelial cells (the serosal component of the visceral pericardium) over the entire surface of the heart. In those areas of the heart with epicardial adipose tissue, the mesothelial cells cover the adipose tissue, while in areas devoid of adipose tissue, the mesothelial cells are in very close proximity to the myocardium (Fig 4). Blood vessels, lymphatic vessels and nerves supplying the heart are found in the subepicardium.

The pericardial inflammatory response to acute injury is manifested by increased vascular permeability with exudation of fluid, fibrin and/or inflammatory cells and mesothelial cell desquamation.¹⁸ Fibrin strands and aggregates of inflammatory cells become incorporated into a layer of granulation tissue with proliferation of fibroblasts and newly formed thin-walled blood vessels. The presence of granulation tissue with neovascularization in the organizing phase of pericardial inflammation has been associated with pericardial late gadolinium enhancement on cardiac magnetic resonance imaging.¹⁹ The formation of this new layer of connective tissue results in focal or diffuse adhesions between the parietal and visceral pericardium and in pericardial thickening that may lead to constriction (Fig 16).

Statement of conflict of interest

None of the authors have any conflicts of interests with regard to this publication.

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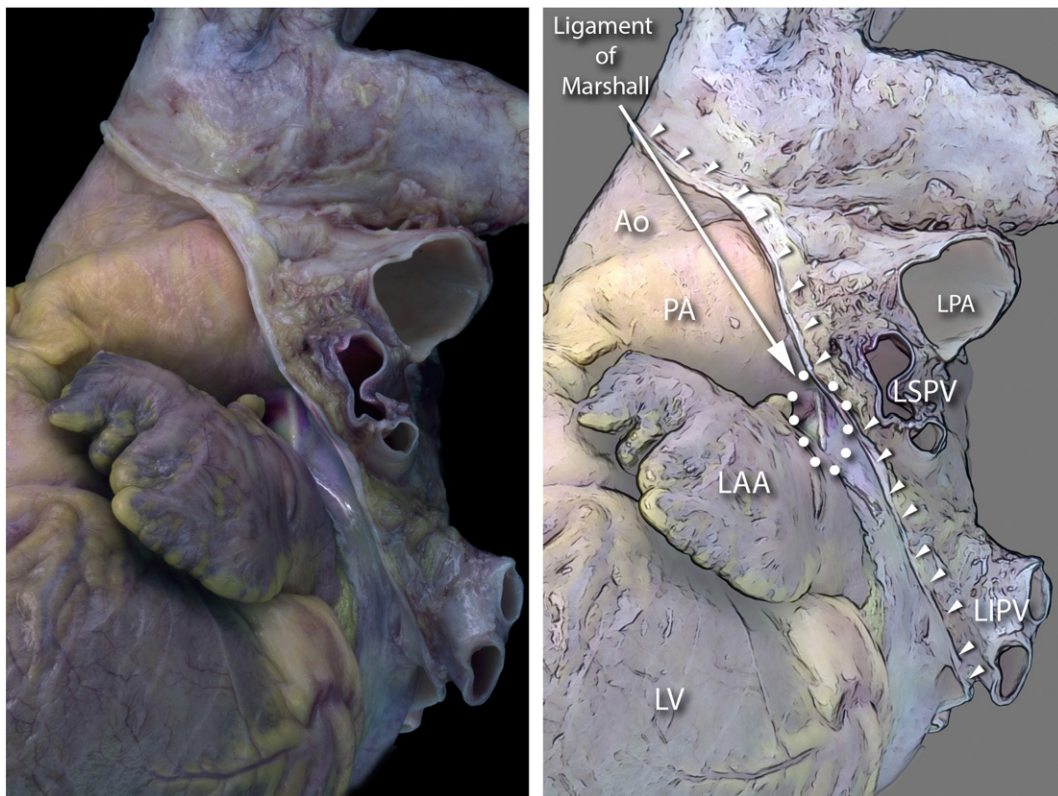


Fig 9 – Left lateral view of the base of the heart. The pericardial attachment to the great vessels and pulmonary veins is highlighted by the white arrowheads. A small ridge (dots) is present on the lateral aspect of the left atrial wall, just superior to the opening of the left atrial appendage and anterior to the left superior pulmonary vein. This ridge is a vestigial remnant of the left superior vena cava which involutes during embryonic development. It is also known as the ligament of Marshall. Abbreviations: Ao = Ascending aorta. LAA = Left atrial appendage. LPA = Left pulmonary artery. LIPV = Left inferior pulmonary vein. LSPV = Left superior pulmonary vein. LV = Left ventricle. PA = trunk of the pulmonary artery.

