UNIT 4 RADIOLOGY OF THE HEART: THE CHEST RADIOGRAPH

Structure

4.0 OBJECTIVES

After going through this unit, you should be able to:

- name the cardiac and mediastinal structures that are border forming on the normal chest radiograph;
- measure and interpret the cardiothoracic ratio;
- identify specific cardiac chamber and great vessel enlargement; and
- list the features of common cardiac and related pathology on the chest radiograph.

4.1 INTRODUCTION

More than a century after its introduction to clinical practice, the chest radiograph (CXR) remains an important diagnostic tool in the routine investigation of patients with cardiac symptoms, and may also be useful in monitoring the response to treatment.

If the patient's condition permits, a postero-anterior (PA) view must be obtained, with the patient facing the film. This reduces magnification of the heart and mediastinum, and reduces bony overlap of the lungs by the scapula. High kVp technique and a focus film distance of 6 feet are now widely practiced.

A quick assessment of the technical aspects of the PA film must initially be made, as indicated in Fig. 4.1.

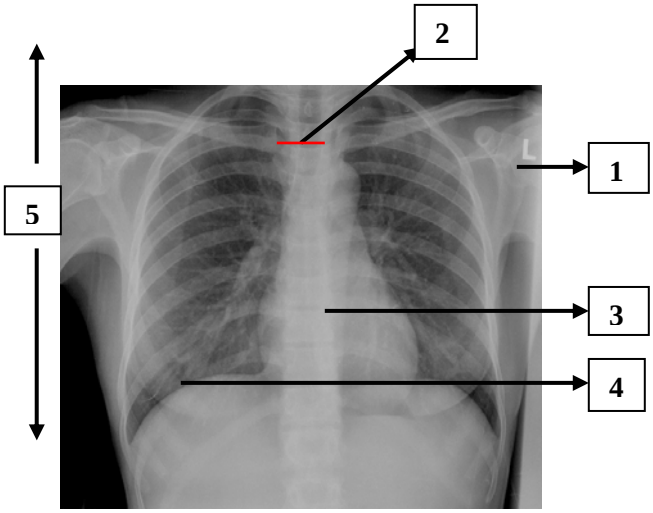


Fig. 4.1: CXR: Technical aspects

Key to Figure 4.1

1) **Identification**: Patient identification and side marker must be present.

2) **Centering**: The thoracic spinous process should be equidistant from the medial ends of both clavicles. Rotation to the left or right may produce incorrect assessment of cardiac size, as well as undue prominence of normal structures.

3) **Penetration**: The vertebral bodies and disc spaces must be just visible through the cardiac shadow. These may not be defined in an underpenetrated film. Pulmonary vascularity or lung pathology may then be exaggerated. Overpenetration may lead to poor visualization of pulmonary vascularity and soft opacities in the lung parenchyma.

4) **Inspiratory Effort**: If the inspiratory effort is adequate, the 6th rib anteriorly or 8th rib posteriorly must cross the dome of diaphragm. The cardiac size cannot be assessed if the inspiratory effort is inadequate, and pulmonary vasculature may appear unduly prominent.

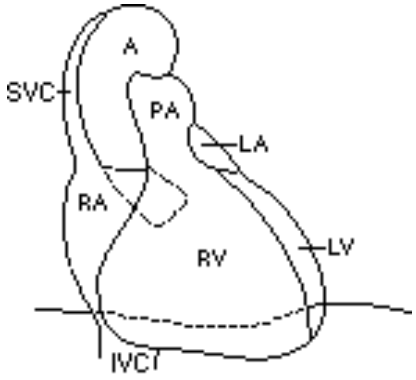
5) **Field of View**: The entire lung, from the apex to the depth of costophrenic angle must be included in the film.

4.2 RADIOLOGICAL ANATOMY

The borders of the mediastinum on the CXR are defined by the contrast produced by adjacent air filled lung.

Postero-Anterior View

Fig. 4.2(a) and 4.2(b) indicate the structures that form the mediastinal contours. The right ventricle is the only chamber that does not contribute to the cardiac silhouette on the PA view.



