1

THE RADIOGRAPHS AND ANATOMY OF THE CHEST X-RAY

Posterior anterior x-rays

The chest x-ray is normally taken PA (posterior anterior) standing, when the patient's condition permits, at a distance of 180cm, the scapula rotated away from the lungs, centred at thoracic vertebra 4 (T4) on full inspiration (as demonstrated below). However, some centres suggest centring at T4, then angling the x-ray tube to T6 to avoid irradiating the sensitive eyes. X-raying the chest PA and at 180cm reduces magnification of the heart. Removing the scapula from the lungs avoids misinterpretation of the overlying scapula as pathology. It also allows clear visualisation of the lungs. Poor inspiration will make the heart look larger, and may give the appearance of basal shadowing and cause the trachea to appear deviated to the right. If the patient is standing, it is easier for them to take a deep breath in.

Figure 1.1: The X-ray room with digital wall stand

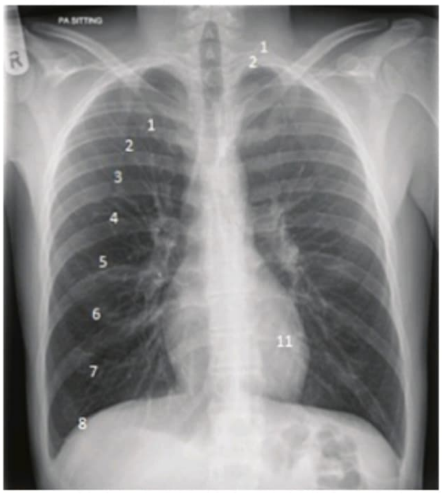
Figure 1.2: X-raying a PA chest

When reviewing the chest image, the first thing to check (before the anatomy or anything else) is whether the correct patient has been x-rayed on the correct date. Having checked these details, you can then assess the quality of the image, as this may affect your final interpretation.

Table 1.1: Quality issues

Issue	
PA, AP, sitting or supine	This will affect magnification/heart size
Rotation	Medial ends of clavicles should be equidistant from spinous process of vertebra
Lordotic/kyphotic	Clavicles should be posterior end of 4th rib, not above or below
Scapula removed from lungs	If not, be careful with interpretation
Full inspiration	Inspired to 5–6.5 anterior ribs, or 10/11 posterior ribs
Entire lungs included on image	If not, repeat may be required
Artefacts	Beware that an artefact is not misinterpreted as pathology
Correct marker/annotations	Is the patient really dextracardia?

Anterior ribs being counted at this side



Posterior ribs being counted at this side

Figure 1.3: Counting ribs

If assessing inspiration, we first need to know which ribs we are counting – anterior or posterior. The above image demonstrates this. In certain conditions the lungs will be hyperventilated, and more than 11 posterior ribs will be visualised. In emphysema, the lungs may be so hyper-inflated that the diaphragm is flattened. The height of the diaphragm should normally be 1.5cm (see Figure 1.4, which shows how the diaphragm is measured).

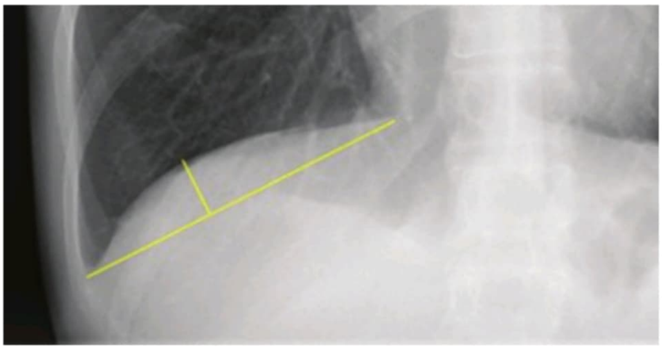


Figure 1.4: Measuring the height of the diaphragm, which is normally 1.5cm

If the patient is rotated, this will affect how the mediastinum is projected. Rotation to the right on a PA chest x-ray will result in the superior vena cava and/or other vessels arising from the arch of the aorta becoming more prominent. Severe rotation may result in one lung appearing darker than the other, giving a false impression of some underlying pathology.

A lordotic chest x-ray makes it difficult to accurately assess the pathology of the bases next to the diaphragm. The bases may become ill defined, mimicking pathology, and/or abdominal structures may be projected over the diaphragm and bases. A kyphotic image is most often produced when the patient is kyphotic due to vertebral collapse.

Obtaining a perfect-quality chest x-ray is difficult and the patient's condition may sometimes make it impossible. You will therefore often have to review a less than perfect-quality chest x-ray. Do this with caution, remembering the effects that rotation, poor inspiration and other factors may have on the final image. In most cases, it is still possible to answer the clinical question. However, if you have any doubt, a repeat x-ray (often when the patient is more able to cooperate), a lateral view (if possible), or further imaging may be required.

The patient's condition may often prohibit a PA image. In this case, the patient may have to be x-rayed anterior posterior (AP) in a chair, trolley or bed, or even supine. This will result in increased magnification of the heart and mediastinal structures. An AP sitting image is still taken at a distance of 180cm. However, a supine image is often taken at much less – around 140–120 cm, depending on the x-ray equipment, and how low the trolley or bed can go.

The AP sitting image may be lordotic. If so, take this into consideration when reviewing. Remember also, with a supine patient, fluid within the lungs will tend to sink to the posterior lungs, whereas air will rise. Likewise, effusions and a pneumothorax will appear differently in a supine patient compared to an erect patient (for more on this, see pp. 51–2). In both patient types, increased magnification makes it difficult to accurately assess the mediastinum.

Figure 1.5: AP sitting chest x-ray
(slightly lordotic, requiring angulation of x-ray tube)

Figure 1.6: Supine chest x-ray

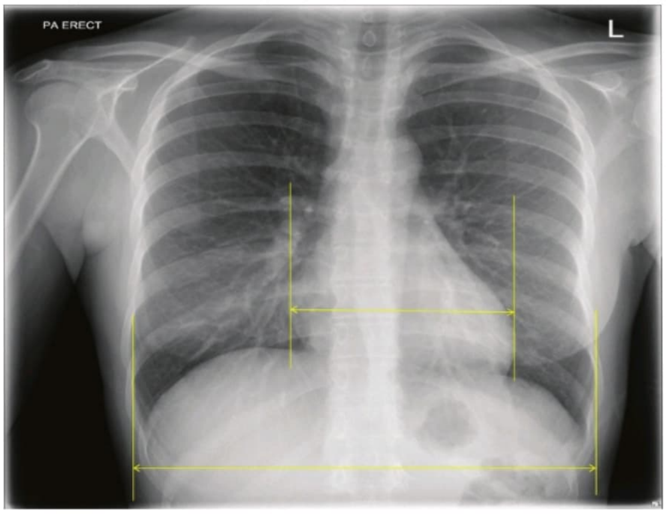


Figure 1.7 Measuring the heart size

The cardiothoracic ratio (CTR) in a PA patient is normally 50%, whereas on an AP sitting or supine image 60% is a good guideline. Please see Figure 1.7 for guidance on measuring CTR.

PA/AP/supine x-rays

Now we move on to the anatomy demonstrated on a PA/AP/supine chest x-ray. The basic anatomy is best visualised on a labelled chest radiograph.

