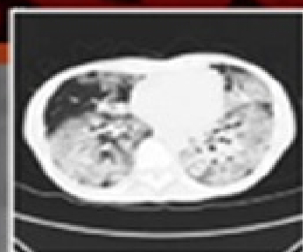
# Chest X-Ray Made Easy

Fourth Edition



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ELSEVIER

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FOURTH EDITION


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# Preface

The chest x-ray is one of the most frequently requested hospital investigations and its initial interpretation is often left to junior doctors. Although there are a large number of specialist radiology textbooks, very few are targeted at junior doctors and medical students. This book was designed to fill this gap and make interpretation of the chest x-ray as simple as possible. It is not meant as an alternative to a radiological opinion but rather as a guide to making sense of the common abnormalities one is likely to encounter on the wards, for speedy recognition of these will expedite effective treatment of the patient.

Following the success of the last three editions, we have expanded the book and enlarged the images, making them even clearer. Additional CT scans have been added, as well as an extra section on the sick patient, including the patient on ICU and the appearance of lines and tubes. Common pathologies and radiological appearances have dedicated focus chapters and the book concludes with a self-assessment section. The book should remain a useful aid, not just for medical students but also for nurses, physiotherapists and radiographers.

Chapters 1 to 3 provide some ground rules that must be applied when interpreting the chest x-ray. Chapter 4 onwards takes the readers through some of the most common abnormalities, arranged according to their x-ray appearance. Each topic contains an example x-ray with an explanatory legend and at the end extra learning points are displayed in the shaded boxes. The outline drawings above the x-rays assist in the interpretation of the abnormality shown.

**J.C.**

**M.K.**

# Acknowledgements

We would first like to acknowledge the other co-authors of the previous editions: Ivan Brown, David Delaney, Mary Carroll and Kate Pointon. We would like to thank Dr S K Sharma, Senior Professor and Head, Department of Internal Medicine, All India Institute of Medical Sciences for his contribution and his colleagues Dr Anunay Gupta, Dr Abhishek Sharma, Dr Saurabh Mittal and Dr Sajal Ajmani for reviewing the previous edition and providing suggestions for important updates to the new edition. We would like to thank Mary Matteson of the Department of Radiology, Southampton General Hospital for her work in copying the original x-rays and Karen Mullin for contributing some of the additional images for this edition.

We would also like to thank staff at Elsevier.

**J.C.**

**M.K.**

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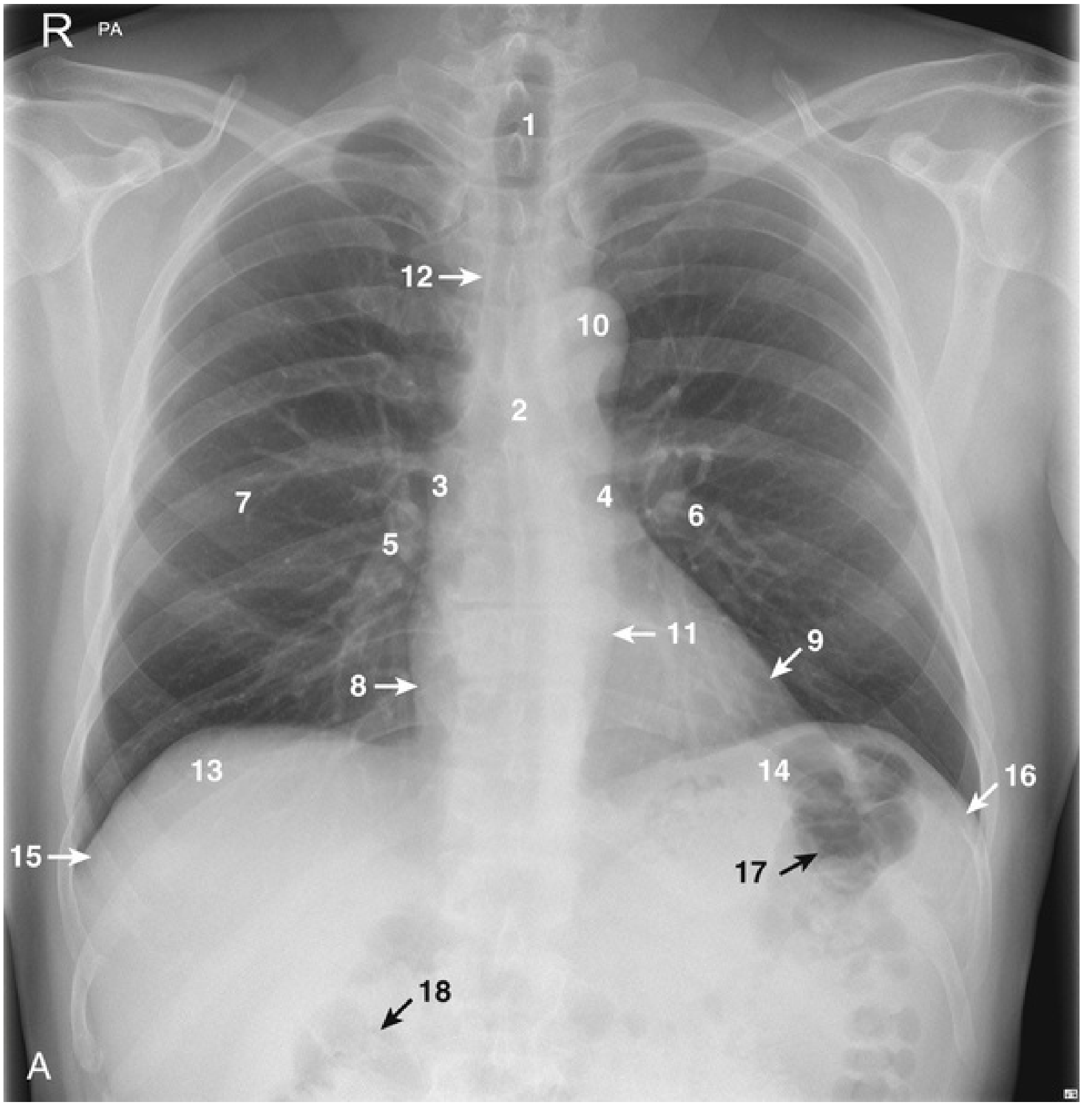
# How to look at a chest x-ray



## Basic Interpretation is Easy

Figure 1.1A, B shows the appearance of a normal CXR. You can use these as reference images as you progress through the book.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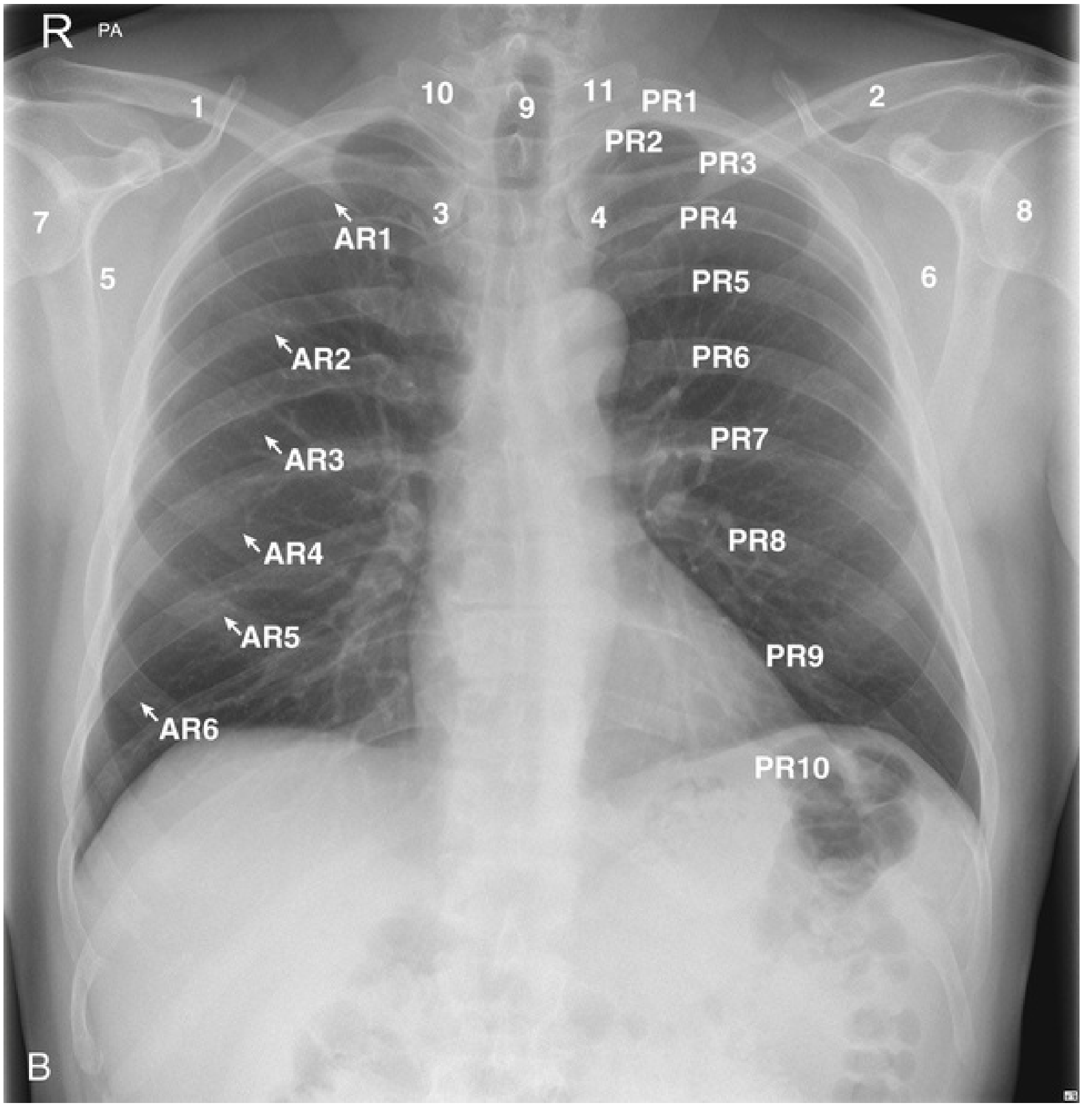



**FIGURE 1.1** **(A)** The normal chest x-ray (CXR). Anatomic features: **(1)** Trachea; **(2)** Carina; **(3,4)** Right and left main bronchi; **(5,6)** Right and left hilar structures; **(7)** Right horizontal fissure; **(8)** Right cardiac border formed by right atrium; **(9)** Left cardiac border formed by left ventricle; **(10)** Aortic knuckle; **(11)** Descending thoracic aorta; **(12)** Right paratracheal line; **(13,14)** Right and left hemidiaphragms; **(15,16)** Costophrenic angles; **(17)** Gastric air bubble; **(18)** Gas in the colon. **(B)** Bony thorax. **(1,2)** Right and left clavicles; **(3,4)** Right and left sternoclavicular joints; **(5,6)** Right and left scapulae; **(7,8)** Right and left humeral heads; **(9)** Spinous process of T1; **(10,11)** Right and left transverse processes of T**1**; Anterior ribs (AR) **1–6**; Posterior ribs (PR) **1–10**.

*Basic* interpretation of the chest x-ray (CXR) is easy. It is simply a black and white film and any abnormalities can be classified into:

(a) Too white.

(b) Too black.

(c) Too large.

(d) In the wrong place.

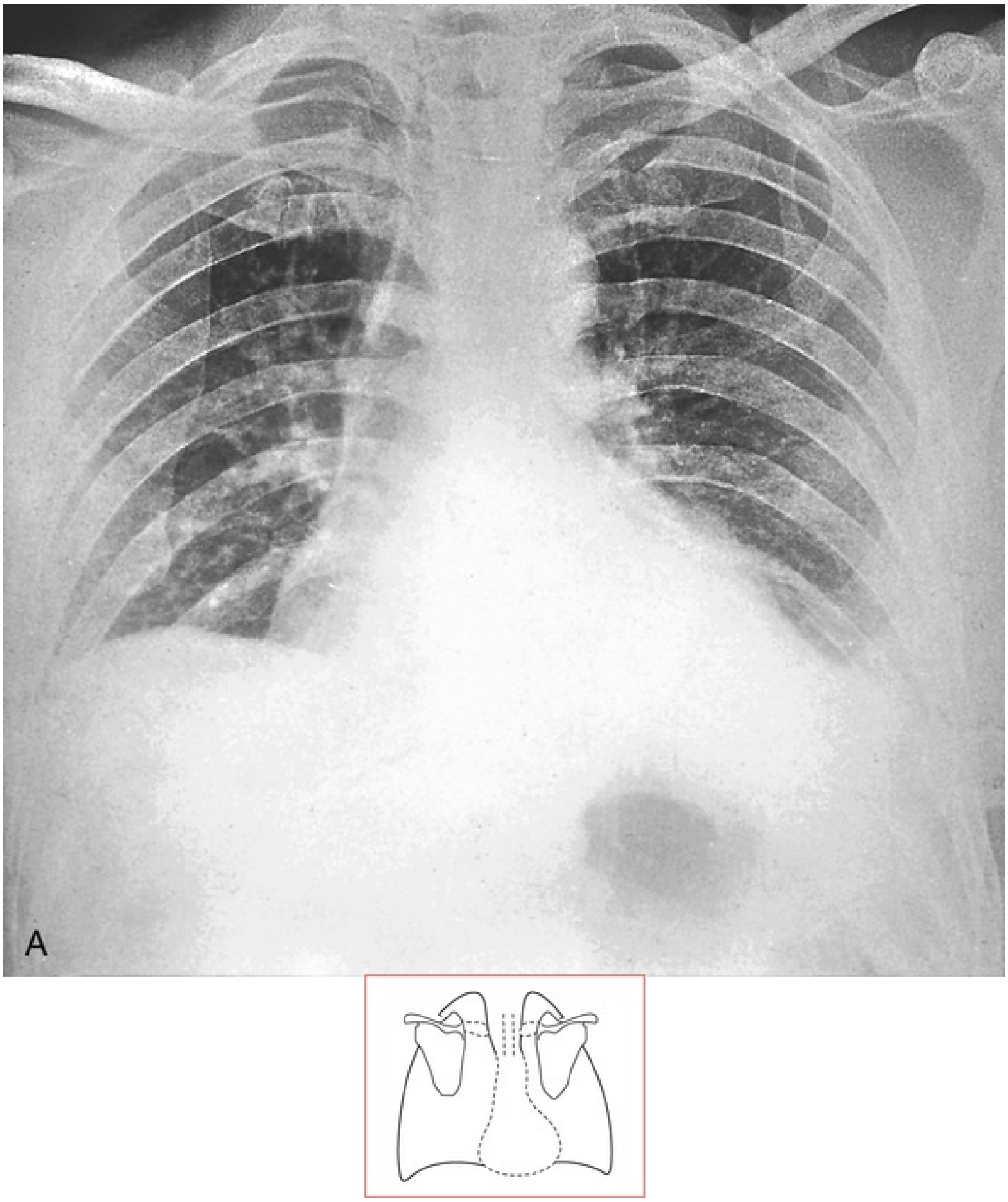
To gain the most information from an x-ray, and avoid inevitable panic when you see an abnormality, adopt the following procedure:

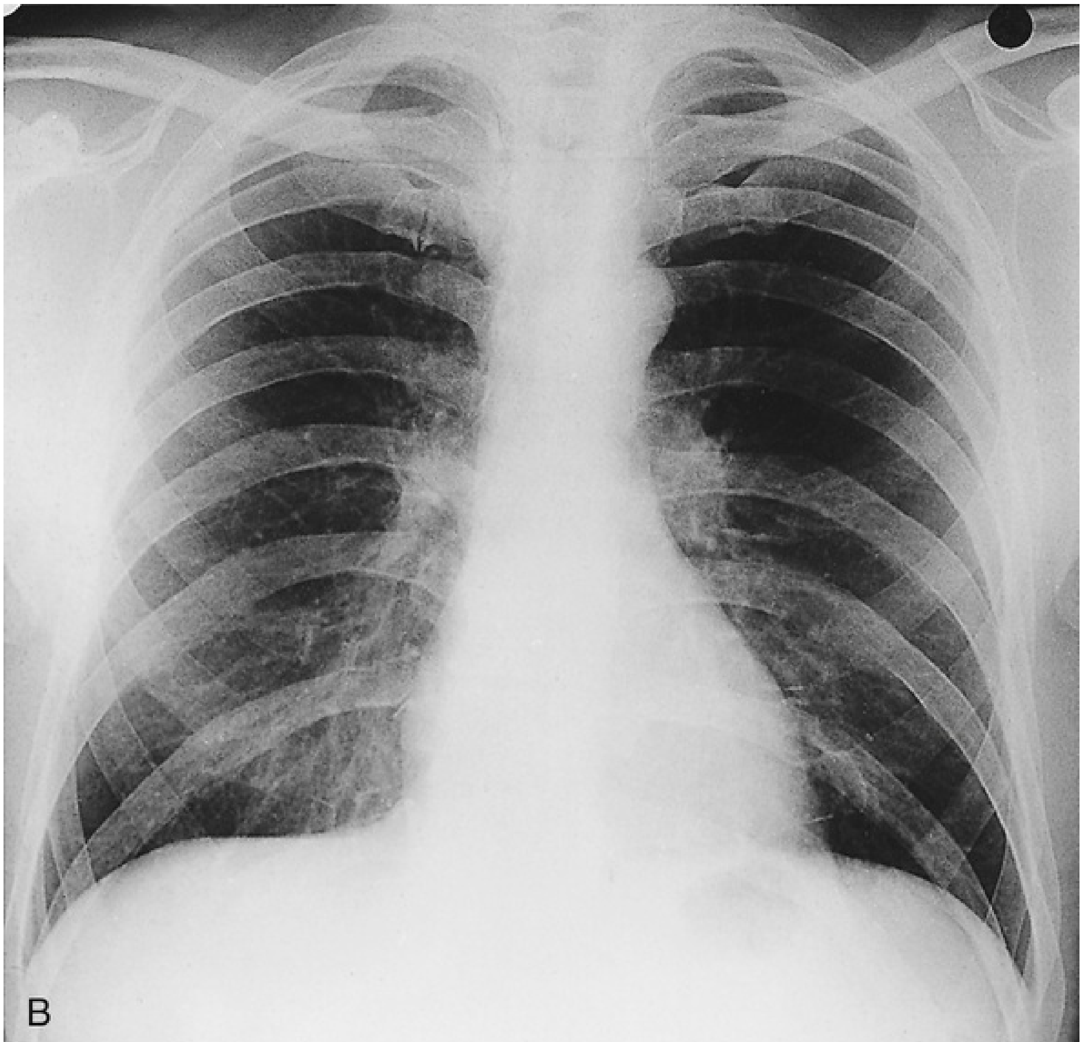
1. Check the name and the date.
2. If you are using a picture-archiving system, see whether previous x-rays are on the system for comparison. The patient may have had previous x-rays which are stored on film. If you cannot access previous films, look for old radiology reports, which may be helpful.
3. Check the technical quality of the film (see p. 4).
4. Scan the film thoroughly and mentally list any abnormalities you find. Always complete this stage. The temptation is to stop when you find the first abnormality but, if you do this you may get so engrossed in determining what it is that you will forget to look at the rest of the film. The explanation of how to scan a film is given on pages 8–11.
5. When you have found the abnormalities, work out where they are. Decide whether the lesion is in the chest wall, pleura, within the lung or mediastinum. Chapter 2 explains how to localise lesions within the lung and the heart, Chapter 8 the mediastinum and Chapter 9 the ribs.
6. Mentally describe the abnormality. Which category does it fall into:
   (a) Too white.
   (b) Too black.
   (c) Too large.
   (d) In the wrong place.

   Chapters 4 to 11 will take you through how to interpret your findings.
7. Always ensure that the film is reported on by a radiologist. Basic interpretation of the CXR is easy, but more subtle signs require the trained eye of a radiologist. Seeking a radiologist's opinion can often expedite a diagnosis or the radiologist may suggest further imaging.
8. Finally, do not forget the patient. It is possible and, indeed, quite common for a very sick patient to have a normal CXR.

## Technical Quality

Always check the technical quality of any film before interpreting it further. To do this you need to examine in turn the projection, orientation, rotation, penetration and degree of inspiration. Problems with any of these can make interpretation difficult and unless you check the technical quality carefully you may misinterpret the film (Fig. 1.2A–D).

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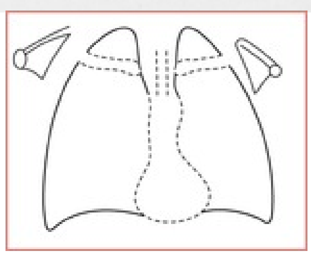

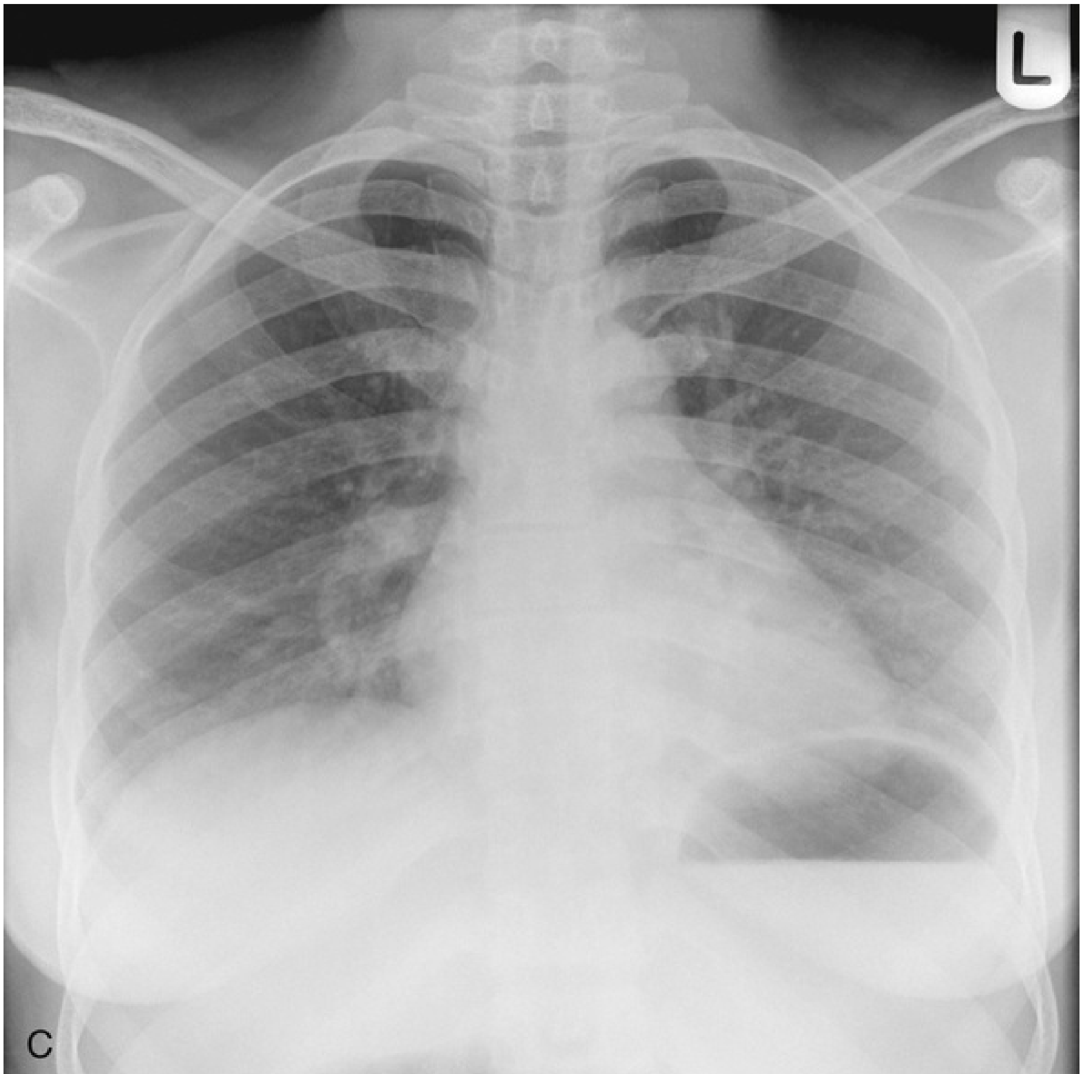
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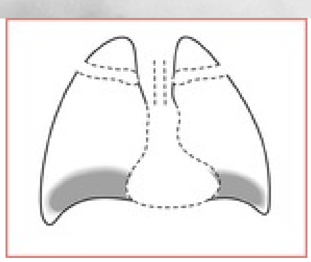


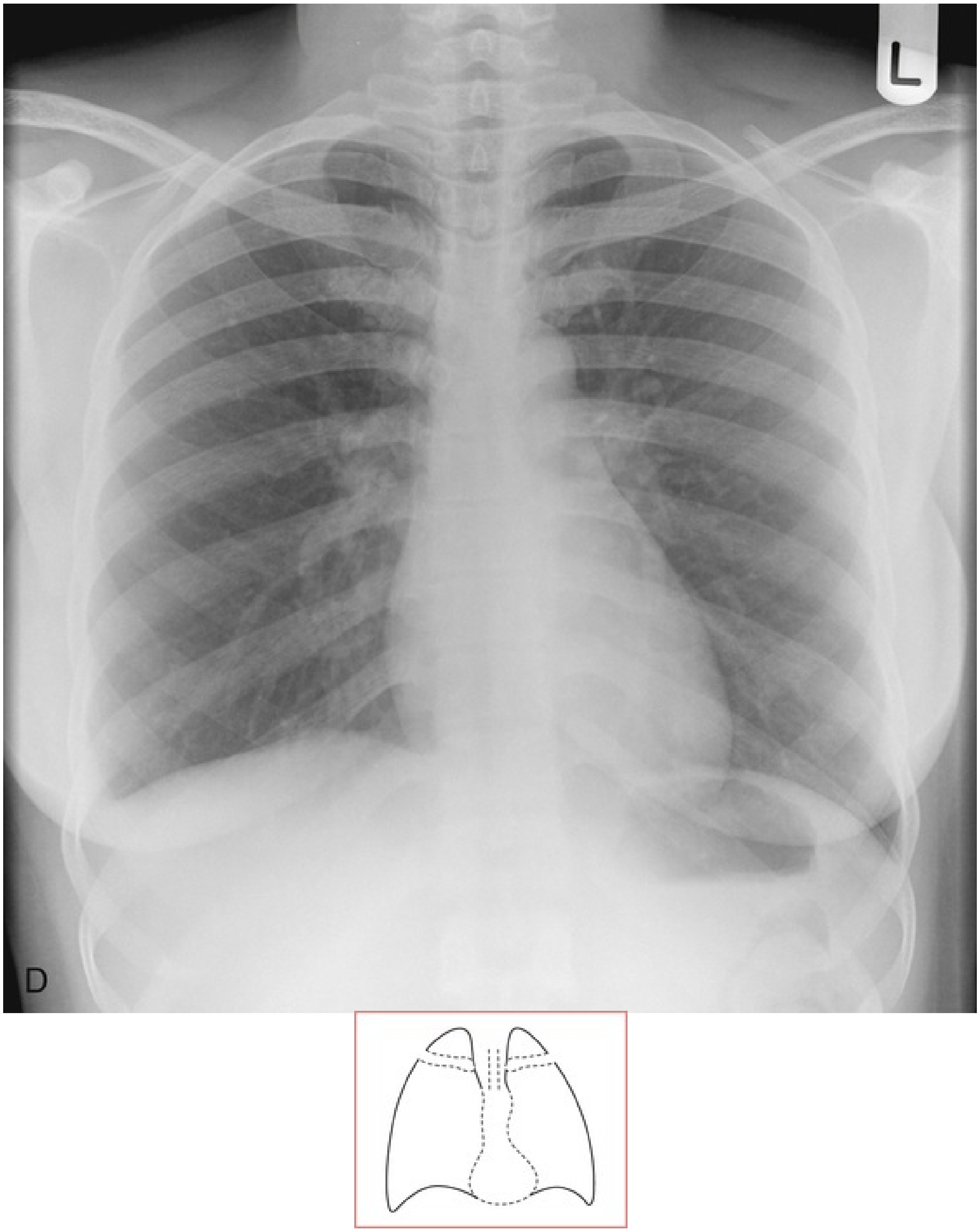



**FIGURE 1.2** The next four x-rays are examples of how the technical quality of a film can affect its appearance and potentially lead to misinterpretation. **(A)** is an anterior-posterior (AP) film which shows how the scapulae are projected over the thorax and the heart appears large.**(B)** is a standard posterior-anterior (PA) projection showing how the scapulae no longer overlie the thorax and the heart size now appears normal. **(C)** is taken with a poor inspiration. Note how poor inspiration makes the lung bases look whiter, and the heart size appears larger.**(D)** is taken with a good inspiration. Note how poor inspiration makes the lung bases look whiter, and the heart size appears larger.