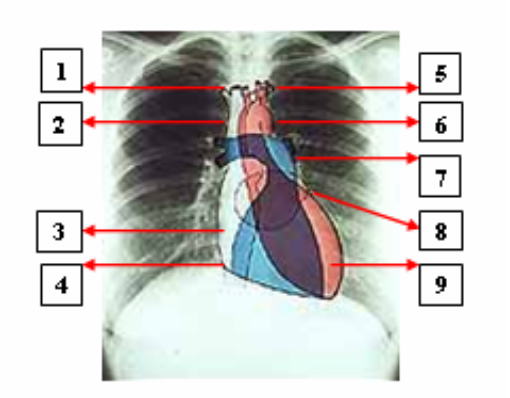


Fig. 4.2(a): Cardiac contours: Frontal **Fig. 4.2(b): Chest PA: Mediastinal borders**

Mediastinal Borders

1 = Right brachiocephalic vessels

2 = Superior vena cava

3 = Right atrium

4 = Inferior vena cava

5 = Left subclavian artery and brachiocephalic vein

6 = Aortic knuckle

7 = Pulmonary trunk/conus

8 = Left atrial appendage

9 = Left ventricle

Lateral View

The lateral view is always used in combination with the PA view. In addition to defining specific chamber enlargement, it is particularly useful in the following situations:

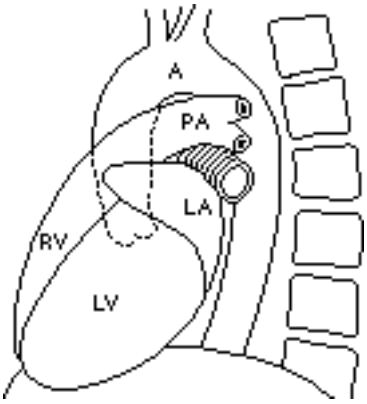
i) Demonstrates lesions in the retrosternal and costophrenic regions.

ii) Localizes lung pathology to its lobe and assesses lobar volume loss.

iii) Defines interlobar or small pleural effusions.

iv) Separates diaphragmatic variants from adjacent lung or subdiaphragmatic pathology.

Fig. 4.3(a) and 4.3(b) illustrates the structures that are border forming on the lateral view. The right ventricle and pulmonary trunk form the anterior margins of the cardiac contour. The posterior border is formed by the left atrium and the left ventricle. There is a small contribution from the inferior vena cava (IVC).



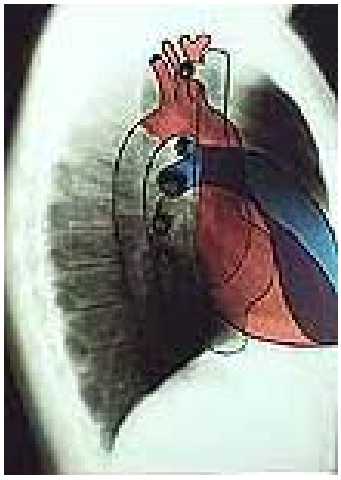
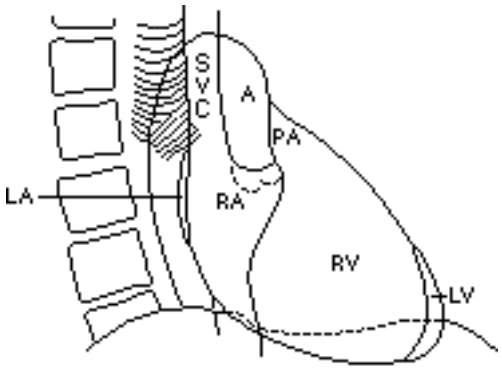


Fig. 4.3(a): Cardiac contours: Lateral view

Fig. 4.3(b): CXR: Lateral view

Right Anterior Oblique View

Because the long axis of the heart lies at about 45° to the sagittal plane, patient rotation such that the right shoulder is closer to the cassette (RAO) enlarges the cardiac image. Fig. 4.4(a) and 4.4(b) demonstrate the cardiac borders defined by this view.