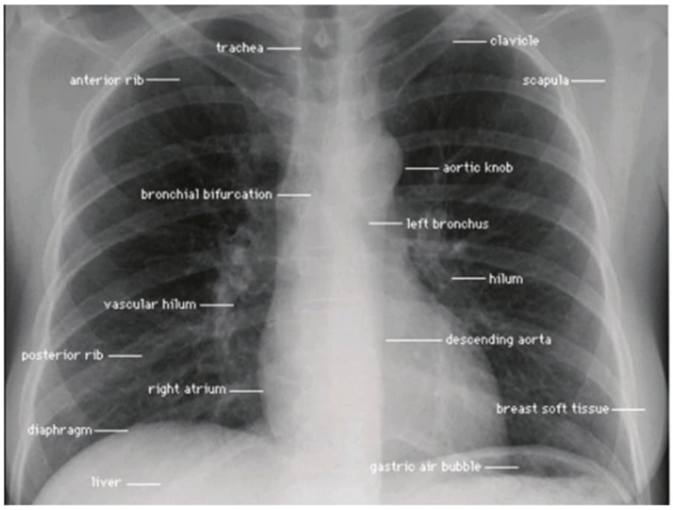


Figure 1.8 Know your chest anatomy

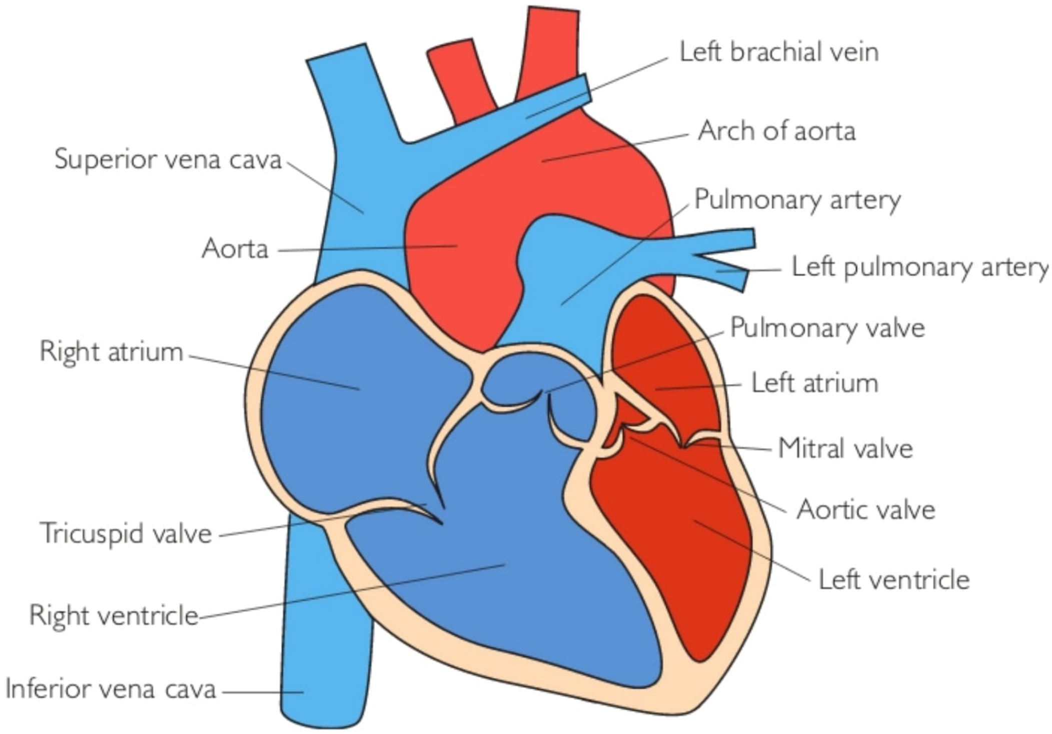


Figure 1.9 The heart structures on the chest x-ray

There are several other anatomical structures you need to know about when reviewing/reporting chest x-rays. The diaphragms, as previously mentioned, may be flattened in the hyperventilated chest. However, the right diaphragm is normally 1–2cm higher than the left, as demonstrated in Figure 1.10 below.

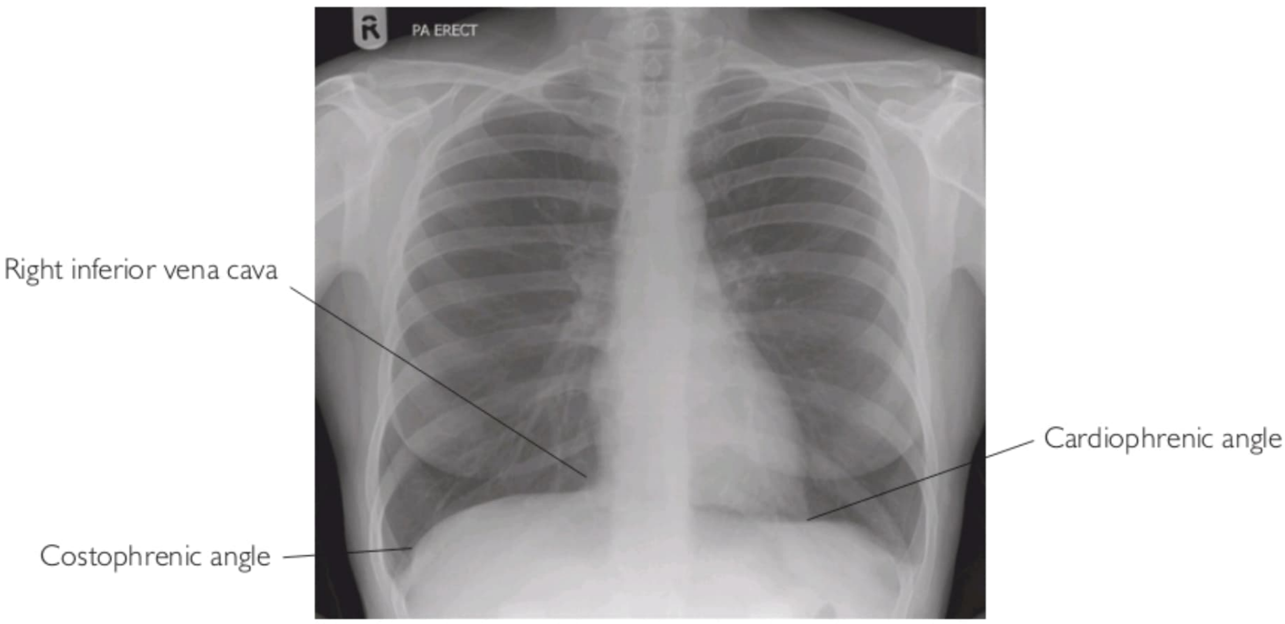


Figure 1.10 The diaphragms

The right lung has three lobes: the right upper lobe (RUL), the right middle lobe (RML), and the right lower lobe (RLL) as demonstrated in Figure 1.11. Meanwhile, the left lung has two lobes: the left upper lobe (LUL) and the left lower lobe (LLL), and also has the lingula. Figure 1.11 shows how little of the posterior base of the lungs is demonstrated on the frontal chest radiograph.

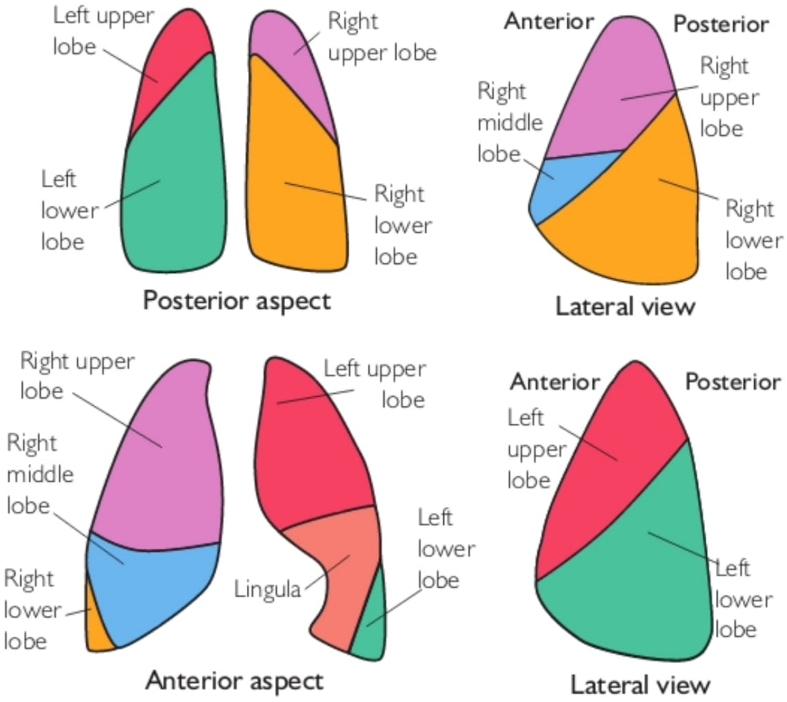


Figure 1.11 The lobes of the lungs

However, when describing the chest x-ray in a report, it is more common to divide the lungs into zones as demonstrated in Figure 1.12.

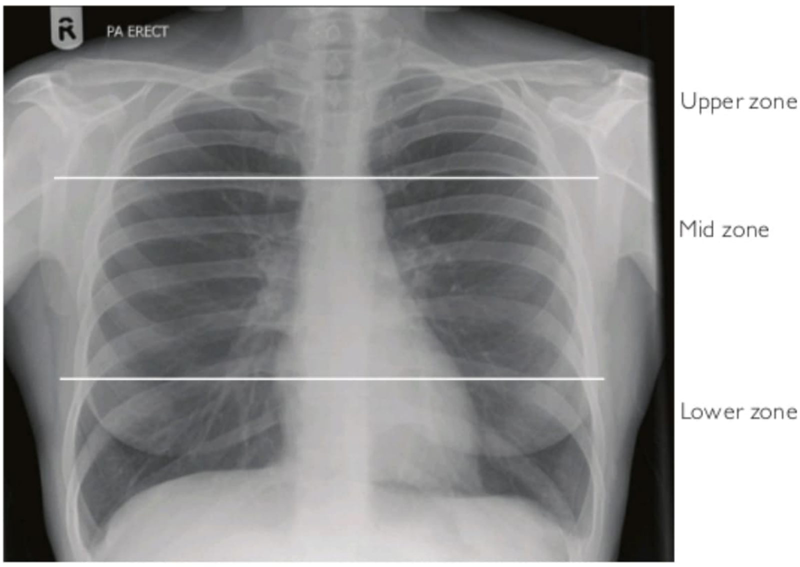


Figure 1.12 Zones on the chest x-ray

Displacement of the fissures on a chest x-ray may be due to collapse or mass so you should always try to visualise these. The middle fissure should lie around the 6th posterior rib.

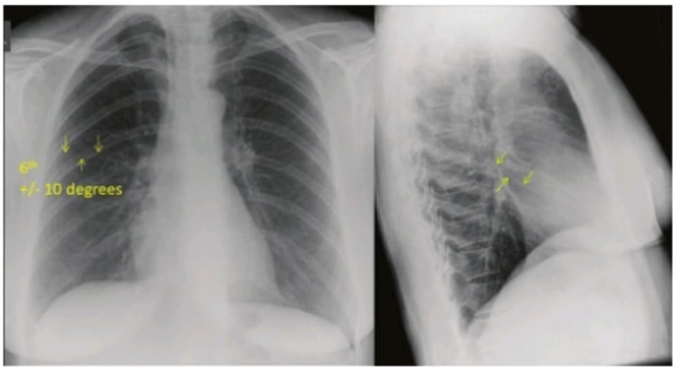


Figure 1.13 Lung x-ray showing fissures

There are several mediastinal lines that should be reviewed on a frontal radiograph, although they are often difficult (and sometimes impossible) to visualise. These include the:

- Anterior junction line: where the lungs meet anteriorly, not present above the sternal notch
- Posterior junction line: where the lungs meet posteriorly, seen superior to the sternal notch
- Right paratracheal stripe: normally up to 5mm with a bulge inferiorly where the azygos vein crosses the right main bronchus.