## Projection

Look to see if the film is anterior-posterior (AP) or posterior-anterior (PA). The projection is defined by the direction of the x-ray beam in relation to the patient. In an AP x-ray, the x-ray machine is in front of the patient and the x-ray film at the back. In a PA film, the beam is fired from behind the patient and the film placed in front. The standard CXR is PA but many emergency x-rays are AP because these can be taken more easily with the patient in bed. AP films are marked AP by the radiographer and PA films are often not marked since this is the standard projection. If you are not sure then look at the scapulae. If the scapulae overlie the lung fields then the film is AP. If they do not it is most likely PA. If the x-ray is AP you need to be cautious about interpretation of the heart size, which will appear magnified on an AP film because the heart is anterior. The shape of the mediastinum can also be distorted. An AP film can be taken with the patient sitting or lying. The film should be marked erect or supine by the radiographer. It is important to note this since the appearance of a supine x-ray can be very different to that of an erect one.

## Orientation

Check the left/right markings. Do not assume that the heart is always on the left. Dextrocardia is a possibility but more commonly the mediastinum can be pushed or pulled to the right by lung pathology. Radiographers always safeguard against this by marking the film left and right. Always check these markings when you first look at the film, but remember the radiographer can sometimes make mistakes – if there is any doubt re-examine the patient.

## Rotation

Identify the medial ends of the clavicles and select one of the vertebral spinous processes that falls between them. The medial ends of the clavicles should be equidistant from the spinous process. If one clavicle is nearer than the other, then the patient is rotated and the lung on that side will appear whiter.

A patient with a thoracic scoliosis may appear to have a rotated film. Check whether the spinous processes on the vertebral column are aligned. If they are, it is more likely that the patient is rotated.

## Penetration

To check the penetration, look at the lower part of the cardiac shadow. The vertebral bodies should only just be visible through the cardiac shadow at this point. If they are too clearly visible then the film is over-penetrated and you may miss low-density lesions. If you cannot see them at all then the film is under-penetrated and the lung fields will appear falsely white. When comparing x-rays it is important to check that the level of penetration is similar.

## Degree of inspiration

To judge the degree of inspiration, count the number of ribs above the diaphragm. The midpoint of the right hemidiaphragm should be between the 5th and 7th ribs anteriorly. The anterior end of the 6th rib should be above the diaphragm as should the posterior end of the 10th rib. If more ribs are visible the patient is hyperinflated. If fewer are visible the patient has not managed a full intake of breath, perhaps due to pain, exhaustion or disease. It is important to note this, as a poor inspiration will make the heart look larger, give the appearance of basal shadowing and cause the trachea to appear deviated to the right. Remember also that patients are all different shapes. Some are broad with relatively short chests and some are tall with long chests. To assess whether the patient has failed to take a deep breath in or simply has a short chest it can be useful to compare the current x-ray with previous ones. If the number of ribs above the diaphragm has changed then it is likely to be due to changes in the degree of inspiration.

# Scanning the POSTERIOR-ANTERIOR (PA) Film

If you are using a workstation or computer screen, the amount you will see will depend on the resolution of the screen. Make sure you are using a suitable screen and turn down the ambient lighting. You may wish to use an alternative screen if the image is not clear enough. At a workstation the contrast and brightness of the image can be altered to bring out subtle abnormalities; for example, inverting black and white can help make detection of rib abnormalities easier.

If you are looking at a printed film, use a decent viewing box and lower the ambient lighting. Survey the x-ray from a distance (about 4 ft/1.2 m) and then close up (Fig. 1.3).

1. *Lung fields*. These should be of equal transradiancy and one should not be any

whiter or darker than the other. Try to identify the horizontal fissure **(1)** (this may be difficult to see) and check its position. It should run from the hilum to the 6th rib in the axillary line. If it is displaced then this may be a sign of lung collapse.

An important sign of many lung diseases is loss of volume of that lung and so you need to determine whether either of the lung fields is smaller than it should be. This is difficult since the presence of the heart makes the left lung field smaller. As you see more and more CXRs, however, you will gain an appreciation of how the two lung fields should compare in size and therefore be able to detect when one is smaller than it should be.

Look for any discrete or generalised shadows. These are described in Chapter 4 – The white lung field. Remember that the shadows that appear to be in the lung can represent abnormalities anywhere from the patient's clothing and jewellery inwards.

2. *Look at the hilum*. The left hilum **(2)** should be higher than right **(3)** although the difference should be less than 2.5 cm. Compare the shape and density of the hila. They should be concave in shape and look similar to each other. Chapter 6 describes how to interpret hilar abnormalities.
3. *Look at the heart*. Check that the heart is of a normal shape and that the maximum diameter is less than half of the transthoracic diameter at the broadest part of the chest. Check that there are no abnormally dense areas of the heart shadow. Chapter 7 takes you through interpretation of the abnormal heart shadow.
4. *Check the rest of the mediastinum*. The edge of the mediastinum should be clear although some fuzziness is acceptable at the angle between the heart and the diaphragm. A fuzzy edge to any other part of the mediastinum suggests a problem with the neighbouring lung (either collapse or consolidation) dealt with in Chapter 4. Interpretation of the widened mediastinum is dealt with in Chapter 8.

   Look also at the right side of the trachea. The white edge of the trachea **(4)** should be less than 2–3 mm wide on an *erect* film. (See Chapter 8 for interpretation.)
5. *Look at the diaphragms*. The right diaphragm **(5)** should be higher than the left **(6)** and this can be remembered by thinking of the heart pushing the left diaphragm down. The difference should be less than 3 cm. The outline of the diaphragm should be smooth. The highest point of the right diaphragm should be in the middle of the right lung field and the highest point of the left

diaphragm slightly more lateral.

6. *Look specifically at the costophrenic angles* **(7)**. They should be well-defined acute angles.
7. *Look at the trachea* **(8)**. This should be central but deviates slightly to the right around the aortic knuckle **(9)**. If the trachea has been shifted it suggests a problem within the mediastinum or pathology within one of the lungs.
8. *Count the ribs*. The posterior ribs are more obvious and appear horizontal. The anterior ribs are more difficult to see and point downwards.
   You need to identify the first rib, which can be difficult as the ribs are crowded at the apex. It is easier to identify the anterior part of the first rib. Follow this backwards.
   You are now looking at the posterior part of the first rib and can count the posterior ribs downwards.
9. *Look at the bones*. Look more closely at the ribs as well as the scapulae and vertebrae, clavicle and humerus. Follow the edges of each individual bone to look for fractures. Look for areas of blackness within each bone and compare the density of the bones, which should be the same on both sides. Sometimes turning the image on its side can make rib fractures easier to see.
10. *Soft tissues*. Look for any enlargement or abnormalities of the soft tissues.
11. *Look at the area under the diaphragm*. Look for air under the diaphragm or obviously dilated loops of bowel. Remember that abdominal pathology can occasionally present with chest symptoms.

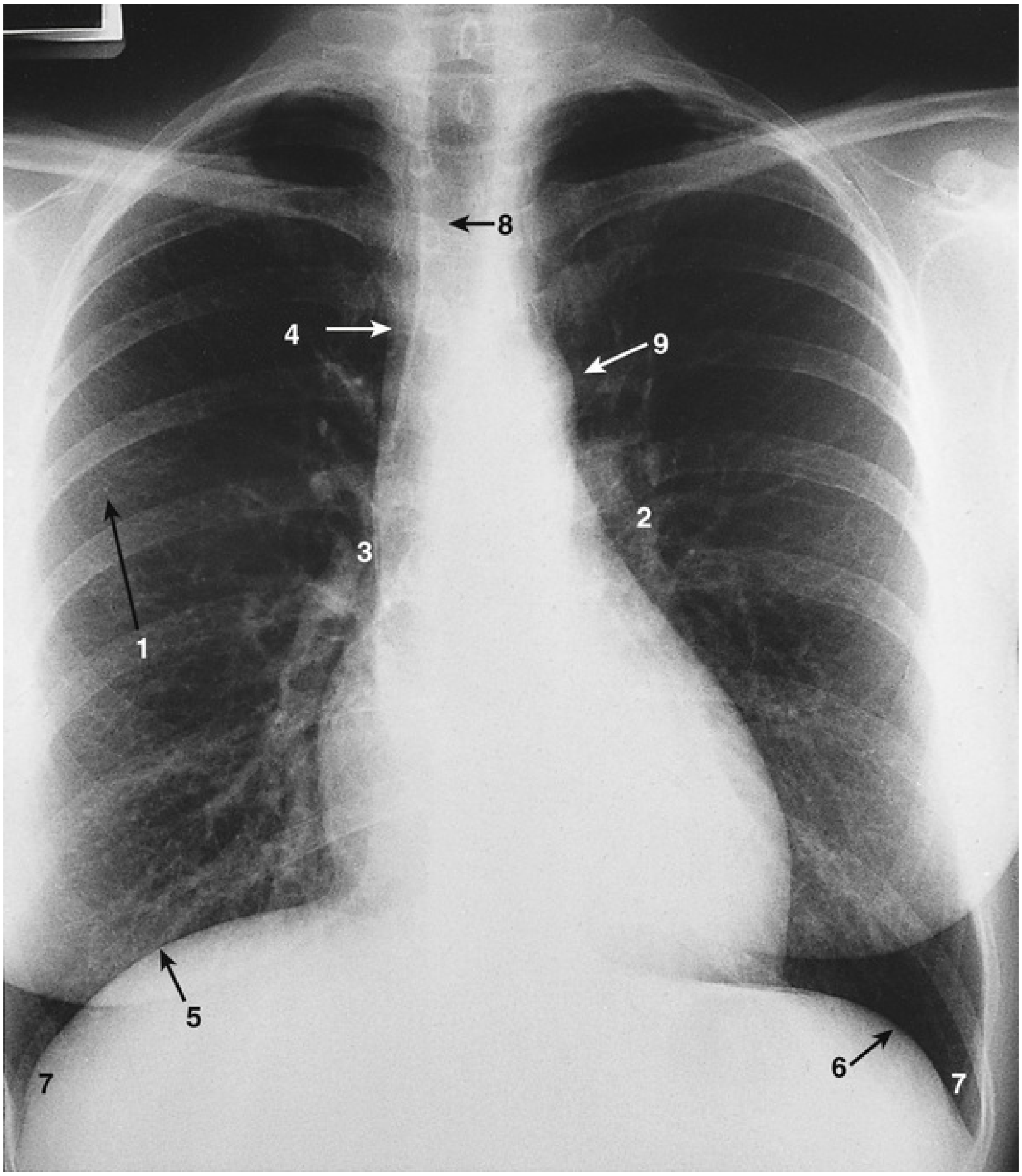



**FIGURE 1.3** The posterior-anterior (PA) film. **(1)** Horizontal fissure; **(2,3)** Left and right hilum; **(4)** Trachea; **(5,6)** Right and left diaphragm; **(7)** Costophrenic angles; **(8)** Trachea; **(9)** Aortic knuckle.

## How to Look at the Lateral Film

A lateral CXR can be taken with either the right or left side of the patient against the film. Do not worry about which way it has been taken, since for all but the most subtle signs, it makes little difference. It is useful to get into the habit of always looking at the film the same way and we suggest looking at the film with the vertebral column on the right and the front of the chest on the left (Fig. 1.4). Once you have done this:

1. Check the name and the date.
2. Identify the diaphragms. The right hemidiaphragm **(1)** can be seen to stretch across the whole thorax and can be clearly seen passing through the heart border. The left hemidiaphram **(2)** seems to disappear when it reaches the posterior border of the heart.

   Another method of identifying the diaphragms is to look at the gastric air bubble **(3)**. Look again at the PA film and work out the distance between the gastric air bubble (which falls under the left diaphragm) and the top of the left diaphragm. Make a note of this. Now go back to the lateral. The diaphragm that is the same distance above the gastric air bubble is the left diaphragm.

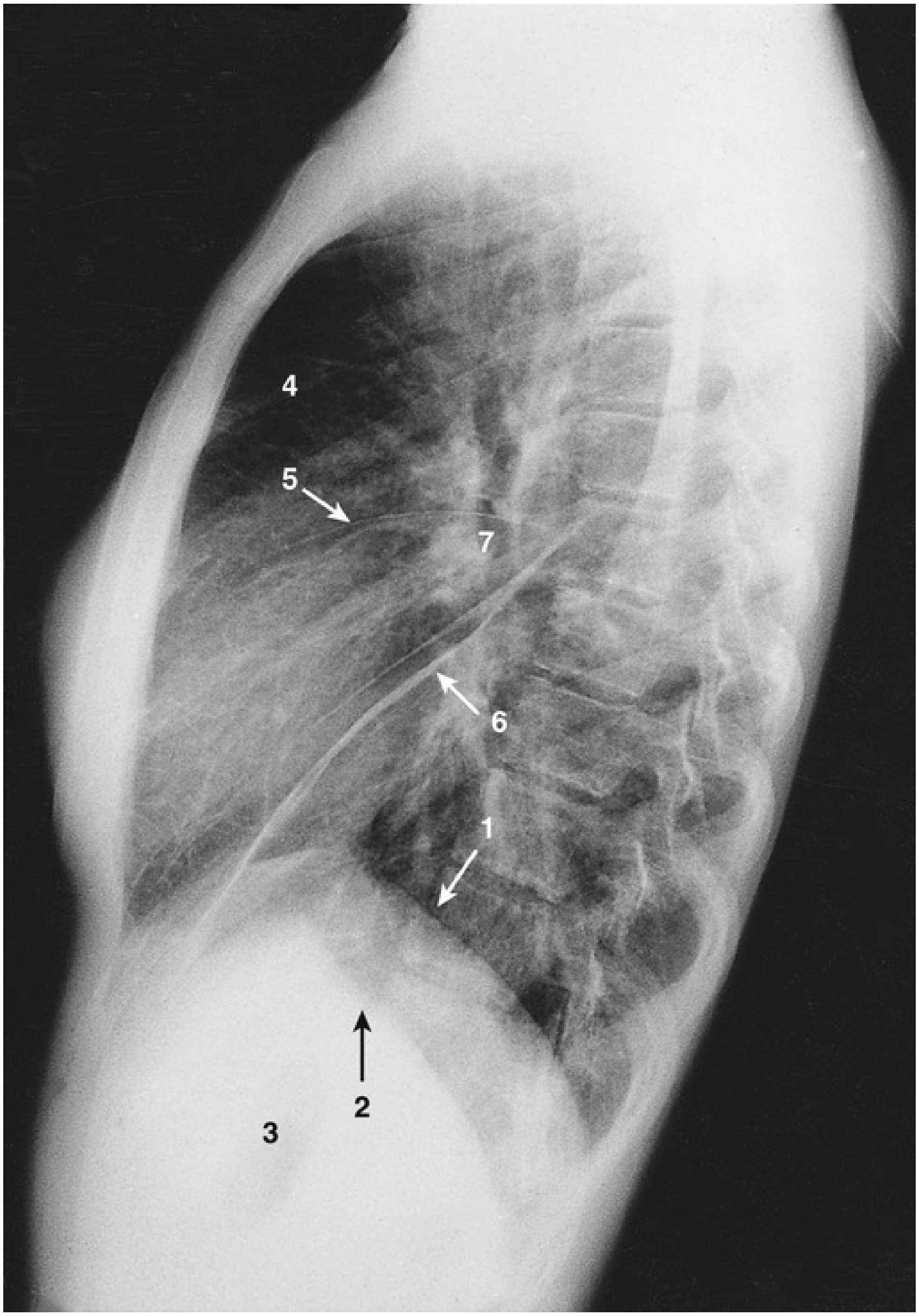


**FIGURE 1.4** Lateral film. **(1,2)** Right and left hemidiaphragm; **(3)** Gastric air bubble; **(4)** Retrosternal space; **(5)** Horizontal fissure; **(6)** Oblique fissure; **(7)** Hila.

You can now set about interpreting the film. Adopt the following process:

1. Compare the appearance of the lung fields in front of and above the heart to those behind. They should be of equal density. Check that there are no

discrete lesions in either field.

2. Look carefully at the retrosternal space **(4)**, which should be the blackest part of the film. An anterior mediastinum mass will obliterate this space, turning it white.
3. Check the position of the horizontal fissure **(5)**. This is a faint white line which should pass horizontally from the midpoint of the hilum to the anterior chest wall. If the line is not horizontal the fissure is displaced. Check the position of the oblique fissure **(6)**, which should pass obliquely downwards from the T4/T5 vertebrae, through the hilum, ending at the anterior third of the diaphragm.
4. Check the density of the hila **(7).** A hilar mass may make the hila whiter than usual.
5. Check the appearance of the diaphragms. Occasionally a pleural effusion is more obvious on a lateral film. Its presence would cause a blunting of the costophrenic angle either anteriorly or posteriorly.
6. Look at the vertebral bodies. These should get more translucent (darker) as one moves caudally. Check that they are all the same shape, size and density. Look for collapse of a vertebra or for vertebrae that are significantly lighter or darker than the others, which may indicate bone disease. Consolidation in the posterior costophrenic sulcus can also make the vertebral bodies appear abnormally white.

2

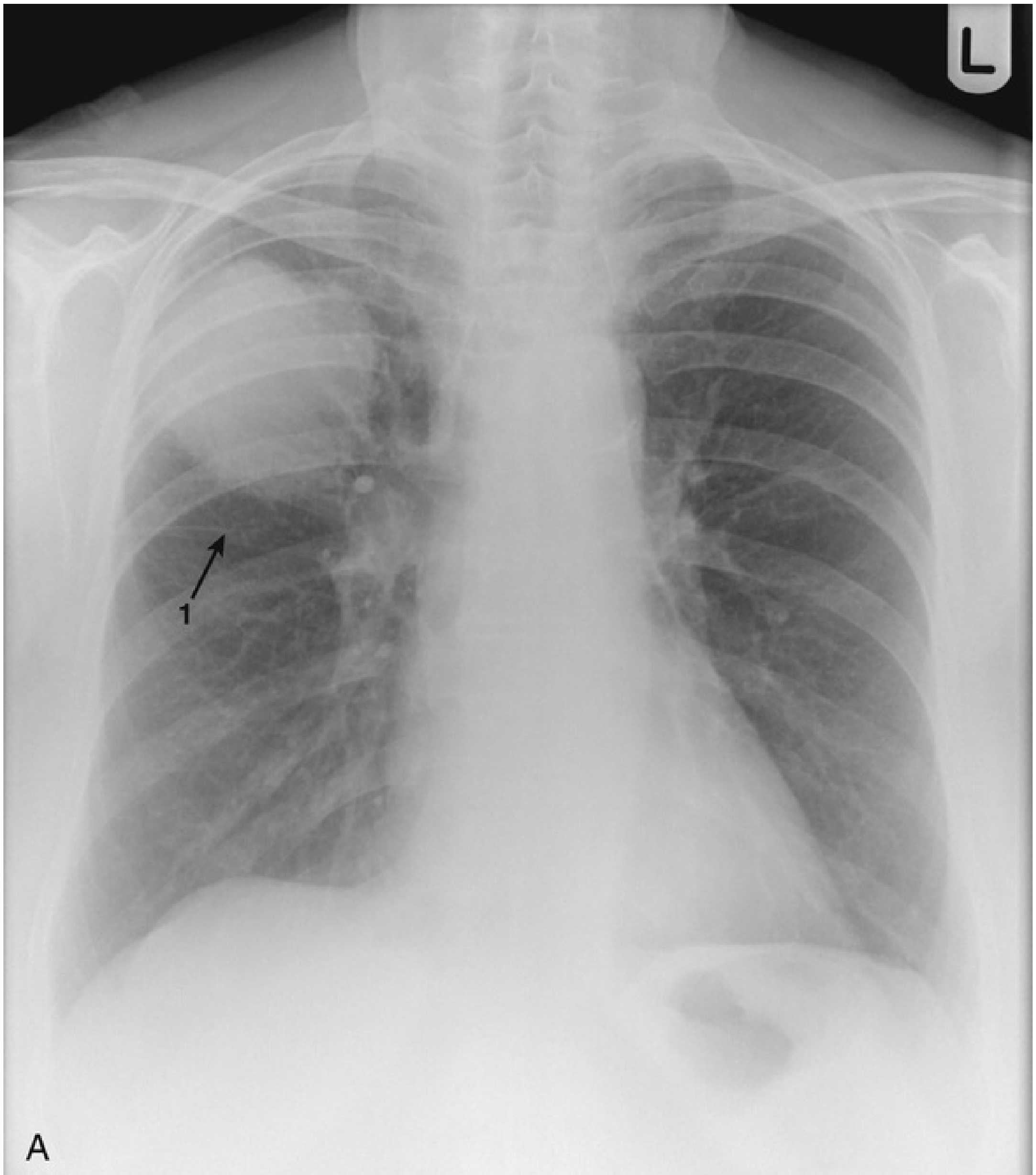
# Localising lesions



## The Lungs

As well as knowing what a lesion is, it is often important to know its position within the lung. To accurately localise a lesion on a chest x-ray (CXR) you need to look at both the posterior-anterior (PA) and lateral films. First look at the PA film (Fig. 2.1A, B):

1. The position of the lesion can be described in terms of zones. The upper zone lies above the right anterior border of the 2nd rib, the middle zone between the right anterior borders of the 2nd and 4th ribs, and the lower zone between the right anterior border of the 4th rib and the diaphragm. Although this is useful descriptively it does not give any information about the lobes of the lung.
2. Look at the borders of the lesion. If the lesion is next to a dense (white) structure then the border between the lesion and that structure will be lost – this is called the silhouette sign. Therefore if the lesion is in the right lung and obscures part of the heart border it must be in the right middle lobe. If it obscures the border of the diaphragm it is in the right lower lobe.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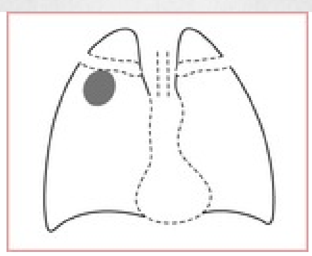
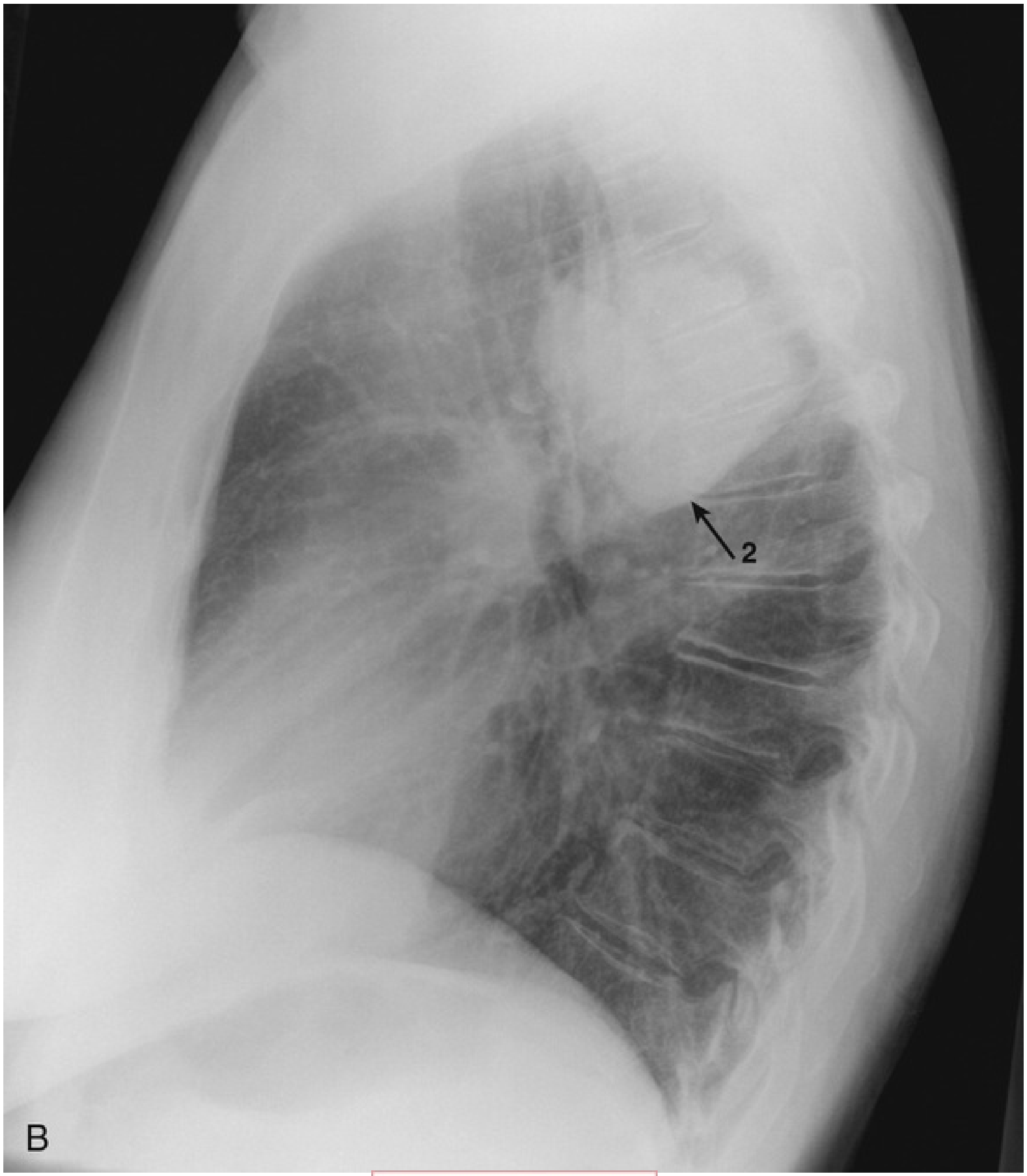




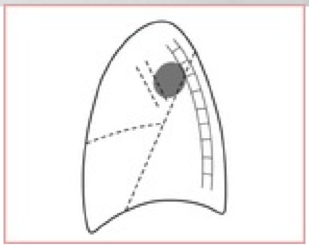



**FIGURE 2.1** The x-ray shows a right upper zone mass lesion. **(A)** The PA film shows that it lies above the horizontal fissure **(1)**. The lateral film **(B)** shows that it lies in front of the oblique fissure, as well as above the horizontal fissure **(2)**, so the mass lies in the right upper lobe.

If the lesion is not going to be localised by computed tomography (CT), then a lateral film will be needed.

Using the lateral film, if the lesion is in the right lung:

1. Identify the oblique fissure (see p. 11). If the lesion lies posterior to the oblique fissure it must lay within the lower lobe no matter how high it appears on the PA film.
2. If the lesion lies anterior to the oblique fissure it may be in the upper or middle lobe. Identify the horizontal fissure (see p. 11). If the lesion is below the horizontal fissure it is in the middle lobe. If it is above it is in the upper lobe.