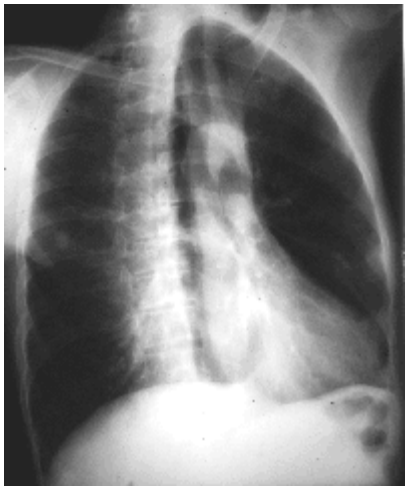


Fig. 4.4(a): RAO view: Cardiac contours

Fig. 4.4(b): CXR: LAO view

Left Anterior Oblique View

As the long axis of the heart lies at about 45° to the sagittal plane, patient rotation with the left shoulder forward (LAO) reduces the cardiac size. Fig. 4.5(a) and 4.5(b) show the cardiac borders defined by this view. The aorta is better seen.

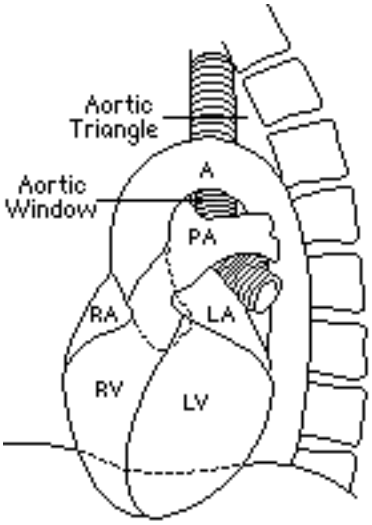


Fig. 4.5(a): LAO view: Cardiac contours

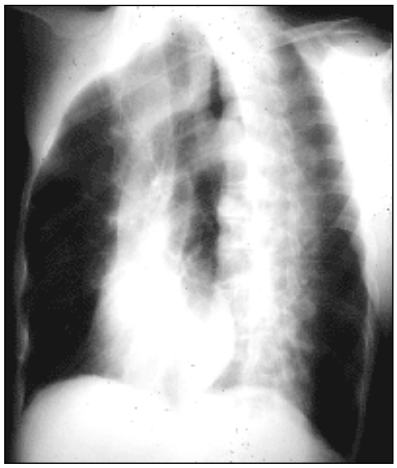


Fig. 4.5(b): CXR: LAO view

4.3 CARDIOTHORACIC RATIO

The cardiothoracic ratio (CTR) shown in **Fig. 4.6** is the transverse cardiac diameter (the horizontal distance between the most rightward and leftward borders of the heart seen on a PA chest radiograph) divided by the transverse chest diameter (measured from the inner rib margin at the widest point above the costophrenic angles on a PA chest film).

A cardiothoracic ratio of more than 50 per cent is generally considered abnormal in an adult. It may be upto 55 per cent in blacks and Asians and 60 per cent in neonates and the elderly. The cardiac diameter alone can also be measured. It is less than 13.5 cm in 90 per cent of males and 12.5 cm in 90 per cent of females. A change in diameter of greater than 1.5 cm between two radiographs is considered significant.

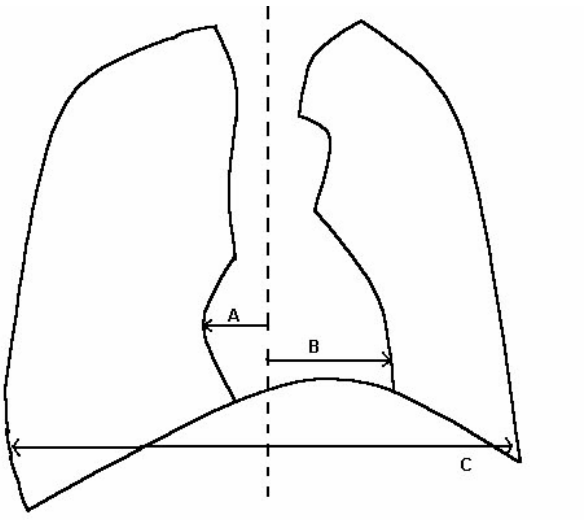


Fig. 4.6: CXR: Measuring the CTR (A + B/C)

Check Your Progress 1

1) What is the focus film distance used to obtain a Chest PA radiograph?

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2) If the vertebral bodies are not seen through the cardiac silhouette, is the film over or underpenetrated? What effect is this likely to have on the appearance of the pulmonary vasculature?