Bulging or widening of any of these lines may be a sign of a mediastinal mass.

Paravertebral stripe displacement is something else that should be reviewed. A left-sided thoracic vertebral stripe is normally visualised on the PA chest image. It is a deflection of the pleura posteriorly by the descending aorta, and it extends from the arch of the aorta to the diaphragm. Bulging of the left paravertebral stripe is consistent with pathology, the most common cause being haematoma following trauma/fracture of the thoracic spine. Alternatively, it may be caused by tumour or infection of the spine.

The right paravertebral stripe is not normally seen until older age when osteophytes cause displacement of the pleura; if seen in younger patients, there is some pathology present.

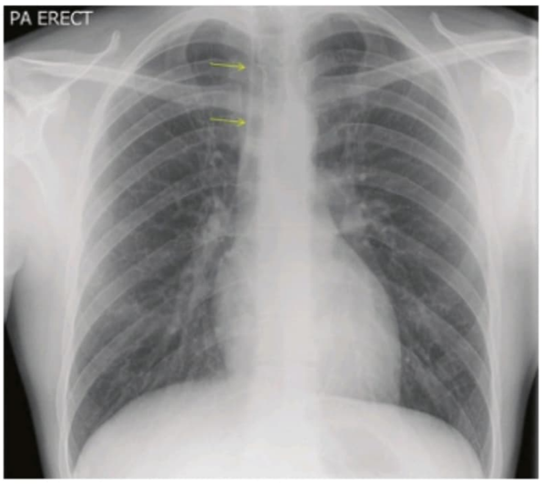
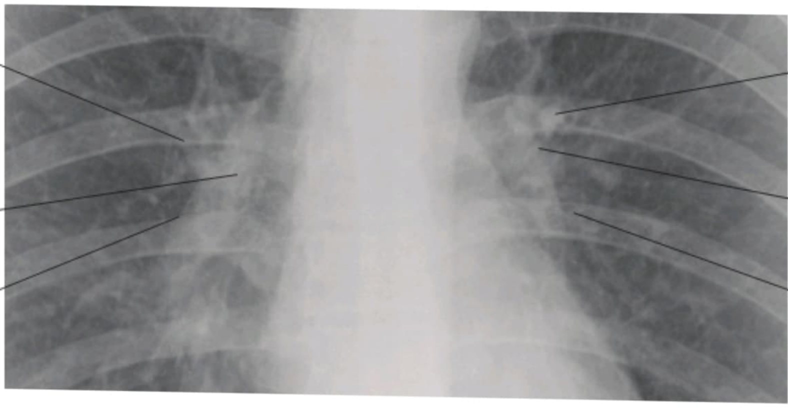


Figure 1.14 Right paratracheal stripe

Figure 1.15 Anterior junction line

When reviewing the chest x-ray, you need to assess where the hilar are. Look for the hilar point in both lungs, as shown in Figure 1.16. The left hilum should be at the same level or higher than the right, never lower. The hilar density on each side should be similar. The hilar shadows are almost entirely due to the pulmonary arteries and veins. Air in the major bronchi can be visualised, but their walls are not usually visible.



1.16 The hilar

Most Trusts in the UK rarely take lateral chest x-ray images. In fact at a recent study day I heard a radiologist say, ‘No one takes lateral views as they don’t know what they are looking at.’ Surely this is a training issue?

In the large Leeds Trust where I work, a lateral chest x-ray is taken on GP patients over 55 years of age. If there is an area of suspicion on the PA radiograph, a lateral image will be taken by the examining radiographer. The radiation dose of a lateral chest x-ray is much lower than that of a CT (computerised tomography) scan; and when there is an area of suspicion on the PA image, taking a lateral radiograph may immediately answer the clinical question without resorting to CT. For instance, the lateral chest x-ray may demonstrate that the area of suspicion on the PA image is in fact a composite shadow, pericardial fat pad or artefact.

Though a CT may still sometimes be required (e.g. to investigate a mass), a lateral chest x-ray often clarifies questionable abnormalities. For instance, the GP patient over the age of 55 with a cough is often having a chest x-ray not only to look for consolidation but to assess for lung cancer. In this case, the addition of a lateral radiograph gives much more information, indeed the tumour on occasions may only be identified on the lateral radiograph. Feigin (2010), in his paper 'Lateral chest x-ray; a systematic approach', agrees that the lateral chest x-ray 'is valuable; and should be thought of as a full half of the routine chest radiograph'. He says, 'The lateral often provides key findings that are not visible on the frontal'.

Remember, when reviewing the PA image, some of the lungs are not visualised. The posterior/inferior sections are only visualised on the lateral chest image. In fact, when reviewing a PA image, I have seen a mass demonstrated below the diaphragm, but when reviewing the lateral I saw that it was within the lungs at the posterior base. The hilar are also often more easily visualised on the lateral view, where they are free from overlying structures.

Lateral x-rays

We will now look at reviewing the lateral chest image.

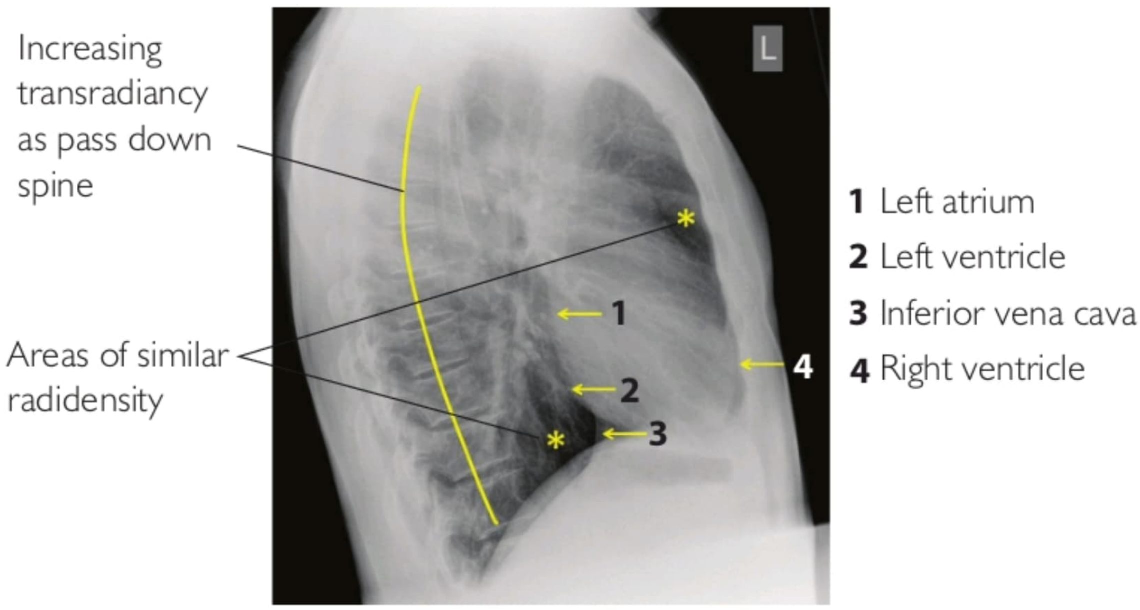


Figure 1.17 The lateral chest x-ray

The density of the upper retrosternal and retrocardiac (1 and 2, in the above diagram) should be of equal radiolucency. If this is not the case, this raises suspicion of a mass, which may be consolidation but could also be an anterior mediastinal mass, such as lymphoma. As you review the thoracic spine, there should be increasing transradiancy as you travel caudally because of the increased density of the shoulders. If the lungs over the lower thoracic spine are as dense as the upper, there is overlying pathology, which may indicate consolidation/mass or collapsed lung.

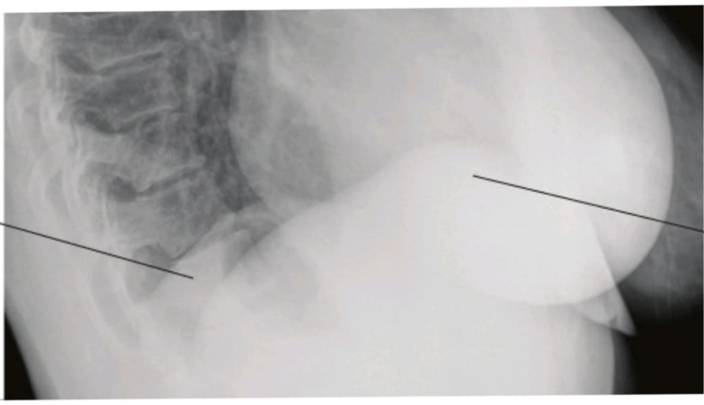


Figure 1.18 The diaphragms on the lateral view

The right diaphragm is easily identified on the lateral radiograph, as it is visualised as far as the anterior chest wall. The left diaphragm, however, is only visualised up to its junction with the heart. If either diaphragm is not clearly demonstrated, you should begin to consider overlying consolidation/ mass or collapse at the lower lobe. Review the PA image to assess further.

Review the hilar area very carefully on the lateral image, as this is the area where lung nodules/ masses may be visualised. The distal end of the left bronchus is visible as a round lucency, which is normally located near the apparent centre of the lungs. If there are two round lucencies in this area, the upper one is the right upper lobe bronchus and the lower one is the left main bronchus.