If the lesion is in the left lung:

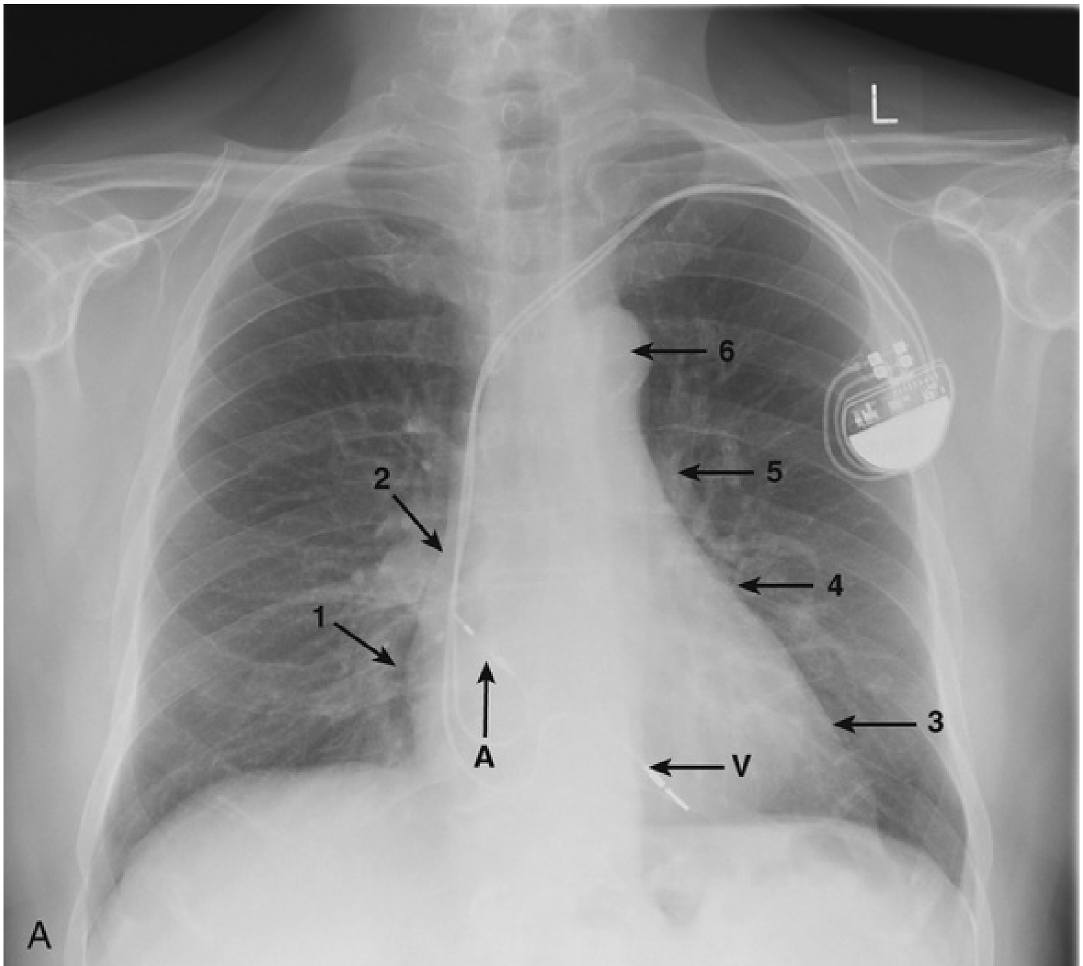
1. Identify the oblique fissure. If it is behind the oblique fissure it must be in the lower lobe. If it is anterior to the oblique fissure it is within the upper lobe – there is no middle lobe on the left!

See Chapter 3, which describes localising using CT scanning.

## The Heart

In order to fully assess any abnormalities of the shape of the heart it is important to understand the composition of the heart shadow. Look at Figure 2.2A, B and Figure 2.3A, B.

1. Look at the right heart border and follow it up from the diaphragm. From the diaphragm to the hilum the heart border is formed by the edge of the right atrium (**1**). From the hilum upwards it is formed by the superior vena cava (**2**).
2. Follow the left heart border up from the diaphragm. From the diaphragm up to the left hilum it consists of the left ventricle (**3**). The left border is then concave at the lower level of the left hilum and here it is made up of the left atrial appendage (**4**). This concavity is lost when the left atrium is enlarged, leading to a straightening of the left heart border and sometimes the development of a convexity at this point. At the level of the hilum the border is made up of the pulmonary artery (**5**) and above this the aortic knuckle (**6**).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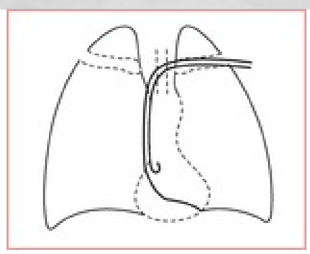
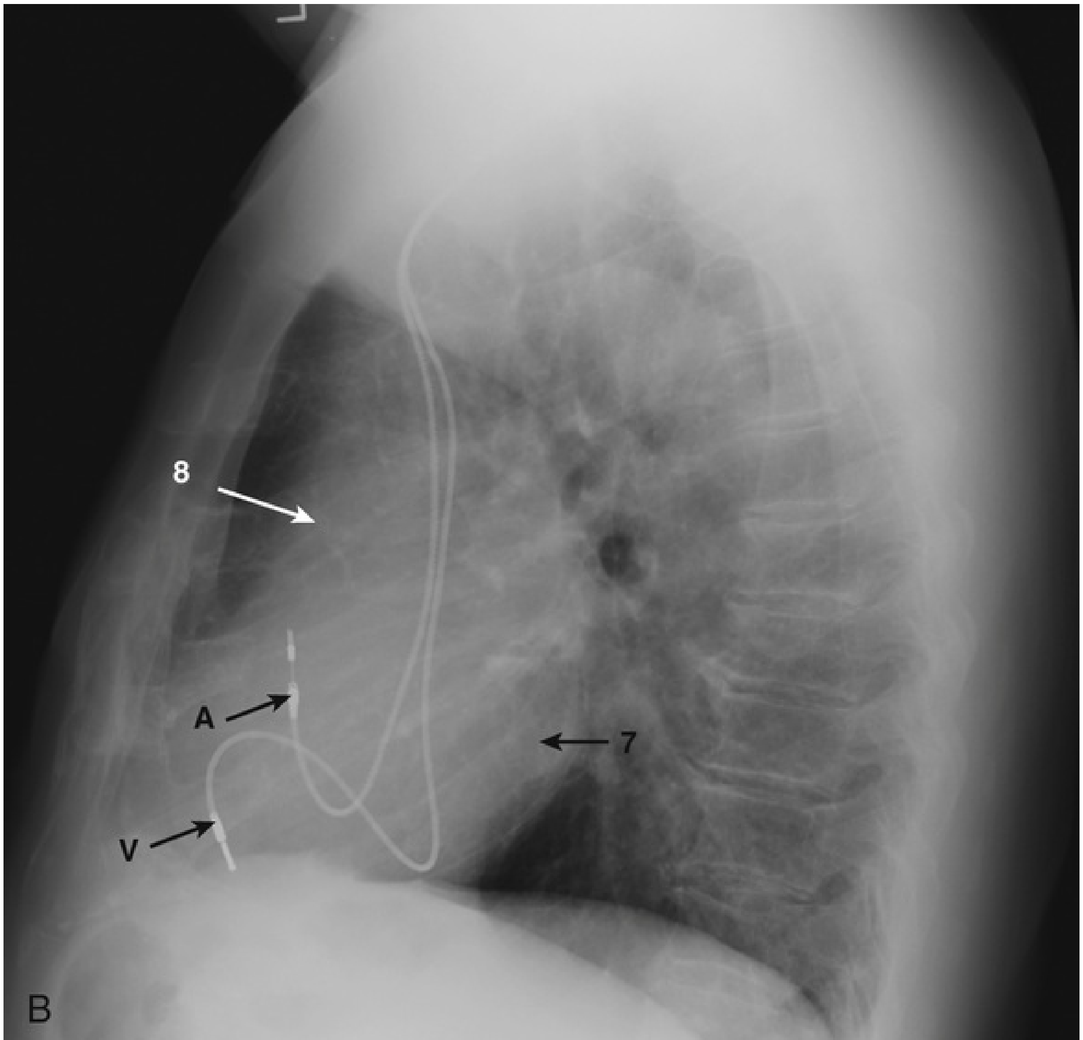




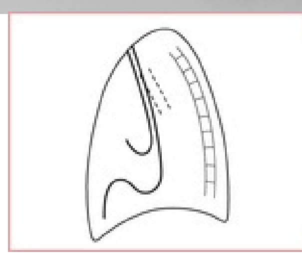
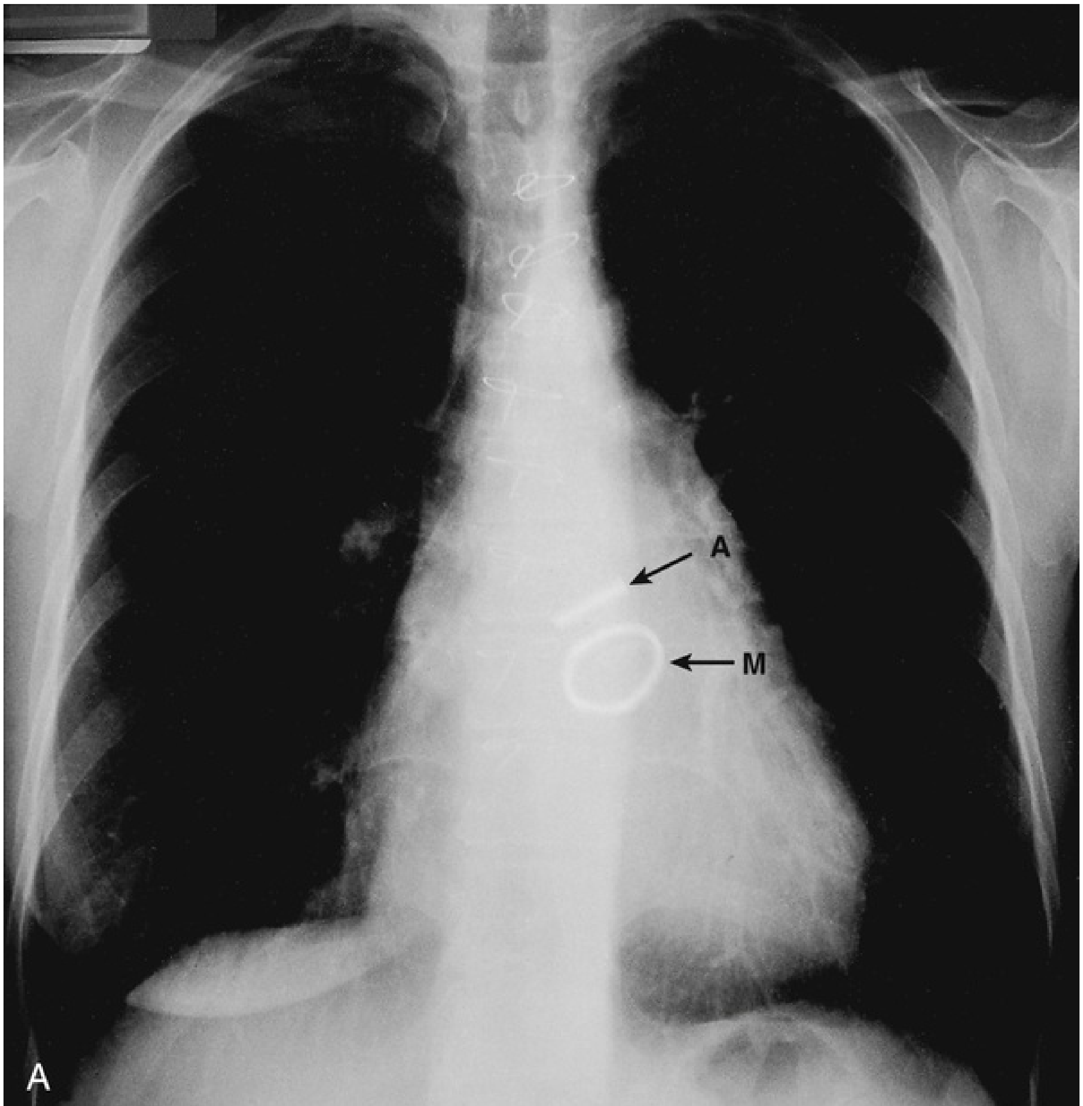



**FIGURE 2.2** **(A)** This x-ray is of a patient with an atrial (A) and ventricular (V) pacing wire, with the pacemaker box over the left anterior chest **(1–6)**. **(1)** Right atrium; **(2)** Superior vena cava; **(3)** Left ventricle; **(4)** Left atrial appendage; **(5)** Pulmonary artery; **(6)**, Aortic knuckle. **(B)** The atrial wire attaches in the right atrial appendage, and the ventricular wire lies across the tricuspid valve and attaches to the wall of the right ventricle. **(7,8)** Left and right ventricle.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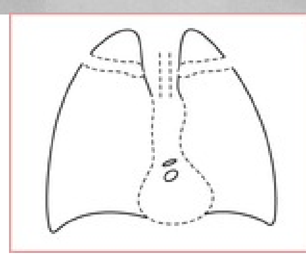


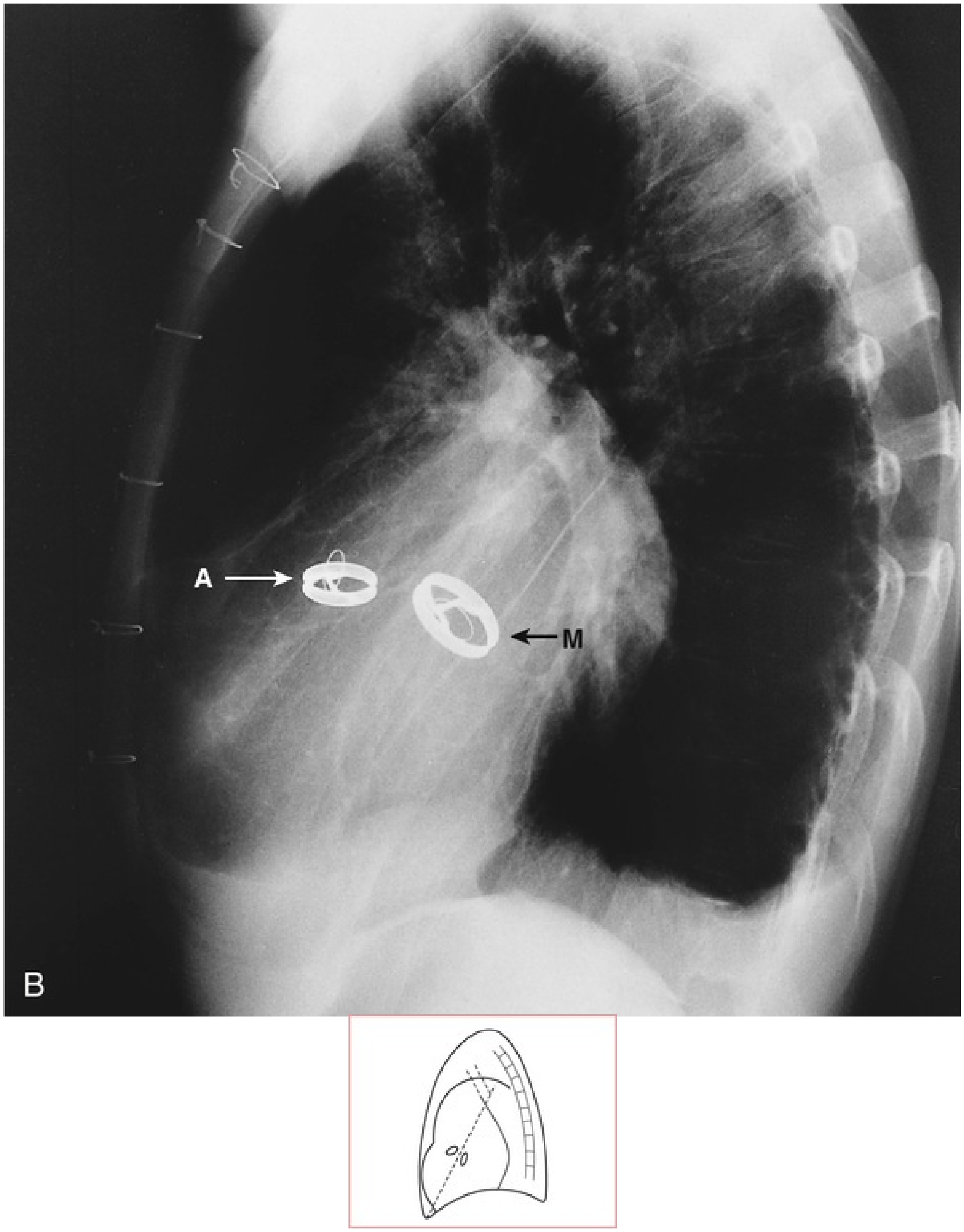



**FIGURE 2.3** Radiographs of a patient with prosthetic aortic (A) and mitral (M) valves showing their position in the **(A)** AP and **(B)** lateral films.

The lateral film is useful. The posterior border of the heart shadow is made up of the left ventricle (**7**) and the anterior border the right ventricle (**8**). For example (see Fig. 2.3A and B), to identify whether a valve replacement is mitral or aortic, draw an imaginary line from the apex of the heart to the hilum. If the replacement valve lies above this line it is aortic and if it lies below or on, it is mitral.

3

# The CT scan

Although the plain chest x-ray (CXR) is one of the most useful imaging techniques, it is limited by the fact that it is a two-dimensional image and small or subtle abnormalities can be overlooked. In other circumstances the CXR will identify an abnormality but will give limited information as to its extent or detailed appearance. Remember also that, although particularly useful for detecting lung abnormalities, the CXR is a very poor way of imaging the mediastinum.

## Computed tomography (CT) scanning

A computed tomography (CT) scanner takes multiple cross-sectional images of the body. A completed CT scan of the chest usually consists of two complete sets of images, one showing mediastinal structures (in which the lung fields look relatively black) and one showing the lung fields in which the mediastinum looks relatively white. These are called the mediastinal and lung windows. These two sets are necessary because there are not enough shades of grey to display adequately both the high-density mediastinal structures and the low-density lungs using one linear scale. In the lung windows the grey scale is expanded across the range of lower-density structures, whereas in the mediastinal windows the scale is expanded over the higher-density structures.

## Types of CT scan

Two main types of CT scans are performed for the chest: contiguous (spiral) and high resolution. You will need to understand the difference between these in order to know what to request and also to appreciate their limitations. If you include all the relevant history on the scan request, and clearly state the question that needs answering, the radiologist is much more likely to undertake the most appropriate scan.

## High-resolution CT scanning (HRCT)

This is a sampling test, which means that not all the lung is examined. With this technique 1–2 mm slices are taken about 10 mm apart. This technique is very good for detecting interstitial lung disease since the thin slices allow for a very detailed assessment of lung architecture (rather like a thin tissue slice enables a pathologist to see more detail). It is not a good technique for finding mass lesions (for example, lung tumours) because the lesion could occur in one of the spaces between the slices and so be missed. The high-resolution CT (HRCT) scan is usually acquired over several breath holds.

Intravenous contrast would not be used with HRCT, since contrast would need to be given before each individual image was taken – something that is clearly impossible.

## Contiguous (spiral) CT

This is also called helical CT or volumetric CT. In this technique the anode of the scanner rotates continuously whilst the table on which the patient lies is moved at a predetermined speed. This technique has the advantage that it is extremely quick – 7 to 10 seconds. The whole chest is scanned, so that small lesions are not likely to be missed, unlike in HRCT where there is a gap between the slices. Sometimes patients are so breathless that they breathe during the scan, causing blurring of the images and making interpretation more difficult.

Spiral CTs are used when intravenous contrast needs to be administered, for example when staging a lung cancer or detecting a pulmonary embolus. The exact timing of the administration of contrast depends on the abnormality being sought. For example, contrast will be injected at a different time for the detection of a pulmonary embolus than it would be if it was being used to enhance the structures of the mediastinum. This is why it is important to give full clinical details when ordering a CT scan and to be specific about the question being asked. A scan performed to detect a pulmonary embolus will use a different protocol for administration of contrast than a scan performed for the full staging of a lung cancer. The scan can only be interpreted fully if the appropriate protocol has been used.

## Combined imaging

Many CT scanners are able to acquire spiral images, and with the same data set can process the image to produce a high-resolution study. If a patient only needs a HRCT, this should be requested, as combined imaging exposes the patient to a higher radiation dose.

## Interpreting the images

Interpretation of the CT scan requires significant expertise and should only be done by a radiologist. As well as having the experience to interpret the image slices, radiologists have access to software that will allow them to display the images in other forms, for example in the sagittal and coronal planes as well as cross-sectional and three-dimensional images. The CT scans we have included in this book have been chosen because they illustrate situations in which, working on the wards, emergency department or outpatients, you are likely to order scans and a basic knowledge of how they are interpreted will be of use.

## Finding your way around the CT scan

It is complicated, but if you learn a few basic areas of anatomy, the rest can be built on later. As with a plain CXR it is important that you have a scheme to work with. The way to make the anatomy as simple as possible is to learn the basic structures at key slices of the CT scan. Once you have identified the slice and the structures, you can follow these up and down the chest by looking at consecutive slices.

### The mediastinal windows

You first need to look at the mediastinal windows. Figure 3.1A–F illustrates the key slices you should identify. If you learn the anatomy at each of these levels you should be able to find your way around the CT scan.

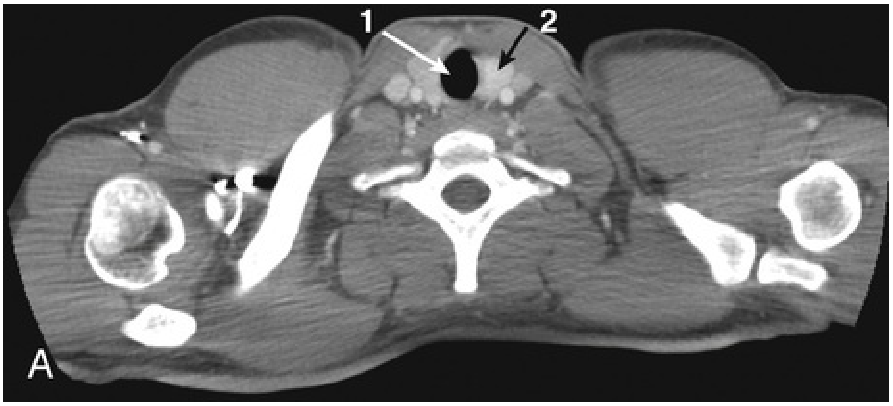



**FIGURE 3.1** **(A)** The trachea in the midline at the front is shown as a dark air-filled structure **(1)**. Around the trachea the white area is the thyroid, which appears white since it contains a lot of iodine **(2)**.

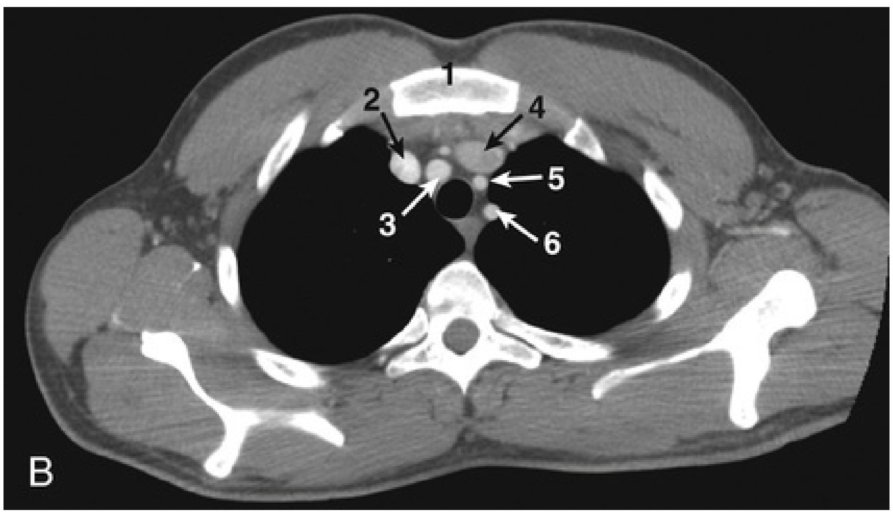



**FIGURE 3.1** **(B)** Starting on the patient's right, the first structure is the right brachiocephalic vein **(2)**. Medial to this is the brachiocephalic artery **(3)**. Just anterolateral to the trachea is the left brachiocephalic vein **(4)**. The two smaller vessels on the left are the left common carotid artery **(5)** followed by the left subclavian artery **(6)**. The manubrium can be seen anteriorly **(1)**.

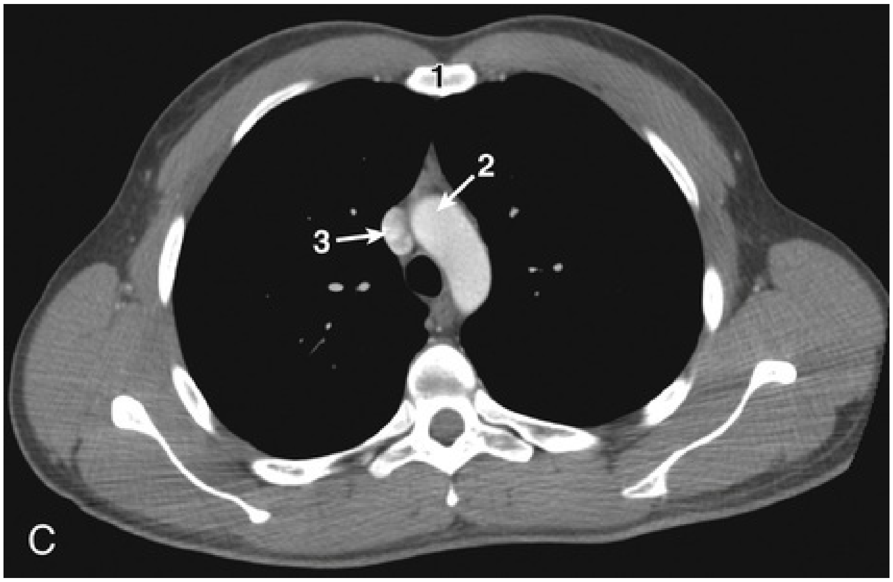



**FIGURE 3.1** **(C)** The most prominent structure is the arch of the aorta **(2)**, which appears as a white oblong structure. The trachea is still visible. Next to this, to the patient's right, is the superior vena cava **(3)**, which has an oval structure. The manubrium can be seen anteriorly **(1)**.

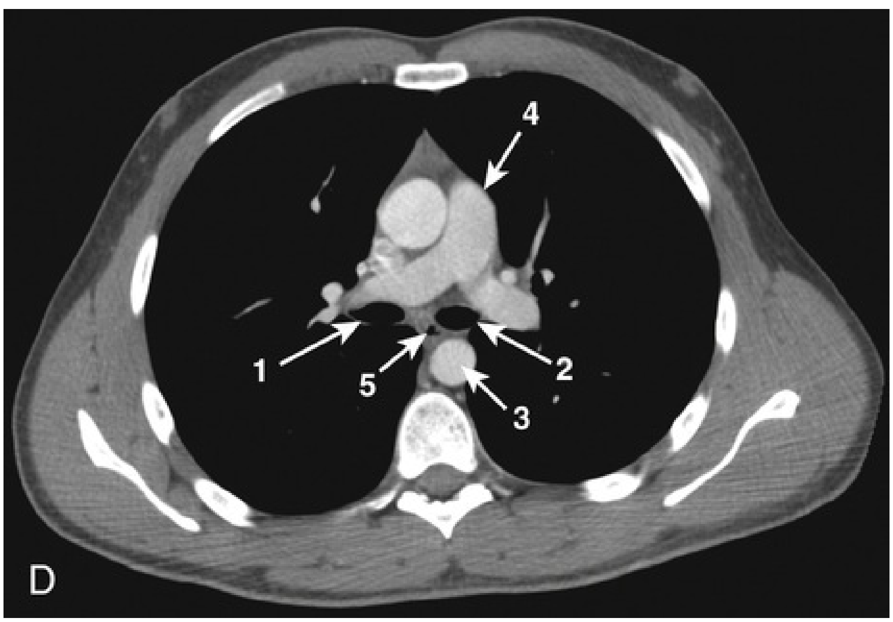



**FIGURE 3.1** **(D)** The main pulmonary trunk **(4)** splitting into the right and left pulmonary branches. You can no longer see the trachea since by this point it has split into the right and left bronchi **(1,2)**. The other big vascular structures are the ascending and descending aorta. The ascending aorta is anterior and the descending aorta **(3)** is posterior next to the spine. The very small black hole in front of the descending aorta is the oesophagus **(5)**.

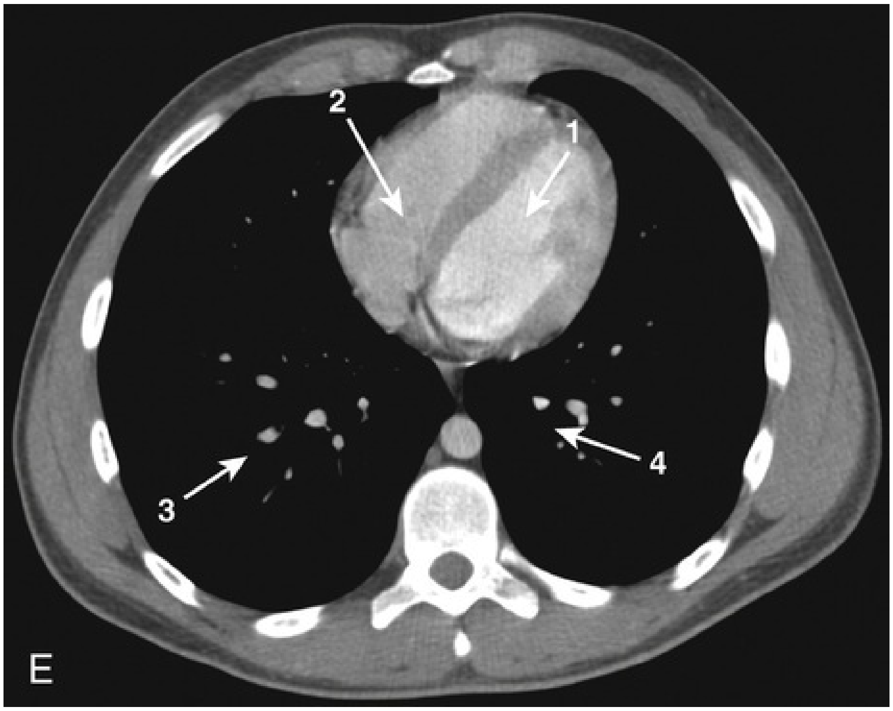



**FIGURE 3.1** **(E)** The left ventricle is the white-filled area on the patient's left **(1)**. It has thick walls which appear around the white area. The right ventricle **(2)** is seen anteriorly to the patient's right. Pulmonary arteries and veins are also visible **(3,4)**.

