Chest X-ray cardiac anatomy and pathology: correlation with Angiocardiography, CT, and MR imaging

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Authors: F. Pirro\textsuperscript{1}, V. Silvestri\textsuperscript{1}, G. Savino\textsuperscript{1}, R. Marano\textsuperscript{2}, B. Merlino\textsuperscript{2}, A. Meduri\textsuperscript{1}, L. Bonomo\textsuperscript{2}; \textsuperscript{1}Roma/IT, \textsuperscript{2}Rome/IT
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Learning objectives

To review chest X-ray cardiac anatomy and pathology and to correlate radiographic, angiocardiographic, CT and MR cardiac anatomy and pathology.

To improve the fundamental knowledge of cardiac imaging on chest X-ray illustrating the correlation of CXR cardiac silhouette with Angiocardiography, CT, and MR imaging.
Background

The emergence of non-invasive imaging techniques for the definitive diagnosis and monitoring of cardiovascular disease, has greatly altered cardiac imaging in the past 30 years. Non-invasive revolution in cardiovascular imaging has improved the visualization of normal cardiac anatomy and pathology and has consequently modified the diagnostic algorithm for all types of acquired and congenital cardiovascular disease.

Despite that, chest radiography remains the first diagnostic step for the evaluation of lung parenchymal and mediastinal disease, providing a vast amount of useful information. The knowledge of chest X-ray cardiac anatomy and pathology is fundamental to recognize the typical radiographic findings of different cardiomyopathies, while cardiac CT and MR are tailored to evaluate cardiac anatomy and function.
CHEST X-RAY

The chest film is often the first imaging procedure performed when heart disease is suspected and, more commonly, it is used to assess and follow the severity of cardiac disease. Because the chest film forms images by projection, this technique detects only those cardiopulmonary abnormalities that change the shape of the heart, mediastinum and lungs and those that alter the structure of the pulmonary vasculature. On the other hand, because blood, myocardium and other tissue have similar radio-densities in the diagnostic Kilovoltage range, the normal heart presents a homogeneous shadow on the chest film without any internal detail.

Clinically silent heart disease may also be detected on a chest film taken for other reasons. Extracardial structures, particularly in the abdomen and thoracic cage, may produce additional clues including heart disease.

There are only a few gross pathologic process that produce alterations of the cardiac silhouette:

- Myocardial hypertrophy
- Dilatation of a chamber
- Calcification of cardiac structure

Posterior-anterior (P-A)

On a normal posterior-anterior CXR, the silhouette of the heart borders, the ascending and descending aorta, the thoracic arch, the lateral profile of the superior vena cava (SVC), the right and left hilum and the hemidiaphragms are clear, being outlined by adjacent air-contained lung. In the frontal view, the direction of X-ray beam through the patient. There is a minimal magnification of the mediastinum and different structures are represented on a single plain (Fig. 1 on page 14).

In the frontal film, the right heart border is roughly divided into two equal parts: an upper, straight margin formed by the wall of the superior vena cava and lower, convexly curved segment representing the lateral wall of the right atrium. The left contour is composed of four segments. The aortic knob forms the uppermost bulge. The knob is not an anatomical structure, but simply represents the distal-most portion of the aortic arch as it curves down-ward to become the ascending aorta. The next bulge represents the main pulmonary artery and a small tract of the out-flow tract of the right ventricle. Immediately beneath there is a small, flat, or slightly concave segment where the left appendage
reaches the left cardiac border. The remainder of the left cardiac silhouette is formed by the broad curve of the lateral wall of the left ventricle (Fig. 2 on page 14, Fig. 3 on page 15, Fig. 4 on page 16, Fig. 5 on page 16, Fig. 6 on page 17).

Lateral (L-L)

On lateral CXR, patient's left side of chest is held against the x-ray cassette. This projection is important in the visualization of anterior to posterior structural relationships (Fig. 7 on page 18).

In the lateral view, almost the entire anterior margin of the heart is formed by the right ventricle and main pulmonary artery. If the posterior border of the cardiac silhouette from the tracheal bifurcation to the diaphragm is divided in half, the upper portion represents the left atrium and the lower, the posterior wall of the left ventricle. A short, straight segment extending upward and anteriorly from the right diaphragm to the right atrium represents the posterior margin of the inferior vena cava (Fig. 8 on page 19, Fig. 9 on page 20, Fig. 10 on page 20, Fig. 11 on page 21, Fig. 12 on page 22, Fig. 13 on page 23).

In a normal CXR we can immediately evaluate some pathologies as situs inversus (Fig. 14 on page 24) and pectus excavatum (Fig. 15 on page 25).