The opacities of the normal hilum are the two main pulmonary arteries as they enter the lungs. The bronchi follow the same path as the pulmonary arteries but are not visualised. All right pulmonary arteries are anterior and lateral to their respective bronchi. I am quite a visual person and recognise anatomy in musculoskeletal (MSK) reporting by shapes and appearance. I find the same applies to chest x-rays. The right pulmonary artery has a very white opacity, anterior to the airway in the centre, and has an ovoid appearance. The left pulmonary artery is less opaque and lies above the lucency of the left main bronchus. Its posterior margin curves inferior to the aorta with the same shape as the arch of the aorta.

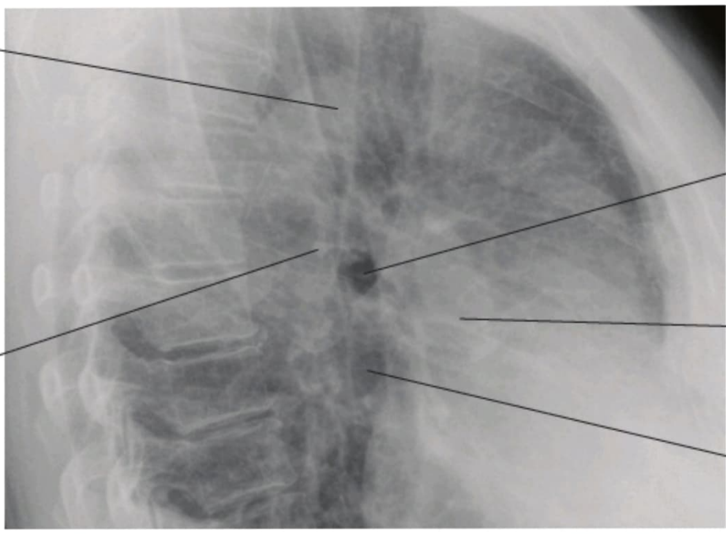


Figure 1.19 The hilar

Conclusion

This chapter has looked at the projections of the chest, and how the quality of the image may affect your review/report and the anatomy visualised. Another important aspect is to have a system when reviewing chest x-rays, and this is the subject of the next chapter.

Key points to remember

- *Is this the correct patient?*
- *Have you checked the clinical details and previous history?*
- *How was the patient x-rayed?*
- *Will the quality/position affect your interpretation and report?*
- *Look at previous images.*
- *Know your anatomy inside out.*

2

A SYSTEMATIC APPROACH TO REVIEWING THE CHEST IMAGE

When reviewing any x-ray image, you need a system, and this is even more important with the chest x-ray. Firstly, check that you are reviewing the correct patient's image, x-rayed on the correct date.

Then, very importantly with the chest, check previous images and review them, comparing them with the current image you are reviewing. Previous images will give you additional information that might not be included on the request card, such as a history of cancer or the fact that the patient has had a previous lobectomy. They will also allow you to assess whether a certain appearance is chronic or acute.

Next, you need to assess the quality of the image and consider whether it is going to affect your report/review.

Look at the clinical details – for instance, what is the clinician looking for, if it is cardiac failure? Of course, you should review everything on the images, but look especially carefully for signs that will answer the clinical question. For instance, state on the report whether or not cardiac failure is seen.

Now assess the radiograph in minute detail, magnifying and windowing as required. Review everything. It doesn't matter which system you use, as long as you have a system that includes everything, with special attention paid to the hidden areas behind the heart, the hilar, apices and bases. Don't forget to look at all the bones and joints and all the lines and other features mentioned in Chapter 1, as well as the cardiothoracic ratio.

The ABCDEF method is a useful way of remembering to review each of the areas in turn:

A – Apices and angles

B – Bases and bones

C – Cardiac (behind and within the heart)

D – Domes of diaphragm

E – Extra-thoracic

F – Foreign bodies (lines, tubes position)

Key points to remember

- *Check everything in minute detail.*
- *Window and magnify.*
- *Check lungs, heart, mediastinum, hilar and diaphragms.*
- *Check all anatomical lines mentioned in Chapter 1.*
- *Do not forget the bones and joints.*
- *Use the ABCDEF system.*
- *Check for inserted lines – are they in the correct position?*
- *Relate findings to clinical details.*

3

FELSON'S SILHOUETTE SIGN

What is the silhouette sign?

The silhouette sign gets its name from the fact that an intrathoracic radiopacity, if in anatomical contact with a border of the heart, diaphragm or aorta, will obscure that border. The first reference to it was made in around 1935, by Dr H. Kennon Dunham of Cincinnati, who often stated that obliteration of the left border of the heart by a contiguous pulmonary density indicated disease of the lingula. Interestingly a similar finding on the right was never mentioned (Felson 1973a). But it was Ben Felson, a twentieth-century American radiologist, who first fully described the silhouette sign in 1950, and continued to research its uses for the next 20 years, documenting his findings in his many chest radiology books.

Felson's first experiments in this field involved using an x-ray film carton filled with heated paraffin and waiting for it to solidify. This represented the heart, and air in another box represented the lungs; mineral oil was placed in a third carton to represent a diseased area of the lung. These were then placed in different positions and x-ray images taken. From these experiments, Felson hoped to find out how to localise an intrathoracic lesion on the posterior anterior radiograph.

One may wonder why, as a lateral radiograph would confirm the location of the lesion. However, there are many situations (e.g. when the patient is in intensive care, or being resuscitated) where a lateral view is not possible or practical. Also, routine chest x-rays are often posterior anterior view only, so it is important to be able to identify and locate lesions on this one image, although one could always recall the patient for a lateral chest x-ray.

Today, if a lesion was found, a CT scan would be carried out, but Felson's experiments took place before chest CT was thought of. It is better, however, to obtain as much knowledge as possible concerning chest radiographs so that subtle findings are not missed. A quote from Felson himself best sums up the silhouette sign: 'the explanation of the silhouette sign rests on the fact that the delineation of any roentgen shadow depends partly on differences in radiographic density' (Felson & Felson 1950, Felson 1973a).

At this stage, it is useful to list some of the relative absorption values for different tissues for an image taken at 60kv, before we proceed to look at the uses of Felson's silhouette sign. (Note that chest x-rays today are taken at a higher kv value of 80.)

Relative absorption values of tissues for 60kv radiation

- Water 1.0
- Carbon 0.7
- Fat 0.5
- Air 0.0001

(Felson 1973a)

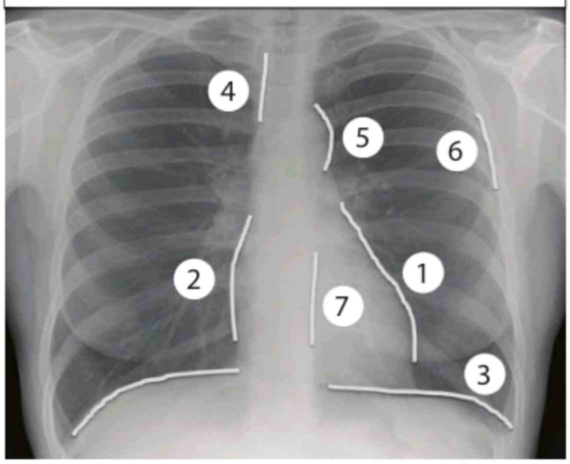
Uses of Felson's silhouette sign

The silhouette sign has two important applications. Firstly, it enables us to localise a shadow by observing which borders are lost. For instance, loss of the heart border must mean the shadow lies in the anterior half of the chest; alternatively, loss of part of the diaphragm outline indicates disease of the pleura or lower lobes.

Secondly, it enables us to diagnose disorders such as consolidation even when there is uncertainty as to the presence of an opacity. A wedge- or lens-shaped opacity may be difficult to see because of the way the shadow fades out at the edges, and a completely collapsed lobe may also be difficult to see; if these lesions are in contact with the mediastinum or diaphragm, it causes loss of their normal sharp boundaries.

To conclude, when examining the lungs on a normal chest x-ray, the silhouettes of the heart borders, the ascending and descending aorta, the aortic knob and the hemidiaphragms should be clear. Obliteration of any of these silhouettes can be caused by consolidation, mass, etc. However, all these structures are in contact with a specific portion of the lung. By determining which structure is obliterated, you can therefore determine where the lung pathology is located (Armstrong & Wastie 1989, Felson 1973a).

If there was increased shadowing with silhouette sign at the following interfaces, where would the pathology be located?



1 Left heart border: lingular disease
2 Right heart border: right middle lobe disease
3 Diaphragms: lower lobe pathology
4 Right paratracheal stripe: nodal disease
5 Aortic knuckle: anterior mediastinum or left upper lobe
6 Chest wall: lung/pleura/rib pathology
7 Paraspinal line: posterior thorax or posterior mediastinum

Figure 3.1 Silhouette sign – locating pathology

Areas where caution is needed when using the silhouette sign

Several journal articles and texts, in particular De Lacey and his colleagues in their book, *The Chest X-ray: A survival guide* (2008), suggest that caution is needed in some areas when using the silhouette sign. These are outlined below.

- Be careful when viewing an anterior posterior sitting or supine chest x-ray, as angulation cranially may project extra-pleural fat over the base of the left lung, resulting in loss of the left diaphragm.
- A large amount of fat may be situated between the pericardium, lung and dome of the diaphragm, which may blur the dome.
- A depressed sternum can produce loss of the right heart border
- In some patients, pulmonary vessels or fat are close to the heart border, resulting in blurring of the right heart border.

(De Lacey et al. 2008, Hollman et al. 1989, Reed 2003, Zylak 1988).