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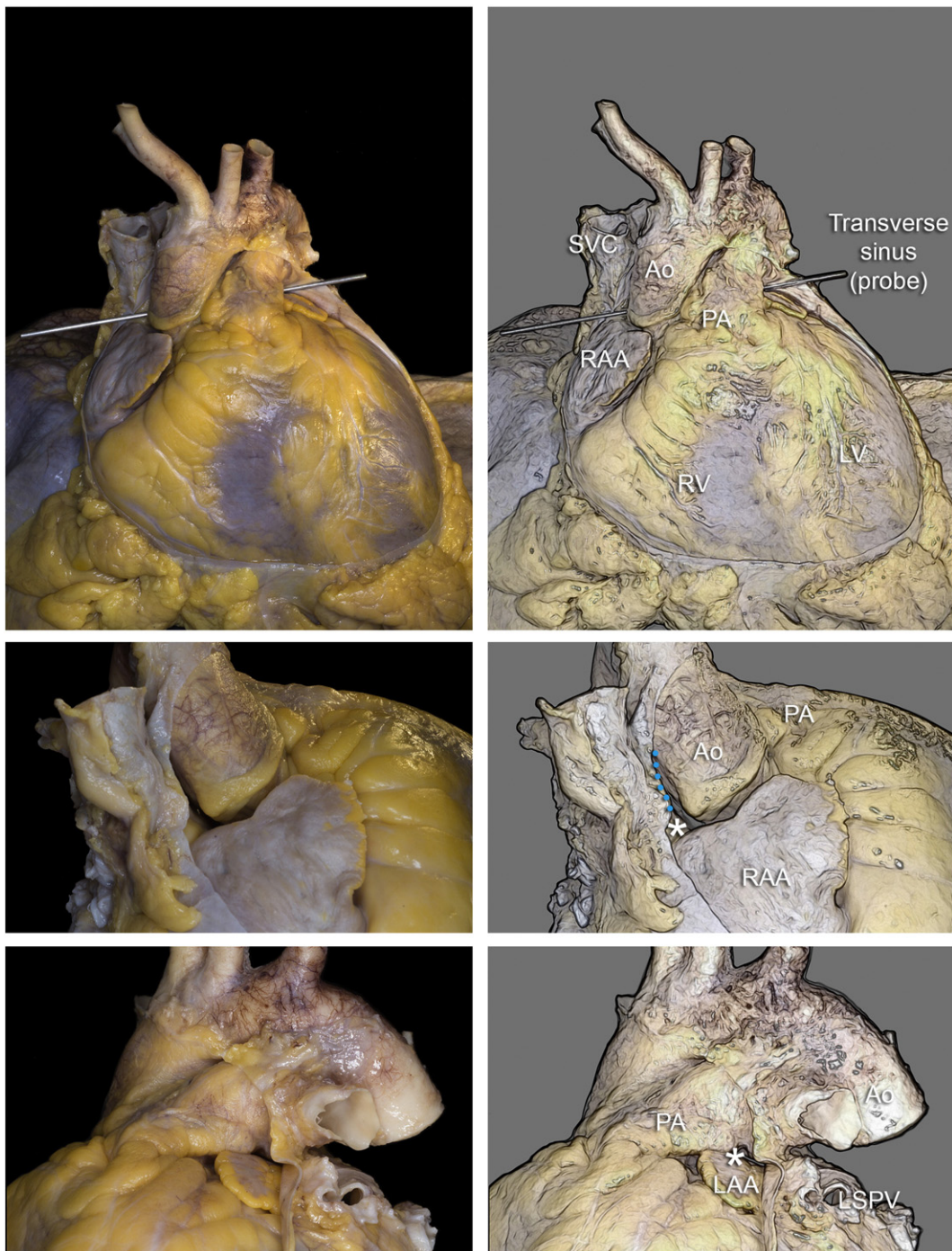