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4.4 CHAMBER/VESSEL ENLARGEMENT

Left Ventricle Enlargement

The left ventricle (LV) is ellipsoid in shape. It lies behind, and to the left of the right ventricle. Its long axis lies at about 45 degrees to the vertical. When this chamber enlarges, all its diameters increase, but particularly its long axis. This results in a downward displacement of the apex. On the PA view this causes the left ventricular border to elongate, and move downwards or outwards or both. On the lateral view, the chamber may extend posterior to the esophagus. Its posteroinferior border may project behind the IVC at a point 2 cm above the diaphragm (Hoffman Rigler sign). The changes in cardiac contour produced by left ventricular enlargement on all four views are shown in Fig. 4.7.

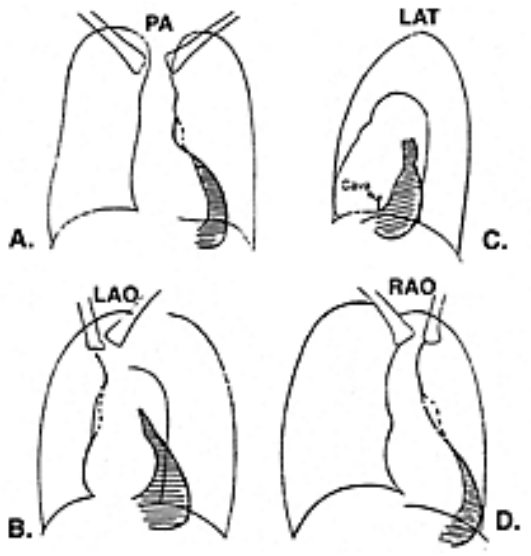

Fig.: 4.7 LV Enlargement

Right Ventricle Enlargement

The right ventricle (RV) is roughly triangular in shape on the PA view, with a near vertical base-apex axis. When this chamber enlarges **(Fig. 4.8)**, there is broadening of its triangular shape. Two patterns of enlargement are generally seen. A bulge may be seen along the left heart border above the apex, formed by the enlarged ventricle. The change in contour could also be due to the enlarged RV elevating a normal LV. This causes a long prominent upper contour above the apex,

and a second shorter contour turning medially below the apex. On the lateral view, an enlarged RV fills in the retrosternal clear space, owing to its anterior location.

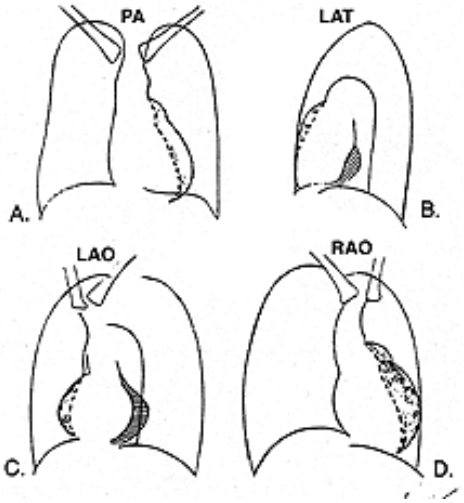

Fig. 4.8: RV Enlargement

Left Atrial Enlargement

This chamber is oval in the frontal projection and flattened in lateral projection. On the PA view, its appendage makes a small contribution to the left heart border. The left atrium (LA) may enlarge in many directions. Rightward enlargement is seen as increased density, producing a convex border overlying or to the right of the right heart border. This could mimic a dilated aortic root. When the chamber enlarges to the left, it causes straightening or convexity of the left heart border in the region of the left atrial appendage. Posterior enlargement of the LA is seen as increased central heart density on a PA view and as posterior displacement of the left atrial border and the pulmonary veins on the lateral view. Superior enlargement is manifested as widening of the carinal angle, which is usually less than 90 degrees. Occasionally, the LA may be aneurysmally dilated. On the PA view, the right border may approach the right chest wall, with a markedly enlarged appendage on the left, and splaying of the carinal angle to 180 degrees. On the lateral view, the massively enlarged LA is convex posteriorly, forming the entire heart border. Fig. 4.9 shows the changes in cardiac contour that result from LA enlargement on four views.