Felson's research and observations of other possible uses of the silhouette sign in the posterior anterior chest x-ray

Felson continued to observe and research uses of the silhouette sign and its principles. (The air bronchogram sign is explained in Chapter 4.) Bronchi are not normally demonstrated radiographically, but in an opacified lung they may be seen (Oktay 2011).

Felson observed that applying the silhouette sign to the border of the trachea is unreliable, as in many normal patients it cannot be seen; and the same applies to the cephalic aspect of the aortic knob. However, it can be applied to the right and left pulmonary arteries, as the lateral portion profiled by the lungs is visible on the posterior anterior chest x-ray.

The hilum convergence sign does not always work, as it requires a Bucky image and any obliquity makes it invalid, according to Felson (1973a). However, De Lacey *et al.* (2008) describe the hilum convergence sign and hilum overlay sign in detail, as useful so-called 'power tools' when reviewing chest radiographs. Today, highly detailed digital images of chest x-rays are found in most radiology departments. These are often taken with an incorporated grid and are equally useful (indeed better) than the Bucky images Felson (1973a) speaks about. With good-quality chest x-ray images, the hilum convergence sign and hilum overlay sign are useful when assessing the posterior anterior chest image, but treat these signs with caution when assessing a rotated image (again, you need to consider how the quality of the image may affect your final report).

What are the hilum convergence and overlay signs?

The hilum convergence sign allows an enlarged hilum that is due to enlarged pulmonary arteries to be distinguished from enlargement due to tumour. If the vessels appear to arise medial to the enlarged hilar, then it is a tumour. However, if the vessels arise from or converge directly onto the enlarged hilar shadow, then the pathology is vascular.

The hilum overlay sign helps us distinguish between cardiac enlargement and anterior mediastinal mass. If the hilum is lateral to the lateral border of the mass, there is cardiac enlargement; if the hilum is medial to the lateral border of the mass, it is a mediastinal mass.

The cervicothoracic sign is based on the fact that if a thoracic lesion is in contact with the soft tissues of the neck, its continuous border will be lost. The cephalic border of the anterior mediastinum ends at the clavicles, whereas the posterior border ends much higher. Hence a lesion above the clavicles on the frontal view must lie posteriorly and be entirely within the thorax. If anterior, the cervical soft tissues would have obscured it. Both Felson (1973a) and De Lacey *et al.* (2008) agree the cervicothoracic sign is useful when assessing the posterior anterior chest x-ray.

Since the abdominal structures are mainly of water density, a sharply marginated mediastinal mass seen through the diaphragm, on a chest or abdominal image, must lie in the thorax; this is the thoracoabdominal sign (Felson 1973a, Lacey *et al.* 2008, Oktay 2011).

Conclusion

The silhouette sign is an extremely useful tool when assessing the posterior anterior chest x-ray. When we fully understand its use, it can allow us to visualise subtle lesions/pathologies and locate them. There are only minor areas of caution required in its use, and its main principles can be applied in other areas.

To conclude, a positive silhouette sign is very helpful. However, a negative silhouette sign does not guarantee that a given lobe of the lung is disease-free because it may be partially aerated and therefore not cause a silhouette sign.

Interestingly, newer texts and journals add little information to the initial research Felson did on the silhouette sign in the 1950s and his continued work in this area over the following 20 years. It is therefore extremely useful to read Felson's research and textbooks on the silhouette sign to fully understand its use.

Key points to remember

- *'…the explanation of the silhouette sign rests on the fact that the delineation of any roentgen shadow depends partly on differences in radiographic density' (Felson 1950, Felson 1973a).*
- *Always use Felson's silhouette sign when reviewing the chest x-ray.*
- *Know and use the hilum convergence and overlay signs.*
- *Know the cervicothoracic sign and its use.*
- *Know the limitations of Felson's silhouette sign.*

4

CONSOLIDATION AND COLLAPSE

What is consolidation?

Consolidation is caused by fluid filling the smaller bronchi, bronchioles and alveoli. The nature of the fluid cannot be determined radiographically. It could be pus as in infection, water as in pulmonary oedema, haemorrhage as in trauma or some of the vasculitides, or malignant cells as in alveolar carcinoma. Consolidation shadowing can range from subtle patchy areas to widespread confluent shadows.

The hallmark of consolidation is the presence of air bronchograms, as described by Felson's silhouette sign. Pure consolidation shows no loss of volume, but consolidation is often accompanied by collapse.

Air bronchograms

Air is seen in the trachea and proximal bronchi in a normal chest because these are surrounded by the soft tissues of the mediastinum. The airways distal to the proximal segmental bronchi are thin walled and not normally visible. However, when the normally aerated pulmonary parenchyma is replaced by non-aerated tissue (as in consolidation), the bronchi and bronchioles become visible as branching linear lucencies, which are known as air bronchograms. The air bronchogram sign specifically indicates a lung parenchyma process, as distinct from a pleural or mediastinal process.

Consolidation of a whole lobe

Consolidation of a whole lobe is often diagnostic of bacterial pneumonia. It is one of the commonest causes of morbidity and mortality in the UK (Das & Howlett 2009). Lobar consolidation produces an opaque lobe, except for the presence of air bronchograms. As the consolidated lobe is airless, the fissure between it and the normal lung does not appear as a line, but as a clear-cut border to the opacity.

Using the silhouette sign, we know that the boundary between the affected lobe and the adjacent heart, mediastinum and diaphragm will be invisible; this allows us to locate the area of consolidation accurately on the posterior anterior view. A lateral chest x-ray, if possible, in what could potentially be an extremely ill patient, will confirm the locality of the consolidation. However, if the posterior anterior/anterior posterior (PA/AP) chest x-ray view gives enough information for the consolidation to be located (reasonably accurately), diagnosed and treated appropriately, why do a lateral radiograph? Performing a lateral radiograph will increase the radiation dose to the patient (albeit by a small amount), as well as potentially causing them discomfort. Yet it won't alter the management of the patient. This is an area where a lateral view is not helpful or required (Armstrong & Wastie 1989, De Lacey *et al.* 2008, Felson 1973b).

Streptococcus pneumoniae is the commonest cause of lobar pneumonia, usually affecting one lobe only, with little or no collapse. Other less common causes of lobar pneumonia include:

- Staphylococus aureus – especially in children; 40 to 60% of children develop pneumatoceles; effusion and pneumothorax are common
- Klebsiella pneumonia – often multilobar
- Streptococcus pyogenes – mainly affects the lower lobes
- Tuberculosis – most common in primary tubercolosis; collapse is common; right lung is affected twice as often as the left (Chapman & Nakielny 1992).

Patchy consolidation

Patchy consolidation (for example, one or more patches of ill-defined shadowing) is usually due to infection or infarction, or (less commonly) contusion or allergy. When spherical in shape, consolidation may be difficult to distinguish from a lung tumour; but usually serial films over a short interval show change if the shadow is due to consolidation. The air bronchogram sign is helpful, since it is common in consolidation but rare in tumours. However, if there is any reason to suspect a lung tumour a high-resolution computed tomography (HRCT) scan should be done and an appropriate referral pathway followed (Armstrong & Wastie 1989, Clarke 2012, Corne *et al.* 1997, De Lacey *et al.* 2008, Felson 1973b).

De Lacey *et al.* (2008) suggest adopting a 6-week chest x-ray rule in patients who have chest x-ray evidence of pneumonia, who smoke or have clinical or radiological features that suggest there may be an underlying bronchial carcinoma. If the chest x-ray at 6 weeks (following treatment for the pneumonia etc.) is not clear and there are no worrying features and the patient is clinically well, he suggests a further chest x-ray at 4 weeks, to ascertain that clearing is continuing.

However, for all smokers over 40 years of age, who have any clinical features of lung cancer de Lacey suggests a CT and bronchoscopy. NICE guidelines also suggest a 6-week follow-up in patients over 50 with consolidation or collapse, to ensure resolution of appearances. If consolidation/collapse is not starting to resolve after appropriate treatment after this time period and in this age group, this raises suspicion of lung cancer.

In the Leeds Trust it is more likely that an HRCT would be arranged for any patient whose chest x-ray was not clear after 6 to 8 weeks. This is a more cautious route, so that potential bronchial carcinomas are diagnosed and treated sooner, and I believe many other UK Trusts have adopted this pathway.

In the more elderly patient with consolidation, an 8-week (rather than 6-week) follow-up should be considered, as these patients may take longer to recover.

Pulmonary collapse

Pulmonary collapse (loss of volume of a lung or lobe) is sometimes referred to as atelectasis, and can be associated with consolidation. Location of both collapse and consolidation on a PA/AP chest x-ray may be obtained by the use of Felson's silhouette sign (see Chapter 3). Pulmonary collapse may be due to any of the following:

- Bronchial obstruction
- Pneumothorax or pleural effusion
- Fibrosis of a lobe, usually following tuberculosis
- Bronchiectasis
- Pulmonary embolus.

Collapse due to bronchial obstruction

This occurs because no air can get into the lungs to replace the air absorbed from the alveoli. The most common causes are (Armstrong & Wastie 1989, Davies *et al.* 1990, Sunderamoorthy *et al.* 2005):

- Intraluminal occlusion, such as a mucous plug postoperatively or in asthmatic patients, or it may be due to a foreign body
- Bronchial wall lesions, usually primary carcinoma; rarely, endobronchial tuberculosis or bronchial adenoma
- Invasion or compression by adjacent mass, such as malignant tumour or enlarged lymph nodes
- A wrongly placed endotracheal tube
- Inhalation of a foreign body.