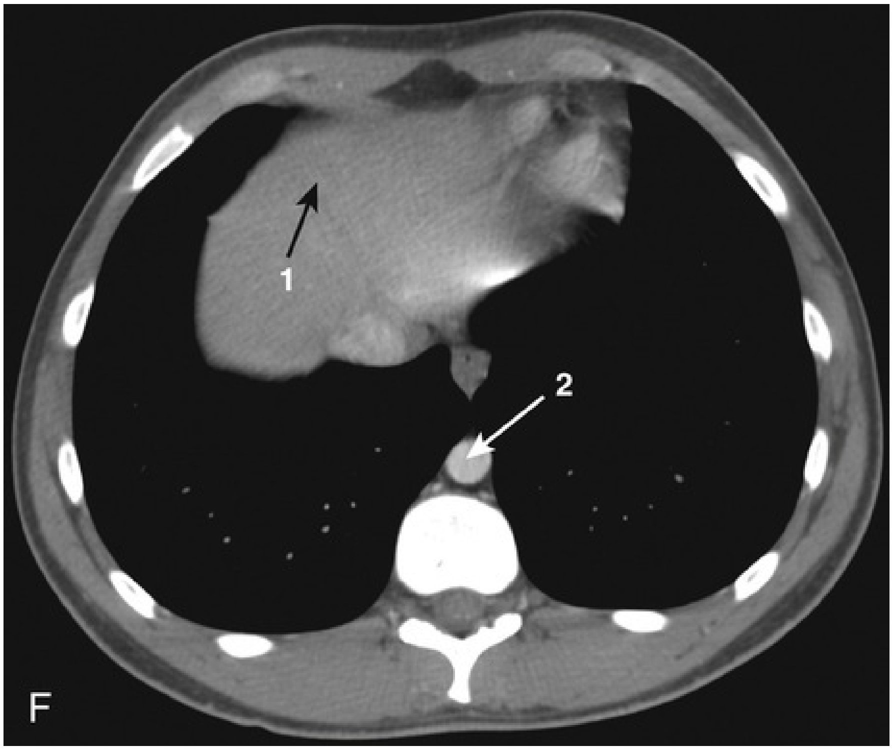



**FIGURE 3.1** **(F)** The liver is now visible **(1)**. Inferior vena cava is visible. The vessel in front of the spine is the descending thoracic aorta **(2)**.

In Figure 3.1A you can see the slice taken through C1 vertebra at the level of the shoulder joints. Figure 3.1B is taken at the level of manubrium, which can be seen as a flat bone anteriorly (**1**). You can see a number of blood vessels which are circular structures within the mediastinum. You need to know the anatomy of these vessels. In Figure 3.1C, you can see the slice taken at the level of the aortic arch. The sternum is visible at the front.

The slice in Figure 3.1D has been taken at the level of the main pulmonary artery seen shaped as an inverted ‘Y’. In Figure 3.1E, the slice has been taken at the lower at the level of the heart. The walls of the right ventricle are thinner than the walls of the left ventricle. At this level you can see a number of small grey/white areas within the lung (**3,4**). These are the pulmonary arteries and veins. In Figure 3.1F, the slice has been taken at the bottom of the lungs and the liver is now visible.

## Focus on Lymph Nodes

The CT scan is a sensitive method for looking at enlarged mediastinal and other nodes. These have to be substantially enlarged to be visible on CXR.

Lymph nodes tend to be oval in shape and are discrete structures. In contrast, blood vessels connect to smaller and larger branches which you can see on adjacent slices. If the scan is contrast enhanced, blood vessels will appear whiter than lymph nodes. Lymph nodes often have a central low-density area as they contain fat in the middle.

An inflamed or malignant node will be enlarged. We describe lymph nodes as enlarged when their shortest diameter is more than 10 mm.

The lymph nodes are situated in particular areas of the mediastinum:

a. Next to the trachea, at many levels.

b. Underneath the aortic arch.

c. In front of and beneath the tracheal bifurcation (known as the carina).

d. At the hila, next to the pulmonary arteries and veins.

The main lymph node groups are shown in Figures 3.2–3.4.


**FIGURE 3.2** Image shows large nodes **(1)** situated to the right of the trachea, which is seen as a black hole **(2)**. These are called paratracheal nodes since they lie to the side of the trachea.

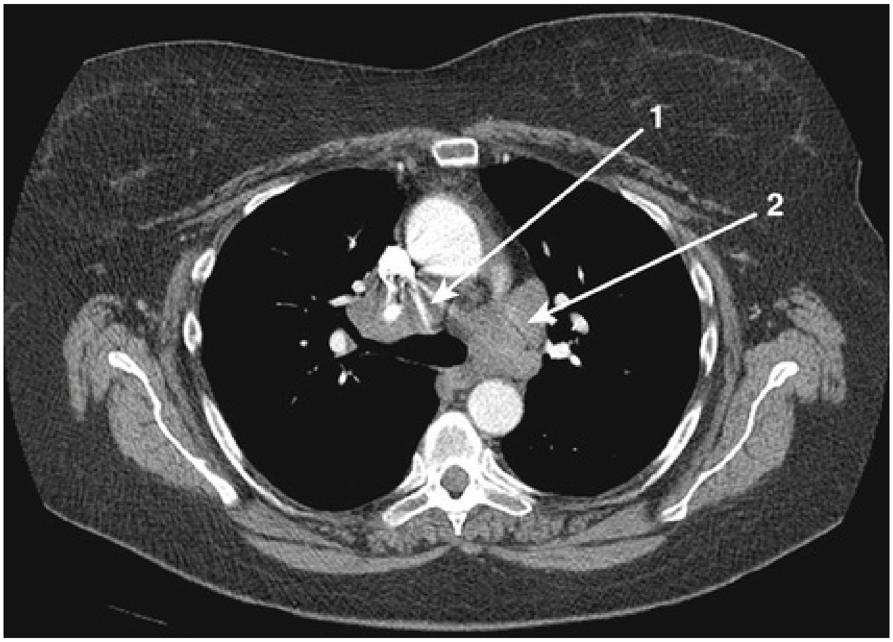



**FIGURE 3.3** Image is taken at the level of the carina. You can see two groups of lymph nodes. The first group **(1)** is in front of the carina and therefore at the lower end of the trachea, and these are called lower paratracheal nodes. The second group **(2)** sits between the ascending and descending aorta just beneath the arch of aorta. These are called aortopulmonary nodes.

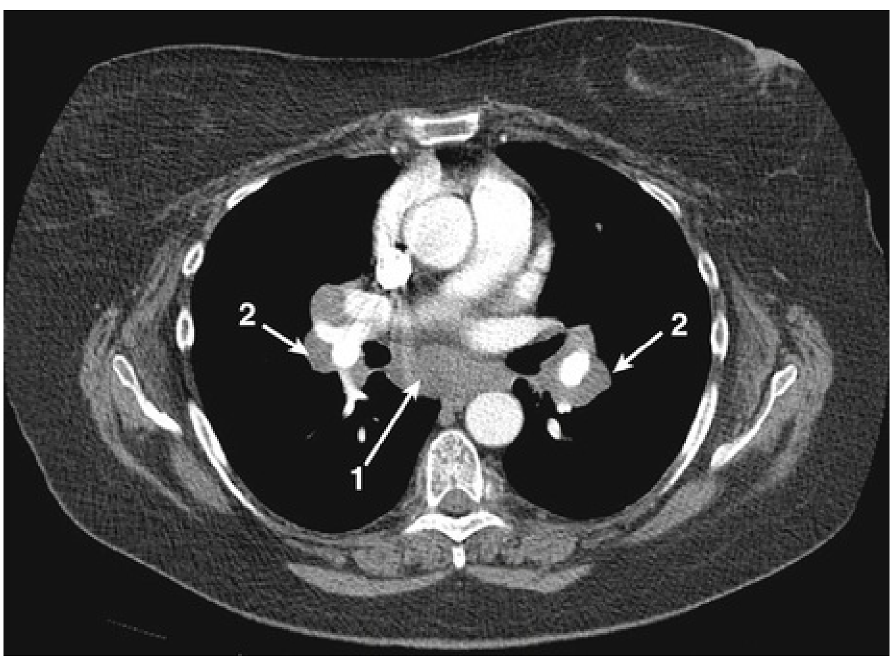



**FIGURE 3.4** This image was taken beneath the level of the carina and you can see the right and left bronchi. There are three groups of enlarged

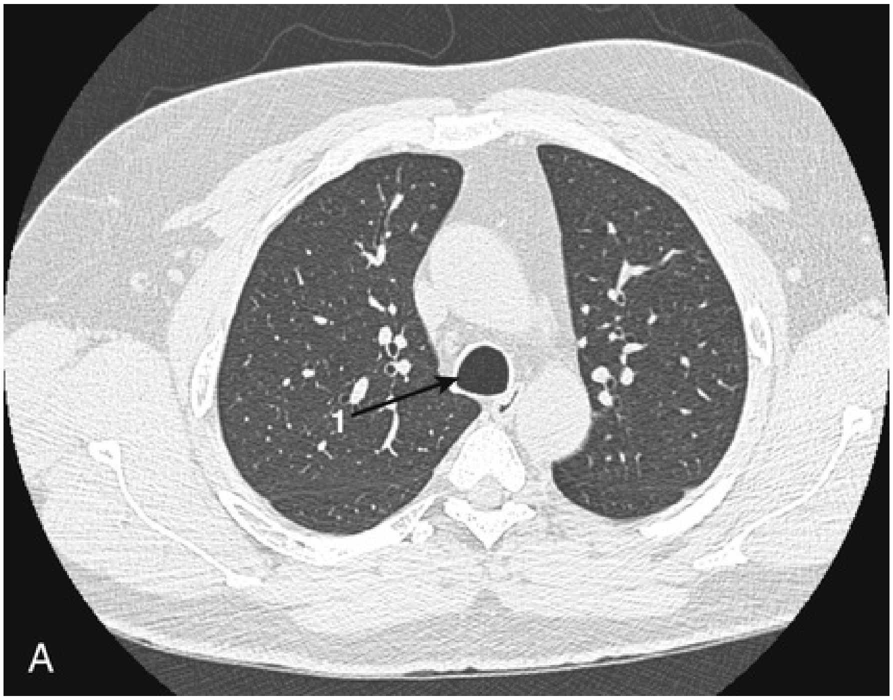
nodes. The first group is situated between the right and left bronchi just under the carina **(1)**. These are called the subcarinal nodes. The other two groups are situated lateral to the right **(2)** and left **(3)** bronchi and are called hilar nodes. The hilar nodes are situated next to the branches of pulmonary arteries, which are seen as white structures since they contain contrast. This illustrates the importance of giving contrast to differentiate lymph nodes from blood vessels.

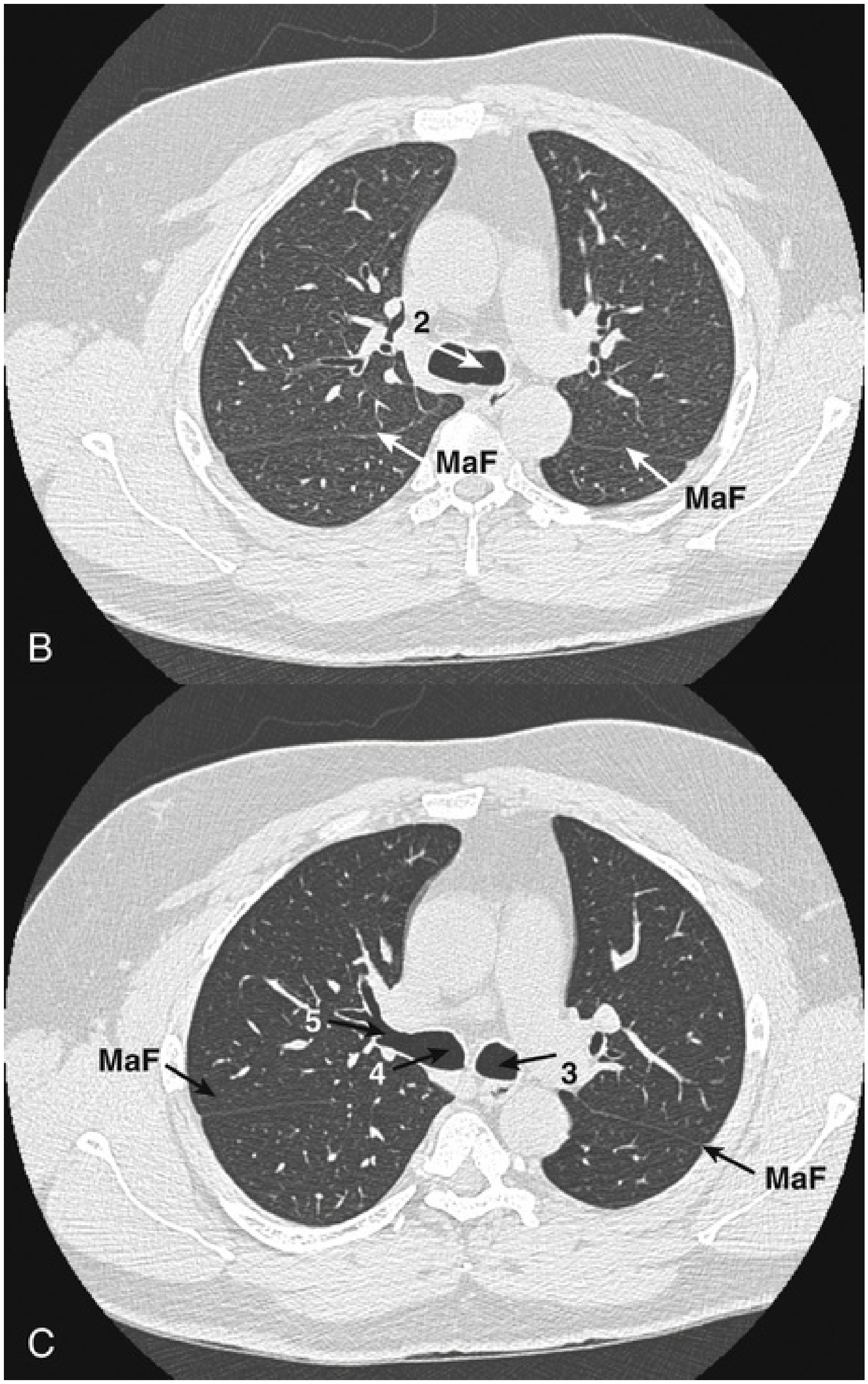
## Bones and other soft tissue

Remember to complete your review of the mediastinal windows by looking at the bones and soft tissues surrounding the lungs. Check that the surfaces of the bones are continuous, as fractures and metastases need to be considered. Also review the soft tissues; the CT enables you to see the skin and subcutaneous fat as well as muscles.

## The lung windows

Now look at the lung windows (see Fig. 3.5A–H). You will need to know how to identify the lobes of the lung, so that you can localise any pathology.

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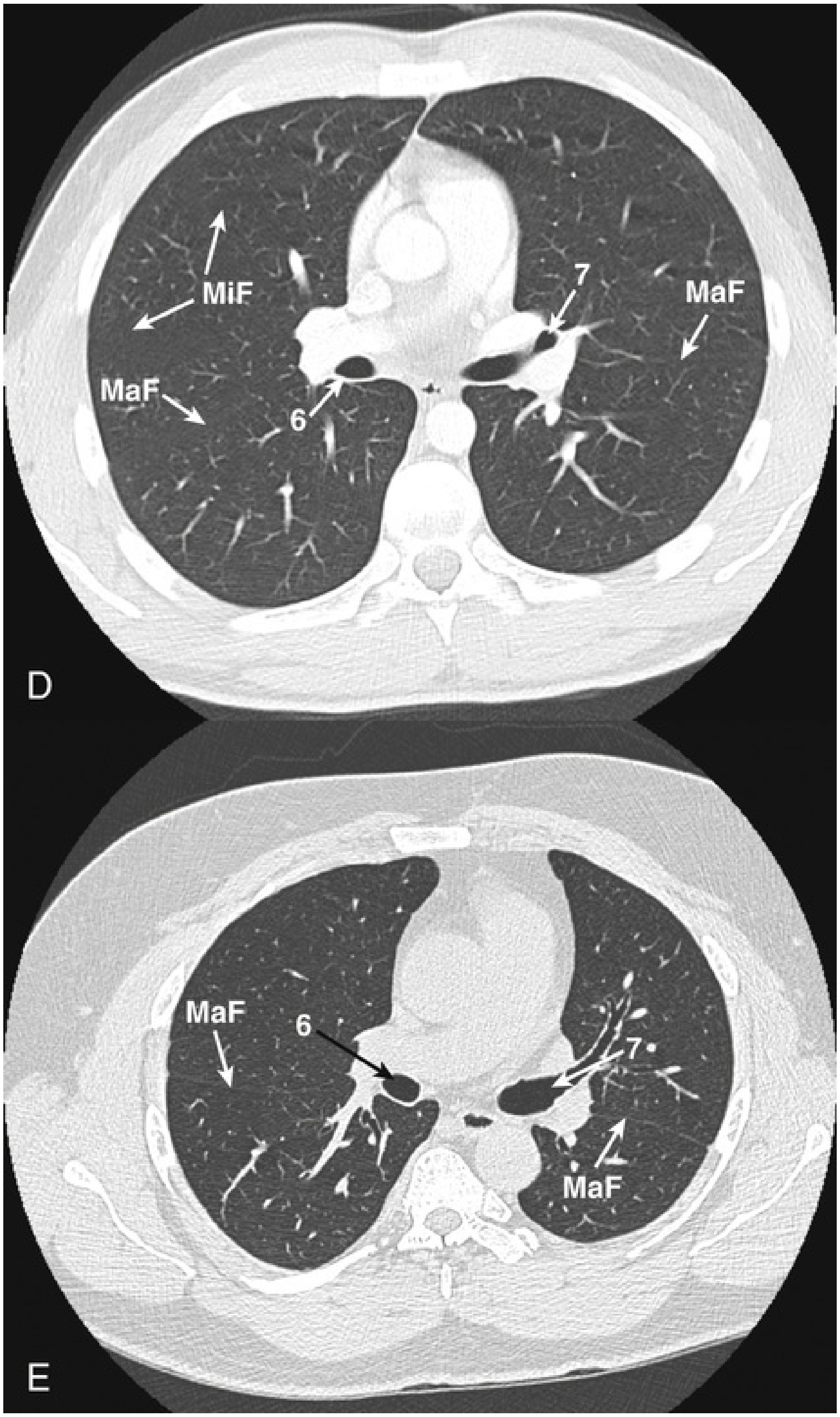
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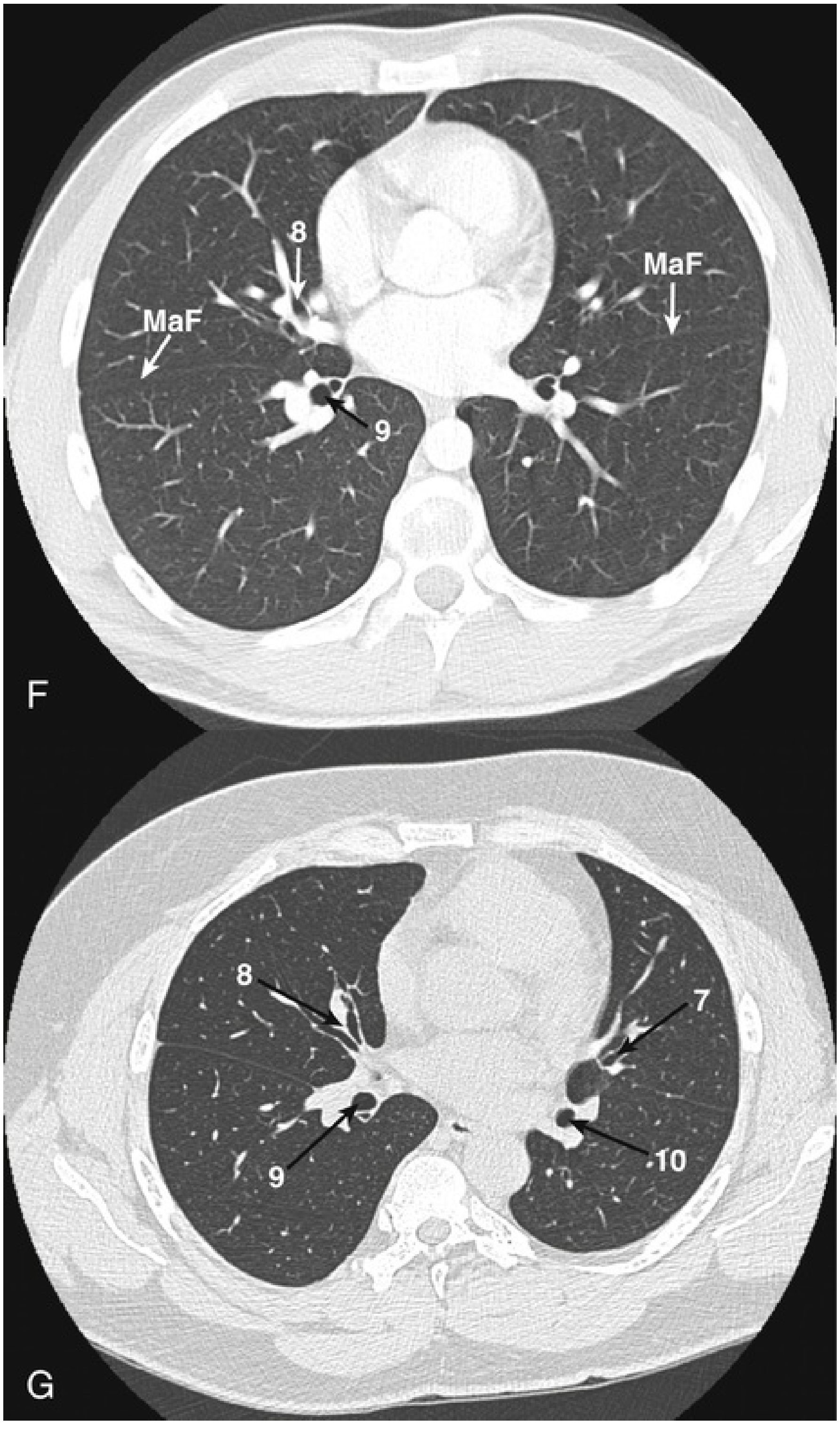
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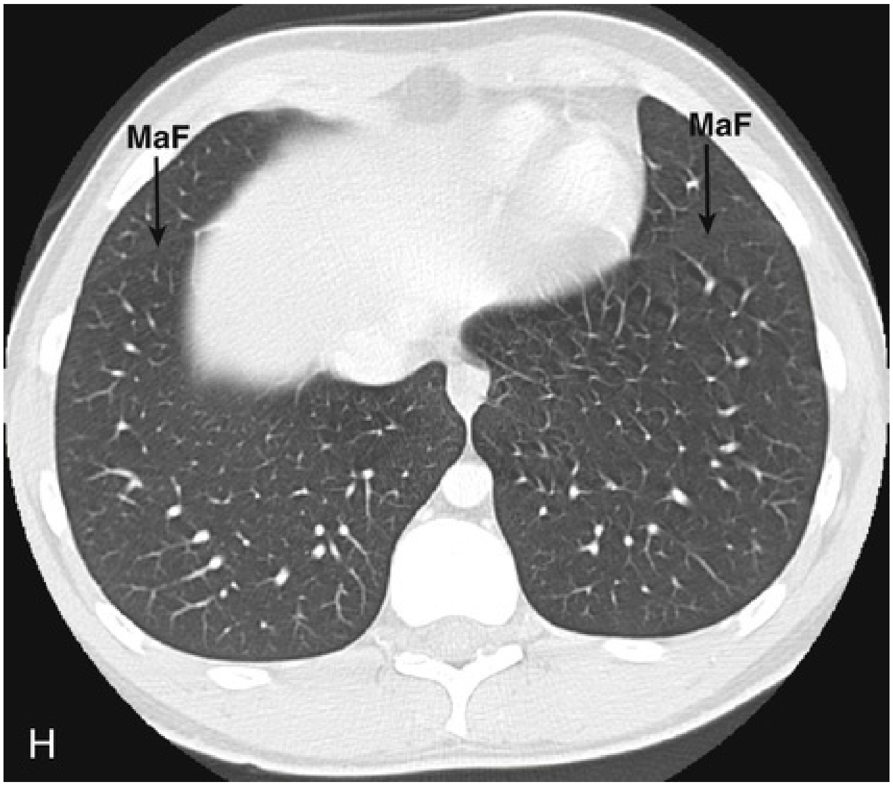



**FIGURE 3.5** **(A)** The trachea **(1)**. **(B)** Major fissures (MaF) on the left and right, and the carina **(2)**. **(C)** Left and right main bronchi **(3,4)** and upper bronchus **(5)**. **(D,E)** Minor fissure (MiF), bronchus intermedius **(6)** and left upper lobe bronchus **(7)**. **(F,G)** Upper lobe bronchus gives rise to the airway going to the lingula **(7)**, and middle lobe bronchus **(8)** and lower lobe bronchi **(9,10)**. **(H)** The right and left MaF are shown.

On Figure 3.5A–C, you will be able to identify the trachea (**1**). Follow this down until it splits at the carina (**2**) into the left (**3**) and right (**4**) main bronchi.

To identify the main bronchi look at Figure 3.5C–F. In C, on the right, the right main bronchus splits to give off an oval black tube, the upper lobe bronchus (**5**). The remaining airway is now called the bronchus intermedius (**6**). This gives off an anterior branch, which is the middle lobe bronchus (**8**), and the rest continues downwards and backwards as the lower lobe bronchus (**9**).

Figure 3.5G, on the left, the upper lobe bronchus gives rise to the airway going to the lingula (**7**), and the lower lobe bronchus is left by itself (**10**). It may help to remember that the left lower lobe is smaller than the right because of the space taken by the heart.

You can follow the bronchi to identify the main lobes of the lung. The lobes of the lung are surrounded by fissures and you should try to identify these in order to work out the borders of each lobe. The appearance of a fissure will differ, depending on the slice thickness. On a HRCT the fissure will appear as a thin white line. On a spiral CT with thicker slices the fine white line is often lost. The blood supply to each lung comes from the hilum, and the vessel branches get smaller as you go to the periphery of the lung; therefore on a thicker slice CT, instead of a white line, you see a darker linear strip. No blood vessels are seen to cross the fissure.

Identify the major fissures (MaF) on the left and right and the minor fissure (MiF) on the right (Fig. 3.5D). You can follow the course of these fissures up and down the slices (Fig. 3.5A–H). On the left the major fissure separates the upper and lower lobes. On the right the major fissure separates the lower lobe from the rest of the lung and the minor fissure separates the upper and middle lobes. The minor fissure can be difficult to spot.

Now look at the edge of the lungs. You should not be able to see normal pleura, as it is so thin; if there is density here, it must be abnormal.

Being able to identify the bronchi is important as it confirms which lobe any pathology lies within, but also remember to look inside the bronchi themselves, as there may be a tumour or an aspirated foreign body.

## Artefacts

There are several artefacts that can be seen on an image and can cause confusion. These may be related to patient movement, such as breathing or moving on the table, which causes a blurring of the image. There will also be cardiac motion, which can blur the appearance of the lung closest to the heart.

When contrast is being injected there is very dense fluid flowing through the veins into the right heart. This density, especially when it is in the superior vena cava, causes white streakiness in the adjacent structures. This is called a streak artefact and can sometimes obscure important information. To counter this, the radiologist will sometimes wash the contrast out with a second injection of saline. Metalwork such as spinal fixators will also cause significant streak artefact.

## Focus on Radiation

Everyone is exposed to radiation. One of the major contributors to environmental exposure is radon gas which is emitted from a number of rocks such as shale and granite. Exposure to radiation is measured in millisieverts (mSv) and the average exposure to environmental radiation is 2.4 mSv each year.