Fig 10 – The transverse sinus of the pericardium is shown in this anterior view (probe). The transverse sinus is the pericardial space delimited by the superior vena cava and anterior surfaces of the right atrium and left atrium dorsally. The ventral surface of the transverse sinus is formed by the posterior aspect of the ascending aorta and the inferior–posterior surface of the right and left pulmonary arteries before they emerge from the pericardial sac. The right upper image shows a close up of the cephalad anterior portion of the right atrium, the superior vena cava and the ascending aorta flanking the right side of the transverse sinus (asterisk). The dotted blue line shows the superior extension of the transverse sinus between the ascending aorta and the superior vena cava or the superior aortic recess. The right lower image shows the transverse sinus flanked by the posterior aspect of the pulmonary trunk, the lower aspect of the left pulmonary artery and the anterior aspect of the left atrium (asterisk). *Abbreviations:* Ao = Aorta. LAA = Left atrial appendage. LSPV = Left superior pulmonary vein. LV = Left ventricle. PA = Pulmonary artery. RAA = Right atrial appendage. RV = Right ventricle. SVC = Superior vena cava.

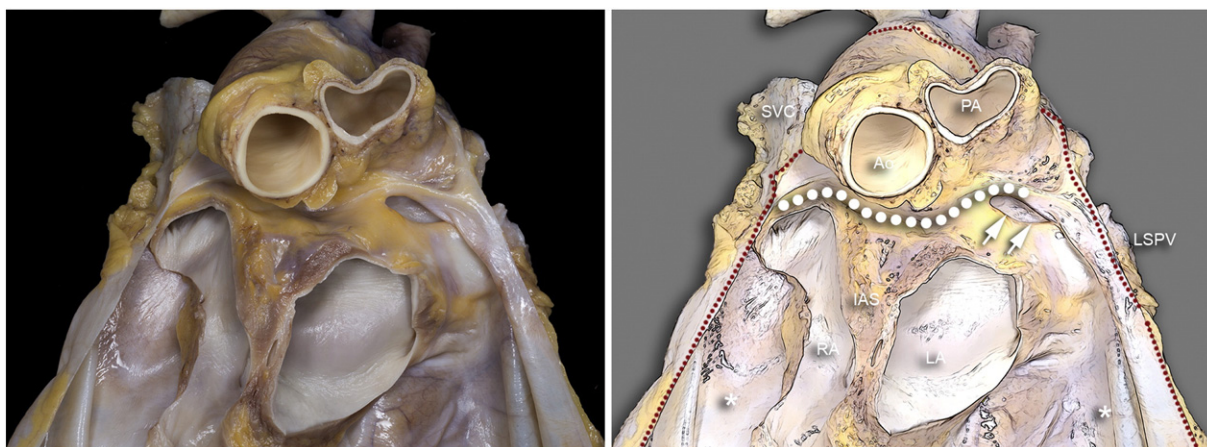


Fig 11 – Transverse sinus of the pericardium. In this anterior view, most of the heart and the anterior portion of the pericardial sac have been removed. Only the dorsal segments of the right atrium, interatrial septum and left atrium remain. The red dots delineate the cut border of the pericardial sac. The asterisks below the atria mark the pericardial space. The white dots delineate the transverse sinus as it spans from right to left. The pericardial space bounded by the cephalad surface of the left superior pulmonary vein and inferior–posterior surface of the left pulmonary artery is designated the left pulmonary recess (double arrows). *Abbreviations:* Ao = Aorta. IAS = Interatrial septum. LA = Left atrium. LSPV = Left superior pulmonary vein. PA = Pulmonary artery. RA = Right atrium. SVC = Superior vena cava.