Oblique Projections

Right anterior oblique (RAO) and left anterior oblique (LAO) refers to the patient's side of chest held against the x-ray cassette.

In right anterior oblique the patient's right shoulder is held against the x-ray cassette, while the left shoulder is moved back (Fig. 16 on page 25).

In left anterior oblique the patient's left shoulder is held against the x-ray cassette, while the right shoulder is moved back.

The angle between the x-ray cassette and the patient's chest is about 45-60°.

When the heart is located in front of the column, and the aortic arch in not visible, this is a right anterior oblique (Fig. 17 on page 25, Fig. 18 on page 26).

When the aortic arch is open, this is a left anterior oblique (Fig. 19 on page 27, Fig. 20 on page 27). The gastric air can help in distinguishing the left hemidiaphragm.

The hemitorax behind the column must be half compared to the anterior one.
This two projections have different significance: left anterior oblique represents the real frontal projection of the heart, as the heart is turned right; right anterior projection represents the lateral projection of the heart.

Furthermore right anterior oblique demonstrates the posterior part of right lung, the anterior part of left lung and vascular ilum of left lung; while left anterior oblique demonstrates the posterior part of the left lung, the anterior part of the right lung and vascular ilum of right lung.

These projections can be used to evaluate pathologies of the aortic arch.

HEART DIMENSIONS

Enlargement of the cardiac silhouette is an obvious radiographic sign of heart disease. The problem lies in determining what "enlarged" means. A simple measurement of the transverse diameter of the heart is of little value, because it varies widely with body size. This can be compensated by obtaining the cardiothoracic ratio (CTR), which is still one of the most common measurements of overall heart size. It compares the transverse cardiac diameter (representing the size of the heart) with the widest diameter of the chest (an indicator of body habitus) (Fig. 21 on page 28). Fifty percent is popularly quoted as the upper limit of normal, but this is too restrictive. There is a considerable overlap of normal and abnormal hearts in the "grey region" of CTRs between 50% to 60%. Accepting 60% as the top normal value will eliminate almost all false positive without adversely affecting the treatment of those with "questionably enlarged hearts".

Because it measures the transverse heart diameter, the cardiothoracic ratio is usually normal when either the left atrium or the right ventricle is moderately enlarged, because neither of these two chambers is reflected in the transverse dimension. The left atrium and right ventricle become border-forming when they are severely enlarged.

When the heart size is subjectively evaluated based on the configuration of the heart with respect to the thorax, the specificity and sensitivity are quite similar to the measured cardiothoracic ratio. For this reason and because quantitative measurements from CT are commonly available, the cardiothoracic ratio is now used mainly as an adjunct in assessing heart size on the chest film.

MRI may accurately assess ventricles volumes, dimensions and mass (Fig. 22 on page 29).

CARDIAC VALVES
Drawing a bisector line between sternum and diaphragm in lateral CXR projection, we can find the aortic and mitral valve: above the line we find the aortic valve, below the mitral valve (Fig. 23 on page 29, Fig. 24 on page 30).

The role of CXR for the study of mitral and aortic valve is minor. It can reveal the size of the heart and show left atrial enlargement and severe calcification of the valves and can also show evidence of raised pulmonary venous pressure and any pulmonary oedema.

On the other hand, MR provides important information concerning cardiac chamber size, myocardial mass, pulmonary blood flow and pulmonary venous pressure (Fig. 25 on page 31, Fig. 26 on page 32, Fig. 27 on page 33). Furthermore, MRI demonstrates the jets of valvular dysfunction and also provides a means of quantifying valvular dysfunction and its sequelae.

The response of the heart to valvular dysfunction leads to characteristic changes in chamber volume and myocardial thickness.

CARDIAC CHAMBERS

Angiocardiography is an invasive diagnostic technique, performed by tracing via x-ray the course of a contrast agent directly injected into the cardiac chamber by an intravascular catheter. Through this technique we have anatomical (structure) and functional (hemodynamic) findings.

Advances in CT and MRI have allowed to replace the invasive angiocardiographic assessment, except for some conditions.

Right atrium

The right atrium (Fig. 28 on page 34, Fig. 29 on page 35) has an appendage that is larger than the left atrial appendage and has a broad-based connection to the main chamber. The inflow structures of the right atrium are the inferior vena cava, the superior vena cava and the coronary sinus. The internal structure are difficult to identify angiographically, but MRI usually shows the fossa ovalis, the crista terminalis and the pectinate muscles.