Radiation can cause cancer and birth abnormalities and it is important to limit a patient's exposure to radiation by avoiding unnecessary procedures. For every 1000 patients exposed to 10 mSv of radiation one will develop cancer as a result: for example, a CT pulmonary angiogram (CTPA) results in exposure to 15.0 mSv (Table 3.1). Although exposure resulting from a standard x-ray is small you must remember that there will be cumulative effects in patients that have multiple CXRs. In pregnancy the danger from chest imaging is to the mother rather than the fetus. The fetus lies outside the field of radiation but in pregnancy the mother's breast tissue will be far more sensitive than usual and the risk of causing breast cancer is assumed to be higher.

## Table 3.1

### Exposure to radiation from different procedures

| Procedure | Radiation exposure (mSv) |
|---|---|
| Chest x-ray | 0.02 |
| Ventilation perfusion scan | 2.0 |
| CT chest* | 7.0 |
| CT pulmonary angiogram (CTPA) | 15.0 |

*Recent low dose CT techniques deliver doses of 0.8-1.0 mSv and are being used for lung cancer screening.

Unnecessary x-rays can be avoided by giving the radiologist full clinical details when the request is made or by discussing the request directly with the radiologist who may suggest alternative methods of imaging. In pregnancy there are two dangers. The first is exposing a pregnant patient to unnecessary radiation but the second is not carrying out necessary tests and missing important diagnoses. Discussion with a radiologist is the best way of avoiding both these dangers.

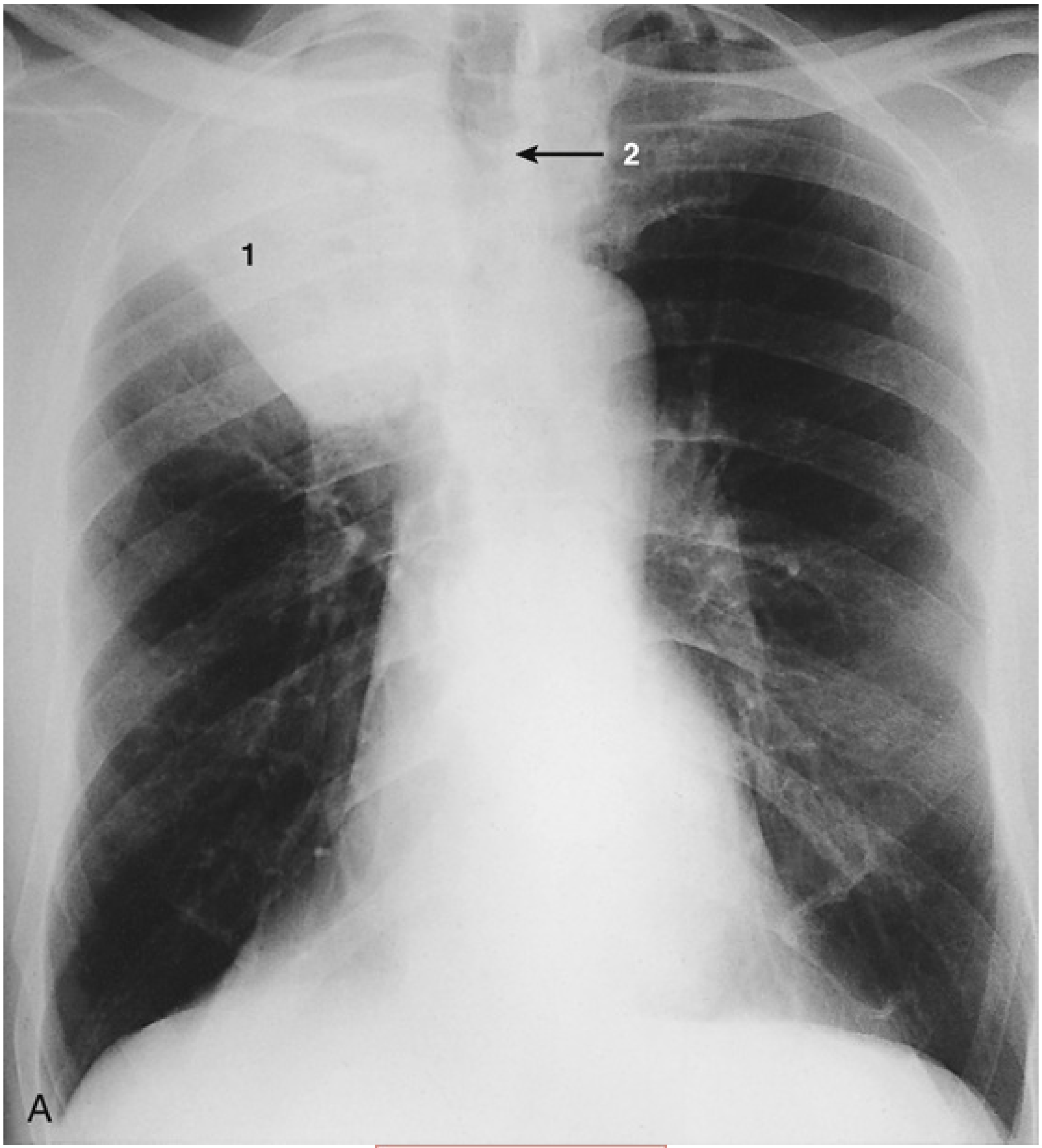
# 4

# The white lung field



## Collapse

Collapse of a lung is an important cause of a white lung seen on x-rays (Figs 4.1–4.5). When confronted with a white lung it is important to be thorough in looking for the features suggestive of collapse since the presence of collapse indicates possible serious pathology.



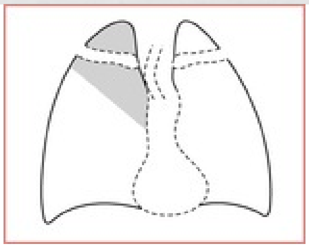




**FIGURE 4.1** **Right upper lobe collapse. (A) There is an area of whiteness in the upper zone of the right lung (1). The horizontal fissure is elevated, there is an apparent right upper hilar 'mass', the trachea is deviated to the right (2) and the ribs over the area of whiteness are closer together than is normal. (B) On the lateral film the increased whiteness in the uppermost part of the chest may be seen.**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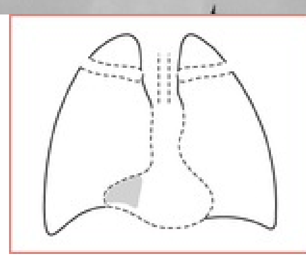
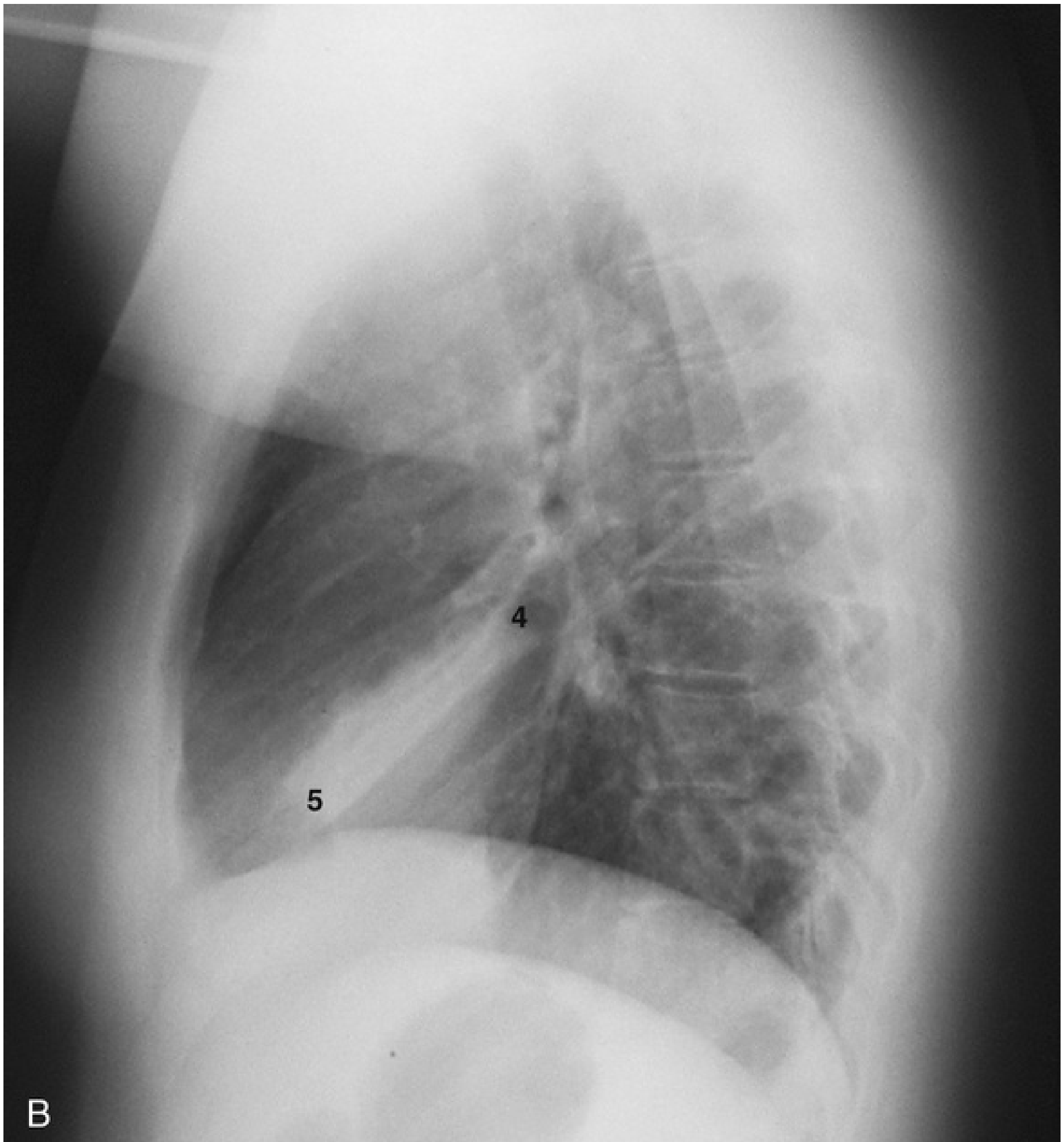




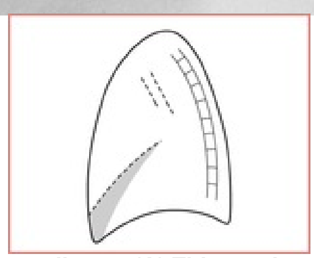
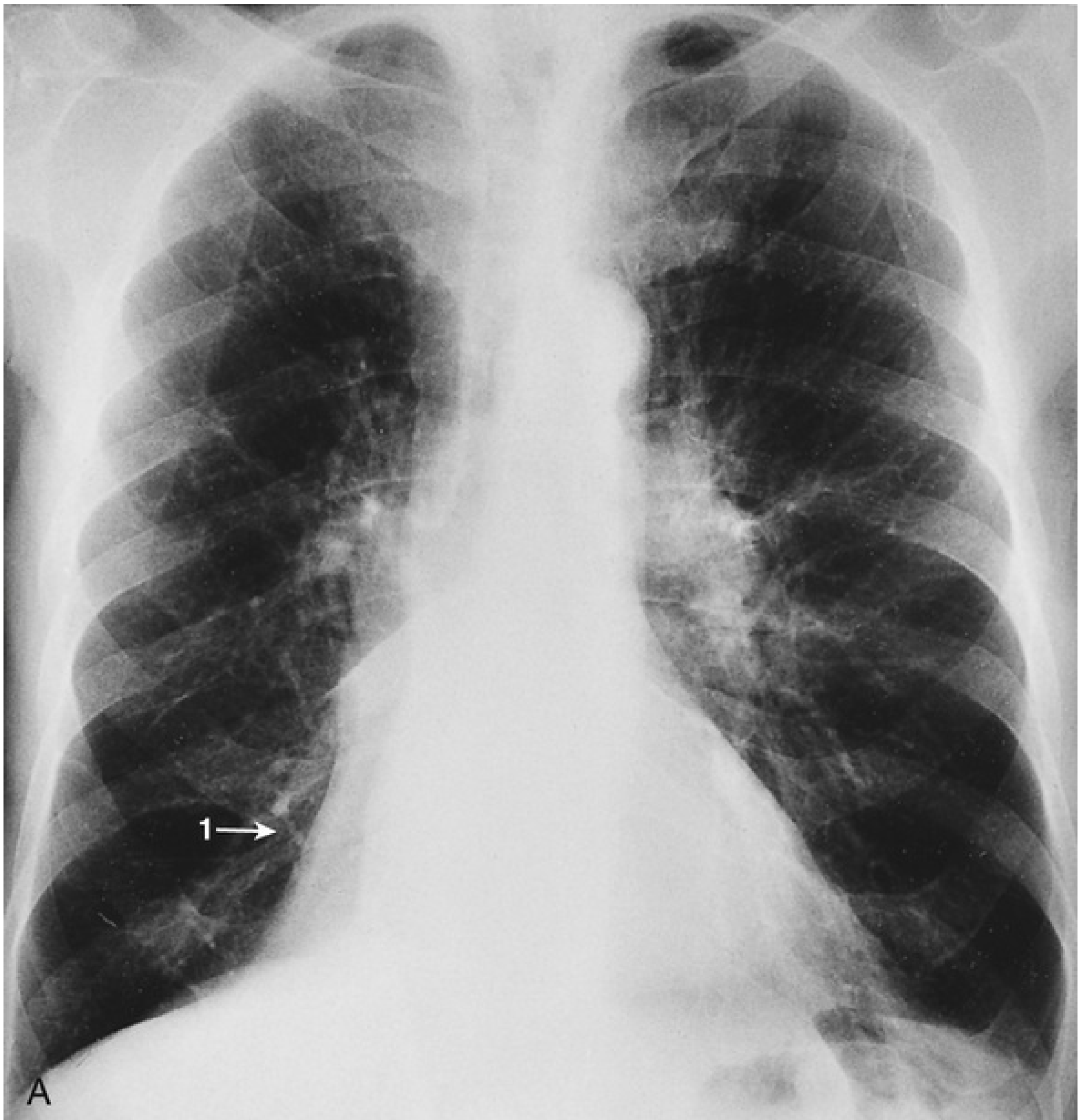



**FIGURE 4.2** **Right middle lobe collapse. (A) This can be difficult to spot. The right diaphragm may be slightly raised (1) and the horizontal fissure (2) may be lower than usual. The upper part of the lower zone may have a hazy white appearance (3) and the heart border is sometimes indistinct. (B) It is easier to detect in the lateral film. There is a triangular area of whiteness with its apex at the hilum (4) and its base running between the sternum and the diaphragm (5).**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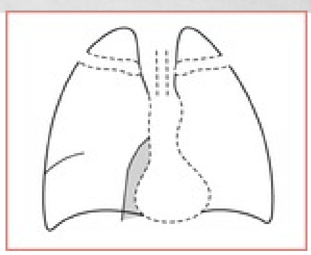


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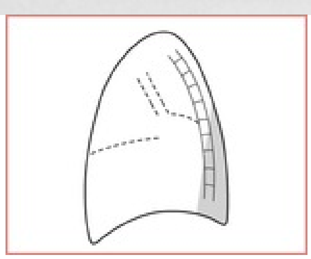
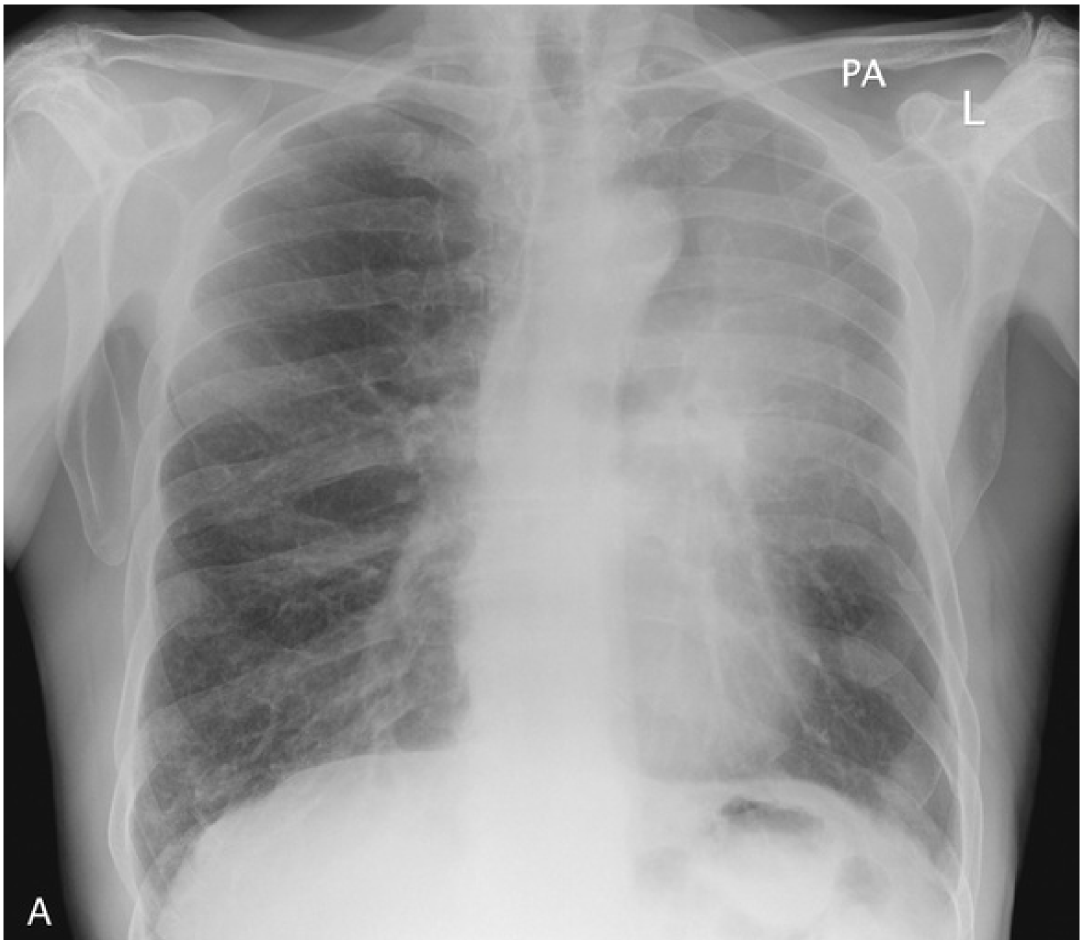
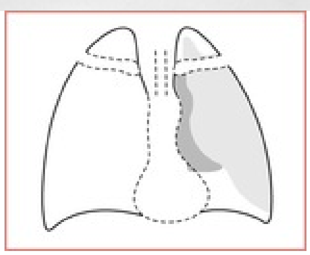


**FIGURE 4.3** Right lower lobe collapse. (A) There is a whiteness immediately above the diaphragm (1), causing a loss of its outline. (B) On the lateral film there is a white triangle at the lower posterior part of the lung field (2). Note how the outline of the right heart border is maintained.



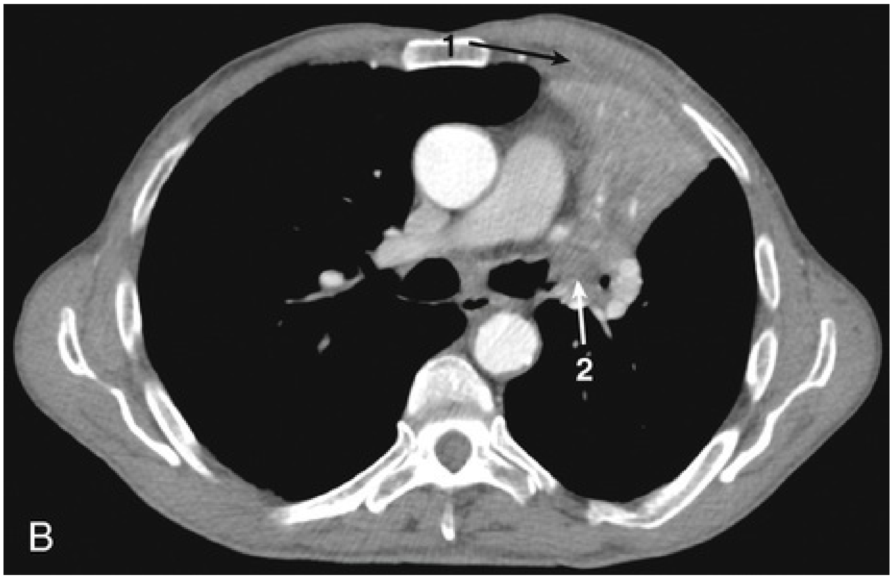
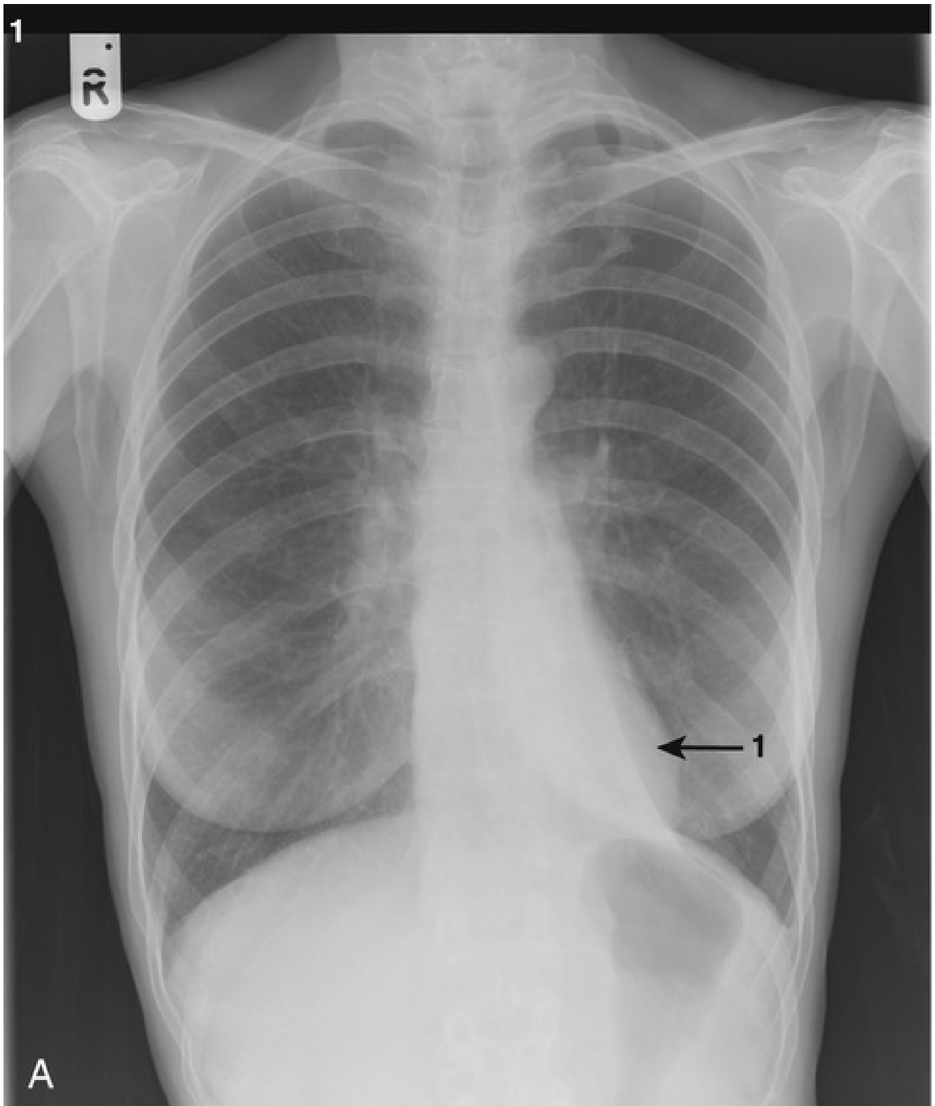



**FIGURE 4.4** Left upper lobe collapse. (A) This is difficult to spot. Remember that most of the left upper lobe lies in front of, as opposed to above, the left lower lobe. When it collapses it causes a haze to appear over the whole of the left lung field. (B) The CT image shows the midpoint of the mediastinum shifted to the left (1). The left upper lobe bronchus is filled by a soft tissue density: a tumour (2). The diagnosis can be easily achieved at bronchoscopy.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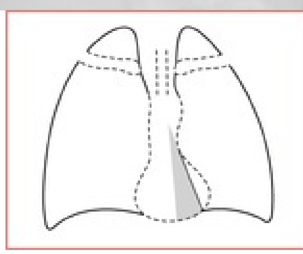
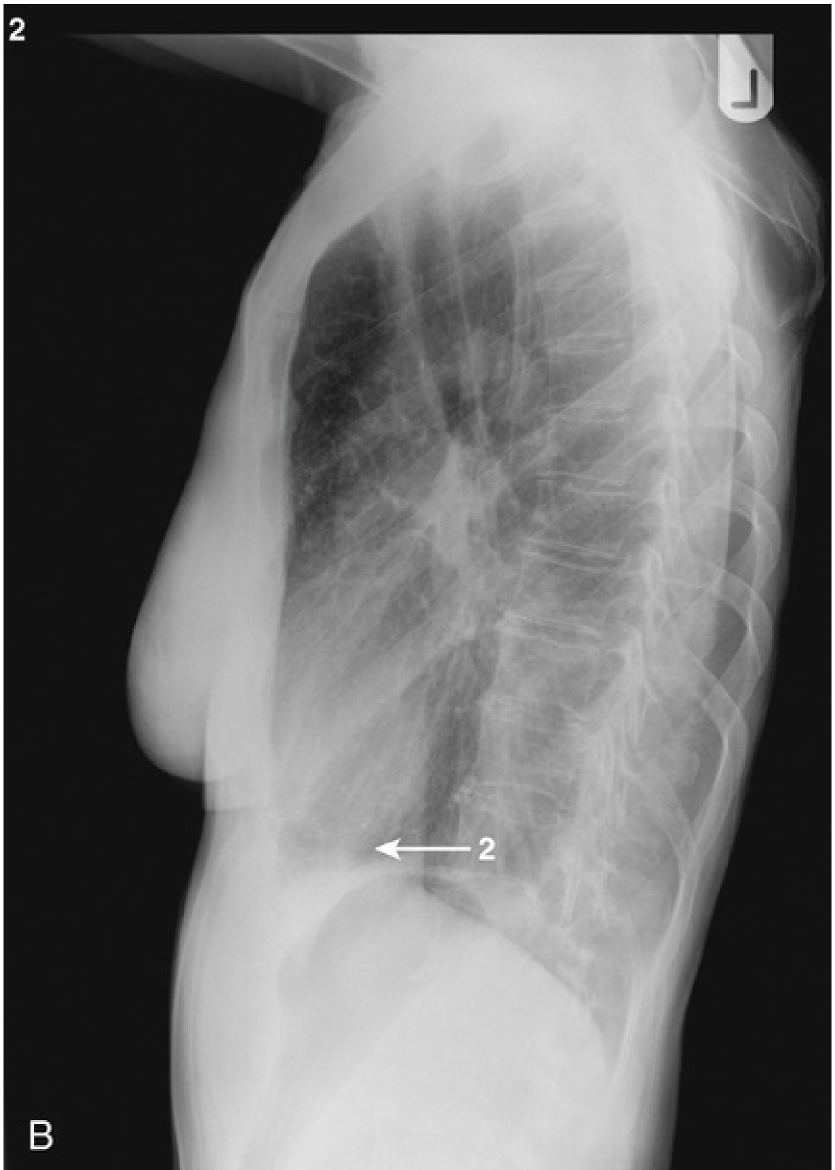




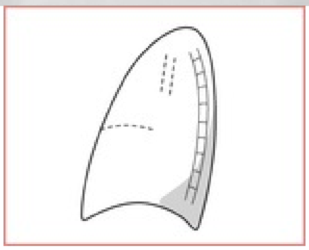



**FIGURE 4.5** Left lower lobe collapse. (A) This is easy to miss. The left lower lobe collapses down behind the heart. The left lung field appears much darker than normal and the heart shadow will appear much whiter than normal. If you look carefully you can see a white triangle behind the heart (1). This is sometimes called the sail sign.(B) On the lateral film you may see a white triangle at the bottom posterior corner of the lung fields (2) and the vertebral bodies will appear whiter.

Collapse of the lung leads to a loss of volume of that part of the lung and so the normal radiological landmarks will be distorted. To diagnose collapse look at each of these markings carefully and decide whether they are in the correct position. You may need to look at the lateral x-ray as well as the posterior-anterior (PA) view.

