Cardiovascular imaging

Imaging methods

Radioscopy

Radioscopy is one of the main imaging techniques used to explore the heart in dynamic and is characterized by a long examination time and increased exposure to ionizing radiation.

Imaging methods

Cardiac radiography

Cardiac radiography is performed in posterior-anterior and left lateral incidences during maximum inhale, at a distance of 2 m (teleradiography), with concomitant opacification of the esophagus (barium administration).

Imaging methods

Angiocardiography

Angiocardiography is performed by injecting a iodinated contrast agent rapidly and under pressure in a peripheral vein using an automated syringe, followed by multiple X-ray acquisition at small intervals of time as the contrast agent moves along the vessels towards the heart.

Imaging methods

Aortography

Aortography involves administration of a contrast agent in the aorta through a catheter that can be inserted in the femoral or subclavian arteries.

Imaging methods

Ultrasonography (US)

Ultrasonography is a non-invasive imaging technique, accessible, with low costs and increased utility in practice. Regarding heart imaging exploration, US can be used in the form of ***transthoracic echocardiography*** (for morpho-functional exploration of the cavities, heart, myocardium, pericardium, interatrial and interventricular septum) or in the form of ***transesophageal echocardiography*** (the preferred imaging method when aortic dissection or acute complications of myocardial infarction are suspected, such as rupture of the interventricular septum or papillary muscles). ***Doppler echocardiography*** is used to measure blood flow velocity and to detect atrio-atrial and ventriculo-ventricular reflux in the event of atrial or ventricular septal defect.

Imaging methods

Cardiac Computed Tomography (CT)

Cardiac computer tomography (CT) is an irradiating imaging technique used to evaluate myocardial, pericardial, valvular or aortic calcifications. CT is also useful for calculating the calcium score and for detecting possible pericardial fluid accumulation. The advantages of cardiac CT are lower costs, increased accessibility, the acquisition time of the images is shorter and can be performed in patients who have metallic implants for cardiac pathology (eg. metal stents).

Imaging methods

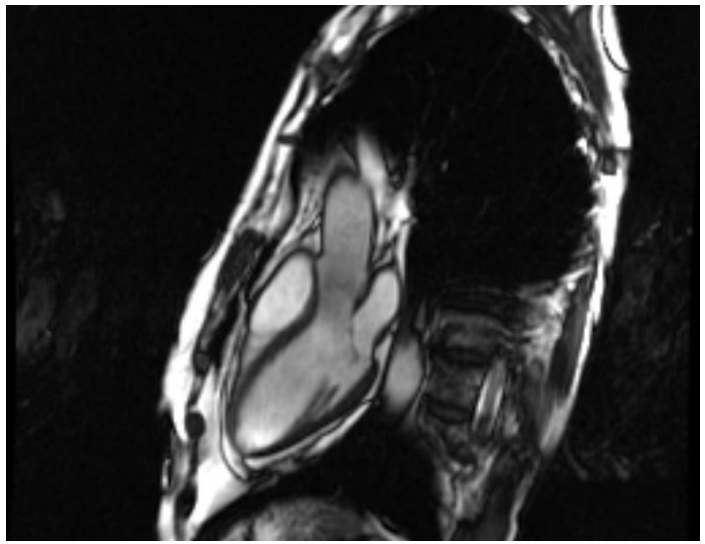
Cardiac Magnetic Resonance Imaging (MRI)

Cardiac magnetic resonance imaging (MRI) uses a magnetic field and radio frequency pulses, thus being a non-radiating imaging technique. In practice, MRI examination of the heart has proved useful in diagnosing and evaluating cardiac pathologies such as cardiomyopathies, congenital heart disease, valvulopathies or cardiac tumors.

Imaging methods

Angio-CT/Angio-MRI

CT angiography is a technique that involves intravenous administration of a iodinated contrast agent using an automated syringe, followed by CT examination in dynamics, which highlights the contrast agent along the blood vessels to the heart. CT angiography allows a good visualization of the vascular structures and can be used to detect pathological changes both in the large vessels and in the coronary arteries. MR angiography is based on the same principle, but the contrast agent is different compared to the CT examination.



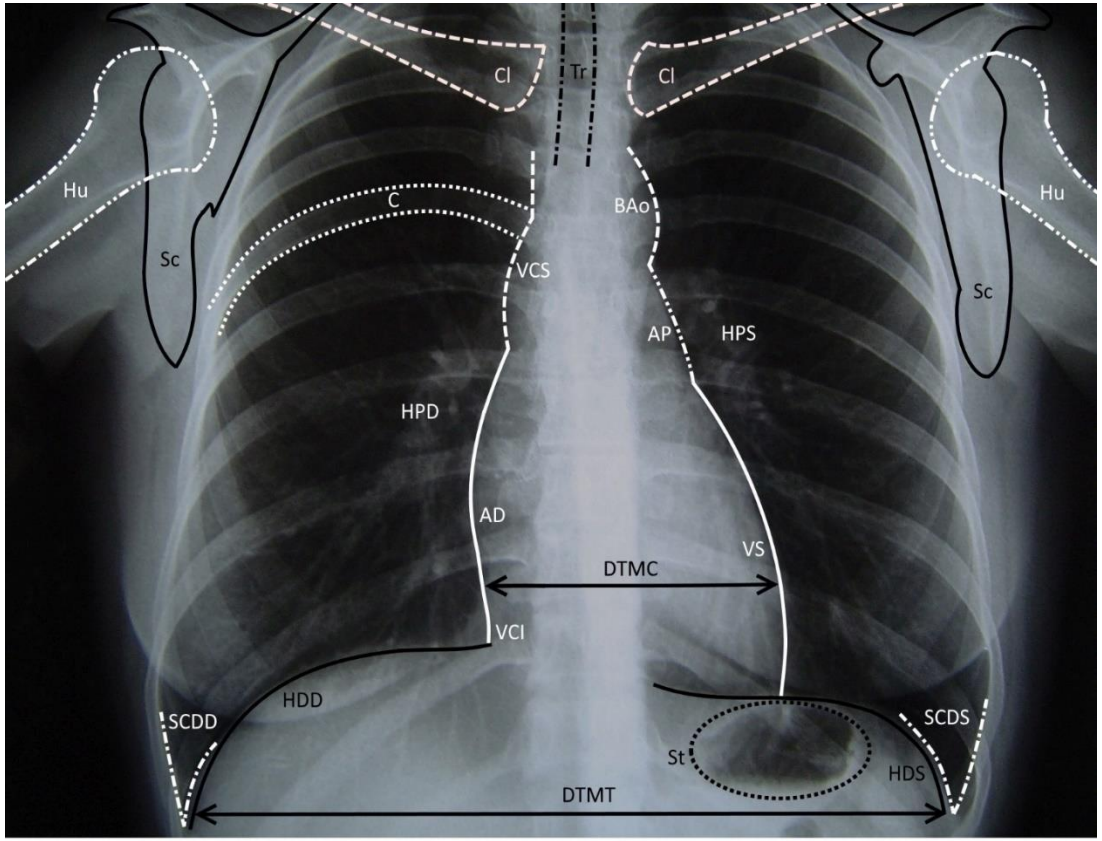
Radiological anatomy

In the posterior-anterior incidence (PA), the right mediastinal contour contains the superior right arch represented by the superior vena cava and the lower right arch represented by the projection of the right atrium.

The left mediastinal contour comprises, from top to bottom, 2 convex arches given by the aortic knuckle (superior) and the left ventricle, (inferior). Between the two convex arches, a middle, concave arch is represented by the pulmonary trunk and the left atrium ear.

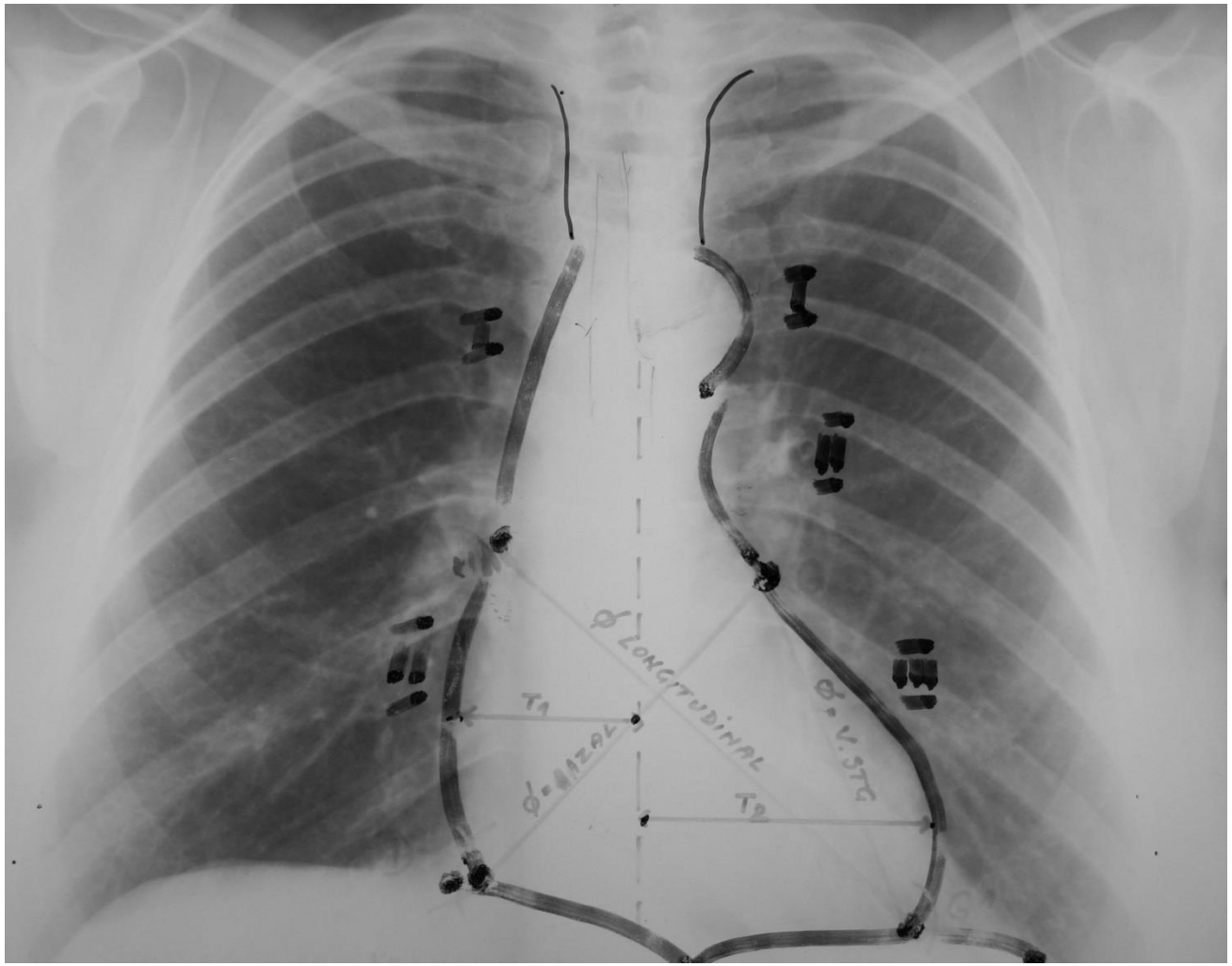
Normal lungs hilum are visualized in this incidence and are radiologically represented under normal conditions by the right and left pulmonary arteries with normal dimensions of 12-14 mm. These are dichotomized into increasingly smaller branches from the hilum to the lung periphery forming the pulmonary vascular pattern that is represented by the pulmonary artery and its arterial branches, being better visible in the lower pulmonary areas. Pulmonary veins, lymphatics, bronchi are not visualized under normal conditions.