Right ventricle

The right ventricle (Fig. 30 on page 35, Fig. 31 on page 36) has a complex shape consisting of a triangular body and a cylindrical outflow tract. Its three parts are the inflow
segment, the body and the outflow segment. Compared to the left ventricle, the right ventricle has larger trabeculations and extend on to the septum. The moderator band is usually the largest trabeculation near the septum.

**Left atrium**

The left atrium is behind and to the left of the right atrium. The body of the left atrium has no trabeculations but the interior of the left atrial appendage may be finely striated.

**Left ventricle**

The left ventricle (Fig. 32 on page 36, Fig. 33 on page 37) has an oval shape and thinner trabeculations than the right ventricle. The papillary muscles may have single or multiple heads and connect about half of the distance between the base and the apex of the left ventricle. Because the papillary muscles look like filling defects on the left ventriculogram, they are occasionally confused with thrombus.

**PULMONARY CIRCLE**

**Pulmonary Arteries**

In the normal adult anatomy, the pulmonary trunk, or main pulmonary artery, may have a diameter as great as 28 mm. The pulmonary trunk is divided in left and right arteries (Fig. 34 on page 37); both main and left and right pulmonary arteries are intrapericardial. The right pulmonary artery has a longer mediastinal course than the left, and it divides into two lobar branches at the root of the right lung (Fig. 35 on page 38). The left pulmonary artery courses over the left main bronchus and penetrates the root of the left lung, where the artery divides into two lobar branches. The right and left pulmonary arteries should be of approximately equal size, although the left pulmonary artery appears slightly larger in most subjects (Fig. 36 on page 38). The segmental arteries are always seen near the accompanying branches of the bronchial tree, and the subsegmental arteries are easily recognized as dichotomous divisions of the corresponding segmental artery.

**Pulmonary Veins**

In the normal adult anatomy, the pulmonary veins either connect with the left atrium as four individual vessels (superior and inferior pulmonary veins for each side) with 4 distinct ostia (Fig. 37 on page 39). The orifices of the left pulmonary veins are located more superiorly than those of the right pulmonary veins (Fig. 38 on page 39). The right superior pulmonary vein and the left superior pulmonary vein project backward and downward. The trunk of the right inferior pulmonary vein projects horizontally (Fig. 39
The right superior pulmonary vein lies just behind the superior vena cava or right atrium and the left pulmonary veins are positioned between the left atrium appendage and descending aorta (Fig. 40 on page 41). The orifice of the left atrium appendage lies in close proximity to the ostium of the left superior pulmonary vein.

The second most common pattern is the presence of a short common left trunk. This pattern differed from typical pulmonary vein anatomy in that junction of the lower wall of the left superior pulmonary vein and upper wall of the left inferior pulmonary vein lies outside the left atrium rim. A third pattern of pulmonary vein anatomy is the presence of a right middle pulmonary vein between the superior and inferior right pulmonary veins (Fig. 41 on page 41). Additional patterns are a short left common trunk, long common left trunk, two right middle pulmonary vein, right middle pulmonary vein and right upper pulmonary vein.

CORONARY ANGIOGRAPHY

Coronary angiography is performed in at least two projections because it is a projectional technique and atherosclerotic lesions are typically eccentric. The initial Right Anterior Oblique (RAO) and Left Anterior Oblique (LAO) angiograms project the coronary arteries away from the spine. The stenoses are then defined and overlapping branches are eliminated with compound views by adding cranial and caudal angulation.

Right Coronary Artery

The right coronary artery normally originates from the right sinus of Valsalva and continues in the right atrio-ventricular groove to the crux of the heart. It is divided in three tracts: proximal, medium and distal. In its proximal tract, it gives origin to two vessels: sinoatrial nodal artery (goes posteriorly by sending an anterior and posterior branch around the superior vena cava at the right atrial junction) and conus artery (goes anteriorly around the right ventricular conus or infundibulum and frequently ends in three short branches). The distal right coronary artery typically ends by dividing into a posterior descending artery and a posterolateral left ventricular artery (Fig. 42 on page 42, Fig. 43 on page 43). In about 90% of people, the right coronary artery ends in the posterior descending artery and is therefore called the "dominant" artery. When the left circumflex artery ends in the posterior descending artery, the right coronary artery is "non dominant" and the left circumflex artery is then the dominant blood supplier of the inferior wall.