When the lobe is not aerated, it will lose much of its volume and will collapse, resulting in increased shadowing of the collapsed lobe on the radiograph and movement of other structures (e.g. trachea, hilum, horizontal fissure) to take up some of the void left by the collapsed lobe. The silhouette sign is important in identifying a collapsed lung or lobe.

Consolidation often accompanies lobar collapse. Occasionally the loss of volume is so severe that, unless it is tangential to the x-ray beam, it may be difficult to see. The silhouette sign is very useful in this situation, as the mediastinal (or diaphragmatic) borders will be ill defined adjacent to the collapsed lobe. The silhouette sign also helps in identifying, from the chest x-ray, which lobe is collapsed. Collapse of the anteriorly located lobes (the upper and middle) will obliterate portions of the mediastinal and heart outlines, whereas collapse of the lower lobes obscures the outline of the adjacent diaphragm and descending aorta.

When a lobe collapses, other structures move to take up the space. The unobstructed lobe on the side of the collapse expands (compensatory emphysema), resulting in displacement of fissures and movement of the hilum towards the collapsed lobe. The fissure is seen as a well-defined boundary to the airless lobe. The mediastinum and diaphragm may move towards the collapsed lobe. CT shows lobar collapse very well and is a useful secondary investigation in some cases. If the whole of one lung has collapsed, the entire hemithorax is opaque and there is marked mediastinal and tracheal shift towards the collapsed lung (Armstrong & Wastie 1989, Clarke 2012, Corne *et al.* 1997, De Lacey *et al.* 2008, Felson 1973b).

Collapse due to lobar fibrosis or bronchiectasis

In both of these, a lobe may be reduced in volume, sometimes quite severely, but normally remains partially aerated.

Collapse due to pneumothorax or pleural effusion

In both of these, the cause of the collapse should be identifiable. With a pneumothorax, it is often located at the apices, but may be demonstrated basally; a sharp fine line should be identified with no lung markings demonstrated distal to it.

When examining elderly patients, be careful not to mistake a skin fold for a pneumothorax. With a pneumothorax lung markings will not be seen distal to the sharp fine line; with a skin fold markings will be seen distal to the skin fold. Also be careful of mistaking large bullae for a pneumothorax; in this case, there will be other signs of emphysema on the image. If a tension pneumothorax is identified, immediate treatment is required (i.e. a chest drain). Theoretically, a tension pneumothorax should never be seen on an x-ray image; it should be diagnosed and treated clinically first.

Figure 4.1 Right-sided pneumothorax

Collapse due to pulmonary embolus

With this condition, the involved lobe or lobes usually show a combination of patchy consolidation and loss of volume (but often not much). However, a plain chest image cannot rule out pulmonary emboli. If a pulmonary embolus is suspected, vascular CT is often carried out (Armstrong & Wastie 1989).

Collapse of the lower left lobe

One area of collapsed lung field that requires extra caution when viewing the PA/AP chest x-ray is collapse of the left lower lobe. It is probably the easiest to miss, as the left lower lobe collapses down behind the heart. In this situation, the left lung field appears much darker than normal, and the heart shadow appears much whiter than normal. With careful observation, a white triangle can be seen behind the heart. The lateral radiograph, if taken, demonstrates a white triangle at the bottom posterior corner of the lung fields, and the vertebral bodies will appear whiter.

Examples of lobar collapse

Below are several examples of lobar collapse and how they are demonstrated on the x-ray image, using Felson's silhouette sign.

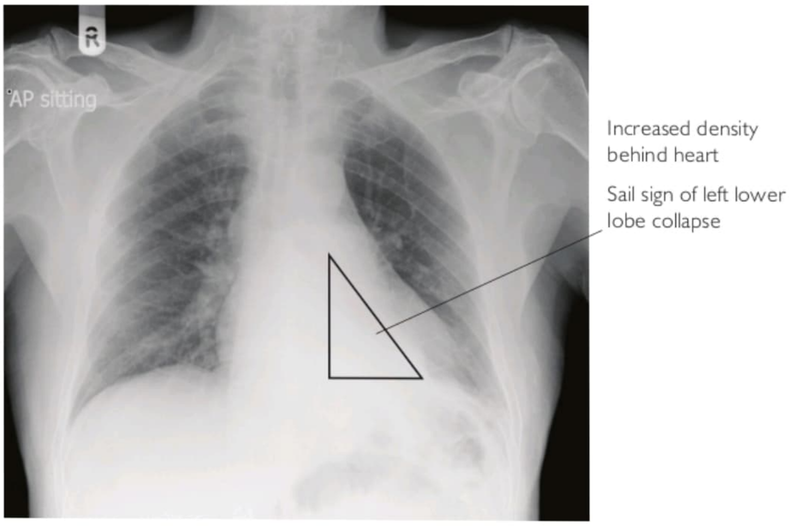


Figure 4.2 Sail sign of left lower lobe collapse (identified on the chest x-ray, investigated by CT)

Figure 4.3 CT of left lower lobe collaps

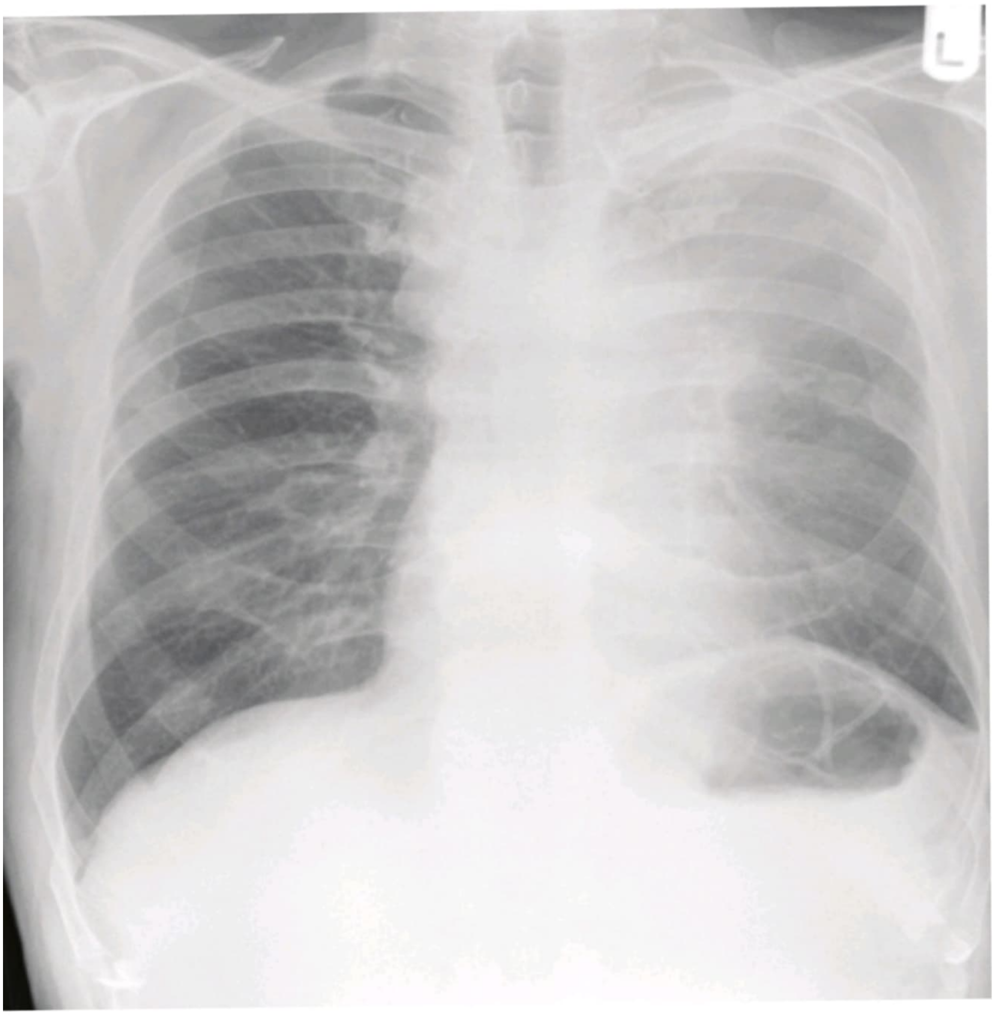
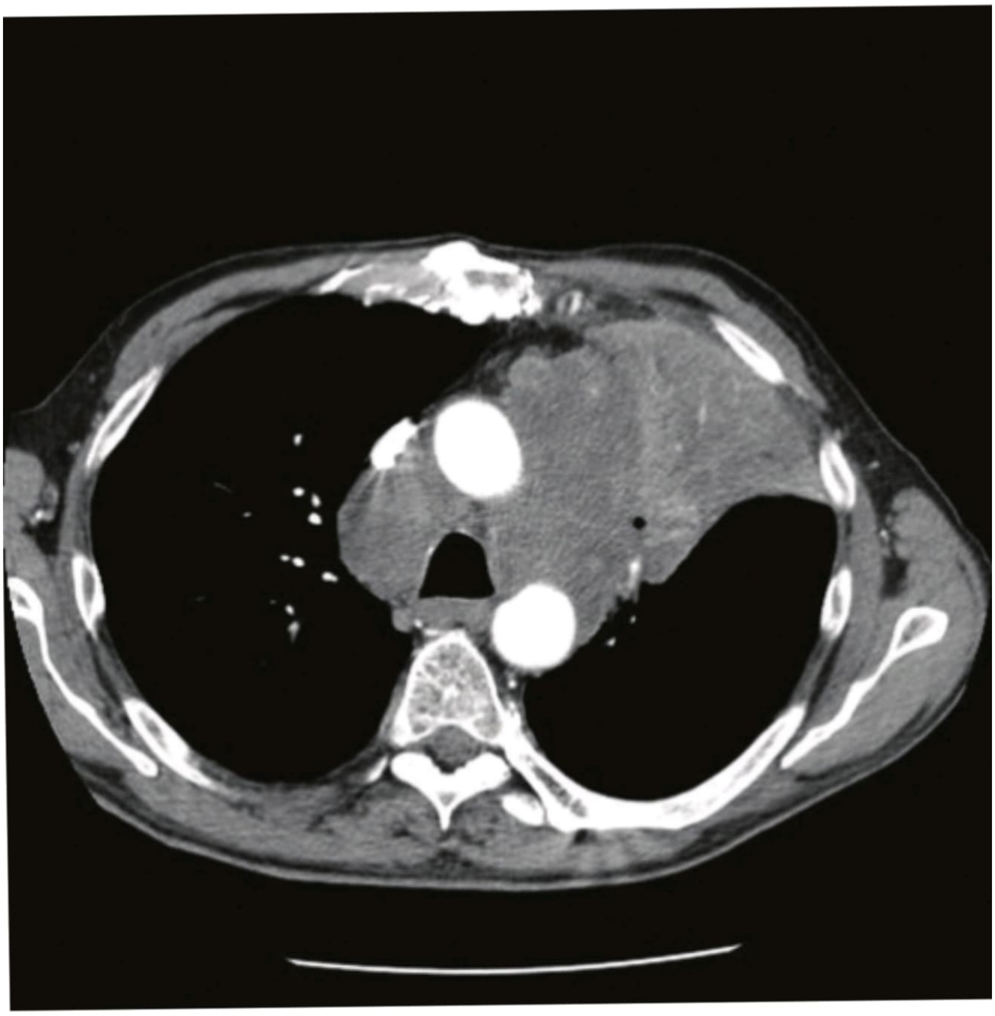