Radiological anatomy



Radiografie pulmonară incidență postero-anterioară: AD – atriu drept, AP – arteră pulmonară, BAo – buton aortic, Cl – claviculă, C – coastă, DTMC – diametrul transversal maxim al cordului, DTMT – diametrul transversal maxim al toracelui, HDS/HDD – hemidiafragm stâng/drept, HPS/HPD – hil pulmonar stâng/drept, Hu – humerus, Sc – scapulă, SCDS/SCDD – sinus costodiafragmatic stâng/drept, St – stomac, Tr – trahee, VCS – venă cavă superioară, VCI – venă cavă inferioară, VS – ventricul stâng.

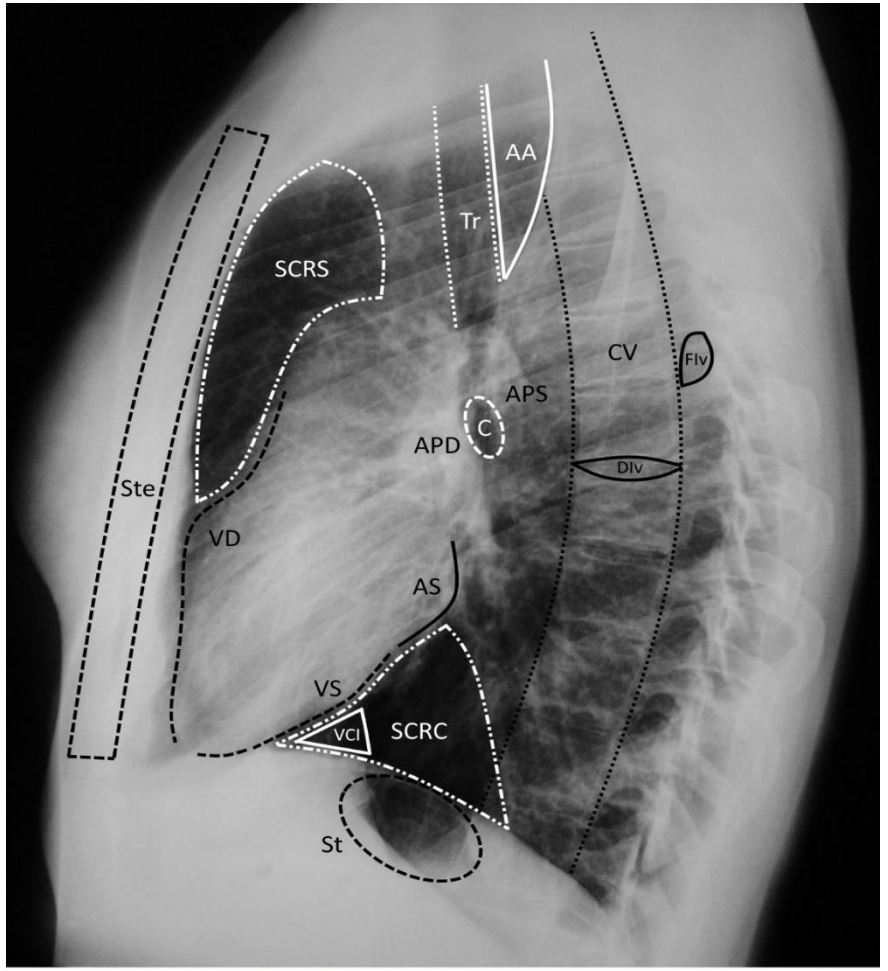
Radiological anatomy



Radiological anatomy

In the left lateral incidence the posterior contour is represented by the left atrium in the upper half and the left ventricle in the lower half. In front of the esophagus filled with barium the inferior vena cava (IVC) can be seen. The IVC, the left diaphragm and the posterior wall of the left ventricle form an equilateral triangle called the "cave vein triangle". Behind the esophagus and anterior to the vertebral bodies the so-called clear retrocardiac space can be highlighted. The anterior contour of the heart in the lateral incidence is represented by the right ventricle that comes in contact with the sternum over a distance of 3-4 cm. Between the sternum and the right ventricle, the clear retrosternal space can be seen.

Radiological anatomy



Radiografie pulmonară profil stâng: AA – arcul aortic, AS – atriu stâng, APS/APD – arteră pulmonară stângă/dreaptă, C – carină, CV – coloană vertebrală, DIv – disc intervertebral, FIv – foramen intervertebral, St – stomac, Ste – stern, SCRS – spatiu clar retrosternal, SCRC – spatiu clar retrocardiac, Tr – trahee, VCI – triunghiul venei cave inferioare, VD – ventricul drept, VS – ventricul stâng.

Changes affecting the pulmonary circulation

Pulmonary arterial hypertension

Pulmonary hypertension is the result of an increased resistance in the pulmonary circulation, thus generating overload of the right heart.

X-ray PA incidence: in the hilum, the pulmonary arteries have an enlarged caliber (more than 14 mm) and the left pulmonary artery is prominent in the cardiac gulf, with rectilinear or convex changes of the left middle cardiac contour. The pulmonary artery branches are dilated near the hilum and end at around 3-4 cm from the lung periphery - X-ray aspect of enlarged and amputated hilum.

X-ray lateral incidence: the clear retrosternal space is smaller due to hypertrophy of the right ventricle, with an increased the contact between the sternum and the right ventricle.

Changes affecting the pulmonary circulation

Pulmonary arterial hypertension

Changes affecting the pulmonary circulation

Pulmonary venous hypertension

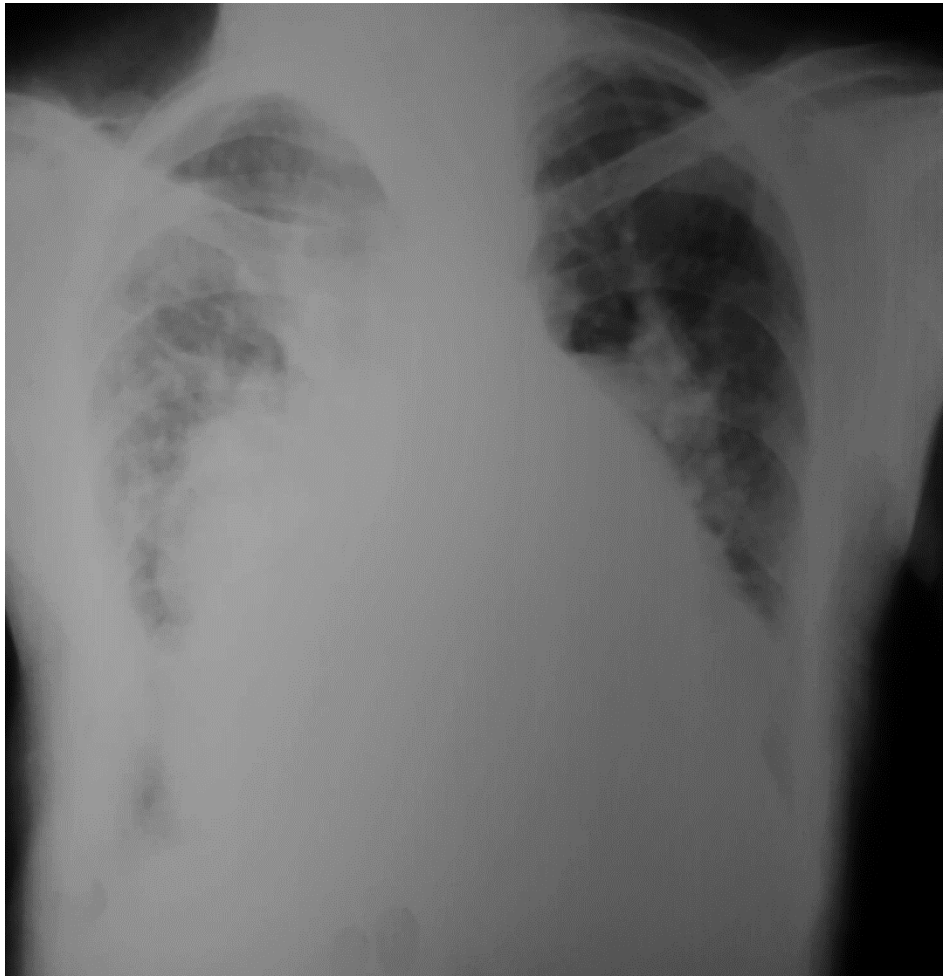
Pulmonary venous hypertension represents an increased resistance in the blood flow to the left atrium, most commonly caused by mitral stenosis.