Left Coronary Artery

The left sinus of Valsalva is normally the origin of the left coronary artery. The left main artery does not taper and typically is about 1 cm long. However, there may be no left main artery, with the left anterior descending and left circumflex arteries originating separately
from the left sinus. The left main coronary artery may trifurcate into a left anterior
descending artery, an intermediate artery or ramus medianus and the left circumflex
artery. The caudal LAO puts the left main and proximal circumflex arteries in the plane
of the film but foreshortens the left anterior descending artery (Fig. 44 on page 43).

The left circumflex artery lies in the left atrio-ventricular groove and may exist only as a
vestigial twig or may be so long that it ends by coming the left posterior descending artery.
Its major branches are called left circumflex marginal arteries or obtuse marginal arteries.

The left anterior descending artery lies in the interventricular groove and supplies two
different types of branches, septal (go to the interventricular septum) and diagonal (over
the anterolateral wall) (Fig. 45 on page 44).

Evaluation of left ventricular function and motion is possible (Fig. 46 on page 44, Fig.
47 on page 45).

**THORACIC AORTA**

The thoracic aorta is composed by four segments: aortic root, ascending aortic, aortic
arch and descending aorta.

The aortic sinus of Valsalva extends to the sinotubular ridge, which marks the junction
with the aorta. The aortic root is divided into three portions: aortic anulus, aortic bulb and
sino-tubular junction (Fig. 48 on page 45). It forms the outlet from the left ventricle.

**CARDIOMYOPATHY**

Cardiomyopathies are heart muscle diseases in which congenital, pericardial, valvular
and coronary causes have been excluded by appropriate clinical, hemodynamic or
imaging methods. Primary cardiomyopathies have an unknown etiology, whereas
secondary cardiomyopathies have an etiologic diagnosis. They are associated with
cardiac dysfunction. These pathologies are mainly genetically transmitted and is possible
to describe five different groups: DCM (dilated cardiomyopathy), HCH (hypertrophic
cardiomyopathy), RCM (restrictive cardiomyopathy), ACM (arrhythmic cardiomyopathy)
and UCM (unclassified cardiomyopathy).

Chest radiography provides information about cardiac and great vessels enlargement
and shows possible rebound of cardiac function on pulmonary circulation.
Dilated cardiomyopathy causes dilatation of both right and left ventricle. The chest film generally shows cardiomegaly and pulmonary venous hypertension with little or no pulmonary oedema.

Hypertrophic cardiomyopathy is characterized by disproportionate hypertrophy of the left ventricle and occasionally right ventricle. In HCM the heart size is usually normal on chest films but it can be manifested by severe biventricular enlargement and from pulmonary oedema. It occurs when the left ventricle is too stiff to allow normal diastolic filling (Fig. 49 on page 46).

MRI should be considered a fundamental technique for the assessment and follow-up of myocardial pathologies. A complete MRI exam should include myocardial morphological analysis and should evaluate the functional impact on ventricular and valvular function detecting and characterizing the pathology of the myocardium (Fig. 50 on page 47).

ATRIAL SEPTAL DEFECTS

Defects in the atrial septum are a common congenital malformation that allows an abnormal passage of blood between the two atria. It represents the commonest asymptomatic form of congenital heart disease often diagnosed during adulthood.

There are 3 major types of atrial septal defects (ASDs) or interatrial communications: ostium secundum, ostium primum and sinus venosus defects.

Most primum ASDs are relatively large and lead to right heart dilation. Ostium primum defects account for about 15% of all atrial septal defects, ostium secundum defects for 75% and sinus venosus defects make up 10%.

In approximately 70% of population, the primum and secundum septa of the interatrial septum fuse shortly after birth. In the rest of population, septal fusion fails or is incomplete.

Atrial septal defects are also integral part of many congenital malformations, a few of which are total anomalous pulmonary connection, transposition of the great arteries, and tricuspid atresia, and occasionally of acquired defects such as mitral stenosis.

Ostium secundum

It is an absence or deficiency of tissue in the mid-portion of the interatrial septum involving the region of the fossa ovalis. (Fig. 51 on page 47, Fig. 52 on page 48, Fig. 53 on page 49). This defect is the commonest involving more frequently female.

Ostium primum
This defect is within the spectrum of the atrioventricular (AV) septal defects also known as AV canal defects or endocardial cushion defects, the complete form of which also includes a large ventricular septal defect and a common AV valve.

**Sinus venosus**

This defect is usually located at the junction of the right atrium and superior vena cava and is almost always associated with partial anomalous pulmonary venous return.

The superior form of the sinus venosus ASD constitutes 5% to 10% of all ASDs. Its posterior aspect is the right atrial free wall, and its superior border is often absent because of an overriding superior vena cava. Anomalous connection of some or all of the right pulmonary veins to the SVC or the right atrium is very common.