Figure 4.4 Left upper lobe collapse

ty, with loss of definition of the left heart border, consistent with Fe



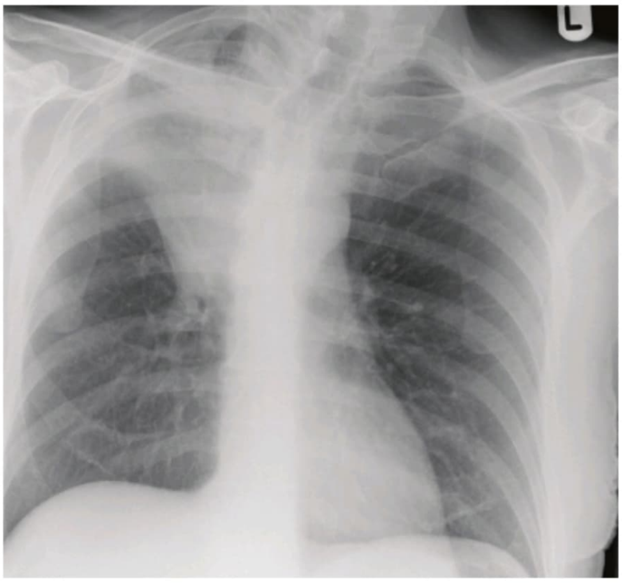


Figure 4.6 Right upper lobe collapse (using Felson's silhouette sign – loss of right upper mediastinal border)

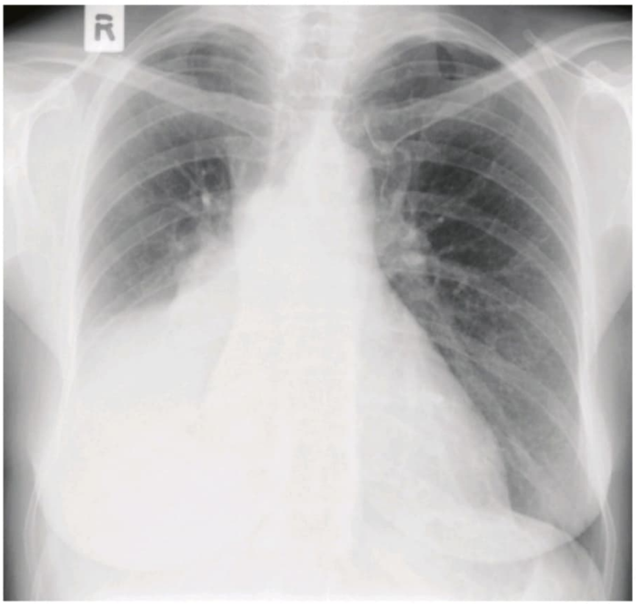


Figure 4.7 Right lower lobe collapse (using Felson's silhouette sign – loss of right diaphragmatic border)

De Lacey *et al.* (2008) describe various benign appearances that may be mistaken for lobar collapse. If in doubt, a lateral chest x-ray will confirm whether it is a benign appearance or not, and this will of course affect management of the patient. Below are some examples of benign appearances that may be mistaken for lobar collapse:

- Right upper lobe – be careful of the azygos fissure, and unfolded neck vessels, in the elderly
- Middle lobe – be careful of a depressed sternum, or fat touching the heart border
- Right lower lobe – be careful of epicardial fat pad, and the accessory fissure
- Left lower lobe – be careful of the unfolded aorta in the elderly, and a hiatus hernia
- Left upper lobe – no benign appearances requiring caution.

Conclusion

Collapse and consolidation may occur together or separately. Consolidation is a generic term; and if the cause of the consolidation is identifiable, this should be stated in the report. An air bronchogram may be seen in the consolidated area. Felson's silhouette sign is a useful tool for identifying the location of the collapse or consolidation on the PA/AP chest x-ray. Where there is any radiological or clinical suspicion that the collapse or consolidation is due to bronchial carcinoma, or any other carcinoma, then an HRCT should be performed, with appropriate referral.

Key points to remember

- *Know and use Felson's silhouette sign to identify consolidation and collapse.*
- *Be able to recognise the air bronchogram sign.*
- *If possible, assess and state cause of consolidation.*
- *Be able to identify different types of lobar collapse.*
- *Suggest follow-up 6–8 weeks in appropriate patients, as per NICE guidelines.*
- *Be able to distinguish pneumothorax from skin folds, bullae, etc.*

5

OVERVIEW OF CARDIOVASCULAR DISORDERS AND HEART FAILURE

Introduction

There are several clues to cardiovascular disorders on the chest x-ray, but only a few are specific enough to make a definitive diagnosis. Many patients will continue to have other diagnostic investigations, the most common being echocardiography, particularly when looking at valve function and chamber size. Other investigations may include angiography (to demonstrate the coronary arteries and other vessels), and in some centres magnetic resonance imaging (MRI).

This chapter will firstly look at identifying some of the clues to cardiac problems on the plain chest x-ray; and then briefly summarise some of the main cardiovascular disorders, identifying their possible appearance on the radiograph.

Signs of heart disease

Heart size

The cardiothoracic ratio (CTR) is a widely used but crude method of measurement (Armstrong & Wastie 1989). Most normal adult hearts have a CTR that does not exceed 50% when assessed on a posterior anterior erect chest x-ray on full inspiration. The observation of increasing heart size in comparison with previous images is often more useful than the CTR in isolation. De Lacey (2008) comments that the CTR in an individual can vary up to 0.5cm. This of course depends on rotation, position (PA versus AP, or supine), depth of inspiration, and whether the image is taken in diastole or systole. Another thing to be aware of is whether or not there is a cardiac fat pad – do not include this in the measurement of the heart.

Chamber hypertrophy and dilation

This is more accurately determined by an echocardiograph, which will determine whether enlargement is due to pericardial effusion or chamber enlargement. Diagnosing ventricular enlargement on chest x-rays is difficult, as only one or two of the borders of either ventricle will be visible. It is also difficult to distinguish ventricular hypertrophy from dilation. Often, all that can be determined is an increase in transverse cardiac diameter.

Assessing the atrial size on a chest x-ray is easier. The border of an enlarged left atrium is visible as a double contour within the right cardiac shadow. When dilated, the left atrial appendage is seen on the chest x-ray as a bulge below the main pulmonary artery; with gross enlargement, the left main bronchus is pushed superiorly. The posterior margin of the left atrium is best demonstrated on the lateral view. Right atrial enlargement causes an increase in the curvature of the right heart border.

Common causes of chamber enlargement

Armstrong and Wastie (1989) give a good summary of the common causes of chamber enlargement, as listed below.

Left atrial enlargement:

- Mitral stenosis
- Mitral incompetence
- Left atrial tumour, e.g. myxoma.

Right atrial enlargement:

- Right ventricle failure
- Tricuspid stenosis
- Tricuspid incompetence.

Left ventricular enlargement:

- Aortic and mitral incompetence
- Aortic stenosis
- Ischaemic heart disease and cardiomyopathy
- Patent ductus arteriosus and ventricular septal defects in cases with left to right shunts.

Right ventricular enlargements:

- Atrial septal defect
- Tricuspid regurgitation
- Pulmonary stenosis and pulmonary hypertension.

Pericardial disease

Chest x-ray is not the modality to diagnose a pericardial effusion. A patient may have life-threatening pericardial effusion and only mild cardiac enlargement. However, a marked increase or decrease in the cardiac diameter within 2 weeks is diagnostic of pericardial effusion.