X-ray PA incidence: the pulmonary arteries have a diffuse contour and a caliber greater than 14 mm in the lungs hilum. When the pulmonary capillary pressure reaches values between 12 and 25 mmHg, the pulmonary circulation is redistributed to the upper areas, with vascular linear opacities of lower intensity compared to the arteries, being represented by the Sylla lines (venous stasis). If the pressure in the pulmonary capillaries reaches values between 25 and 35 mmHg, the patient will develop interstitial edema, radiographically objectified in the form of Kerley lines A, B or C. The most common are the Kerley B lines, which are radiologically translated by the presence of linear opacities near the pulmonary bases, perpendicular to the thoracic wall, usually located on the right side. At values of pulmonary capillary pressure greater than 35 mmHg, alveolar edema appears, which is confirmed by the presence of micronodular opacities located near the hilum generating the so-called butterfly wings aspect.

X-ray lateral incidence: signs of overload of the right heart in the context of an increased resistance in the pulmonary venous circulation.

Changes affecting the pulmonary circulation

Pulmonary venous hypertension



Changes affecting the pulmonary circulation

Increased pulmonary circulation

Pulmonary arterial hypervascularization is defined by increased pulmonary arterial blood flow, most commonly due to a left-right shunt, thus generating overload of the pulmonary circulation.

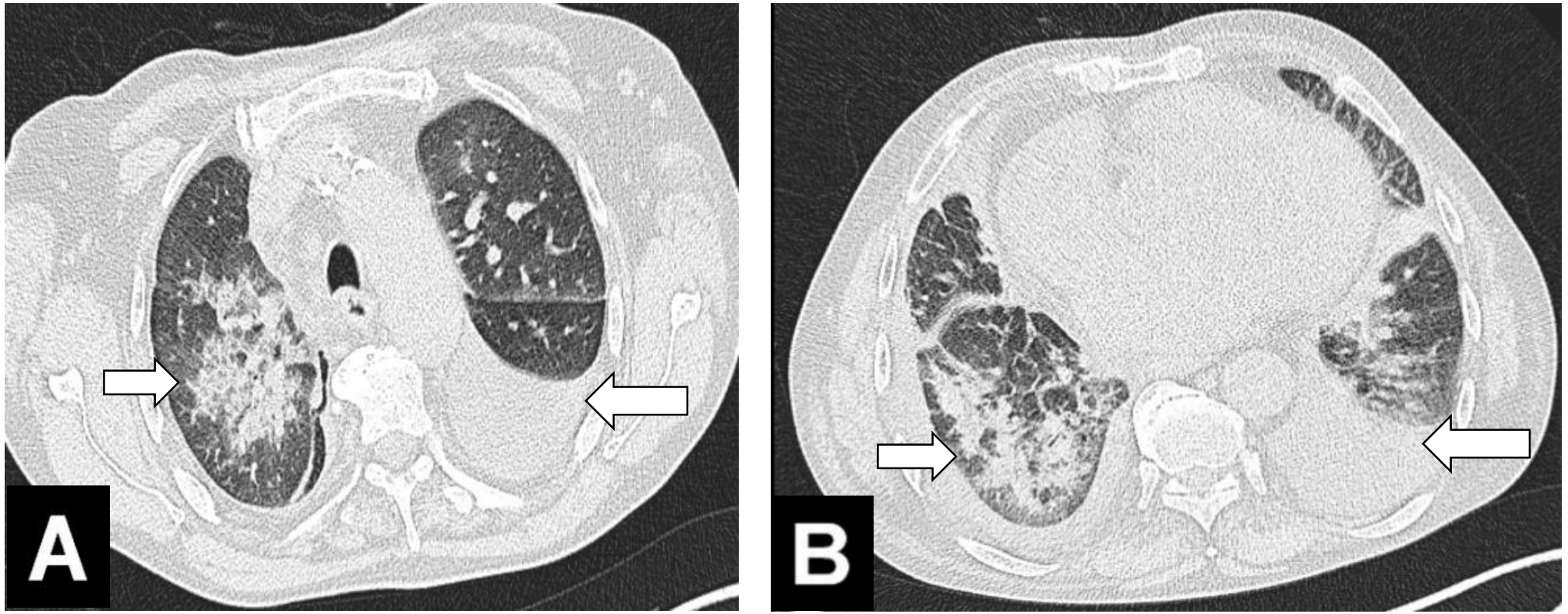
X-ray PA incidence: due to an increased blood volume in the pulmonary circulation, the diameter of the pulmonary arteries exceeds 14 mm at the lungs hilum, and the distal divisions of the pulmonary arteries have a larger size and are visible up to the periphery of the lung. Also, an increased pulmonary vascularization in the upper areas and an overall reduced lung transparency are noted.

X-ray lateral incidence: the right ventricular hypertrophy can be noted given the reduction of the clear retrosternal space.

CT and MRI: enlarged heart cavities and enlarged pulmonary arteries.

Changes affecting the pulmonary circulation

Acute pulmonary edema



Changes affecting the pulmonary circulation

Decreased pulmonary circulation

Pulmonary arterial hypovascularization is defined by the reduction of the pulmonary arterial flow .

X-ray PA incidence: the diameter of the pulmonary arteries in the lung hilum is below 10 mm and there is diffuse pulmonary hyperlucency, unilaterally or bilaterally, which is due to the decrease of the blood flow in the pulmonary arterial branches.

Aortic pathology

1. Aortic aneurysms

Aortic aneurysms are defined as dilatation of an aortic portion and may be fusiform or saccular. The fusiform ones are the most widespread and involve a circumferential involvement of the aortic wall. The segment of the aorta most commonly involved in the development of aneurysms is the abdominal one.

a) Ascending aortic aneurysm

X-ray: an enlargement of the mediastinum in the superior 2/3 and bulging of the right superior arch (which is formed by the superior vena cava) are noted due to the intimate relation between the superior vena cava and the ascending aortic aneurysm. The trachea and esophagus are shifted to the left.

b) Aortic cross aneurysm

X-ray: an enlargement of the mediastinum in the superior 2/3 and an enlarged aortic knuckle are noted. The trachea and esophagus are shifted to the right.

Aortic pathology

c) Abdominal aortic aneurysm

X-ray: low accuracy in diagnosing this condition. Linear calcifications in the paravertebral area can be observed in case of a profile spine X-ray.

CT and MRI: CT is the imaging method of choice in the diagnosis of aortic aneurysms. Using this investigation, one can accurately assess the dimensions, location and extension at the level of the aorta, as well as any complications (rupture). A transverse diameter of the ascending aorta more than 5 cm or of the abdominal aorta greater than 3-4 cm can diagnose an aneurysmal dilatation. MRI can detect aortic abnormalities, but costs are high and accessibility is low.

Aortic pathology

Aortic pathology

Aortic pathology

2. Aortic dissection

In its structure, the aorta comprises 3 tunics: intima, media and adventitia. In case of aortic dissection, the blood flow causes a rupture in the intima and separates the intima from the media thus creating a false lumen.

The classification of aortic dissection is performed according to the two models: ***Stanford*** and ***DeBakey***.

Aortic pathology

2. Aortic dissection

<u>Stanford classification:</u>

- **Type A:** the ascending aorta and the aortic cross are affected (requires surgical treatment);
- **Type B:** the dissection of the aorta is located distally from the emergence of the left subclavian artery (requires medical treatment).

Aortic pathology

2. Aortic dissection

DeBakey's classification:

- Type I: the ascending aorta, the aortic cross and the descending aorta are affected;

- Type II: only the ascending aorta is affected;

- Type III: only the descending aorta is affected distally from the emergence of the left subclavian artery.

Aortic pathology

2. Aortic dissection

X-ray: an enlarged mediastinum and a pericardial or pleural effusion of hemorrhagic nature in the event of a rupture can be seen.

CT and angioCT: the imaging method of choice in emergency that describes the type of aortic dissection, detects the false and true lumens, and evaluates cardiac, mediastinal and pleural complications.

MRI and angioMR: radiologic changes identical to CT; not indicated in emergency, but in the follow-up of chronic dissections.

Angiography

Aortic pathology

2. Aortic dissection

Aortic pathology

3. Intramural hematoma

The intramural hematoma is a bleeding that occurs in the subintimal space due to a lesion affecting the vasa vasorum.

CT: the intramural hematoma is characterized by the presence of a semilunar area in the aortic wall, hyperdense natively, with no postcontrast enhancement.

MRI: variable signal intensity depending on the amount of methemoglobin inside the hematoma.