Two very uncommon types of ASDs are the inferior vena cava form and the coronary sinus septal defect (in which a defect between the coronary sinus and the left atrium allows a left-to-right shunt to occur through an "unroofed" coronary sinus).

**Atrioventricular Septal Defects**

This group of anomalies share a common atrioventricular (AV) junction with abnormalities of the AV valves (separate valves in partial AV septal defect, common AV valve in the complete form).

The most common associated anomalies are a secundum ASD and a persistent left SVC draining into the coronary sinus.

**POSTOPERATIVE AORTA PSEUDOANEURYSM**

Psueudoaneurysm of the aorta represents a rare but potentially fatal complication of cardiac surgical procedures. Mediastinitis and graft infection are the most common risk factors for the formation of postoperative aortic pseudoaneurysm. Others predisposing factors are aortic dissection, connective tissue disorders, chronic hypertension, aortic calcifications and aortotomy dehiscence.

At the beginning postoperative aorta pseudoaneurysm are usually asymptomatic, but later various symptoms arise as a consequence of vital structures compression. Potential risk of rupture rises with time and pseudoaneurysm enlargement.

The chest radiograph ([Fig. 54 on page 50](#)) can serve to raise suspicion of aortic disease by demonstrating an abnormal mediastinal contour in patients being investigated
for other reasons. It can also indicate alternative pathologies when acute aortic pathology is suspected.

CTA provides excellent views of the thoracic aorta (Fig. 55 on page 51). It describes the location of the pseudoaneurysm with respect to the aortic root or valve prosthesis and coronary arteries, the size of pseudoaneurysm and the pseudoaneurysm neck, any indicators of hemorrhage (mediastinal or pericardial) and the presence of any additional aortic abnormality (for exemple dissection) that would affect surgical planning.
**Fig. 1:** Cardiac borders on a Posterior-Anterior (P-A) chest radiograph (CXR). Relationship between borders of the cardiac shadow and the adjacent lung portion. Ao=aorta arch; SVC=superior vena cava; PA=pulmonary artery; RA=right atrium; LV=left ventricle; RV=right ventricle.

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Fig. 2: Segments of cardiac silhouette. A. P-A CXR. Ao=aorta arch; SVC=superior vena cava; PA=pulmonary artery; RA=right atrium; LV=left ventricle; RV=right ventricle. B. MRI coronal gradient echo acquisition. RV=right ventricle; RV effl=right ventricle outflow tract; LV=left ventricle; IVS=interventricular septum; ADA=descending anterior artery.

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**Fig. 3:** Segments of cardiac silhouette: A. P-A CXR. Ao=aorta arch; SVC=superior vena cava; PA=pulmonary artery; RA=right atrium; LV=left ventricle; RV=right ventricle. B. MRI coronal gradient echo acquisition. RV=right ventricle; RV effl=right ventricle outflow tract; LV=left ventricle; IVS=interventricular septum; ADA=Anterior Descending Artery, RCA=Right Coronary Artery; Rapp=right appendage.

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**Fig. 4:** Segments of cardiac silhouette: A. P-A CXR. Ao=aorta arch; SVC=superior vena cava; PA=pulmonary artery; RA=right atrium; LV=left ventricle; RV=right ventricle. B. MRI coronal gradient echo acquisition. RA=right atrium; RV effl=right ventricle outflow tract; LV=left ventricle; ADA descending anterior artery; Ao=aorta; PA=pulmonary artery; TV = Right Wall Trabeculae.

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Fig. 5: Segments of cardiac silhouette: A. P-A CXR. Ao=aortic arch; SVC=superior vena cava; PA=pulmonary artery; RA=right atrium; LV=left ventricle; RV=right ventricle. B. MRI coronal gradient echo acquisition. Anonymous A=anonymous artery; SVC=superior vena cava; PA=main pulmonary artery; ADA=anterior descending artery; LV=left ventricle; AV=aortic valve; Ao=aorta; alpm=antero-lateral papillary muscle; pmpm=postero-medial papillary muscle; RA=right atrium; sino tubular junction.

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Fig. 6: Segments of cardiac silhouette: A. P-A CXR. Ao=aorta arch; SVC=superior vena cava; PA=pulmonary artery; RA=right atrium; LV=left ventricle; RV=right ventricle. B. MRI coronal gradient echo acquisition. Ao=aorta; PA=main pulmonary artery; rPA=right pulmonary artery; RSL=right superior lobe; RA=right atrium; LV=left ventricle; LA=left atrium; ADA=anterior descending artery; CX=circumflex artery; IVC=inferior vena cava.