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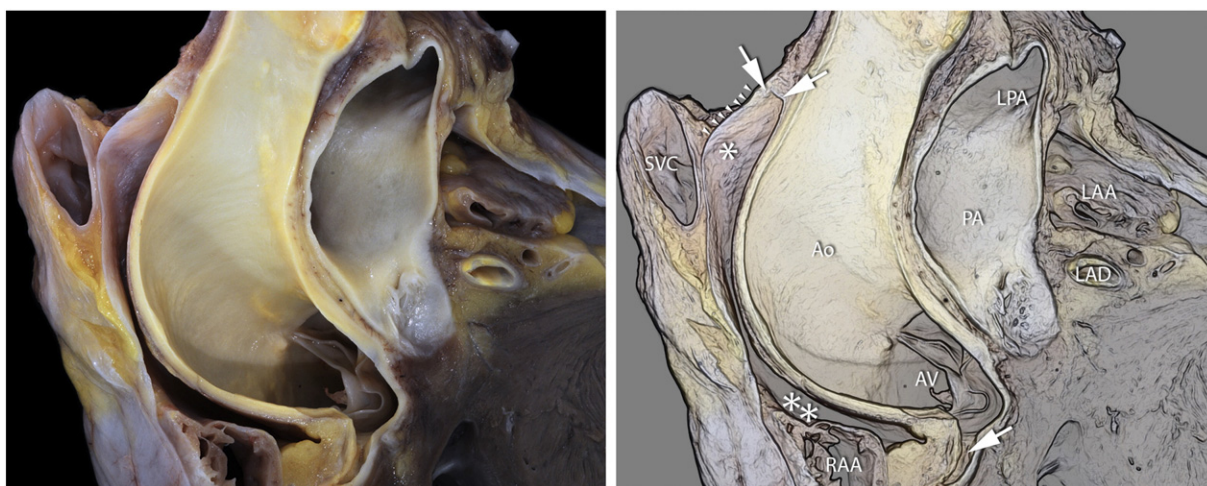


Fig 12 – Superior and inferior aortic recesses. Anterior view of the heart from a right cephalad angle. The anterior half of the ascending aorta has been removed to show the aortic valve and the ostium of the right coronary artery (single arrow). The arrowheads delineate the cut edge of the parietal pericardium as it merges with the aortic adventitia. The point of reflection of the serosal pericardium to invest the ascending aorta is marked by double arrows. Two distinct spaces are visible between the pericardial sac and the adventitia of the intrapericardial ascending aorta. These spaces are the superior aortic recess (asterisk) and the inferior aortic recess of the transverse sinus (double asterisk). *Abbreviations:* Ao = Aorta. AV = Aortic valve. LAA = Left atrial appendage. LAD = Left anterior descending coronary artery. LPA = Left pulmonary artery. PA = Pulmonary artery trunk. RAA = Right atrial appendage. SVC = Superior vena cava.