Cardiac congenital disorders

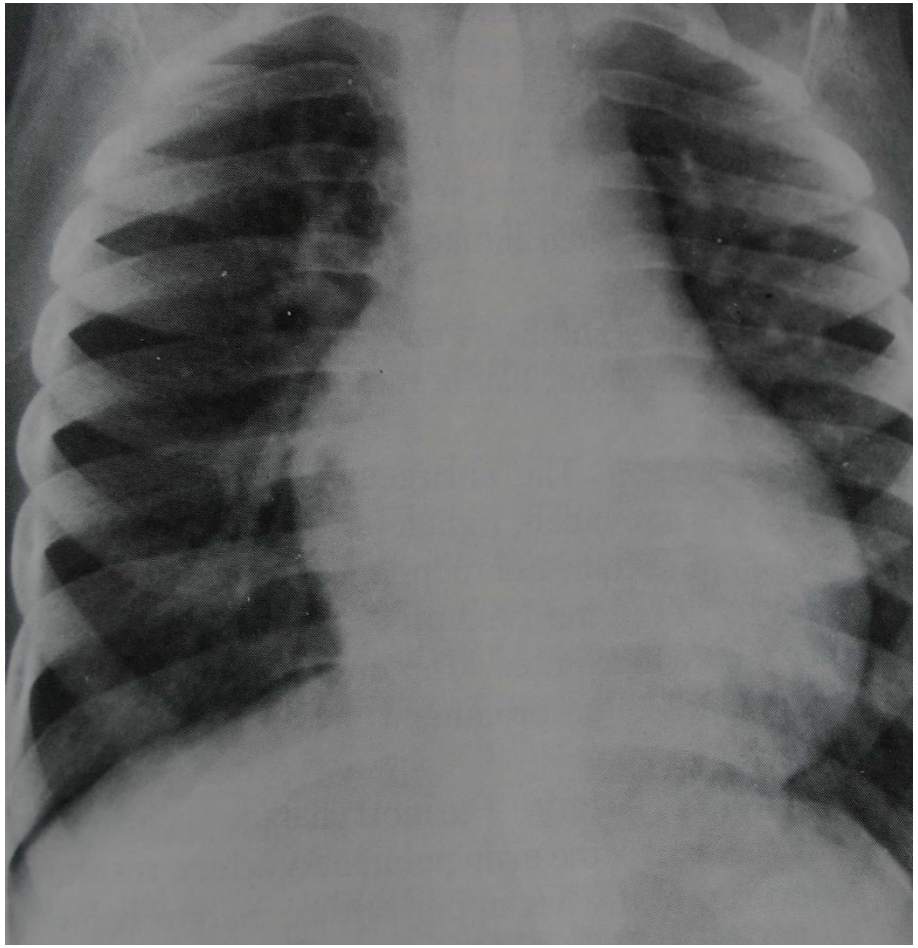
1. Ventricular septal defect (DSV)

X-ray: normal appearance with slight dilatation of the right ventricle. A right ventricle hypertrophy can be noted and, in particular, a dilatation of the left atrium. Also, pulmonary hypertension, pulmonary edema and increased pulmonary circulation may be seen.

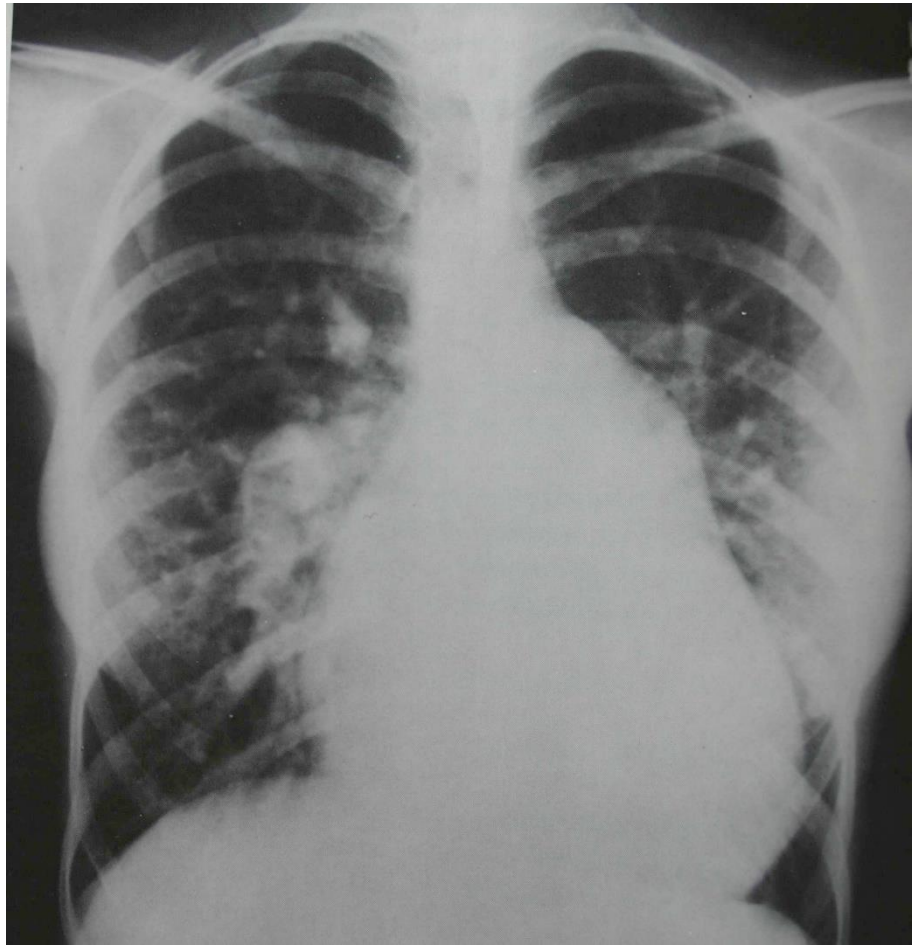
2. Atrial septal defect (DSA)

X-ray: prominent pulmonary arteries in the cardiac gulf, hyperemic pulmonary circulation and cardiomegaly with dilatation of the right heart cavities.

Cardiac congenital disorders



DSV



DSA

Cardiac congenital disorders

3. Congenital pulmonary stenosis

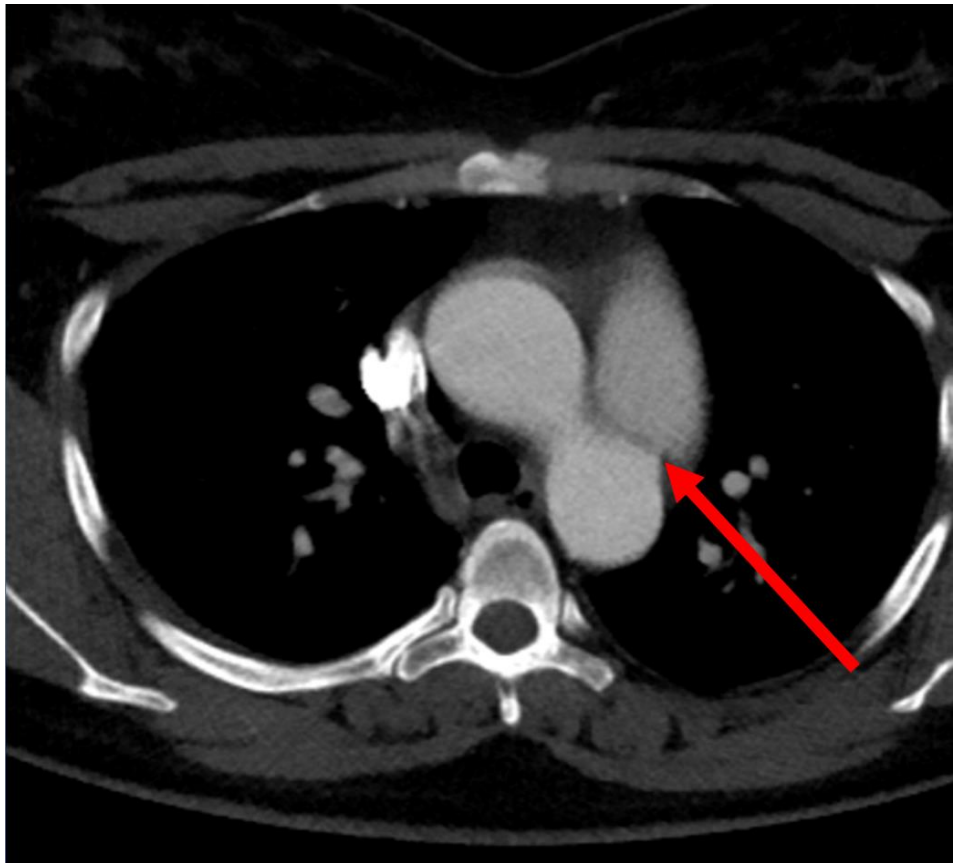
X-ray: normal size of the mediastinal opacity or right ventricular hypertrophy can be observed, while the pulmonary vascularization is often normal in mild cases.

4. Persistence of the arterial canal (PAC) (communication between the descending aorta and pulmonary artery)

X-ray: some of the radiological changes generated by PAC include cardiomegaly with left heart dilatation and increased pulmonary circulation, with pulmonary artery pumping in the cardiac gulf.

CT and MRI: The two techniques highlight the communication between the descending aorta and the left pulmonary artery, as well as the dilatation of the left heart cavities.