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Fig. 7: Cardiac borders on a lateral CXR. Ao=Aorta; PA=pulmonary artery; RV=right ventricle; LV=left ventricle; LA=left atrium.

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Fig. 8: Segments of cardiac silhouette. A. L-L CXR. Ao=Aorta; PA=pulmonary artery; RV=right ventricle; LV=left ventricle; LA=left atrium. B. Sagittal multiplanar CT reconstruction. RV=right ventricle; LA=left atrium; PV=pulmonary valve.

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Fig. 9: Segments of cardiac silhouette. A. L-L CXR. Ao=aorta; PA=pulmonary artery; RV=right ventricle; LV=left ventricle; LA=left atrium. B. MRI sagittal gradient echo acquisition. RV=right ventricle; LV=left ventricle; Mb=moderate band; IVS=interventricular septum; ICX=left circumflex artery; Pas=left Pulmonary artery.

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Fig. 10: Segments of cardiac silhouette. A. L-L CXR. Ao=aorta; PA=pulmonary artery; RV=right ventricle; LV=left ventricle; LA=left atrium. B. MRI sagittal gradient echo acquisition. RV=right ventricle; LCA=left coronary artery; LV=left ventricle; Mb=moderate band; IVS=interventricular septum; LA=left atrium; MV=mitral valve; PA=pulmonary artery; PV=pulmonary valve; IPA=left pulmonary artery; LB=left bronchus.

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**Fig. 11:** Segments of cardiac silhouette. A. L-L CXR. Ao=aorta; PA=pulmonary artery; RV=right ventricle; LV=left ventricle; LA=left atrium. B. MRI sagittal gradient echo acquisition. RV=right ventricle; LV=left ventricle; LA=left atrium; Mb=moderate band; SIV=interventricular septum; PA=pulmonary artery; LCA=left coronary artery; Pas=left Pulmonary artery; LB=left brunchus; MV=Mitral Valve; L sup pulm v=left superior pulmonary vein.

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**Fig. 12:** Segments of cardiac silhouette. A. L-L CXR. Ao=aorta; PA=pulmonary artery; RV=right ventricle; LV=left ventricle; LA=left atrium. B. MRI sagittal gradient echo acquisition. LVeffl=left ventricle outflow; AO=aorta; LA=left atrium; PA=pulmonary artery; LB=left bronchus; LIPV=left inferior pulmonary vein; MV=mitral valve; RV=right ventricle.

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Fig. 13: Segments of cardiac silhouette: A. L-L CXR. Ao=aorta; PA=pulmonary artery; RV=right ventricle; LV=left ventricle; LA=left atrium. B. MRI sagittal gradient echo acquisition. RV=right ventricle; RA=right atrium; LA=left atrium; RCA=right coronary artery; LB=left bronchus; Ao=aorta; rPA=right pulmonary artery.

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Fig. 14: Situs Inversus. The right and left sides of the abdomen and thorax are reversed in a mirror-image fashion. The spleen, stomach bubble, and lowest leaf of the diaphragm are on the right side of the abdomen. The left sided lung has an epiarterial bronchus, indicating a morphologic right lung.
**Fig. 15:** Pectus excavatum.

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**Fig. 16:** Oblique chest projection. RAO (right anterior oblique). Ao=aorta; PA=pulmonary artery; RV=right ventricle; LV=left ventricle; LA=left atrium; RA=right atrium.

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**Fig. 17:** Oblique chest projection. RAO (right anterior oblique); it is the lateral projection of the heart. The patient’s right shoulder is held against the x-ray cassette. The hemitorax behind the column must be half compared to the anterior one.

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Fig. 18: A. Oblique chest projection. RAO (right anterior oblique). B. Angiocardiography of the left ventricle-aorta.

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Fig. 19: Oblique chest projection. LAO (left anterior oblique); it is the real frontal projection of the heart. The patient's left shoulder is held against the x-ray cassette. RA=right atrium; RV=right ventricle; LA=left atrium; LV=left ventricle.

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Fig. 20: Oblique chest projection. A. LAO (left anterior oblique). B. Angiocardiography of the left ventricle-aorta.

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Fig. 21: Measuring the cardiothoracic ratio (CTR). A. A vertical line is first drawn through the cardiac silhouette. The greatest distances from this line to the right (a) and the left (b)
cardiac borders are then measured and summed to give the transverse cardiac diameter. The CTR is obtained by dividing this figure by the widest diameter of the chest (c), measured from the inner margins of the ribs, and expressing the result as a percentage.