On the PA film:

1. If possible, compare with previous films – the change may be long-standing and benign and may not require further investigation. Of course, the clinical context must always be considered.
2. Look at the lung fields. The right lung should be larger than the left – if it is not, suspect an area of right-sided collapse.
3. Look at the diaphragms. The right diaphragm is usually higher than the left. Collapse in the left lung may distort this.
4. Look for the horizontal fissure in the right lung (Fig. 1.1). The horizontal fissure on the right should run from the centre of the right hilum to the level of the 6th rib at the axillary line. If this is pulled up, it suggests right upper lobe collapse or, if pulled down, right lower lobe collapse.
5. The heart should straddle the midline with one-third to the right and two-thirds to the left. The heart shadow will be deviated to the side of collapse.
6. The heart borders should be distinct. If the lung adjacent to the heart is collapsed then the heart border will appear blurred. If the right heart border is blurred this indicates right middle lobe collapse and if the left is blurred, lingular collapse.
7. The trachea should be central. Collapse of the right or left upper lobes can pull the trachea towards the area of collapse. Again this may be easier to spot by comparing with the patient's old films.
8. Look for volume loss. As the lung collapses the unaffected lung will be stretched, pulling the blood vessels apart and decreasing the vascularity. This will make the unaffected lung appear blacker than usual. This is a subtle sign that is difficult to detect.

On the lateral film:

Check the position of the oblique and horizontal fissures (Fig. 1.4). Any displacement from their normal position suggests collapse. Collapse of any of the lobes of the lung gives a distinct appearance on the x-ray.

## Collapse in CT

Collapsed lung causes similar distinct patterns on a computed tomography (CT) scan (Figs 4.6–4.10). When you see an abnormal area of whiteness in the lung windows look for the following (which will suggest it is an area of lung collapse):

1. Look at the mediastinal windows. If a contrast CT has been performed you should still see white blood vessels coursing through the area of collapse. This is because the lung collapses around the blood vessels within it.
2. There would be no air bronchograms since the bronchus proximally would be occluded, stopping air from entering the collapsed lung.
3. Find a large airway that enters the abnormal area. The airway should come to an abrupt end at the area of collapse. Sometimes you can see an area of irregularity within the airway which signifies an obstructing lesion.
4. Look at the shape of the abnormal area. A collapsed lung is often wedge shaped, with the point towards the central hilum.
5. Look for signs of volume loss caused by the collapse; these can be variable in their appearances. Look for mediastinal shift of the fissures.

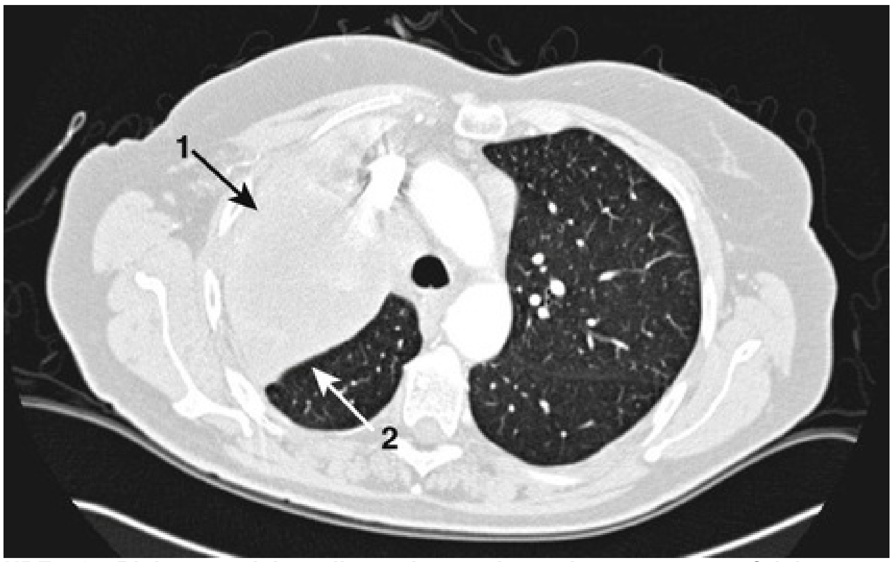



**FIGURE 4.6** **Right upper lobe collapse. Image shows the appearance of right upper lobe collapse on the lung windows of a CT scan. There is a well-defined white area in the anterior part right lung (1). This is bound posteriorly by the oblique fissure (2). The normal lung in the right lower lobe and the left lung appear dark because of the air within.**


FIGURE 4.7 Right middle lobe collapse. Image shows the appearance of right middle lobe collapse on the mediastinal windows of a CT scan. The middle lobe is small and when collapsed is difficult to see on the lung windows. There is a wedge-shaped collapsed lung on the right (1) with no air bronchogram. There is volume loss and mediastinal shift to the right.

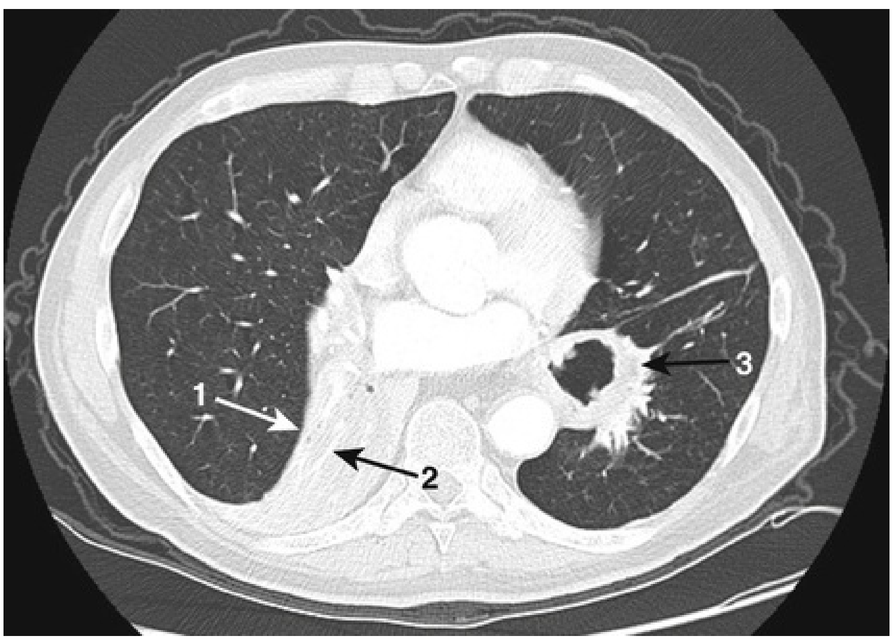



FIGURE 4.8 Right lower lobe collapse. Image shows the appearance of right lower lobe collapse on the lung windows of a CT scan. There is a wedge-shaped opacity (1) with curved edges in the right lung fanning out from the hilum towards the posterior part of the chest wall. No air bronchograms can be seen within. Contrast can just be made out in the blood vessels of the collapsed lung (2). The air-filled structure on the left is gas within the stomach under an elevated diaphragm (3), an unrelated finding.

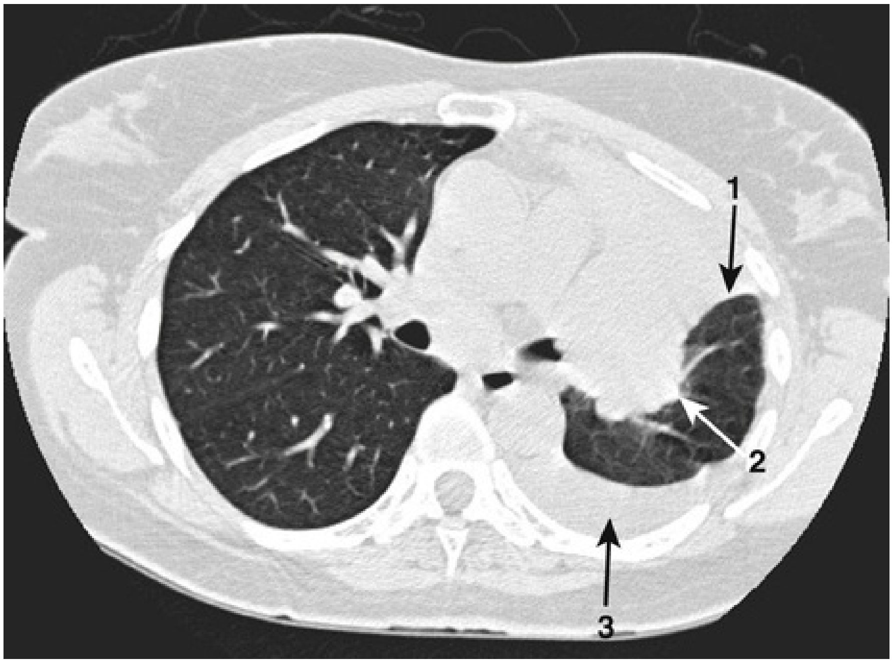



**FIGURE 4.9** **Left upper lobe collapse. Image shows the appearance of left upper lobe collapse on the lung windows of a CT scan. There is a dense white area in the left lung anteriorly with no air bronchograms and a curved edge anterolaterally (1). The area nearer the hilum, which is convex and has irregular margins (2), is a tumour causing bronchial occlusion and distal collapse. There is an associated small left pleural effusion (3). This image nicely demonstrates the difference between the smooth edge of lung collapse and the irregular border of a lung malignancy.**

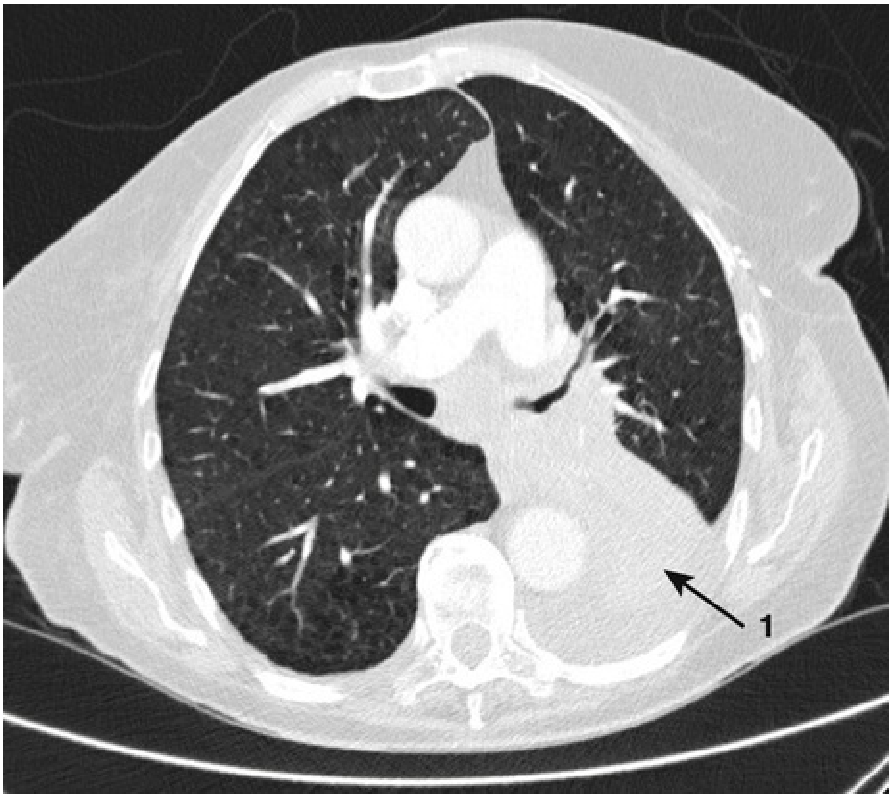



FIGURE 4.10 **Left lower lobe collapse. Image shows the appearance of left lower lobe collapse on the lung windows of a CT scan. There is a dense opacity (1) in the left lung postero-medially with smooth curved edges and no air bronchograms. Contrast is visible in the aorta and pulmonary arteries.**

A collapsed lung can be caused by the presence of a tumour and it is important to be able to identify this. A tumour may give the area of collapse a more lobular, less smooth appearance. A tumour may also cause the adjacent fissure to bulge outwards, something that would not happen with other causes of collapse.

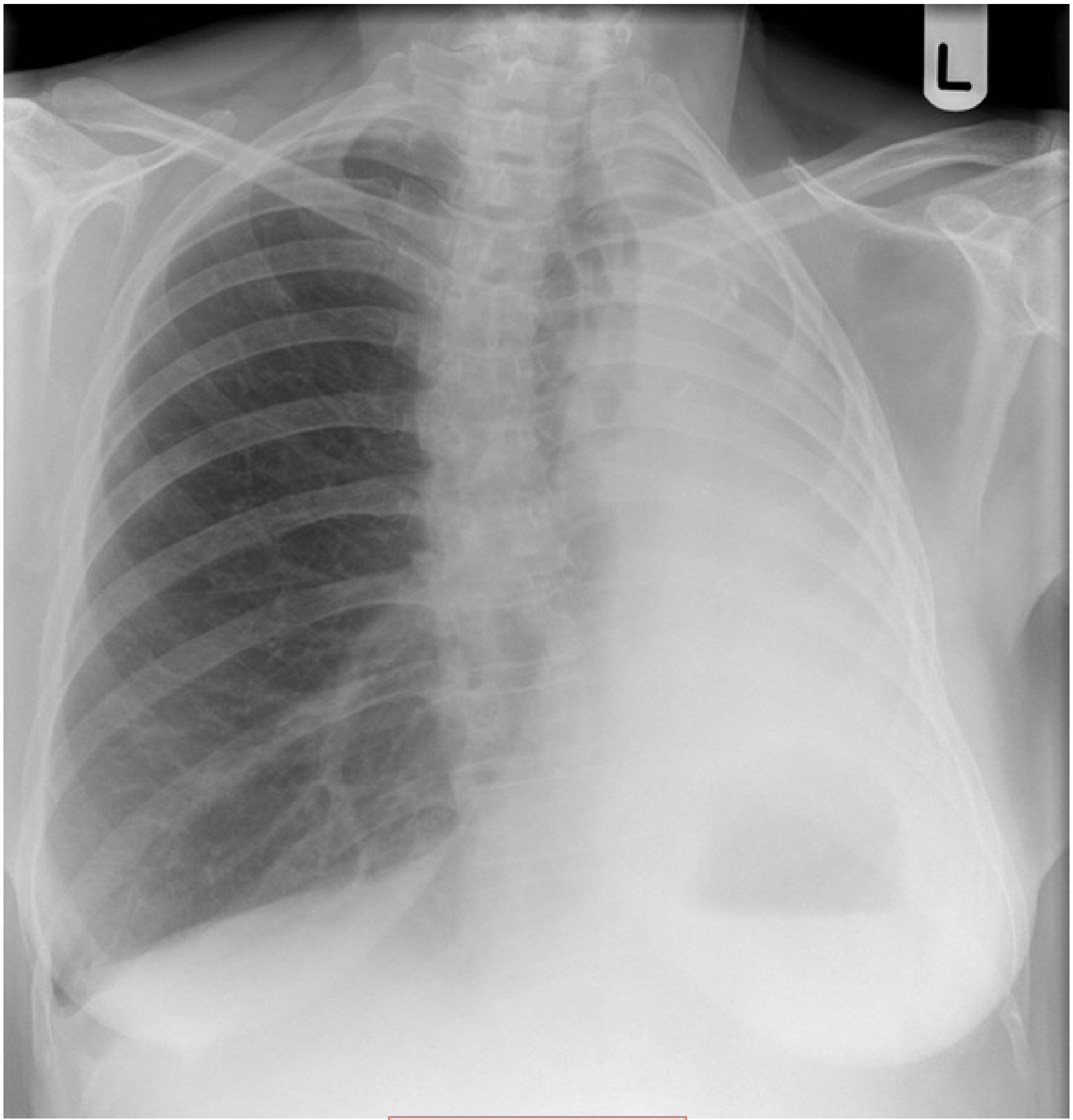
## Volume Loss

A pneumonectomy is another cause of a white lung (Figs 4.11–4.12). You should know from the history and your examination that the patient has had a pneumonectomy. Look at the x-ray for the following features:

1. Look at the mediastinum. Look first at the trachea (Figs 4.11–4.13), which should be shifted to the side of the pneumonectomy, then look at the heart border. With a pneumonectomy the heart is often shifted so far that its border is no longer visible.
2. Look at the opposite lung field. Since the mediastinum is shifted the contralateral lung is hyperinflated and so appears darker than usual.
3. Look at the side of the whiteness. You should not be able to see the upper

border of the diaphragm on the side of the pneumonectomy.

4. Look carefully at the ribs. If the patient has had a pneumonectomy, ribs would either have been cut or removed during the operation. Therefore look for any rib deformity or note the absence of any rib which would help confirm the diagnosis. The most usual rib to be affected is the 5th rib.



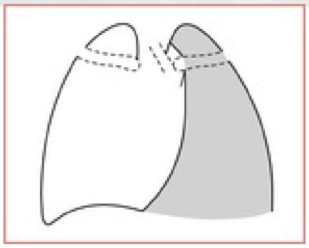
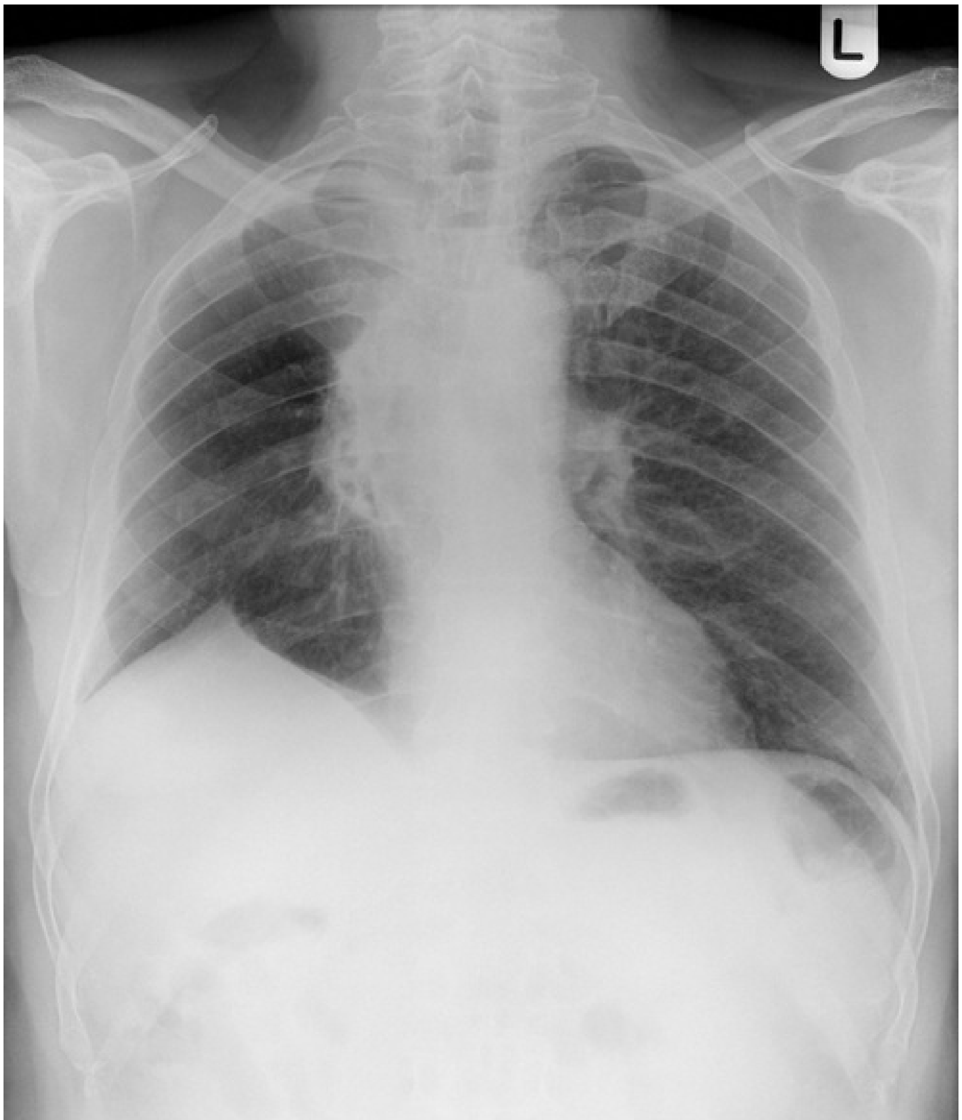



**FIGURE 4.11** Patient had a pneumonectomy several years ago. The left

hemithorax is white, and the mediastinum has shifted to the left. The left-sided ribs are also crowded together compared to the right side, and the patient has developed a slight curvature of the spine. The right lung becomes hyperinflated, and some of the lung crosses over the midline.



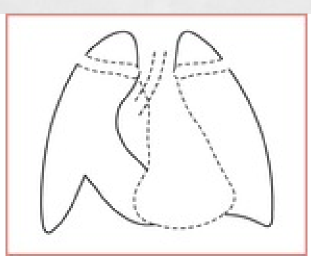
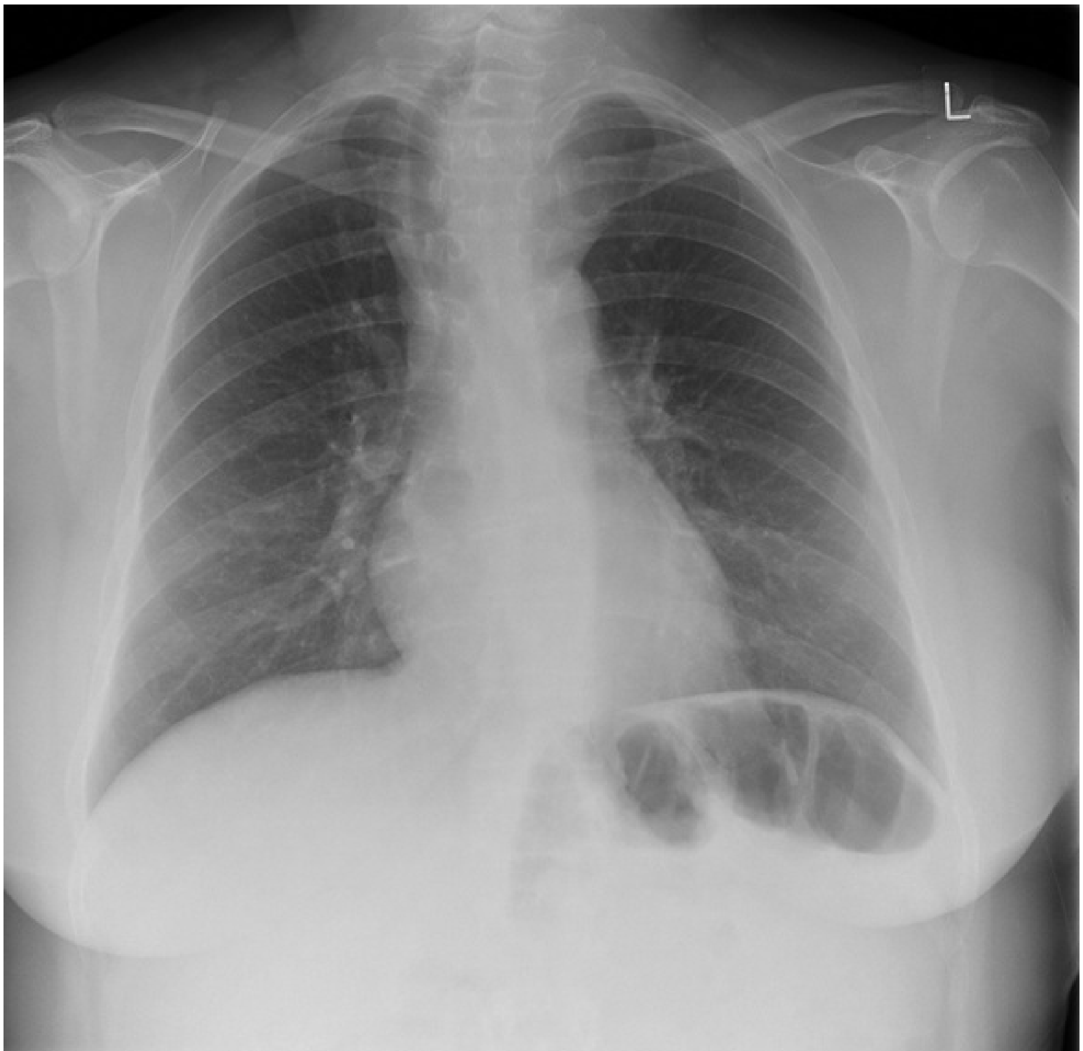



**FIGURE 4.12** Patient had right upper lobectomy and postoperative radiotherapy. Both of these have led to volume loss in the remaining right

lung. The trachea has been pulled to the right as a result. The lung is of increased blackness on the right compared to the left because the remaining lung is hyperinflated. The right diaphragm has also changed shape, and this appearance is known as diaphragmatic tenting. It looks as though a tent pole has been put underneath to push it upwards.



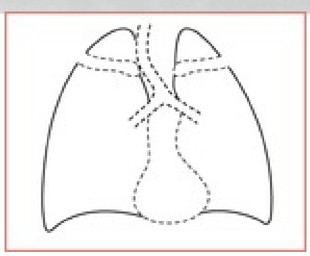



**FIGURE 4.13** Tracheal deviation can be the result of it being pushed by a mass lesion in the mediastinum, most often an enlarged thyroid gland, as in the case shown here. The lung volumes in this case are normal, and the

ribs and diaphragms are in their normal positions. In the elderly a very tortuous aorta may also lead to tracheal shift.

A very rare cause of a similar appearance is extensive hypoplasia or congenital absence of one lung.

## Consolidation

An area of white lung is shown in Figures 4.14 and 4.15. Look first at the nature of the whiteness and its border. If it is uniform with a well-demarcated border, you are much more likely to be dealing with an area of collapse or a pleural effusion. If the shadowing is not uniform and the border is not so well demarcated, the possibilities are consolidation, fibrosis or some other infiltrative condition. It can be difficult to diagnose consolidation, so make your way carefully through the following steps:

1. Remember the clinical history. In the presence of a temperature and signs of infection, consolidation is by far the most likely abnormality.
2. Look at old x-rays. Fibrosis is usually a chronic condition and consolidation much more transient. The presence of a similar abnormality on a previous x-ray should lead you to suspect fibrosis rather than consolidation.
3. Look carefully at the nature of the shadowing. In consolidation the alveolar spaces become filled with fluid, making them appear white, whereas the airways retain air, making them appear black. If you look closely at an area of consolidation you can often make out the small airways as black against a white background – the so-called ‘air bronchogram’ (Fig. 4.14).
4. Look at the distribution of the shadowing. Fluid sinks, so consolidation gets denser as one moves down the lung. The shadowing in consolidation will often be denser and more clearly demarcated at its lower border (Fig. 4.15).