Cardiac congenital disorders



PAC

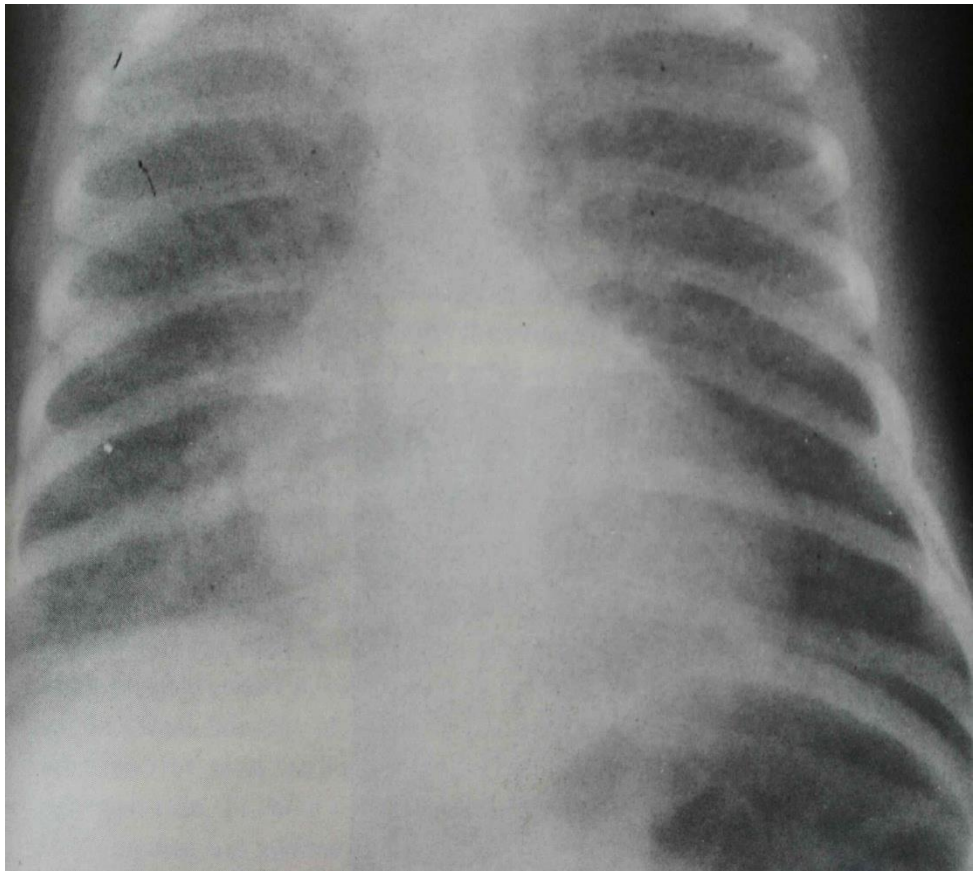
Cardiac congenital disorders

5. Transposition of the large vessels (pulmonary artery and aorta are inverted, eg the aorta exits from the right ventricle and the pulmonary trunk exits from the left ventricle)

X-ray: the transposition of the large vessels is radiologically characterized by the increase of pulmonary vascularization and cardiomegaly and the heart appears like an "egg laid on the diaphragm".

CT and MRI: the two imaging explorations allow visualization of the position anomalies affecting the aorta and the pulmonary trunk.

Cardiac congenital disorders



Transposition of the great vessels

Cardiac congenital disorders

6. Fallot Tetralogy (DSV, DSA, PAC, pulmonary artery stenosis)

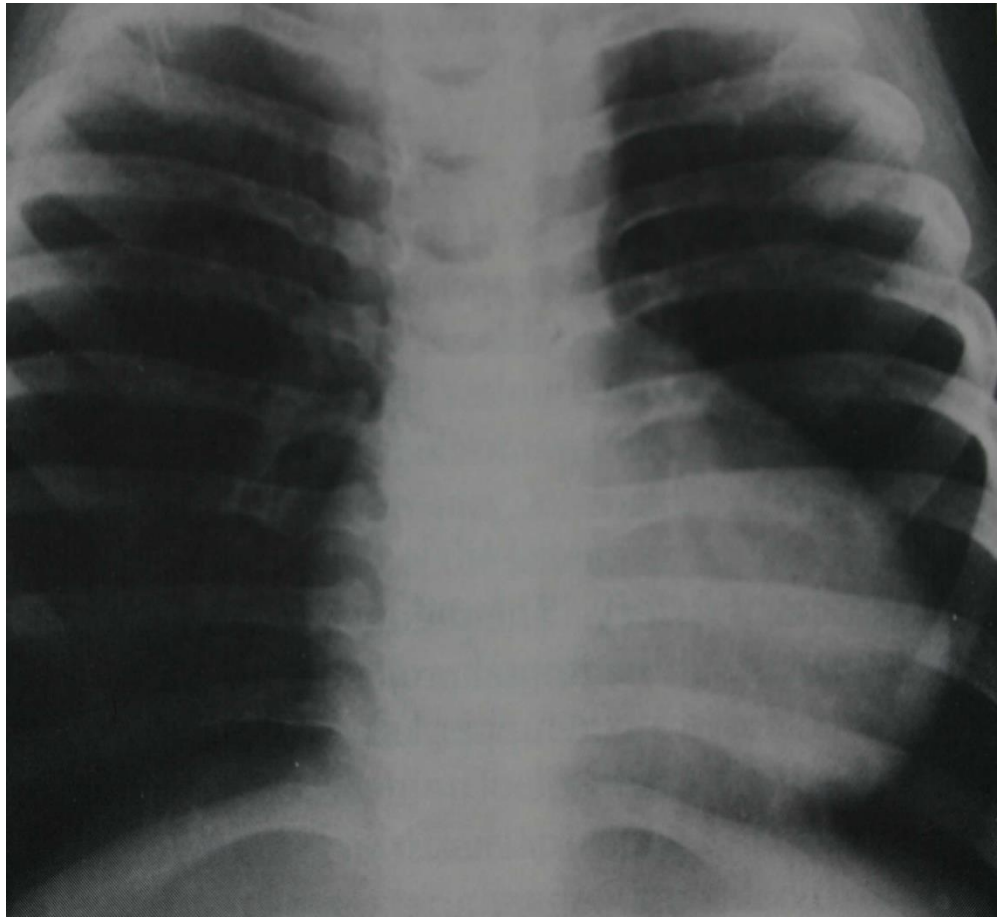
X-ray: hypertrophy of the right ventricle, classic aspect of shoe-shaped heart, with the cardiac apex oriented superior due to hypertrophy of the right ventricle. Also, pulmonary oligemia is observed due to the reduced pulmonary arterial flow. MR is the imaging examination of choice allowing visualization of the cardiac morphology and aorto-pulmonary circulation.

7. Aortic coarctation

X-ray: the radiological changes highlighted include lack of aortic knuckle visualization and hypertrophy of the left ventricle. Also, a relatively rare, but extremely important, sign is given by the prestenotic and post-stenotic dilatation of the aorta, which gives an aspect similar to the number “3”, thus being known as the "sign of 3".

CT and MRI: The stenosed area of the aorta can be objectified by both CT and MRI.

Cardiac congenital disorders



Fallot tetralogy

Aortic coarctation

Valvular cardiac disorders

1. Aortic stenosis

Aortic stenosis is one of the most common types of valvular heart disease, which causes an overload of the left ventricle.

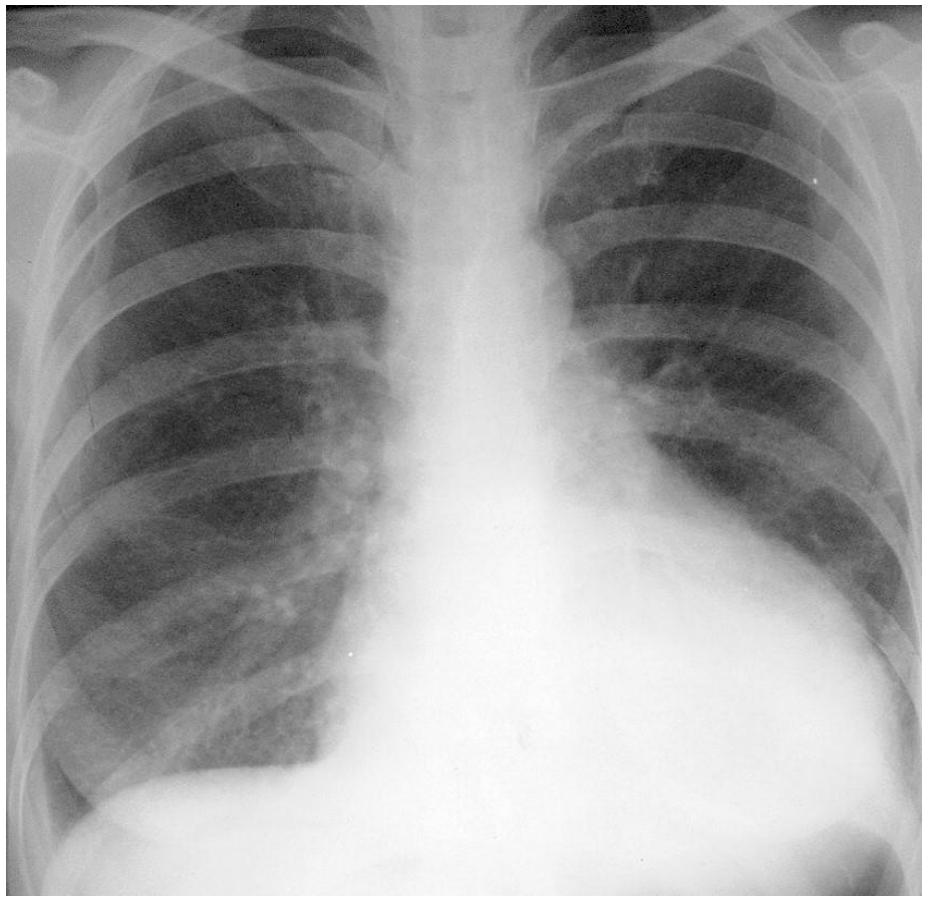
X-ray: The heart often presents a normal size. In the PA incidence, the enlargement of the lower left arch, calcification of the aortic knuckle and pulmonary venous hypertension can be seen when the pressure in the left ventricle increases. In the lateral incidence, the inferior vena cava triangle becomes smaller and smaller until it dissapears and is associated with a large radius imprint over the esophagus filled with barium.

CT: the CT examination can visualize aortic valvular calcifications, left ventricle hypertrophy, post-stenotic dilated ascending aorta and normal-looking pulmonary vascular structures, in the absence of heart failure. In case of cardiac decompensation pulmonary vascular dilatations, alveolar edema and pleurisy can be encountered.