B. Axial CT scan. CT permits a better delineation of heart measures in comparison with frontal CXR.

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**Fig. 22:** MRI short axis cine gradient echo acquisition. Ventricles volumes, dimensions and mass may be accurately assessed by MR (SSFP).

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Fig. 23: A. L-L CXR projection. B. MRI Sagittal Acquisition. Drawing a bisector line between sternum and diaphragm, we can find above the line the aortic valve and below the mitral valve.

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Fig. 24: A. L-L CXR projection. B. Sagittal multiplanar CT reconstruction.

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Fig. 25: A. P-A CXR. B. Oblique multiplanar CT reconstruction. Ao=aorta; RV=right ventricle; IVS=interventricular septum; LV=left ventricle; LA=left atrium. C. D. Multiplanar Thick Maximum Intensity Projection CT image.

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Fig. 26: A. MRI coronal gradient echo acquisition. SVC=superior vena cava; PA=pulmonary artery; Ao=aorta; AV=aortic valve; RA=right atrium; LV=left ventricle; alpm=antero-lateral papillary muscle; pmpm=postero-medial papillary muscle; ADA=anterior descendent artery. B. P-A CXR. Patient underwent to an aortic and mitral valve replacement. C. D. Multiplanar Thick Maximum Intensity Projection CT image.

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**Fig. 27:** A. MRI coronal gradient echo acquisition. PA=pulmonary artery; rPA=right pulmonary artery; Ao=aorta; RSL=right superior lung; Lapp=left appendage; LA=left atrium; LV=left ventricle; RA=right atrium; CX=circumflex artery. B. P-A CXR. Patient underwent to an aortic and mitral valve replacement. C. D. Multiplanar Thick Maximum Intensity Projection CT image.
Fig. 28: Angiocardiography of the right atrium. We can compare P-A CXR projection (A) to P-A angiocardiographic projection (B) and L-L CXR projection (C) to the L-L angiocardiographic projection (D).

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Fig. 29: Angiocardiography of the right atrium. We can compare MRI coronal gradient echo acquisition (A) to P-A angiocardiographic projection (B) and MRI sagittal gradient echo acquisition (C) to L-L angiocardiographic projection (D).

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**Fig. 30:** Angiocardiography of the right ventricle. We can compare P-A CXR projection (A) to P-A angiocardiographic projection (B) and L-L CXR projection (C) to L-L angiocardiographic projection (D).

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**Fig. 31:** Angiocardiography of the right ventricle. We can compare MRI coronal gradient echo acquisition (A) to P-A angiocardiographic projection (B) and MRI sagittal gradient echo acquisition (C) to L-L angiocardiographic projection (D).

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**Fig. 32:** Angiocardiography of the left ventricle in diastole (A, C) and systole (B, D). In systole the mitral valve is closed.

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**Fig. 33:** Angiocardiography of the left ventricle-aorta. Angiocardiography images (A, D) can be compared to angio-CT images (B, C).

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**Fig. 34:** Angiocardiography of the right ventricle and pulmonary artery.

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**Fig. 35:** Angiocardiography of the right ventricle and pulmonary artery. We can compare MRI coronal gradient echo acquisition (A) to P-A angiocardiographic projection (B) and MRI sagittal gradient echo acquisition (C) to L-L angiocardiographic projection (D). Ao=aorta; PA=pulmonary artery; rPA=right pulmonary artery; RSL=right superior lobe; Lapp=left appendage; ada=anterior descending aorta; LV=left ventricle; LA=left atrium; RA=right atrium; RV=right ventricle; CX=circumflex artery; IVC=inferior vena cava; Mb=moderate band; SIV=interventricular septum; LCA=left coronary artery; LB=left bronchus.

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Fig. 36: MR Angiography of pulmonary circle: veins and arteries.

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Fig. 37: Angiocardiography of pulmonary veins-left atrium.

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Fig. 38: MRI coronal gradient echo acquisition (A) and angiocardiography of pulmonary veins-left atrium (B). PA=pulmonary artery; rPA=right pulmonary artery; RSL=right superior lobe; Lapp=left appendage; ada=anterior descending aorta; LV=left ventricle; LA=left atrium; RA=right atrium; IVC=inferior vena cava.

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Fig. 39: Angiocardiography of pulmonary veins-left atrium (B) and P-A CXR (A).
**Fig. 40:** Branching pattern of pulmonary veins (PV) anatomy. Shaded portions indicate different parts from typical anatomy. A. typical branching pattern. B. short common left trunk. C. long common left trunk. D. right middle PV. E. two right middle PVS. F. right middle PV and right upper PV.