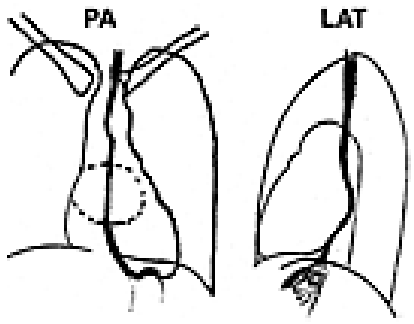

Fig. 4.9: LA Enlargement

Right Atrial Enlargement

The right atrium (RA) is a globular chamber, forming the right heart border on the PA view. On the PA view, the border of the enlarged RA should project to the right and its radius of curvature increases. This may cause its border to be atleast half as long as the total height of the right mediastinal border. These changes on the CXR may not be seen, if the heart is positioned leftward or if the chamber enlargement is more in the AP dimension. Fig. 4.10 shows results of RA enlargement.

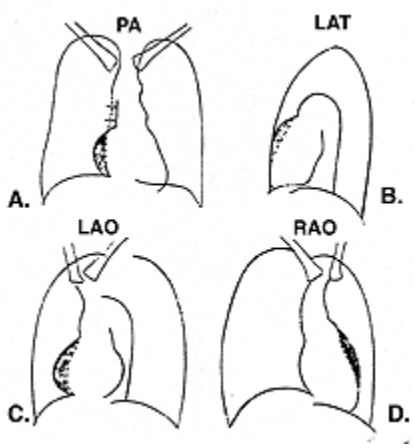

Fig. 4.10: RA Enlargement

Pulmonary Artery Enlargement

On the PA view, the pulmonary trunk is border forming for a short distance between the aortic knuckle and the left atrial appendage. In children and young adults, (especially women), it often has a convex contour which flattens and reaches the adult pattern by the age of 20 years. On the lateral view, the pulmonary trunk may form the posterior margin of the retrosternal space inferiorly.

When the pulmonary conus enlarges, it forms a smooth convexity in the expected position on the PA view, and encroaches on the lower portion of the retrosternal clear space on the lateral view. On the PA view, nodes or masses at the left hilum or adjacent mediastinum may simulate this appearance. Focal post stenotic dilatation of the pulmonary artery tends to involve the roof of the vessel, and is thus relatively high-placed.

Aortic Enlargement

Ascending Aorta: The ascending aorta, along with the SVC forms a portion of the right cardiac border on the PA view. After the age of about 40 years, the ascending aorta may project to the right beyond the SVC. It is often difficult to differentiate age related elongation of the ascending limb from dilatation. On the lateral view, an enlarged ascending limb may encroach on the retrosternal clear space.

Arch: The arch crosses from right to left in front of the trachea and then arches over and behind the left main bronchus, where it lies just to the left of the midline. On the PA view, the aortic knuckle is formed by the distal part of the arch. Again, above the age of 40, the knuckle may be displaced upwards and leftwards.

Descending Aorta: The descending aorta begins at the level of the fourth thoracic vertebra. It is defined through the cardiac shadow on the CXR, as it lies on the anterior aspect of the thoracic vertebral bodies, just to the left of the midline. Lengthening with age may also affect this portion of the aorta, which may resemble an aneurysm. A tortuous aorta may lie to the right of the spine.

In systemic hypertension, the ascending aorta and arch may be dilated. Post stenotic dilatation of the ascending aorta is seen in aortic stenosis. More diffuse dilatation of the ascending limb, arch and descending aorta is usually seen in aortic regurgitation. A small aortic knuckle may be seen in ASD, severe mitral stenosis and supravalvar stenosis.

Check Your Progress 2

1) What forms the right superior mediastinal contour on the frontal chest radiograph?

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2) Which view best demonstrates the left atrium?

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3) What is the transverse diameter of the right descending pulmonary artery?

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4) When are the upper lobe veins considered enlarged?

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4.5 PULMONARY VASCULATURE

Normal Pulmonary Vasculature

Pulmonary vessels are seen in the medial 2/3 of the lung. Vessels are generally not identified in the lateral third. The radiographic appearance of pulmonary vasculature is dependent on technique. Underexposure will lead to prominence of the vasculature, while overexposure will cause an apparent decrease in the vasculature.