Pericardial calcification is seen in approximately 50% of patients with constrictive pericarditis. It is usually post-infective in aetiology – tuberculosis and Coxsackie infections being the most common precursors (Armstrong & Wastie 1989, Ketai *et al.* 2006, Weissleder *et al.* 1997).

Pulmonary vessels

It is possible on the chest x-ray to assess the pulmonary artery for enlargement by looking at its degree of bulging. At the hilar, the right lower lobe artery can be measured; it should be between 9 and 16mm. The size of the vessels within the lungs reflects pulmonary blood flow. By observing the size of these vessels, it may be possible to diagnose increased pulmonary blood flow, decreased pulmonary blood flow, and pulmonary artery and pulmonary venous hypertension.

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Increased pulmonary blood flow

Atrial septal defect, ventral septal defect and patent ductus arteriosus are common causes of blood being shunted from the systemic to the pulmonary circuits, thus increasing blood flow. In patients with severe left to right shunts, all the vessels from the main pulmonary artery to the periphery of the lungs are large; this is sometimes called pulmonary plethora.

Decreased pulmonary blood flow

To be recognised on a chest x-ray, the decrease in blood flow has to be substantial. When the pulmonary vessels are all small, it is known as pulmonary oligaemia. The commonest cause is Tetralogy of Fallot.

Pulmonary artery hypertension

The pressure in the pulmonary artery depends on cardiac output and pulmonary vascular resistance. The conditions that lead to significant pulmonary arterial hypertension tend to increase the resistance of blood flow through the lungs. Many lung conditions can result in this, as can pulmonary emboli and pulmonary arterial narrowing as a result of mitral disease. Pulmonary arterial hypertension has to be severe before it can be diagnosed on a chest x-ray.

The chest x-ray findings will be enlargement of the pulmonary artery and hilar arteries, the vessels within the lungs being normal or small. De Lacey *et al.* (2008) list some of the causes of pulmonary artery hypertension as: longstanding pulmonary venous hypertension, left to right shunts, pulmonary embolism, respiratory disease, high altitude, drugs and poison.

Pulmonary venous hypertension

Mitral valve disease and left ventricular failure are the commonest causes of pulmonary venous hypertension. In raised pulmonary venous pressure, in an upright patient, the upper zone vessels enlarge and in severe cases become larger than those in the lower zone (Armstrong & Wastie 1989, Chapman & Nakielny 1992, De Lacey *et al.* 2008, Ketai *et al.* 2006).

Pulmonary oedema

The commonest cardiac conditions causing pulmonary oedema are left ventricular failure and mitral stenosis. Cardiogenic pulmonary oedema occurs when the pulmonary venous pressure rises above 24mmHg. Initially the oedema is in the interstitial tissues of the lung, but as it becomes more severe, fluid collects in the alveoli. Both interstitial and alveoli pulmonary oedema can be recognised on plain chest x-rays.

Interstitial oedema

There are septa in the lungs that are invisible on a chest x-ray, because they consist only of a sheet of connective tissue. However, when these are thickened by oedema, the peripherally located septa may be seen as line shadows. These are called Kerley B lines; they are horizontal lines seen in the lower zones, never more than 2cm long. These lines reach the lung edge, which distinguishes them from blood vessels which never extend into the outer centimetre of lung. Other septa (known as Kerley A lines) radiate towards the hila or mid and upper zones. These are much thinner than the adjacent blood vessels, and normally 3–4cm in length. Another sign of interstitial oedema is that the outline of blood vessels may be seen, due to oedema collecting around them.

Alveolar oedema

This is a more severe form of oedema where the fluid collects in the alveoli. It is normally bilateral when it occurs, involving all the lobes. Shadowing is maximal close to the hila. This pattern of oedema is sometimes referred to as 'butterfly' or 'bat's wing' pattern (Armstrong & Wastie 1989, Chapman & Nakielny 1992, De Lacey *et al.* 2008, Ketai *et al.* 2006).

Cardiac disorders

Heart failure

One or all of the following signs may be seen on a chest x-ray:

- Cardiac enlargement
- Raised pulmonary venous pressure, i.e. enlargement of the vessels in the upper zones of the lung
- Evidence of pulmonary oedema
- Pleural effusions, usually bilateral, but if unilateral more often on the right side.

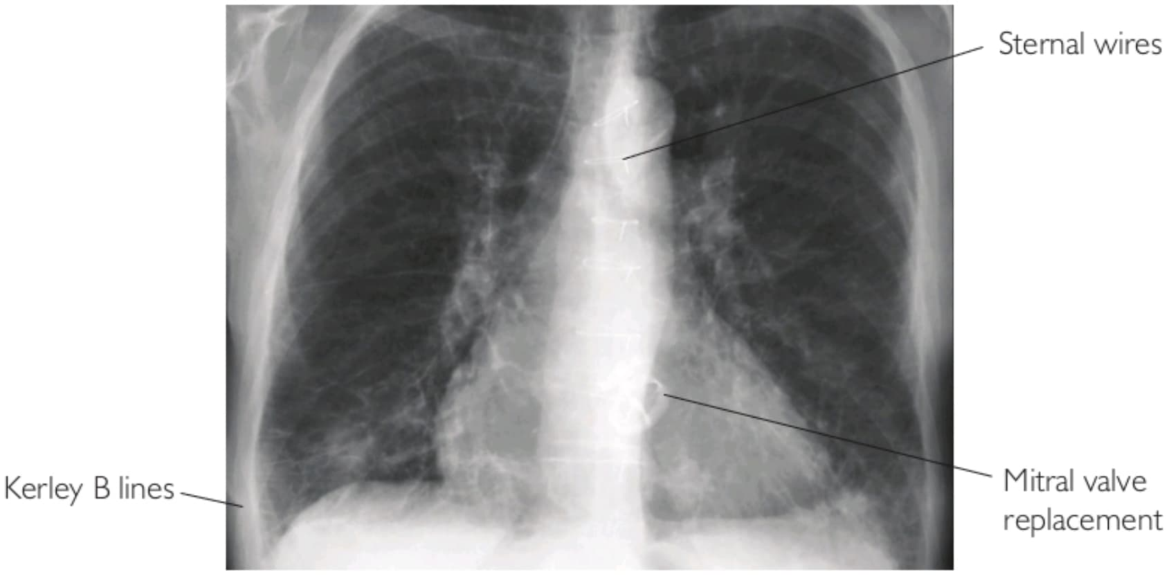

Figure 5.1 Sternal wires from cardiac surgery, with mitral valve replacement; now with heart failure, demonstrating Kerley B lines

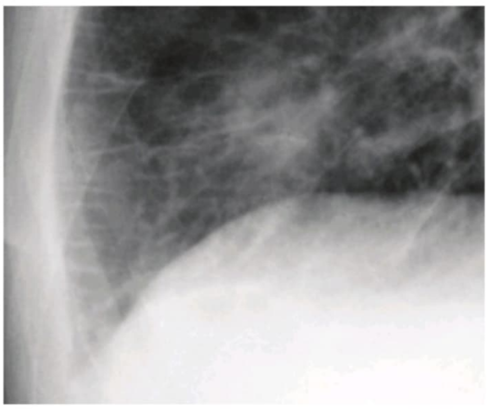

Figure 5.2 Kerley B lines as demonstrated on image above, magnified

Figure 5.3 So-called 'bat wing' of pulmonary oedema

Valvular heart disease

Echocardiography is the image modality that enables the diagnosis.

Mitral stenosis and mitral incompetence

The chest x-ray may demonstrate left atrial enlargement, and sometimes calcification of the valve. The main use of the chest x-ray is to demonstrate raised pulmonary venous pressure and pulmonary oedema. Unless pulmonary hypertension develops, the transverse cardiac diameter is often normal. Pulmonary hypertension leads to other problems, such as dilation of the pulmonary arteries, and right ventricular enlargement. With mitral incompetence, the size of the left atrium corresponds well with the severity of the disease. The difference in chest x-ray appearance of mitral incompetence (compared with mitral stenosis) is the presence of left ventricular enlargement.

Aortic stenosis

The main features on the chest x-ray are aortic valve calcification and post-stenotic dilation of the ascending aorta. Left ventricular enlargement and raised pulmonary venous pressure are late signs, indicating left ventricular failure.

Aortic incompetence

Unlike aortic stenosis, aortic incompetence leads to enlargement of the left ventricle early in the disease. As the severity increases, the left atrium enlarges and raised pulmonary venous pressure develops.

Tricuspid stenosis and incompetence

Both these conditions result in enlargement of the right atrium and superior vena cava. They are rarely seen in isolation; there is often also mitral valve disease.

Left atrial myxoma

This is the commonest type of cardiac tumour, and is benign. It can interfere with the function of the mitral valve, thus mimicking mitral stenosis.

Ischaemic heart disease

Most patients with angina or myocardial infarction have a normal chest. The signs which may be present on a plain chest image are:

- Signs of raised pulmonary venous pressure and pulmonary oedema
- Cardiac enlargement, and aneurysm formation
- Myocardial infarcts occasionally calcify
- Atheromatous calcification may be seen in the coronary arteries.

Conclusion

This is an extensive and complicated subject and this chapter has only briefly reviewed some of the main cardiovascular disorders. It has mainly focused on some of the possible appearances of cardiac disease on the chest image, which enables identification of early cardiac disease.

Key points to remember

- *Remember how to measure CTR (see Chapter 1), its usefulness and limitations.*
- *Remember how to identify atrial enlargement, as well as pulmonary enlargement.*
- *Pulmonary venous hypertension is often caused by mitral valve disease, or LVF.*
- *Know how to identify pulmonary and interstitial oedema.*
- *Be able to identify Kerley A and B lines.*