Fig. 41: Examples of unusual PV anatomy. Long left common trunk A. Coronal-oblique CT reconstruction. B. Shaded Surface reconstruction Left Atrium navigation and right middle with discrete ostium C. Coronal-oblique CT reconstruction. D. Shaded Surface reconstruction Left Atrium navigation.

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**Fig. 42:** Right coronary artery (RCA) selective angiography. A. Lateral projection. B. Cranial LAO projection. C. RAO projection.

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**Fig. 43:** Volume Rendering images shows the RCA arising from the aorta and bifurcating into DPA (descending posterior artery) and PL (right postero-lateral artery).

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Fig. 44: Left coronary artery selective angiography. A. Lateral projection. B. Cranial LAO projection. C. RAO projection.

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Fig. 45: Volume Rendering image shows the LCA (left coronary artery) arising from the aorta and bifurcating into the proximal CX (circumflex) artery and the ADA (anterior descending artery).

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Fig. 46: Angiocardiography of the left ventricle in systole (A) and diastole (B).

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Fig. 47: MRI coronal cine images acquisition in systole (A) and diastole (B) overimposed to a PA projection CXR.

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Fig. 48: Thoracic aorta segments anatomy. A. Multiplanar-oblique Thick MIP reconstruction. B. Multiplanar-oblique CT reconstruction. Aortic root is divided into valvular segment (1), bulbar segment (2), S-T junction (3). C. Angiocardiography of the left ventricle-aorta.

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**Fig. 49:** P-A CRX. A. Hypertrophic cardiomyopathy. The left heart border is uplifted and laterally displaced, indicating both right and left ventricular enlargement. B. Dilated cardiomyopathy. The heart shows enlargement of all four chambers. The azygos vein and superior vena cava are slightly dilated, reflecting high central venous pressure.

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**Fig. 50:** MRI cine images Long Vertical axis acquisition. A. Hypertrophic cardiomyopathy. B. Dilated cardiomyopathy.

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**Fig. 51:** An ostium secundum atrial septal defect due to absence of tissue in the mid-portion of the interatrial septum involving the region of the fossa ovalis and thickening of the muscular portion of the septum. A. In a P-A chest X-Ray an increased transverse diameter of the heart reflects right atrium severe enlargement associated to pulmonary circle redistribution. B. CT scan confirms a wide communication localized in the region of the fossa ovalis, atrial enlargement affecting mainly the right side with appendage involvement and a severe tricuspid regurgitation with intra-hepatic contrast reflux.

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**Fig. 52:** Same case of figure 51. CT images Axial and Multiplanar reconstructions. The defect is limited to the region of the fossa ovalis (A, E) with no involvement of the Inferior Vena Cava ostium (B). Atrial enlargement affects mainly right atrium causing tricuspid regurgitation (C, E).

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**Fig. 53:** Movie from patient shown in Fig. 51. Images clearly show left ventricle enhancement prior to pulmonary vessel opacification, demonstrating the presence of right to left chambers shunt due to an atrial septum defect.

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Fig. 54: 43-year-old man after ascending aortic surgery repair and presenting a pseudoaneurismatic enlargement of the aortic wall in the site of intervention. P-A (A) and L-L (B) radiograph show a sharply defined area of increased opacity with a loss of silhouette sign at the border of ascending aorta. On PA projection prominence of the first right cardiac arch can be detected without cancellation of the right paracaval line.
Fig. 55: Same case of figure 53. CTA exam of displaying MPR (A-C) and VR (D) images. Pseudoanurismatic dilatation of the anterior aortic wall with thick thrombotic deposition in the peripheral zone. CTA clearly shows medium contrast passage in the pseudoanurismatic sac due to blood flow. Pseudoaneurismal contrast presents lower density compared to aortic lumen because of slow filling velocity. VR reconstruction helps to evaluate pseudoaneurismal relation between the aortic dilation and pulmonary trunk which is displaced laterally; on MPR images right atrial compression and SVC posterior displacement can be appreciated.

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Conclusion

CXR cardiac silhouette can be strictly correlated with Angiocardiography, CT, and MR imaging.

The knowledge of chest X-ray cardiac anatomy and pathology becomes fundamental to recognize the typical radiographic findings of different cardiomyopathies.

Radiologist and resident in particular, even if not only exclusively involved in cardiac imaging, should be familiar with these concepts.
References

Personal Information

Federica Pirro, MD

Department of Bioimaging and Radiological Sciences

Institute of Radiology- "A. Gemelli" Hospital

Catholic University- Rome-Italy

federicapirromd@gmail.com