Patient position may vary appearances greatly. In the erect position, there is reduced low to the upper lobes due to gravity. Alveolar pressure tends to collapse the upper lobe veins. The normal size ratio of upper to lower lung vessels is 1/2 or 1/3 on the erect PA radiograph. The hilar angle, which is the angle between the superior pulmonary vein and the descending pulmonary artery is normally concave.

a) ***Arterial***

The main pulmonary artery is seen on the PA view, as its left border forms the pulmonary bay. The right pulmonary artery runs horizontally to the right within the mediastinum and is not seen on the frontal view. Its upper lobe branch is given off in the mediastinum. Thus, the descending

branch of the right pulmonary artery is the vessel first identified, as it forms the lower part of the right hilum. On the lateral view, it is seen as a rounded density just anterior to the carina. The left pulmonary artery, along with its descending branch are identified on the plain film as it forms part of the left hilum and continues into the lower lobe. On the lateral view, it is seen over the left main bronchus, superior and posterior to the right pulmonary artery. The pulmonary arteries within the lung parenchyma, are closely related to the bronchi and taper gradually, as they branch.

b) ***Pulmonary Veins***

The right and left upper lobe or superior pulmonary veins descend lateral to the arteries, cross in front of the hilum, and enter the left atrium. The right inferior veins can be distinguished from the arteries as they follow a more horizontal course to the left atrium. On the left side, the inferior veins are more vertical.

Pulmonary Arterial System Changes

a) ***Pulmonary Plethora***

With increased pulmonary arterial blood flow, pulmonary branches are visualized beyond the inner 2/3 of the lungs. Vessels in upper and lower lobes are dilated to the same degree. The number of end on vessels seen is 5 or more in both lung fields (or 3 or more in one lung field).

b) ***Pulmonary Arterial Hypertension***

The features of pulmonary arterial hypertension are:

i) Central arterial enlargement, manifesting as an increased convexity of the pulmonary conus.

ii) Enlarged descending pulmonary artery, of more than 16 mm. Right descending arterial calibre of more than 25 mm is in keeping with Primary Pulmonary Hypertension.

iii) Sharp pruning of peripheral vasculature.

iv) Features of right ventricular hypertrophy and dilatation.

c) ***Pulmonary Oligemia***

With reduced pulmonary flow, pulmonary vascular markings are markedly reduced, with vessels appearing attenuated. This is diagnosed radiographically only in patients with markedly decreased pulmonary flow.

Pulmonary Venous Congestion

In pulmonary venous hypertension, the earliest change is an increase in calibre of the upper lobe vessels. If the upper lobe veins measure more than 3 mm in the first interspace, they reflect an increase in pulmonary venous pressure.

Grading of Pulmonary Venous Hypertension

Grade 1: Diameter of upper zone vessels greater than or equal to lower zone; right hilar angle obliterated.

Grade 2: Interstitial pulmonary edema or pleural effusion; right hilar angle straightened; Kerley B lines and later Kerley A lines.

Grade 3: Alveolar edema; Right hilar angle convex.

Pulmonary Edema

When the capillary pressure exceeds the plasma osmotic pressure, fluid first accumulates in the interstitial spaces. The components of the interstitium (central and peripheral) are shown in Fig. 4.11.

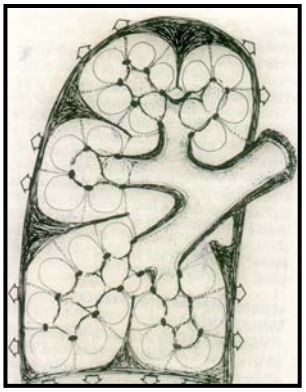

Fig. 4.11: Components of the Interstitium

The central interstitium invests the bronchovascular bundle and extends from centre to periphery. Fluid accumulating in this perivascular and peribronchial interstitium causes an apparent increase in the size of vessels at the hilum, as well as loss of definition of vessels on the CXR.

The peripheral interstitium consists of subpleural, inter and intralobular septal components. One of the early manifestations of interstitial edema on the CXR are septal lines, commonly Kerley B lines. These are short, straight, horizontal lines, best seen in the lower zones, representing thickening of the interlobular septae (Fig. 4.12).