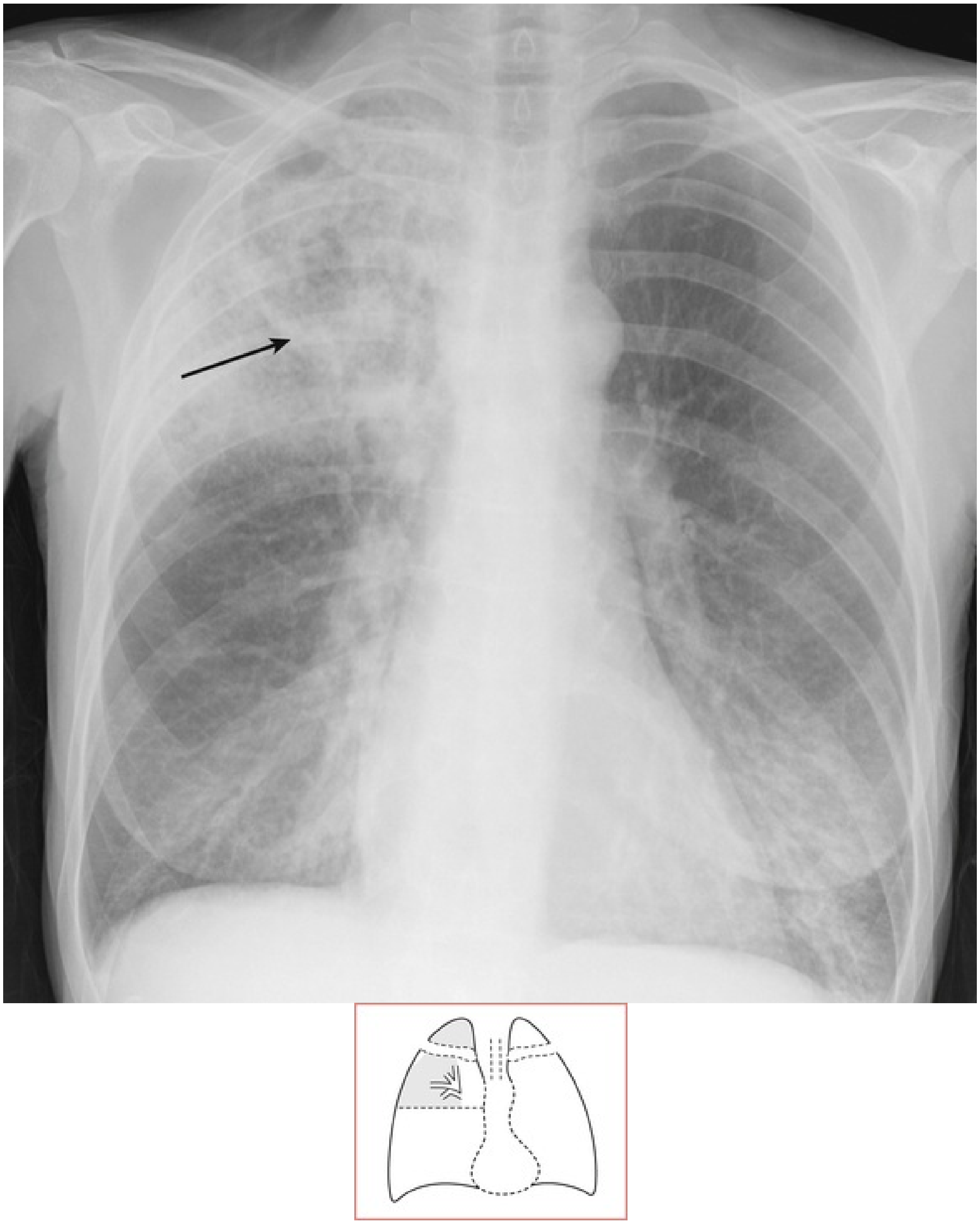


**FIGURE 4.14** This is the appearance of a lobar pneumonia. Notice how the inferior margin of the consolidation is quite straight. This appearance indicates a right upper lobe pneumonia. An air bronchogram **(arrow)** is visible.

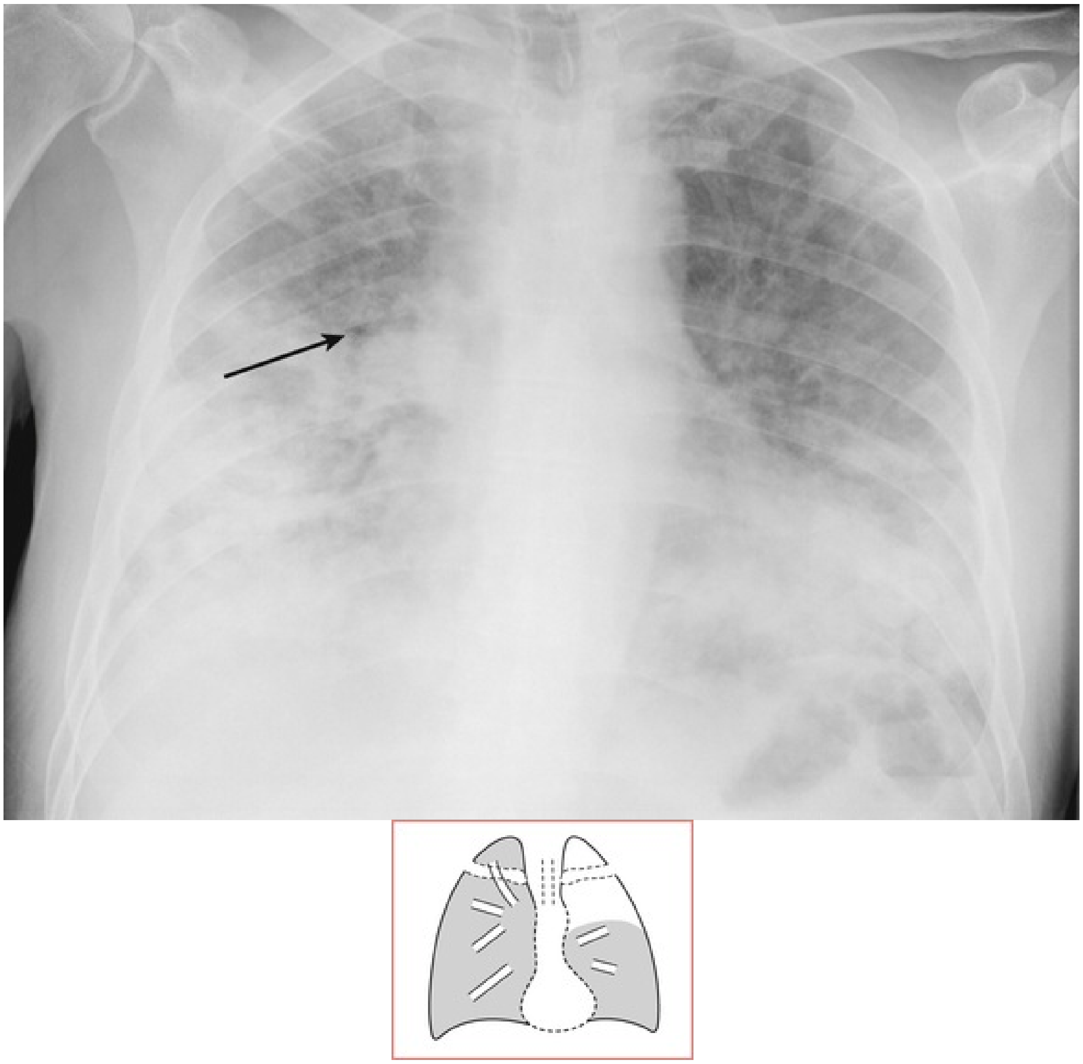


**FIGURE 4.15** A much more widespread consolidation affecting both lungs is shown, especially in the mid to lower zones, and is a bronchopneumonia. An air bronchogram **(arrow)** is visible.

## Consolidation and CT

Figure 4.16 shows the appearance of consolidation on a CT scan. You will see that it has the same characteristics as consolidation on the plain film. The key feature is the presence of the air bronchogram, the airways appearing black against the white background of the consolidated alveolar. This is usually much more obvious on a CT than a plain film.

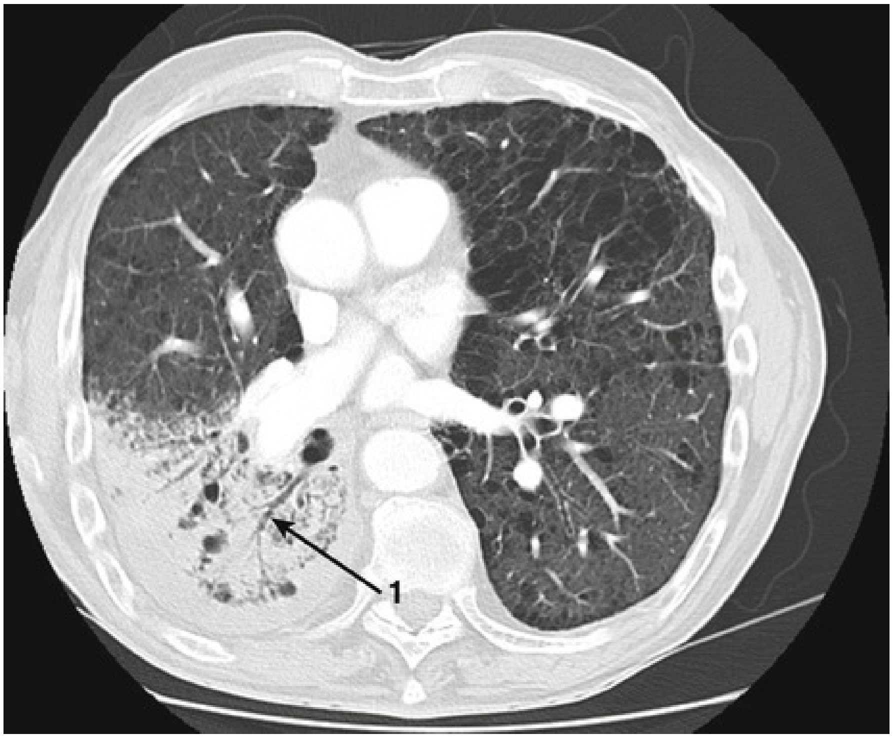



**FIGURE 4.16** CT lung window settings. This is the CT of 69-year-old man with history of COPD, who was admitted severely unwell with history of increased breathlessness, cough and fever. The CT shows an area of dense consolidation in the right lower lobe. The black airways **(1)** against the white background of fluid-filled airspaces indicate consolidation.

Pneumonia is not the only cause of consolidation. Other, rarer causes are shown in Box 4.1.

**Box 4.1**

### Other causes of consolidation

Bronchoalveolar cell carcinoma
Cryptogenic organising pneumonia
Eosinophilic pneumonia
Cardiogenic pulmonary oedema
Noncardiogenic pulmonary oedema
Pulmonary haemorrhage
Alveolar proteinosis

## Focus on Pneumonia

A chest x-ray is needed to confidently diagnose pneumonia and careful examination of the x-ray can give clues to its aetiology. It is important to repeat the x-ray if the patient does not respond to treatment as expected. Otherwise, if the patient makes an uneventful recovery a follow up x-ray is only needed in patients with persistent symptoms or signs or who are at a higher risk of malignancy.

## Aetiology

Although it is not possible to diagnose the aetiology of pneumonia from a chest x-ray, it will give you some helpful clues. Look for multilobular involvement, which is more common with pneumococcal pneumonia and the influenza virus. The presence of multiple cavities suggests *Staphylococcus aureus* infection. Upper lobe infection is more common in *Klebsiella pneumoniae* and tuberculosis (TB). Pneumonia caused by the influenza virus is commonly bilateral and patchy in nature and may cause multifocal ground glass shadowing.

## Persistent pneumonia

If there is no clinical improvement after 48 hours of treatment a follow-up CXR should be ordered. Look carefully at the lung fields for evidence of a pulmonary abscess, which will appear as a thin-walled cavity. This is more common in debilitated patients such as those who are malnourished and means that a much longer course of antibiotics (typically 6 weeks) will be needed. Look carefully at the lung volumes. There may be collapse of areas of the lung secondary to obstruction that will make the pneumonia harder to clear. Look again at the lung parenchyma for evidence of underlying bronchiectasis that may be subtle and easily missed.

Look for the presence of pleural fluid (Fig. 4.2). This may suggest that the patient has developed either a reactive pleural effusion or an empyema. It is impossible on a CXR to distinguish between a reactive pleural effusion and an empyema so any fluid should be sampled, preferably under ultrasound guidance. Thick turbid fluid with a low pH and low glucose indicates the presence of an empyema, which should be drained.

Look at the extent of the consolidation. You would not expect to see significant improvement in the CXR appearance within 48 hours of treatment. However, a worsening of the x-ray shadowing may suggest that the patient is on the wrong antibiotics or may lead you to consider an alternative diagnosis, such as acute respiratory distress syndrome (ARDS).

If your patient does not improve and there is no obvious clinical, microbiological or radiological reason, consider ordering a CT scan. This will allow you to look for obstruction of a bronchus; it may reveal a pulmonary abscess not visible on the plain CXR.

Finally think about the possibility of an alternative diagnosis. Discuss the request with a radiologist who will be able to examine the nature and distribution of the shadowing and advice on whether an alternative diagnosis, for example an eosinophilic pneumonia, is likely.

## Underlying pathology

All patients should be reviewed after 6 weeks and if they have persistent symptoms or signs, or are at risk of malignancy (smokers and those over 50 years of age), a follow-up x-ray should be arranged.

The purpose of the follow-up CXR is to check for complete resolution of the CXR changes. If the 6-week CXR continues to show consolidation you will needto investigate further since one of the commoner causes of persistent consolidation is bronchial obstruction, for example by a lung cancer. The patient's x-rays should be discussed with a radiologist. A CT scan or bronchoscopy may be needed to exclude an underlying lesion.

## *Pneumocystis Carinii* (*Jiroveci*) Pneumonia (PCP)

*Pneumocystis carinii* pneumonia (PCP) can be difficult to diagnose on a CXR and in 10% of patients with PCP the CXR is normal (Fig. 4.17). If a patient presents with shortness of breath and hypoxia that are out of proportion to a relatively normal-looking CXR then PCP should be suspected.

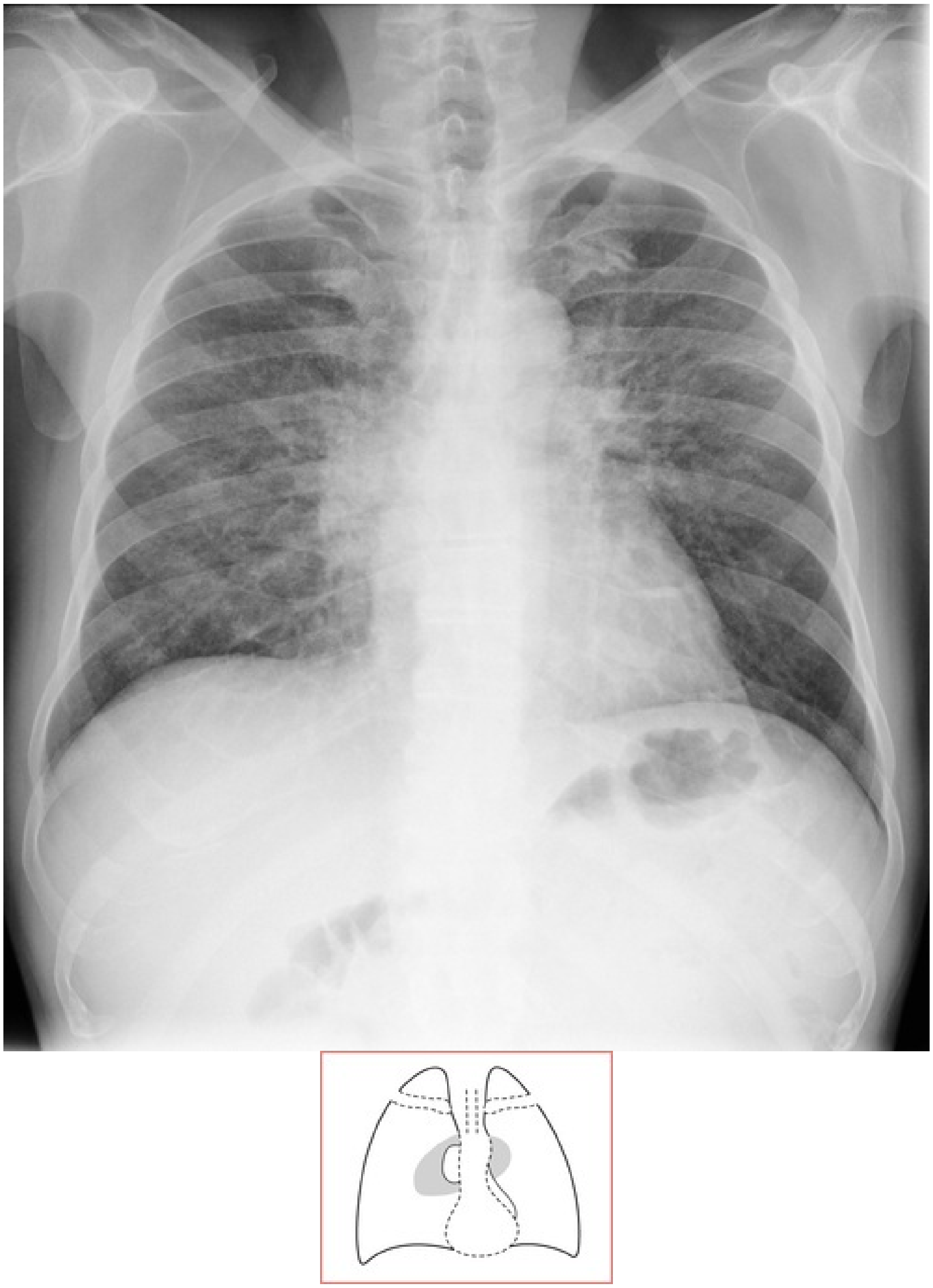


**FIGURE 4.17** This patient is on long-term immunosuppression following renal transplant. He presented with a week-long history of a dry cough and increasing breathlessness. Following bronchoscopy and lavage he was diagnosed with *Pneumocystis* pneumonia, an organism recognised to cause pneumonia in immune compromise from many causes. The film shows vague white shadowing around the hilum. There is also enlargement of the right hilum from lymphadenopathy.

If you suspect that the CXR shadowing may be due to PCP then look for the following features:

1. Look at lung volumes. Very early PCP may be suspected when both lungs show reduced volume. Look for an old CXR. If there is one, compare the lung volumes to those on a CXR taken when the patient was well.
2. Look at the area around the hilum. In PCP there is often white shadowing in this region. This can be very vague. You can best appreciate it by looking at the blood vessels as they come away from the hila. In PCP the blood vessels will appear less well defined than normal.
3. Look for peribronchial cuffing. This is best seen in airways that are seen 'end-on' and is due to fluid seen as increased whiteness within the walls of the airways. This gives the wall of the airway a thickened or fuzzy appearance, with a central hole, rather like a well-sucked 'Polo' mint.
4. Look for large areas of whiteness extending throughout the lung fields. These may develop as the disease progresses and represent large areas of consolidation. Typically, in PCP the whiteness does not extend to the apices or affect the costophrenic angles.

## PCP and CT

A CT scan is much more sensitive than a CXR in the diagnosis of PCP and a normal CT virtually excludes the diagnosis. There are two things to look for on the CT scan (Fig. 4.18).

1. The presence of ground glass shadowing. As described on page 84, this is shadowing that does not obscure the underlying structures of the lung so blood vessels and airways can be seen through it. Look at the distribution of the ground glass shadowing. As with the CXR these are found around the hilar areas and are bilateral and often asymmetrical.
2. You may sometimes see small cysts and areas of consolidation.

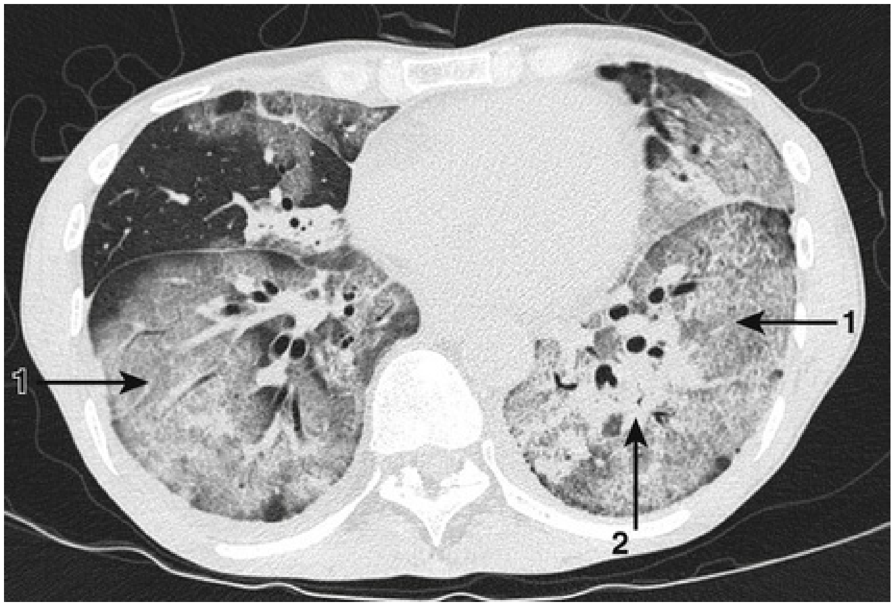


**FIGURE 4.18** CT lung window settings. Male patient presented with a three-day history of increasing shortness of breath and was severely hypoxic on admission. The CT scan is very suggestive of PCP and shows bilateral ground glass shadowing **(1)**. There are also some areas of consolidation **(2)**. Although no obvious risk factors, blood tests taken on admission showed him to be HIV positive and PCP was confirmed on bronchoalveolar lavage.

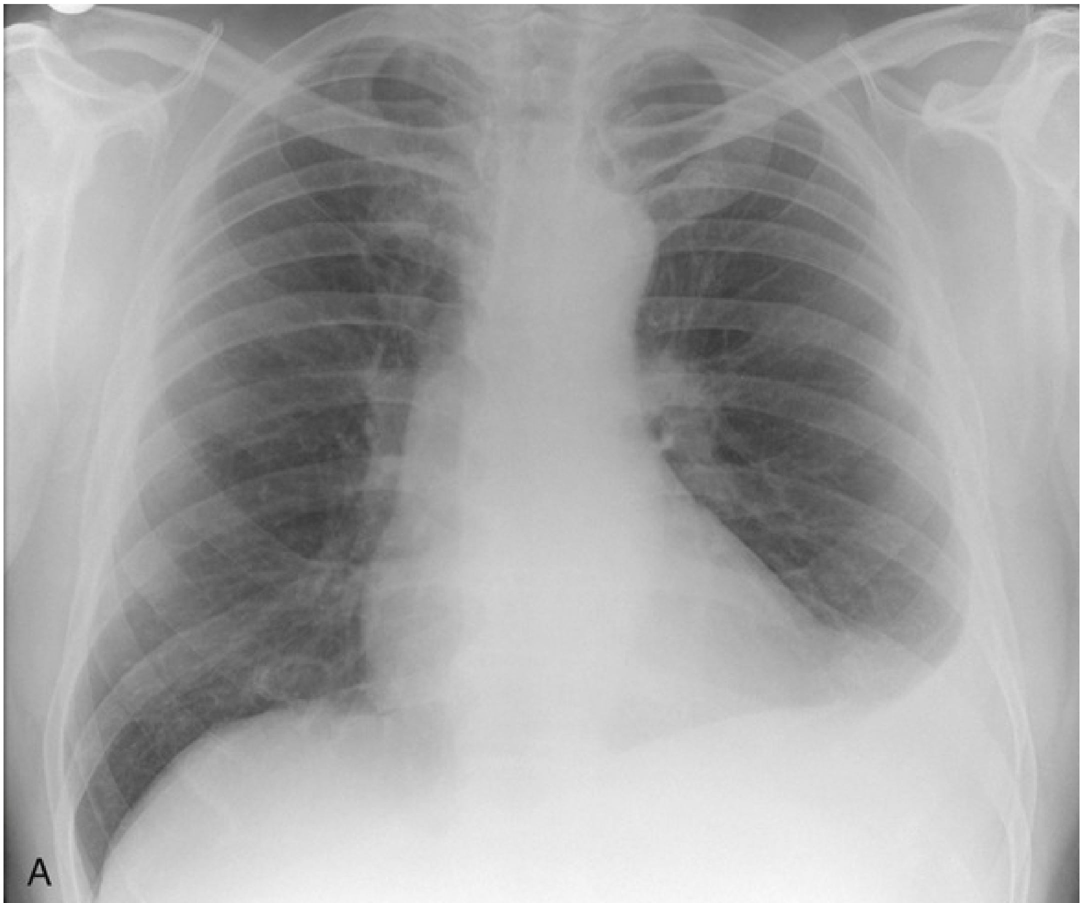
## Pleural Effusion

If you see an area of whiteness at the base of a lung then the possible causes are a pleural effusion (Fig. 4.19A,B), a raised hemidiaphragm and an area of consolidation or collapse. You need to determine which of these it is.

1. Look closely at the texture of the whiteness. Consolidation usually causes more heterogeneous shadowing, typically with the presence of an air bronchogram. Look carefully for an air bronchogram (Fig. 4.15) since its presence will point to consolidation rather than a pleural effusion.
2. Look at the shape of the upper border of the shadowing. Fluid will often have a meniscus, so the upper outer border of an effusion will be concave.
3. To differentiate an effusion from a raised hemidiaphragm look again at the shape of the upper border. The upper border of an effusion will peak much more laterally than you would expect the diaphragm to do. This is a matter of looking at lots of x-rays.
4. Look for mediastinal shift. It can be difficult to differentiate an effusion from lung collapse. Collapse usually causes mediastinal shift towards the white

lung field, so the absence of shift suggests the presence of an effusion. Remember, however, that collapse can accompany an effusion so that, although the absence of shift implies an effusion, its presence does not exclude it.

5. A lateral view is often helpful since the meniscus on a lateral can be much more obvious. Look for the presence of a meniscus, which, often on the lateral, is seen to extend up into one of the fissures.
6. If you diagnose an effusion on CXR look for possible causes (see Box 4.2). Is the effusion bilateral or unilateral? If it is bilateral it is more likely to be a transudate. Check the size of the heart (a large heart points to heart failure) and look at the hilum for possible enlargement. Look at the visible parts of the lung fields for obvious masses and check the bones for signs of metastasis. Look very carefully at the apices of the lungs for tumours and TB.
7. To confirm the presence of pleural fluid request an ultrasound of the chest. This is particularly important if you plan to aspirate the effusion or put in a chest drain.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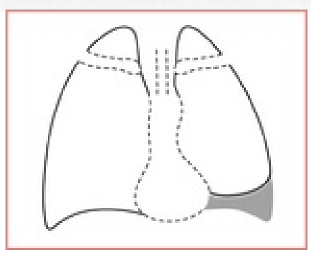
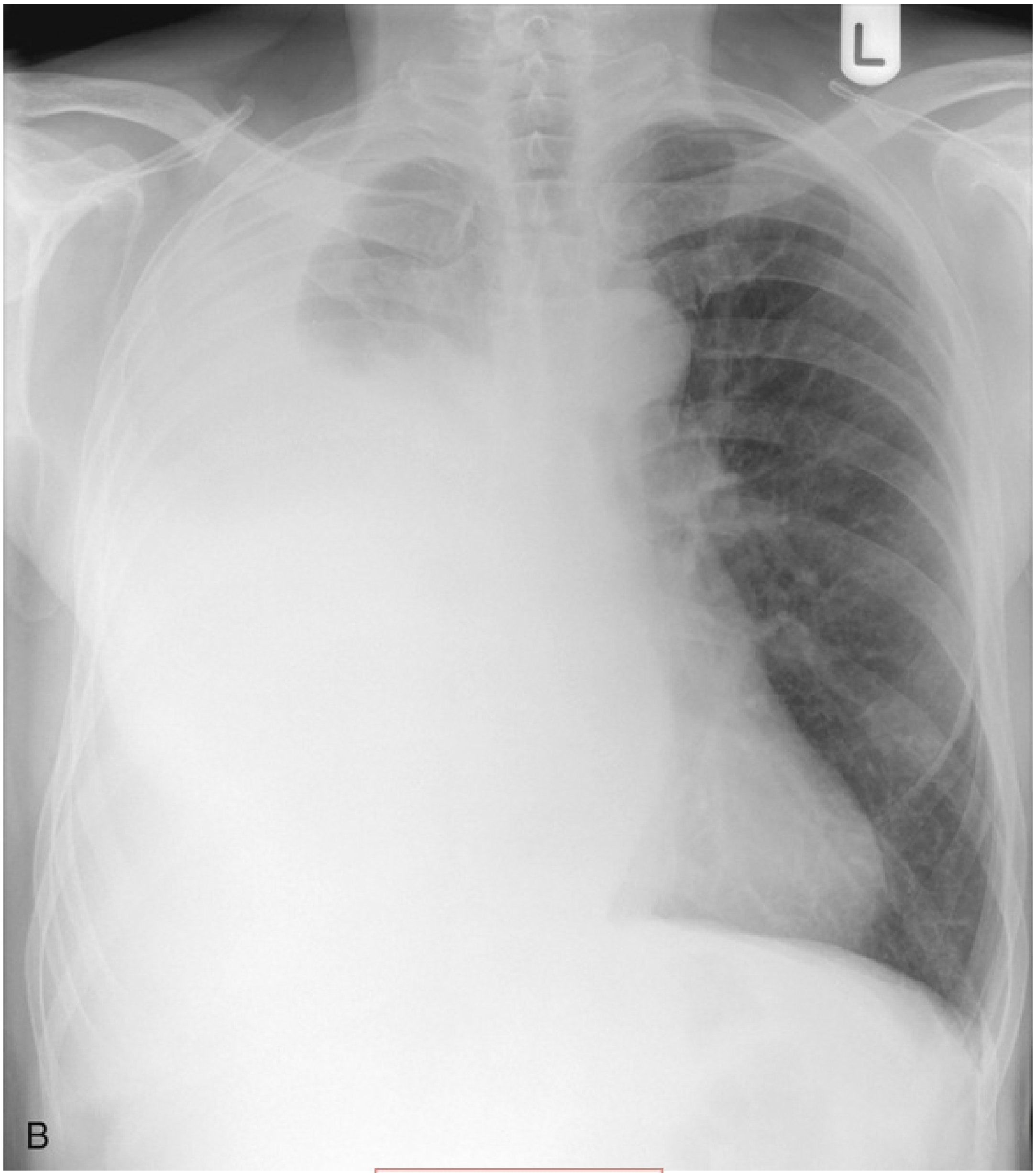




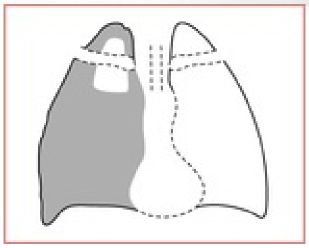



**FIGURE 4.19** The varied appearances of pleural effusions are shown. **(A)** A small left effusion filling the costophrenic angle. It has a curved upper margin. **(B)** A much larger right pleural effusion. The fluid now encases the lung and the increased whiteness can be seen around the apex of the lung. Compare this almost totally white lung with the appearance following a pneumonectomy. In the case of a large pleural effusion, the mediastinum may be pushed away from the midline by the large volume of fluid.