MRI: In most cases, MRI examination is not indicated, valvular calcifications are not visible. The MRI examination can reveal structural (dynamic, bicuspid / unicuspid aortic valve, etc) and dynamic changes.

Valvular cardiac disorders

1. Aortic stenosis



Valvular cardiac disorders

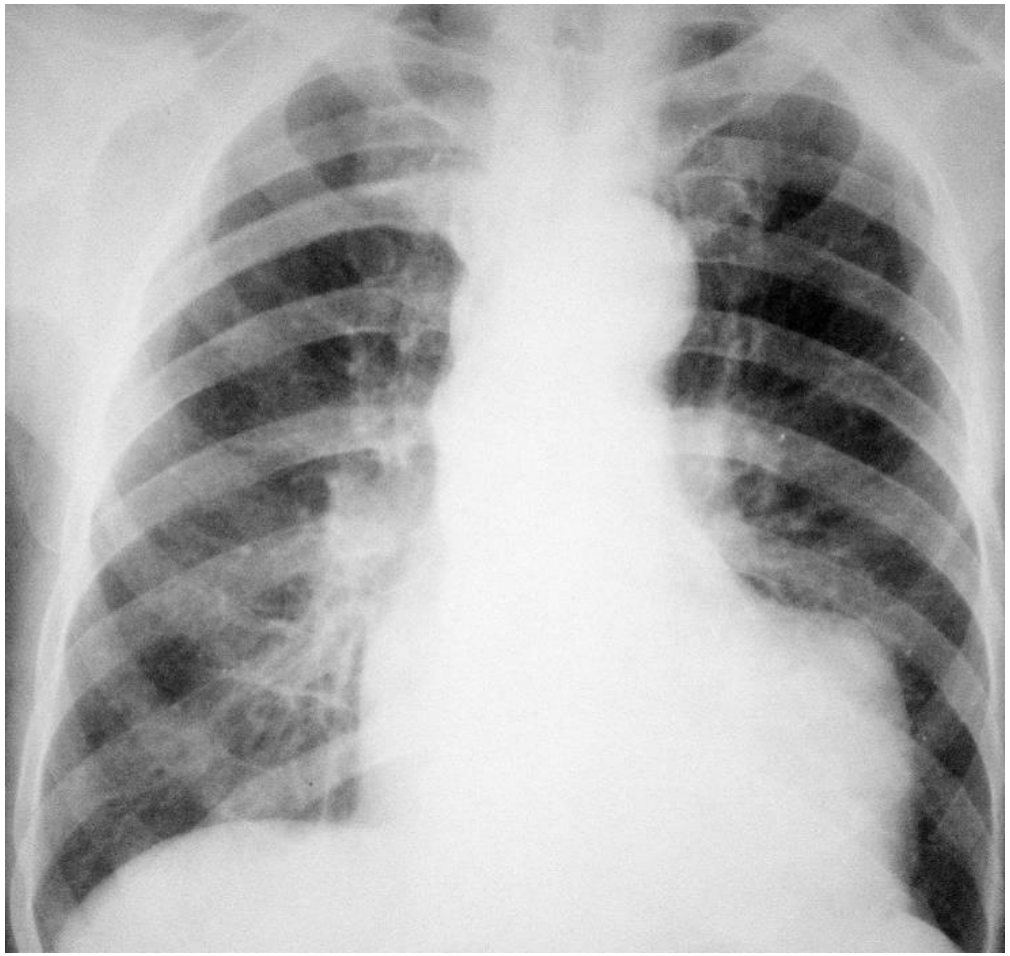
2. Aortic insufficiency

X-ray: The heart shape has increased dimensions, mainly because of the left ventricle. Thus, in the PA incidence, a prominent aortic knuckle is highlighted, sometimes with calcifications, deepened middle arch and the lower left arch appears enlarged, with an increased transverse diameter of the heart. Occasionally, on the right edge of the heart, a convex contour appears because of the ascending aorta, which pushes the structures to the right. In the left lateral incidence, the absence of the inferior vena cava triangle is caused by the hypertrophy of the left ventricle, with a large radius imprint over the esophagus filled with barium.

CT and MRI: can highlight the increased size of the left ventricle and dilatation of the ascending aorta. In addition to those mentioned in the CT examination, the MRI examination can reveal the diastolic jet to the left ventricle, which can be correlated with the severity of the aortic insufficiency and thus can calculate the regurgitation fraction and the systolic / diastolic volume.

Valvular cardiac disorders

2. Aortic insufficiency



Valvular cardiac disorders

3. Mitral stenosis

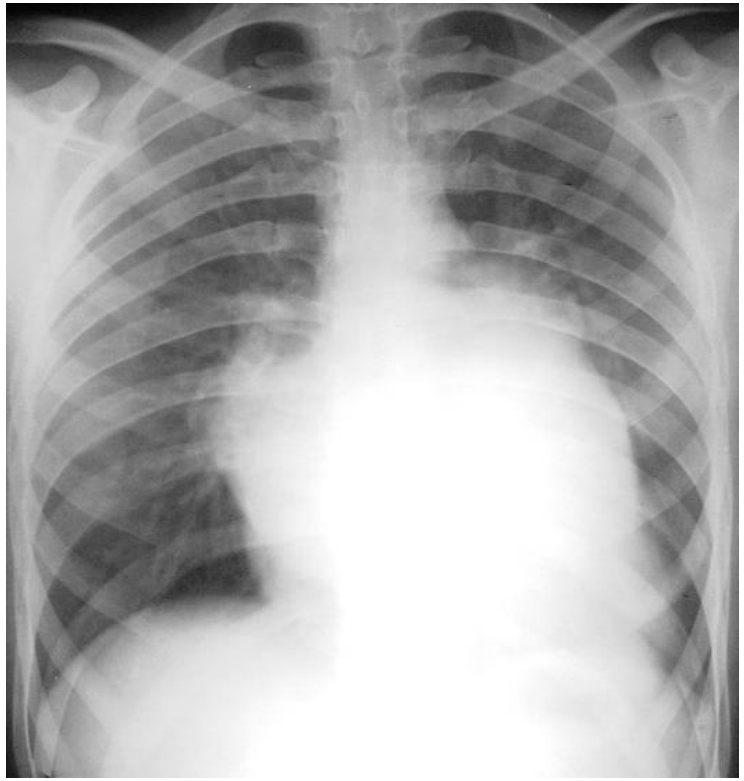
Rx: in the PA incidence, an inferior double arch, biconvex arch or the entire lower arch is prominent, but it does not come in contact with the diaphragm, depending on the degree of dilatation of the left atrium. On the left side, there is a small aortic knuckle due to the reduced blood supply to the left ventricle. The middle left arch is rectilinear or convex due to the dilatation of the left atrium ear and the increased caliber of the pulmonary artery in the hilum. In the left lateral incidence, left atrium dilatation causes a small radius imprint over the esophagus filled with barium. Right ventricle hypertrophy is also translated by reducing the size of the clear retrosternal space. Changes in pulmonary circulation are represented by pulmonary hypertension, initially venous and subsequently global (arterial + venous).

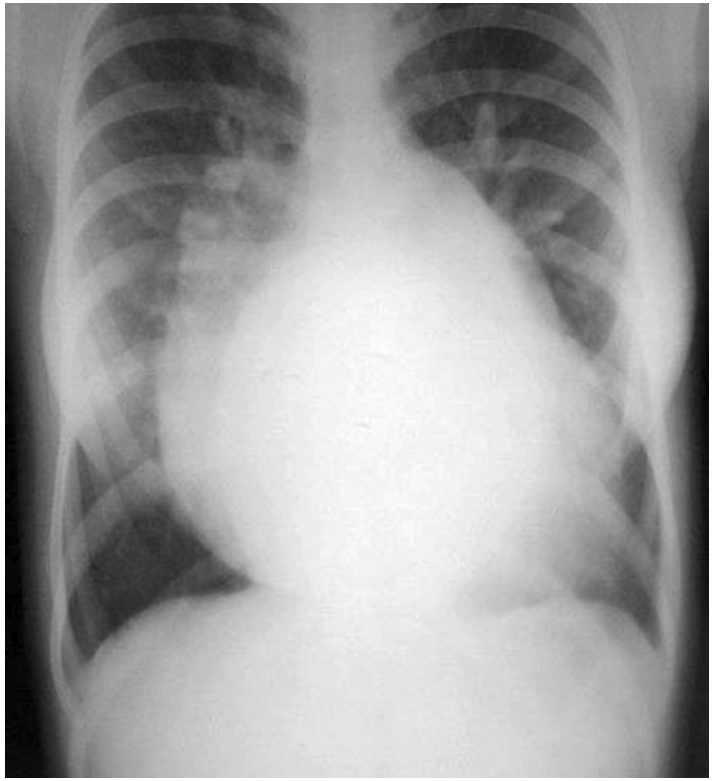
CT: enlargement of the left atrium, mitral valve calcifications as well as thickening and valve fusions, dilatation of the pulmonary vessels and pulmonary edema.

MRI: not indicated.

Valvular cardiac disorders

3. Mitral stenosis





Valvular cardiac disorders

4. Mitral insufficiency

X-ray: in the PA incidence, there is a prominent aortic knuckle, sometimes with calcifications, a deepened middle arch and a rounded lower left arch that bends to the left. In the left lateral incidence, the inferior vena cava triangle is absent and there is a large radius imprint over the esophagus filled with barium caused by the dilatation of the left ventricle.

CT: both the left atrium and ventricle appear with an increased size, mitral ring calcifications, pulmonary vascular dilatations.

MRI: both the left atrium and ventricle appear with an increased size, presence of regurgitant jet from the left ventricle to the left atrium during systole.