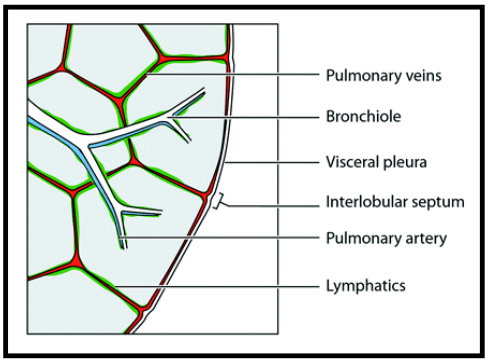

Fig. 4.12:

Other lines described are Kerley A lines (4 to 6 cm, radiating from the hilum, more in the upper zones) and Kerley C lines (short, crisscrossing lines), all representing thickened interstitium.

Further fluid accumulation results in edema of alveolar walls and alveolar edema. This characteristically has an “air-space” appearance with coalescent pulmonary opacities, resembling cotton wool. Air space opacification creates a contrast between air filled bronchi and the surrounding lung, and this may produce an air-bronchogram. Typically, there is a perihilar distribution, resulting in a “bats wing appearance”. Rapid clearing with antifailure measures is seen.

4.6 CARDIAC CALCIFICATION

Pericardial

Calcium is most dense in the atrioventricular grooves and is seen as thick oblique circles or arcs of calcification. From the grooves, calcification spreads over the surface of the atria/ventricles. Calcium localized to the left AV groove may be mistaken for mitral valve calcification. Pericardial calcification is better seen on a lateral view.

Aortic Valve

This valve lies in the centre of the heart, so that calcification overlaps the spine on the anterior view. On the lateral view, it lies midway between the anterior and posterior cardiac borders, largely anterior to a line drawn from the tracheal bifurcation to the anterior costophrenic angle. As the two sides of diaphragm are rarely at the same level, the lower reference pt should be midway between the domes.

Mitral Valve

On the PA view, mitral valve calcification is seen just to the left of the spine, below the position of the aortic valve. The larger the left atrium, the further leftward and caudal is the position of valve calcification. On the lateral view, the valve lies posteroinferior to the aortic valve, below a line drawn form the tracheal bifurcation to the anterior costophrenic angle.

Coronary Arteries

Coronary artery calcification is seen as a plaque or a double line. It is most frequently seen on CXR in the proximal part of the left coronary artery.

Check Your Progress 3

What is the position in which you would expect to see aortic valve calcification on the lateral view?

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4.7 SPECIAL SITUATIONS

Pulmonary Embolism

The CXR is often abnormal in pulmonary embolism. Atelectasis and other focal pulmonary parenchymal abnormalities are the most common findings. Pleural effusions are also common, but usually small and unilateral. Other plain film findings associated with pulmonary embolism are:

i) ***Westermark sign***: Dilatation of the pulmonary vessels at or proximal to an embolism.

ii) ***Fleischner's sign***: The combination of enlargement of the pulmonary artery due to thrombus, with distal oligemia.

iii) ***Hampton hump***: Hampton hump, a triangular or rounded pleural-based infiltrate with the apex pointed toward the hilum represents infarcted lung in pulmonary embolism.

Pericardial Effusion

The configuration of the heart in pericardial effusion depends on the volume of fluid and its distribution. It may have a globular or non-specific shape. In large effusions, there is very often a localized bulge in the left upper cardiac border. There is striking absence of abnormalities of the pulmonary vasculature. The combination of a large heart, with clear rather than congested lungs suggests a pericardial effusion. A rapid change in heart size over serial films also may be seen.

Dissection of the Aorta

The CXR may be abnormal in upto 80 per cent of patients. The abnormalities include:

i) ***Widened mediastinum:*** This is defined as a mediastinal width of more than 8 cm on the AP CXR. A tortuous aorta may be difficult to distinguish from a widened mediastinum. If in doubt, a good PA view is recommended.

ii) ***Abnormal aortic knob:*** Loss of definition or a focal widening of the mediastinal contour in the region of the aortic knuckle may be seen.

iii) ***Ring sign:*** This describes the displacement of the aorta, > 5 mm past the calcified aortic intima. The presence of this as a new finding on CXR, is considered a very specific radiographic sign.

iv) ***Left apical cap:*** This is a result of the pleural effusion that often accompanies an acute dissection.

v) Tracheal deviation and depression of left main stem bronchus or displacement of an NG tube.

Several studies have concluded that it is a combination of several of these findings that lead to suspicion of dissection.