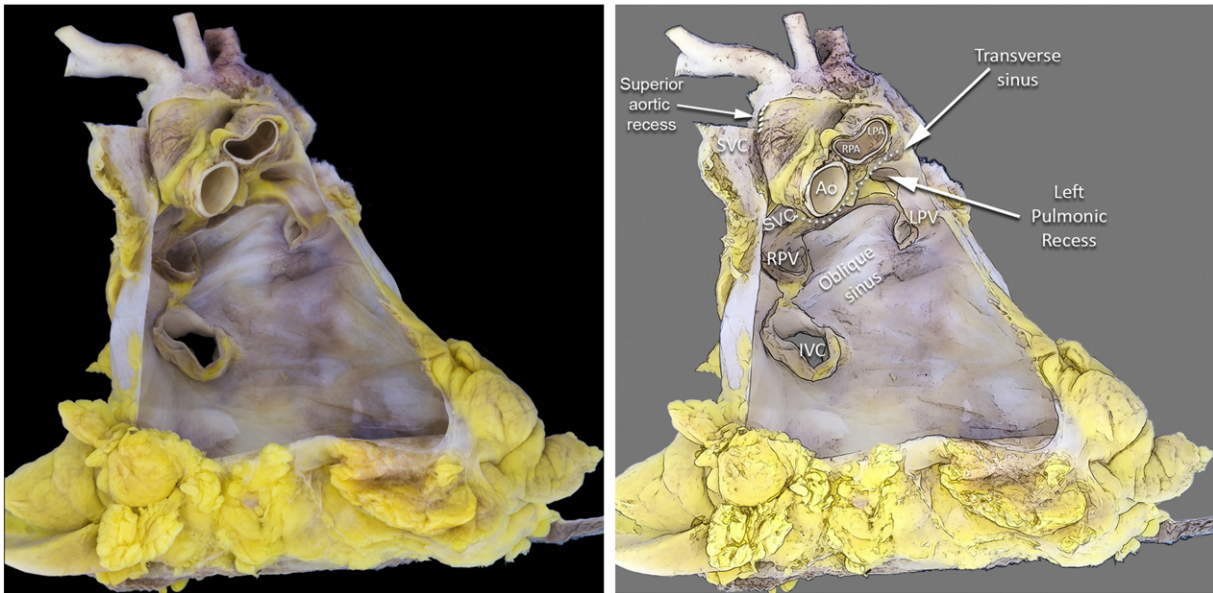


Fig 13 – Anterior view of the sinuses and recesses of the pericardium. Ventral aspect of the pericardium with the anterior portion of the pericardial sac and the heart removed to show the great vessels at the base of the heart. The aorta and pulmonary artery have been transected to show the path of the transverse sinus (dotted line) that separates the arteries from the venae cavae and pulmonary veins. The pericardial reflection extends to the proximal aortic arch and the recess between the aorta and the superior vena cava is called the superior aortic recess (dotted line). The left lateral extension of the transverse sinus is the left pulmonic recess bordered by the left pulmonary artery and left superior pulmonary vein. The oblique sinus is the cul-de-sac behind the left atrium and bound by the pericardial reflection over the inferior pulmonary veins and the inferior vena cava. Note the abundance of adipose tissue between the pericardium and diaphragm. *Abbreviations:* IVC = inferior vena cava. LPA = left pulmonary artery. LPV = left pulmonary veins. RPA = right pulmonary artery. RPV = right pulmonary veins. SVC = superior vena cava.