Valvular cardiac disorders

4. Mitral insufficiency

Valvular cardiac disorders

5. Tricuspid stenosis

X-ray: dilatation of the right atrium, inferior and/or superior vena cava;

CT: dilatation of the right atrium, suprahepatic veins, inferior and/or superior vena cava;

MRI: not indicated.

6. Tricuspid insufficiency

X-ray: enlarged cardiac opacity;

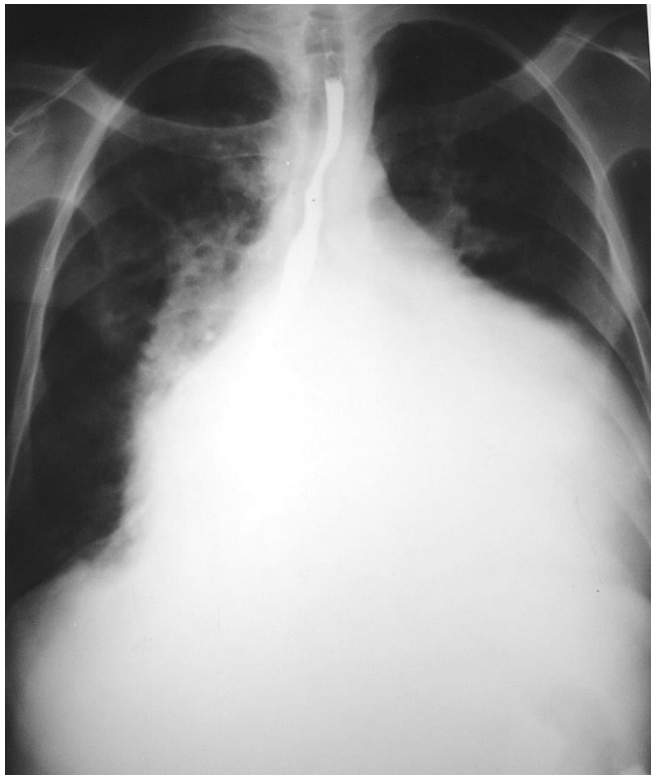
CT: globally increased heart with secondary pulmonary circulation redistribution caused by a left ventricle dysfunction and congestive heart failure, pleural fluid;

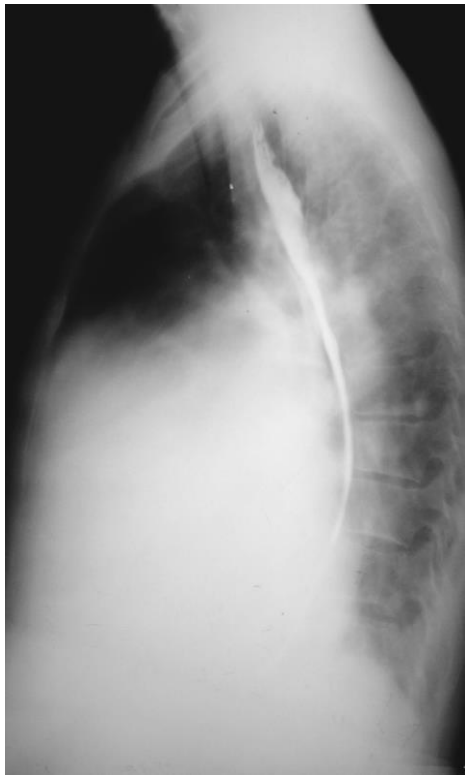
MRI: detects morphological and functional changes of the heart.

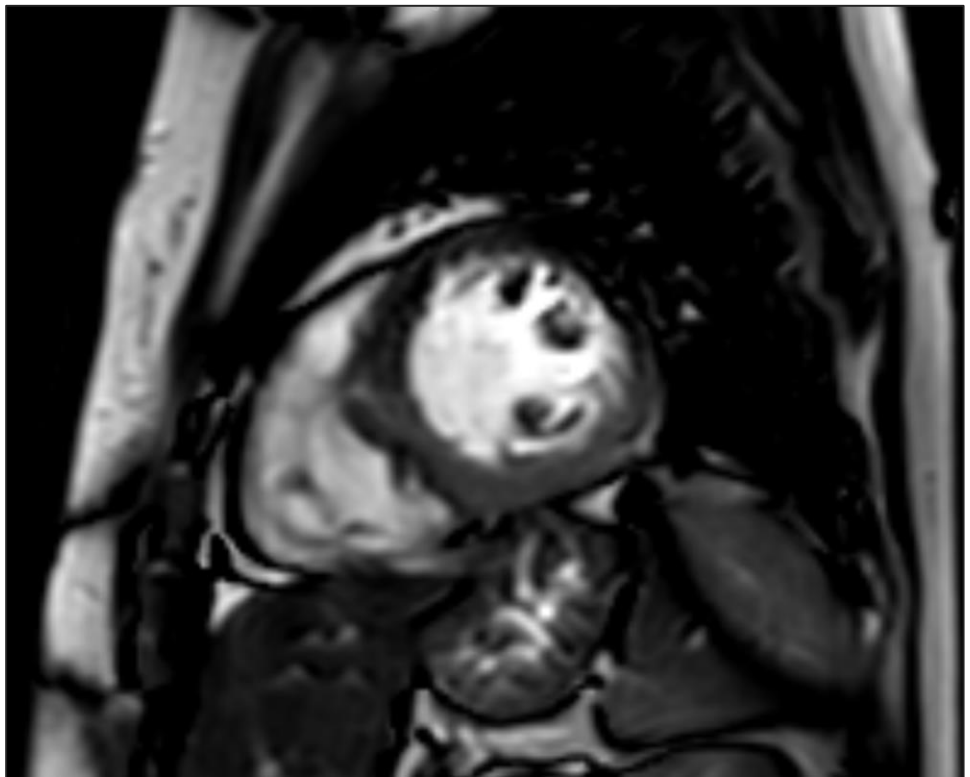
Myocarditis

X-ray: in the PA incidence there is an increase in size, with diffuse contours, the cardio-phrenic angles are obtuse. In the profile incidence, the reduction of the clear retrosternal and retrocardiac spaces is highlighted, and the esophagus filled with barium is displaced posteriorly.

MRI: represents the imaging method of choice that provides morphological and functional heart data.

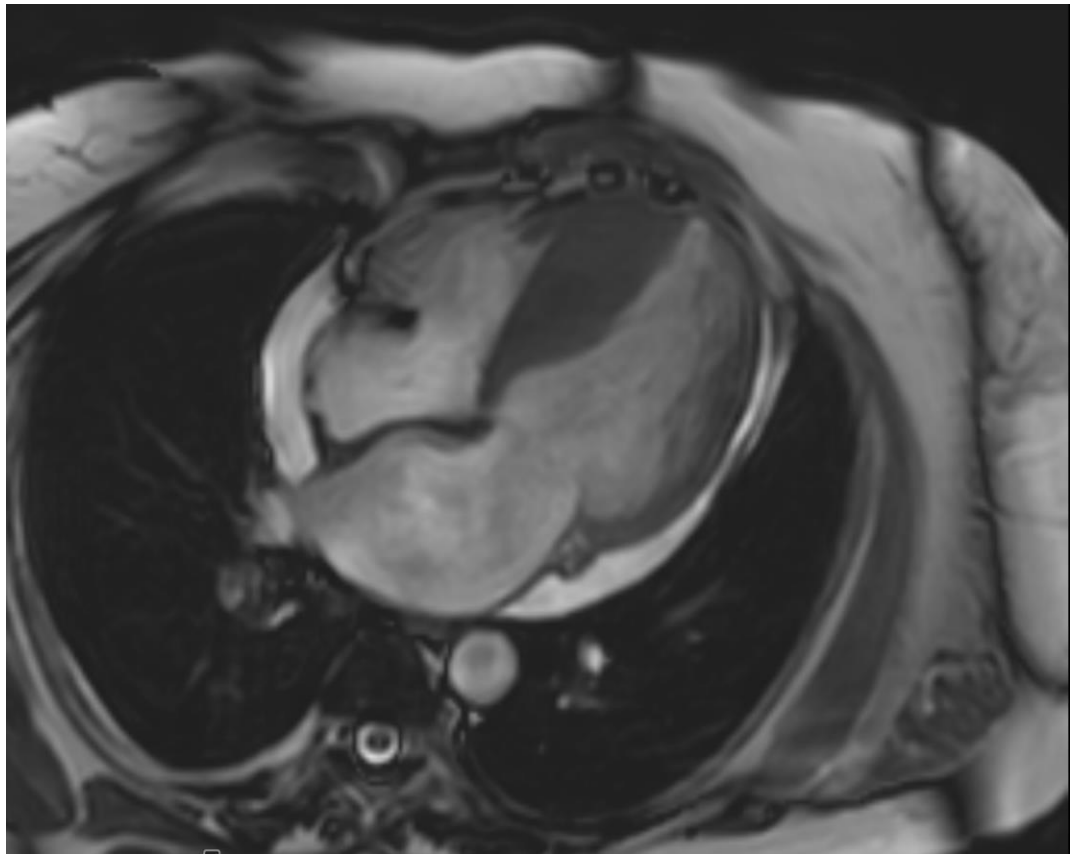






Cardiomyopathy

MRI: represents the imaging method of choice that provides morphological and functional heart data.