Aneurysm of Aorta

CXR findings are an enlargement of the involved portion of the aorta. A focal dilatation may simulate a mass or adenopathy. A more generalized dilatation leads to widening of the mediastinal contours. It may be indistinguishable from an unfolded arch. In the acute situation, left pleural effusion may be present.

Pleural Effusion

Fluid has a density indistinguishable from soft tissue on a radiograph. Pleural fluid tends to accumulate in the deepest part of the posterior costophrenic angle. Small effusions are thus identified earlier on a lateral view. Ultrasonography is also capable of picking up very small effusions.

An effusion may not be recognized on a PA view until 100 to 200 ml of fluid has accumulated and has caused blunting of the costophrenic angle. Larger effusions have a fairly well defined concave upper edge (which is higher laterally than medially) and obscure the diaphragm, and later the mediastinal borders.

Atypical Distribution of Pleural Fluid

i) ***Lamellar effusion:*** These are shallow collections of fluid between the chest wall and the lung surface.

ii) ***Subpulmonic effusion:*** Fluid accumulating between the lung and the diaphragm will cause the contour of the "diaphragm" to be altered, its apex being more lateral than expected. There may be associated blunting of the CP angle. On the left side, a subpulmonic effusion may result in an increased distance between the fundic air bubble and the lung base.

iii) ***Loculated effusion:*** Fluid may be loculated along the lung periphery due to fusion of the visceral and parietal pleura. These collections often have a biconvex shape and when viewed in profile have a sharp outline, with tapered margins forming an obtuse angle with the chest wall. Fluid may be loculated in the interlobar fissures, most commonly seen in heart failure. Fluid in the horizontal fissure is well defined and more easily recognized to be an interlobar effusion. In the major fissure, PA and lateral views may be necessary to make the diagnosis. Typically, these collections disappear rapidly after treatment for heart failure, and are known as pseudo or vanishing tumours.

Pneumothorax

Air in the pleural cavity manifests in a number of ways on the CXR, depending on the volume of air and position of the patient. The typical findings of a pneumothorax are an area of marked radiolucency, with absent vascular markings, and visibility of the adjacent lung margin. On an erect film, a small pneumothorax would be identified at the lung apex. Larger pneumothoraces are easily identified by their radiolucency and the adjacent collapsed lung. A tension pneumothorax would increase the volume of the ipsilateral thoracic cavity by flattening the diaphragm, widening the rib interspaces, displacing the mediastinum to the opposite side and causing complete collapse of the lung.

4.8 LET US SUM UP

In this unit, you have learnt how to viewing a chest radiograph and make a rapid assessment of the technical factors. Identify the cardiac and mediastinal contours. Look for evidence of specific chamber enlargement. Assess the CTR, which may be upto 55 per cent in Asians. There is a significant difference in the size of the pulmonary vasculature in the upper and lower lobes in the erect position, which is altered in venous congestion. Findings in pulmonary edema are related to the volume and location of fluid in the central and peripheral interstitium, followed by the

airspaces. It is important to be able to recognize the findings which may alter the cardiac and mediastinal contours, opacify the lungs, or fill the pleural spaces, in the context of the cardiac patient.

1.9 ANSWERS TO CHECK YOUR PROGRESS

Check Your Progress 1

1) A focus film distance of 6 feet are now widely practiced.

2) The vertebral bodies and disc spaces must be just visible through the cardiac shadow.

   These may not be defined in an underpenetrated film.

   Pulmonary vascularity or lung pathology may then be exaggerated.

Check Your Progress 2

1) Superior vena cava

2) The left atrium (LA) may enlarge in many directions. Posterior enlargement of the LA is seen as increased central heart density on a PA view and as posterior displacement of the left atrial border and the pulmonary veins on the lateral view. Superior enlargement is manifested as widening of the carinal angle, which is usually less than 90 degrees.

3) Enlarged if descending pulmonary artery is more than 16 mm.

4) In pulmonary venous hypertension, the earliest change is an increase in calibre of the upper lobe vessels. If the upper lobe veins measure more than 3 mm in the first interspace, they reflect an increase in pulmonary venous pressure.

Check Your Progress 3

On the lateral view, it lies midway between the anterior and posterior cardiac borders, largely anterior to a line drawn from the tracheal bifurcation to the anterior costophrenic angle. As the two sides of diaphragm are rarely at the same level, the lower reference pt should be midway between the domes.