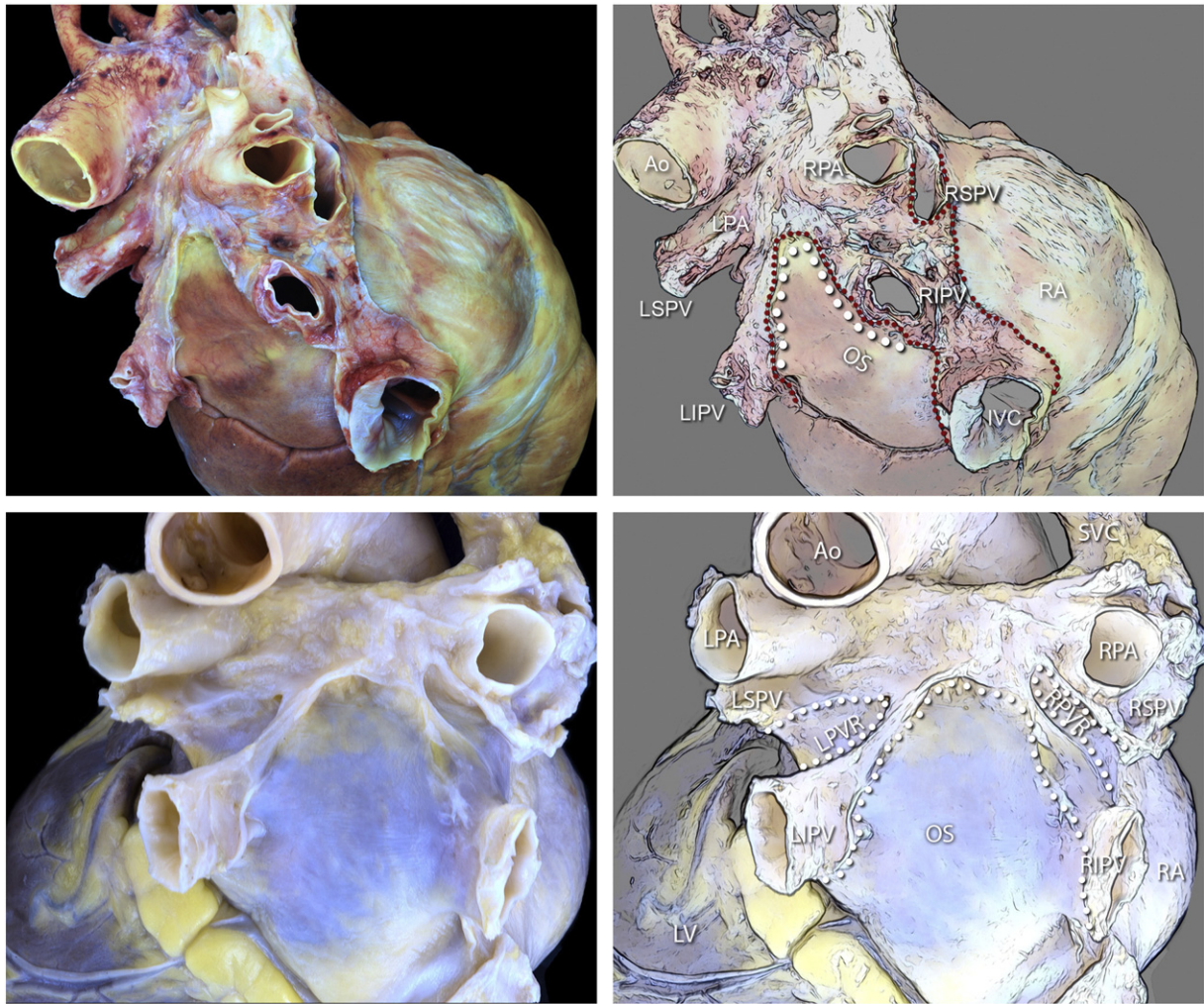


Fig 14 – Oblique sinus and pulmonary venous recesses. The oblique sinus of the pericardium is the space flanked by the reflections of the pericardium below the inferior pulmonary veins. The upper images show a slightly right cephalad–dorsal view of the left and right atria. The four pulmonary veins are shown as they drain into the left atrium. The pericardial sac has been almost entirely removed. The cut border of the remaining pericardial sac is shown delineated by red dots. The white dots mark the contour of the oblique sinus. *Abbreviations:* Ao = Aorta. IVC = Inferior vena cava. LIPV = Left inferior pulmonary vein. LPA = Left pulmonary artery. LSPV = Left superior pulmonary vein. OS = Oblique sinus. RA = Right atrium. RIPV = Right inferior pulmonary vein. RPA = Right pulmonary artery. RSPV = Right superior pulmonary vein. SVC = Superior vena cava. The lower images show a slightly left cephalad–dorsal view of the left atrium, pulmonary veins and pulmonary arteries. The pericardial recesses above the inferior pulmonary veins on the right and the left sides of the left atrium, as well as the oblique sinus are delineated by the white dots. *Abbreviations:* Ao = Aorta. LIPV = Left inferior pulmonary vein. LPA = Left pulmonary artery. LPVR = Left pulmonary venous recess. LSPV = Left superior pulmonary vein. LV = Left ventricle. OS = Oblique sinus. RA = Right atrium. RIPV = Right inferior pulmonary vein. RPA = Right pulmonary artery. RPVR = Right pulmonary venous recess. RSPV = Right superior pulmonary vein.

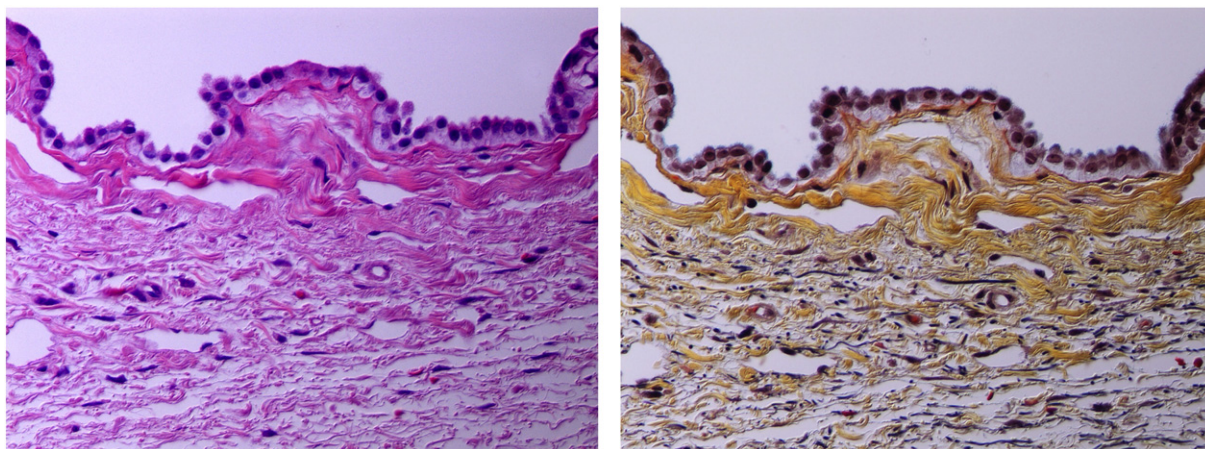


Fig 15 – Light micrograph shows the serosal surface of the epicardium lined by mesothelial cells which impart a “hobnail” appearance to the surface. There are lymphatic channels visible as empty spaces just below the mesothelial lining. Also some small vessels are apparent. The image on the right shows faint dark (almost black) lines which correspond to the scant elastic lamellae. Lymphatic and blood vessels are more abundant in the visceral pericardium (epicardium) compared to the parietal pericardium. ($\times 400$, left: H&E and right: Movat pentachrome stains).