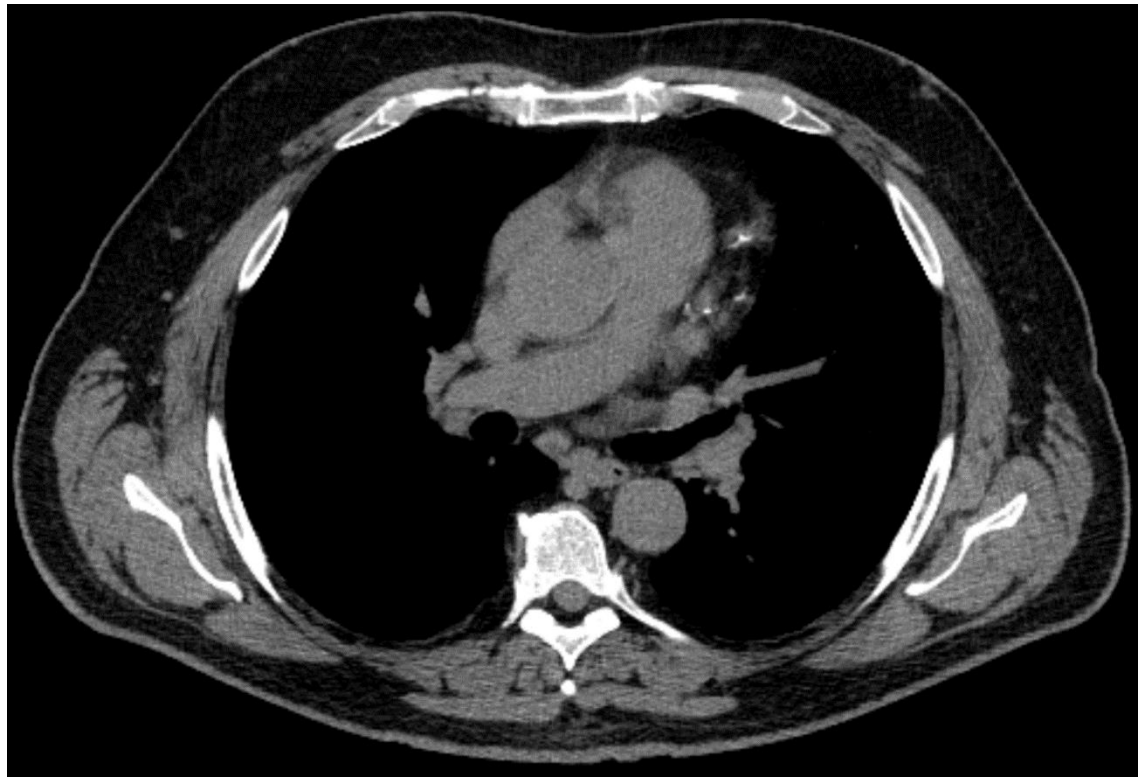


Coronary atheromatosis

Rx: the PA incidence reveals parallel linear opacities with an intensity similar to the bone structures, with the appearance of "tram lines“.

CT: native CT examination detects calcified atheroma plates, while post-contrast intravenous CT examination reveals and quantifies the degree of coronary stenosis. Also, through the CT examination, three-dimensional reconstructions can be performed in all three planes (axial, coronal, sagittal).

Coronarography: the method of choice in the evaluation of coronary vessels stenoses (indirect sign of an atheroma plate). With the help of coronarography, the severity of the stenosis (for example, 50%, 75%, etc.), the type of stenosis (concentric, eccentric) and the diameter of the vessel are evaluated.



Myocardial infarction

Imaging tools useful in the evaluation of a myocardial infarction include: coronarography, echocardiography, CT and MRI.

An acute myocardial infarction is manifested from an imaging point of view as a hypoperfused subendocardial area, associated with hypokinesia / akinesia / dyskinesia of the affected wall. In addition, there is a decrease in the ejection fraction of the left ventricle below 60% (objectified by echocardiography, CT, MRI).

A chronic myocardial infarction is seen as: decrease in thickness of the affected myocardium below 7 mm (detected by echocardiography, CT, MRI), fatty degeneration ± intramyocardial calcifications (detectable by CT), dilatation / aneurysm of the left ventricle, hypokinesia / akinesia / dyskinesia of the affected wall and decreased ejection fraction of the left ventricle below 60% (objectified by echocardiography, CT, MRI).

Cardiac MRI is a complementary imaging technique used in the evaluation of patients with ischemic heart disease. Cardiac MRI can be used to assess cardiac function locally and globally by assessing acute and chronic heart attacks, ischemic areas and myocardial viability.

Echocardiography is the first-line examination for patients with myocardial infarction. **Coronarography** is used for the diagnosis of coronary stenosis and for stent implantation at this level. CT examination is preferred in case of a suspected aortic dissection, a congenital anomaly of the coronary arteries, as well as in the post-surgical evaluation of the aorto-coronary bypass.

Cardiac tumors

Cardiac MRI is considered the gold standard for imaging evaluation of cardiac and paracardiac masses. The most common cardiac mass is intracavitary thrombus, followed by metastatic lesions.

1. Benign cardiac tumors:

a. Myxomas are the most common primary cardiac tumors. They tend to occur in middle-aged patients and are more common in women than in men.

Rx: it may be normal or we may encounter non-specific abnormalities such as cardiomegaly, calcified intracardiac tumor and mitral valve obstruction.

CT: shows heterogeneous hypodense masses, with calcifications, frequently located in the left atrium.

MRI: highlights heterogeneous, round-oval sessile or pedunculated masses, in iso / hypo T1, variable signal T2 and intense contrast enhancement (important differential diagnosis with thrombus).

b. Lipomas are the following primary cardiac tumors in frequency.

CT: homogeneous, hypodense (negative UH densities) masses in the heart or pericardial cavities.

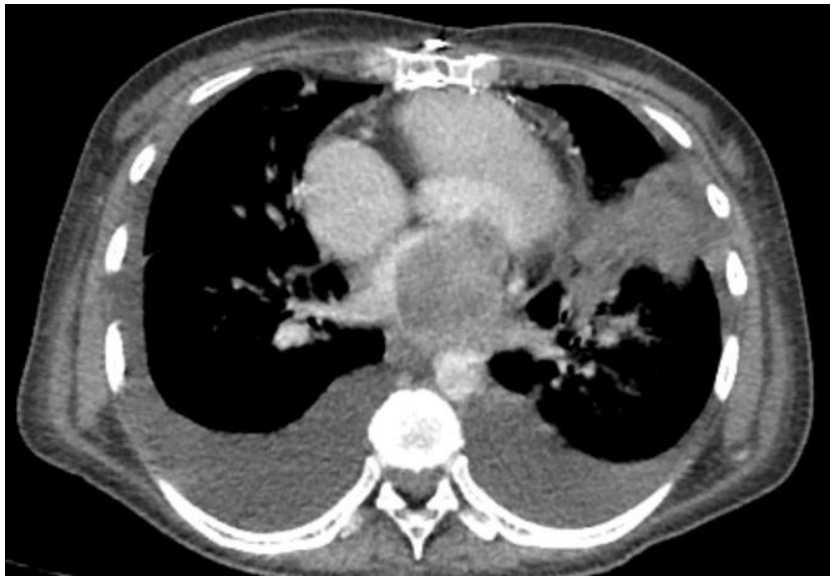
MRI: homogeneous masses with increased signal in the T1 and T2 sequences, canceled in the fat suppression sequences, without postcontrast enhancement.

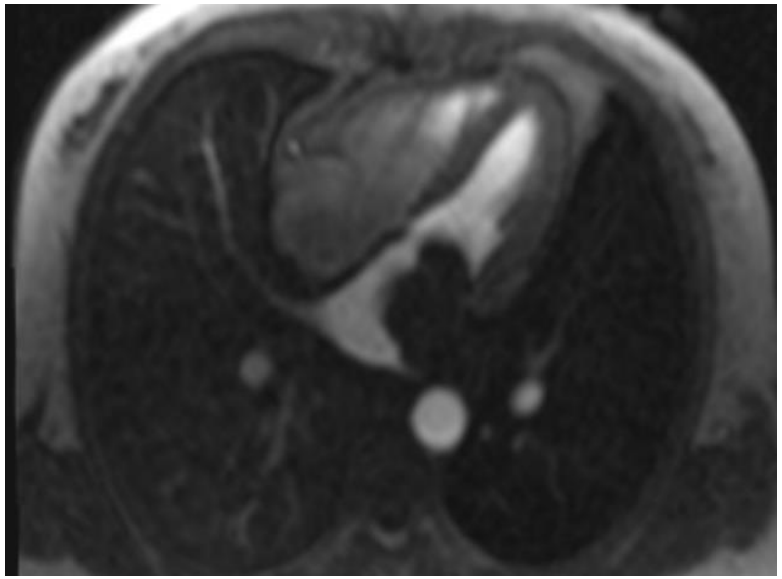
Cardiac tumors

2. Malignant cardiac tumors:

Metastatic tumors are one of the most common malignant tumors detected in the heart. Primary tumors that most commonly metastasize to the heart include lung carcinoma, breast carcinoma, melanoma and lymphoma. Metastases often induce pericardial effusion.

The most common primary malignant disease of the heart is ***angiosarcoma***. This is usually located in the right atrium, being characterized by heterogeneous signal in the T1 sequence, with contrast enhancement.





Cardiac thrombi

Cardiac MRI can diagnose both ventricular and atrial thrombi, with low signal in the specific sequence (echo gradient), with no postcontrast enhancement.

Pericardial effusion

X-ray: in the PA incidence, there is an increased size of the heart, with the so-called carafe-shaped heart, sharp cardio-phrenic angles. In the left lateral incidence, the clear retrosternal and retrocardial spaces appear reduced and the esophagus filled with barium is displaced posteriorly.

CT and MRI: the normal thickness of the pericardium in CT and MRI examinations is 2 mm. The pericardial fluid is incidentally highlighted and these imaging examinations are used to evaluate the caused that lead to the pericardial fluid more than diagnosing this condition. Depending on the thickness of the pericardial fluid, the amount of fluid can be estimated, namely: under 5 mm (50-100 mL), 5-10 mm (100-250 mL), 10-20 mm (250-500 mL) and over 20 mm (> 500 mL). Also, the imaging examinations (**Rx, CT**) can reveal pericardial calcifications as sequelas of the pericardial effusion.