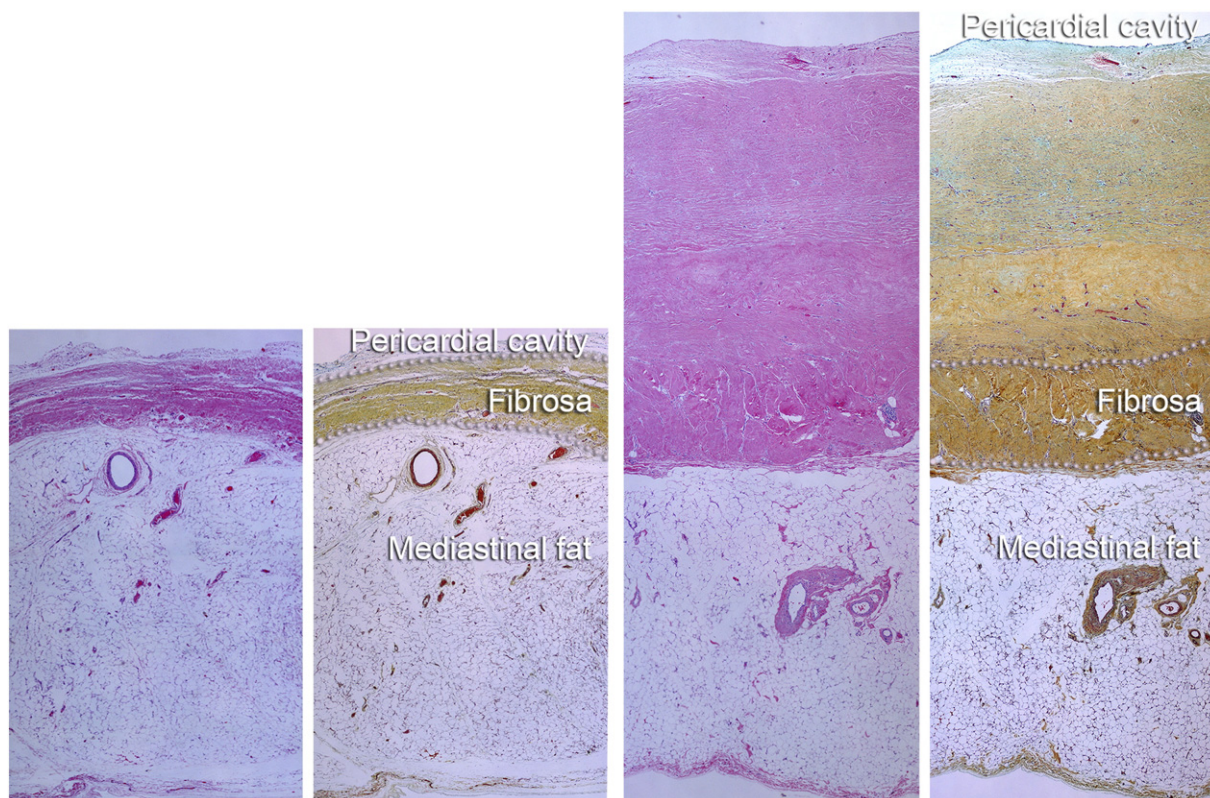


Fig 16 – Light microscopy of normal vs. thick fibrotic pericardium. These histologic images were obtained at the same magnification. The two images on the left correspond to normal human pericardium. The fibrosa layer is delimited by white dots and it is distinctly stained in yellow (fibrous tissue) in the Movat pentachrome stain. In contrast, the images on the right side of the figure show human pericardium where the fibrosa layer is also delineated by white dots. All the tissue above the upper white dotted line corresponds to pathologic fibrous tissue deposition. The fibrous tissue is quite mature with minimal neovascularization and there is no evidence of active inflammation. There is no evidence of abundant fibroblasts (fibroplasia), thus indicating that this process is quiescent at the time of the pericardial resection ($\times 50$, H&E and Movat Pentachrome stains (both panels)).