**Box 4.2**

### Some causes of a pleural effusion

#### Transudate <30 g/L of protein

Heart failure, e.g. congestive cardiac failure, pericardial effusion
Liver failure, e.g. cirrhosis
Protein loss, e.g. nephrotic syndrome, protein losing enteritis
Reduced protein intake, e.g. malnutrition
Iatrogenic, e.g. peritoneal dialysis

#### Exudate >30 g/L of protein

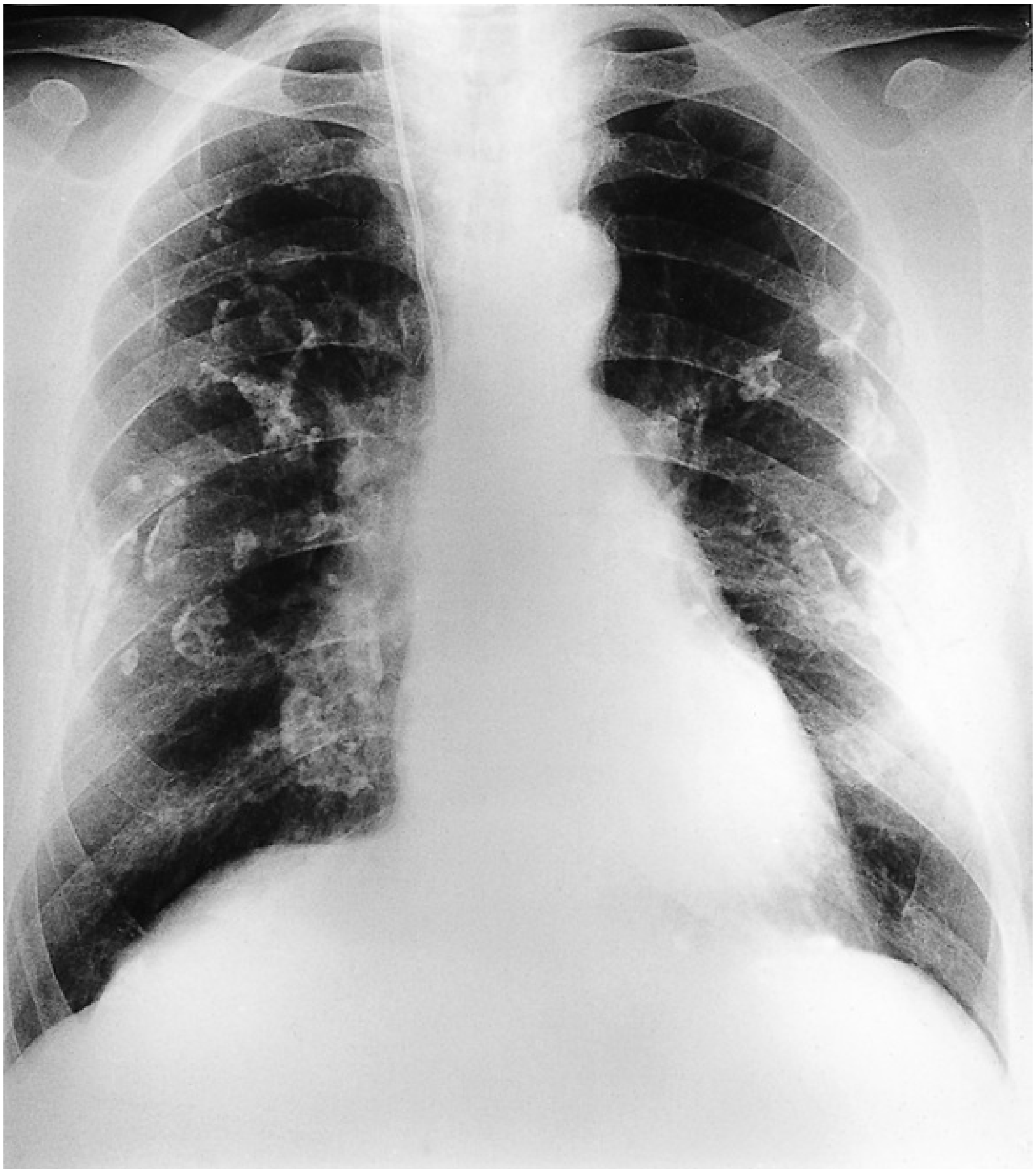
Infection, e.g. pneumonia, tuberculosis
Infarction
Malignancy, e.g. bronchial carcinoma, mesothelioma, metastasis
Collagen vascular disease, e.g. rheumatoid arthritis, systemic lupus erythematosus (SLE)
Abdominal disease, e.g. pancreatitis, subphrenic abscess
Trauma/surgery

## Asbestos Plaques

Pleural plaques represent areas of pleural thickening caused by exposure to asbestos fibres (Fig. 4.20). They may be predominantly soft tissue with small amounts of calcium or be heavily calcified. Isolated pleural thickening is a cause of a localised area of white lung and can be difficult to separate from lung shadows. If you suspect pleural plaques then:

1. Look throughout the lung fields of both lungs. Pleural thickening is easy to identify at the periphery where it appears as a thickened line around the edge of the lung. If you can identify pleural thickening here it makes it more likely that the other areas of whiteness are plaques superimposed over the lung field.
2. Carefully look at the position of the whiteness and compare it to what you know of the anatomy of the lung. If the whiteness follows intrapulmonary structures, for example a lobe of the lung, then it may be originating from the lung itself. If it crosses such structures then it is probably pleural.

3. Compare the distribution of the whiteness to the line of the anterior portion of the ribs. Asbestos plaques are very commonly found running along the line of the anterior portion of the ribs.
4. Look at the distribution of the patches. Pleural plaques are most prevalent in the mid zones and axillary region of the mid chest. They tend to spare the upper zones and costophrenic angles. Look carefully at both lung fields. Pleural plaques are usually bilateral and you should be wary of making this diagnosis if they are present in only one pleural cavity.
5. Look at the diaphragm. Pleural plaques along the diaphragm are often calcified. If you see streaks of dense white material (calcium) running along the diaphragm it implies that pleural plaques are present.
6. Look at the nature of the whiteness. Pleural plaques are patchy in nature as opposed to a pleural effusion, which is more uniform. Plaques are sometimes said to have a map-like appearance due to areas of patchy calcification within them. Look at their edge. This should be well defined as opposed to ‘companion shadows’ that have poorly defined margins.
7. Look at the patient's old x-rays. Pleural plaques are slow growing and are probably visible on previous x-rays.



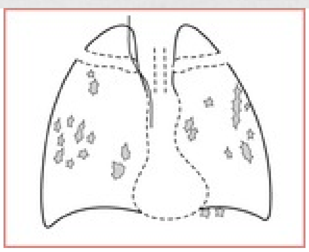


**FIGURE 4.20** A CXR of a 63-year-old man admitted following a gastrointestinal haemorrhage (hence the central venous pressure line) who had been exposed to asbestos whilst working in a naval dockyard. You can see multiple calcified pleural plaques on the inner chest wall.

## Mesothelioma

Mesothelioma is a malignant tumour of the pleura (Fig. 4.21; Box 4.3). The shadowing it causes will have the characteristics of pleural shadowing and some of the characteristics of malignant shadows. If you suspect the whiteness to be mesothelioma then:

1. Look carefully at the spread of the whiteness and determine whether it follows lung boundaries. If it does not, then the whiteness may be pleural in origin.
2. Look at the margins of the whiteness. If they are lobulated in nature, then this suggests malignancy (Fig. 4.21).
3. Look at the upper edge of the whiteness. The main differential is a pleural effusion. A pleural effusion would be unlikely if the upper edge was lobulated and no meniscus was visible.
4. Compare the volume of the affected side. Loss of volume on the affected side may increase your suspicions of a mesothelioma.
5. A radiological diagnosis of mesothelioma usually requires a CT scan.

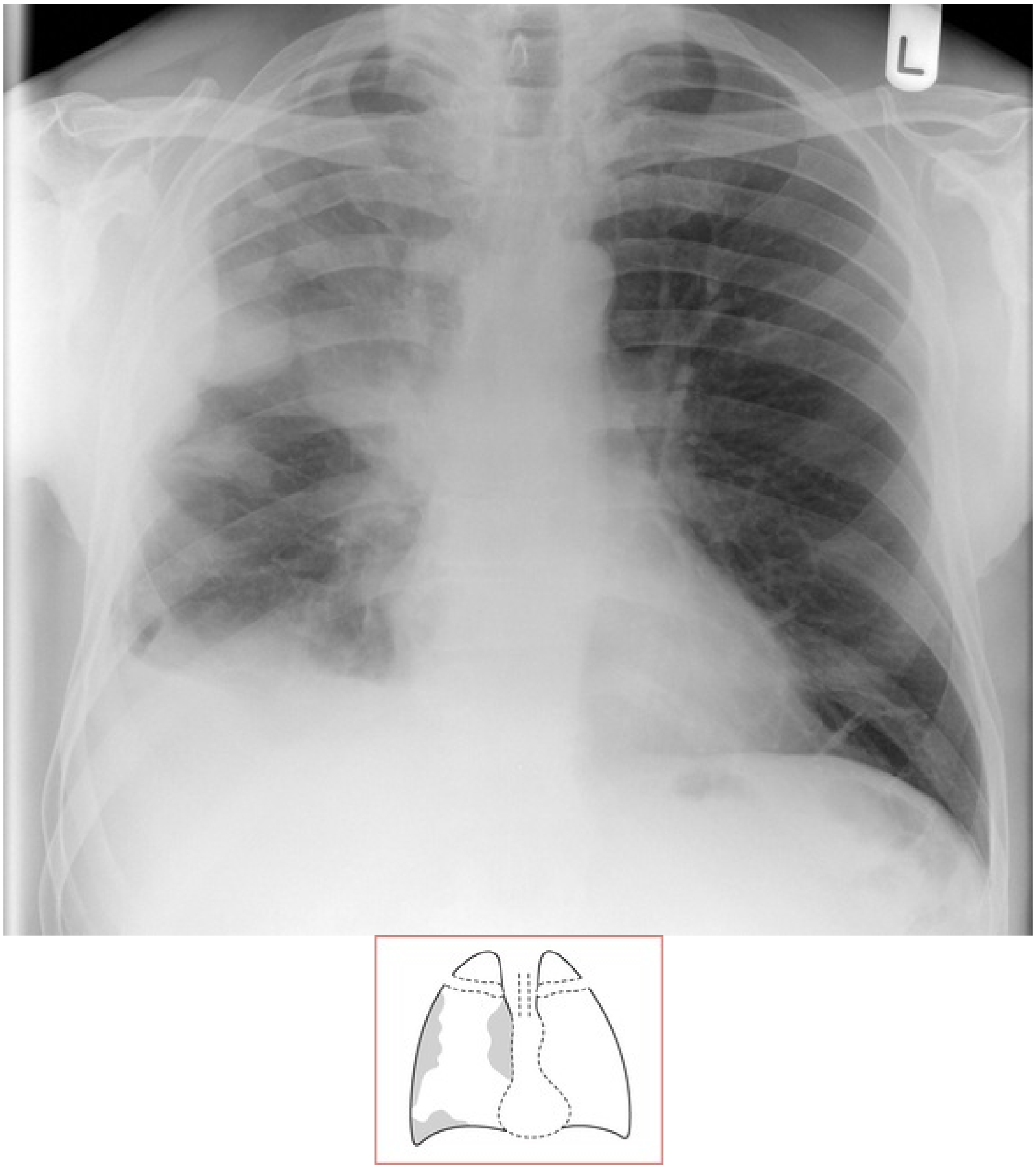


**FIGURE 4.21** A CXR of a 68-year-old man with a history of asbestos exposure. He presented with right lateral chest wall pains. The CXR demonstrates lobulated pleural thickening around the upper, mid and basal right lung, with further pleural thickening evident next to the right side of the mediastinum. CT of a mesothelioma in a different patient is shown in Figure 4.22.

## Box 4.3

### Pleural tumours

Mesothelioma

Primary pleural adenocarcinoma
Pleural sarcoma
Pleural fibromas
Neurofibromas arising paravertebrally or in relation to an intercostal nerve
Secondaries

## Pleural Disease on a CT Scan

The pleura should not really be visible on a CT scan, since they are so thin. If you see an increased grey area on the inner surface of the chest wall, then suspect that the patient may have pleural disease. Pleural abnormalities are best seen on a spiral CT (Figs 4.22–4.25).

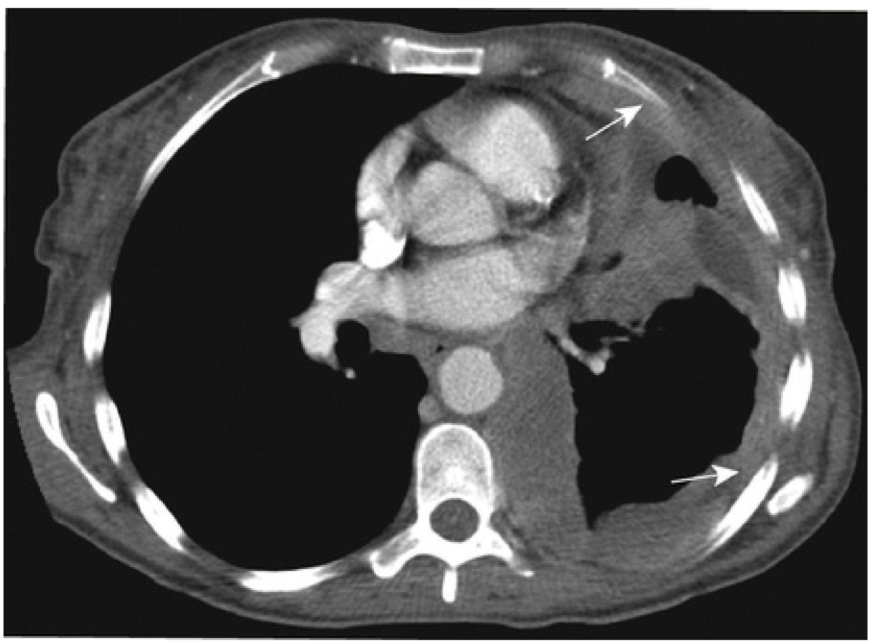


**FIGURE 4.22** CT of a mesothelioma, showing extensive pleural thickening encasing the lung, and tracking into the fissures **(arrows)**.

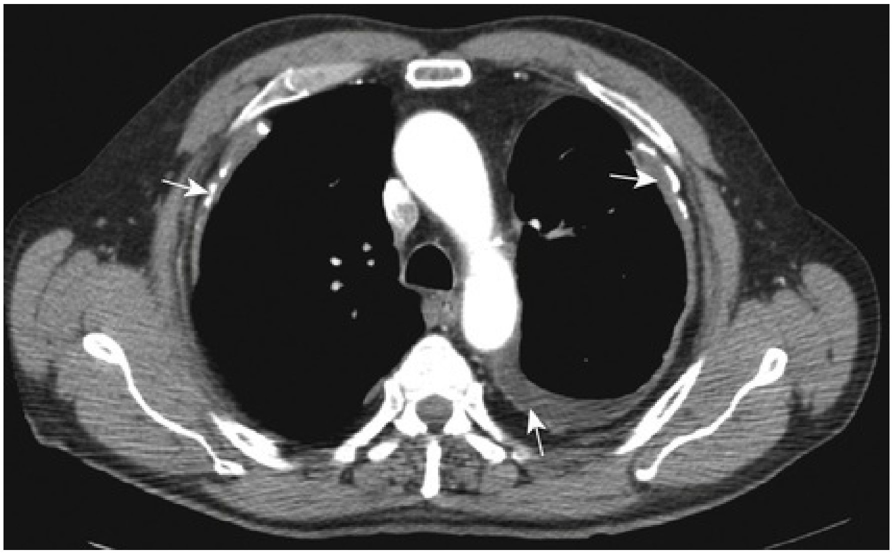


**FIGURE 4.23** CT of a patient with a history of asbestos exposure and an abnormal CXR. You can see areas of thickened pleura as a grey line on the edge of the lung **(bottom arrow)**, showing benign-type pleural effusion. White areas in some parts of thickened pleura can be seen; these are calcified pleural plaques **(top arrows)**.


**FIGURE 4.24** CT of a 63-year-old man with history of asbestos exposure who presented with unremitting chest pain. Marked thickening of the pleura can be seen as a grey area surrounding the left lung **(1)**. Also note the left lung appears smaller. This appearance, together with the history of pain, is very suggestive of malignant mesothelioma.

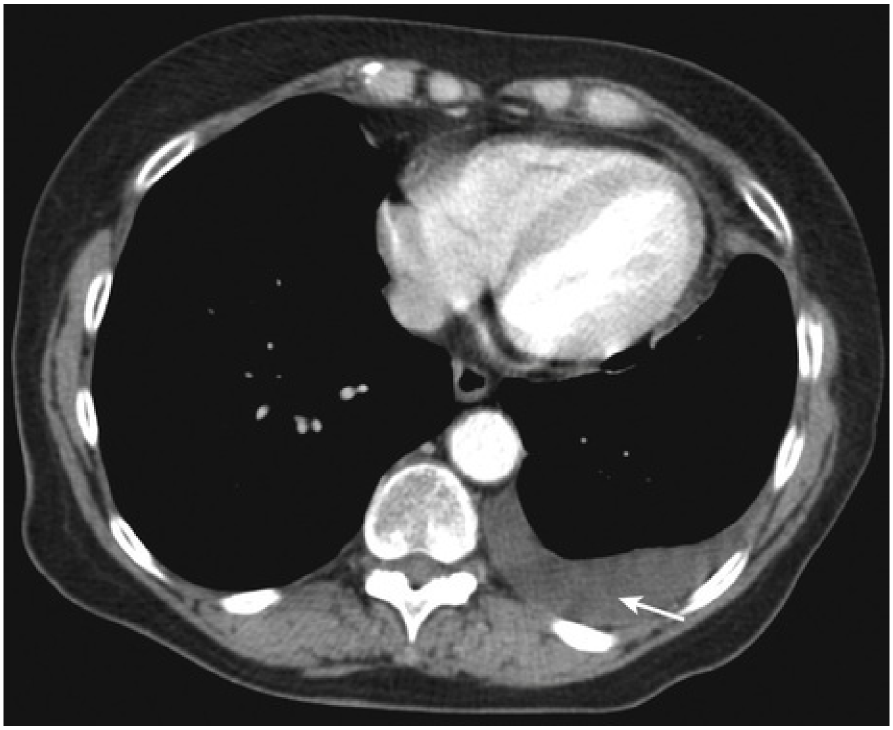


**FIGURE 4.25** CT of a 48-year-old man who presented with increased breathlessness. The patient is lying on their back and a dark grey area can be seen at the posterior part of the left lung with smooth concave edges **(arrow)**. This is a simple pleural effusion showing the CT appearance of the 'meniscus sign'.

Remember, the pleura is in two layers with a potential space in between. Pleural thickening can affect the visceral (next to the lung) or the parietal (next to the chest wall) pleura. The double layers of pleura run into and out of the fissures of the lung.

If you see increased density around the inner chest wall:

1. Look at the colour of the pleural density on the soft tissue window.
   a. Is it grey? The commonest pleural abnormality is pleural fluid. This will appear darker than the muscles of the chest wall. If the pleural density is the same as the chest wall, it is more likely to be pleural thickening.
   b. Is it white? This is more likely to be pleural calcification. Pleural plaques often contain very bright white areas where they have calcified.
2. Are the margins of the pleural density smooth or lobulated?
   a. Does it have smooth margins? This may be pleural fluid or pleural thickening. Multiple discrete lesions that are short but quite deep are probably pleural plaques.
   b. Does it have lobulated margins? This is more likely to be a malignancy.

3. Is the pleural density very extensive or patchy?
   a. Benign pleural thickening and malignant pleural diseases, especially mesothelioma, will give a much more diffuse thickening extending over a much greater area of pleura.
   b. Pleural plaques are smaller (usually 1–4 cm in length) and well defined. As both pleural plaques and mesothelioma can occur following asbestos exposure, the two may be found together.
4. Look at the position. A small pleural effusion will usually lie against the posterior chest wall as the patient is lying flat for the CT. A larger pleural effusion will surround the lung and compress it, causing some of the outer regions of the lung to become solid. This fluid can track into the fissures.
5. Look at the 'normal' pleura. With an empyema, if a contrast-enhanced scan has been performed, as well as the grey fluid the pleura may 'enhance' and appear whiter than normal.

## Lung Nodule

The term 'lung nodule' is used to describe a discrete area of whiteness situated within a lung field (Figs 4.26 and 4.27; Box 4.4). It is less than 3 cm in diameter. A 'coin lesion' refers to any well-defined nodular type lesion, which is usually, though not necessarily, round. The main worry is that these may represent a carcinoma. Other possibilities are a localised area of consolidation, an abscess or a pleural abnormality. Go through the following steps in assessing the abnormality:

1. Look at the edge of the lesion. A spiculated, irregular or lobulated edge is suggestive of malignancy.
2. Look for areas of calcification. These would be dense white (the same density as bone) and be obviously much denser than the rest of the lesion. Calcification is rare in a malignant lesion and would point you to an alternative diagnosis.
3. Look at the nature of the whiteness. If the lesion is cavitating the centre may be darker than the circumference. If looking at an x-ray film, stand back from the x-ray since a cavity is often easier to see from a distance.
4. Look for an air bronchogram. This is a sign of consolidation and so would be a most unusual finding if the lesion was a tumour.
5. Look for other coin nodules. The presence of more than one strongly suggests metastatic disease.

6. Look for abnormalities peripheral to the lesion. A tumour may cause problems distal to it such as infection causing consolidation or an area of collapse.
7. Look carefully at the rest of the x-ray. Malignant tumours may be associated with mediastinal lymphadenopathy or bone metastasis.
8. Look at old films if available. Tumours grow, and so if the lesion was present on an earlier film compare its size. Some tumours grow slowly, but it is safe to say that if the lesion has not changed over a period of 2 years or greater it is unlikely to be malignant.

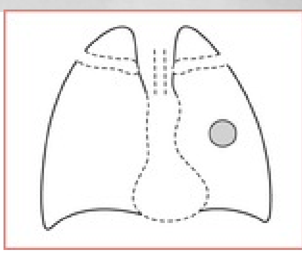



**FIGURE 4.26** There is a 3 cm round nodule in the left mid zone. This would need to be investigated as it may represent a small tumour. The nodule could be biopsied percutaneously under CT guidance.

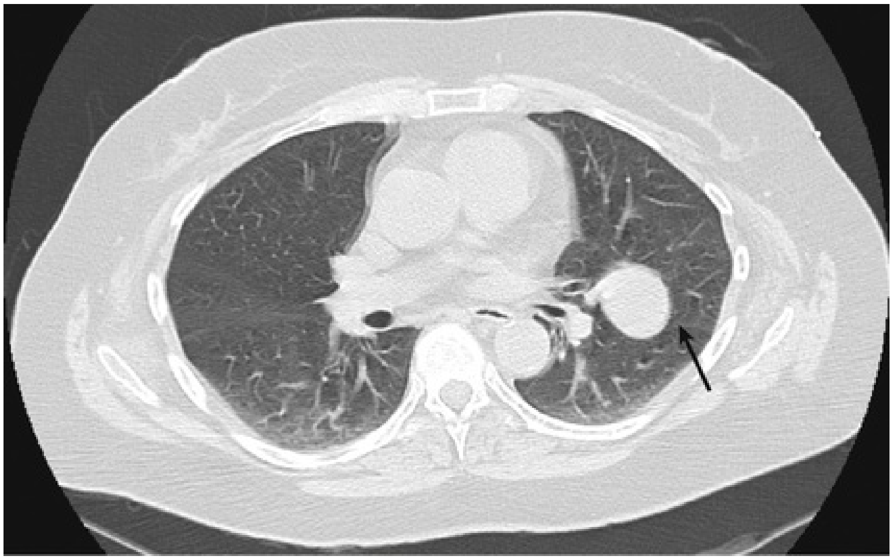


**FIGURE 4.27** Location of the left oblique fissure **(arrow)**. The coin lesion seen on the plain film lies on the oblique fissure and in front of it. The remainder of the CT scan showed no evidence of metastatic disease and no hilar or mediastinal lymph nodes were involved. The patient was referred for a PET scan and subsequently underwent a left upper lobectomy.

**Box 4.4**

### Causes of solitary pulmonary nodules

Benign tumour, e.g. hamartoma
Malignant tumour, e.g. bronchial carcinoma, single secondary
Infection, e.g. pneumonia, abscess, tuberculosis, hydatid cyst
Infarction
Rheumatoid nodule

## Cavitating Lung Lesion

Some coin lesions may cavitate (Box 4.5), and if you have identified a coin lesion, it is important to look for the features of cavitation. Therefore:

1. Look at the centre of the lesion and compare it to the periphery. If the centre is darker this points to cavitation.
2. Look for a fluid level. Look for a horizontal line within the lesion. There will be whiteness (fluid) below the line, with an area of black (air) above. Fluid levels are common in cavities and their presence should suggest one.

3. Look at the lateral film. Cavities and fluid levels are often easier to see on a lateral film, especially when they are posterior or inferior in position.
4. Look at old films. If the lesion is long-standing, it may be possible to see the cavity developing.

**Box 4.5**

### Causes of cavitating lung lesions

Abscess
Neoplasm
Cavitation around a pneumonia
Infarct
Granulomatosis with polyangiitis
Rheumatoid nodules (rare)

If you diagnose a cavitating lesion (Figs 4.28 and 4.29A,B):

1. Look at the wall of the cavity. It is often said that cavity walls are thicker (>5 mm) when the lesion is a neoplasm as opposed to an abscess. This rule does not always hold, but the thicker the wall the more likely it is that the lesion is neoplastic.
2. Look carefully at the inside of the cavity. If there appears to be a white ball within it, this is characteristic of an aspergilloma.

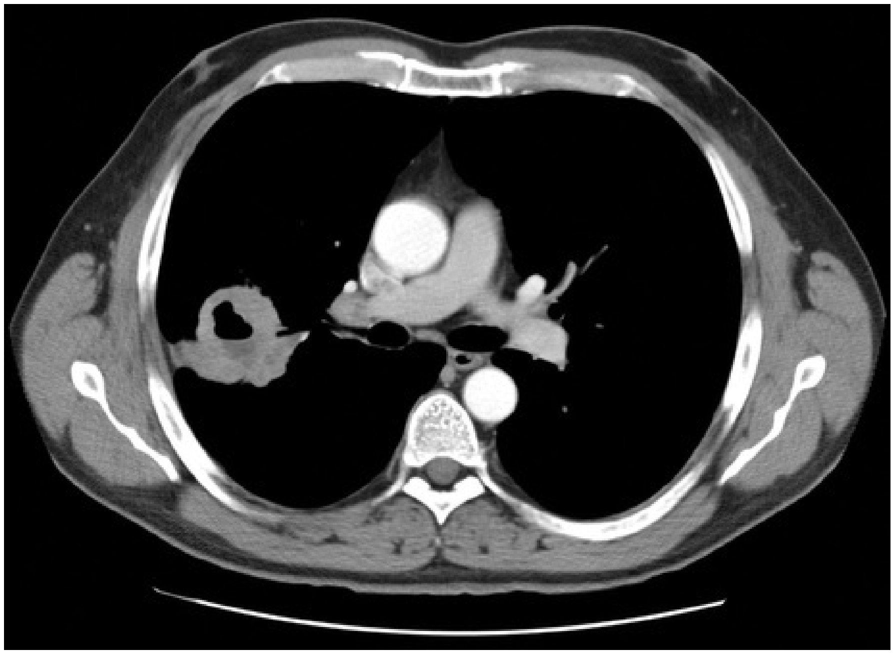
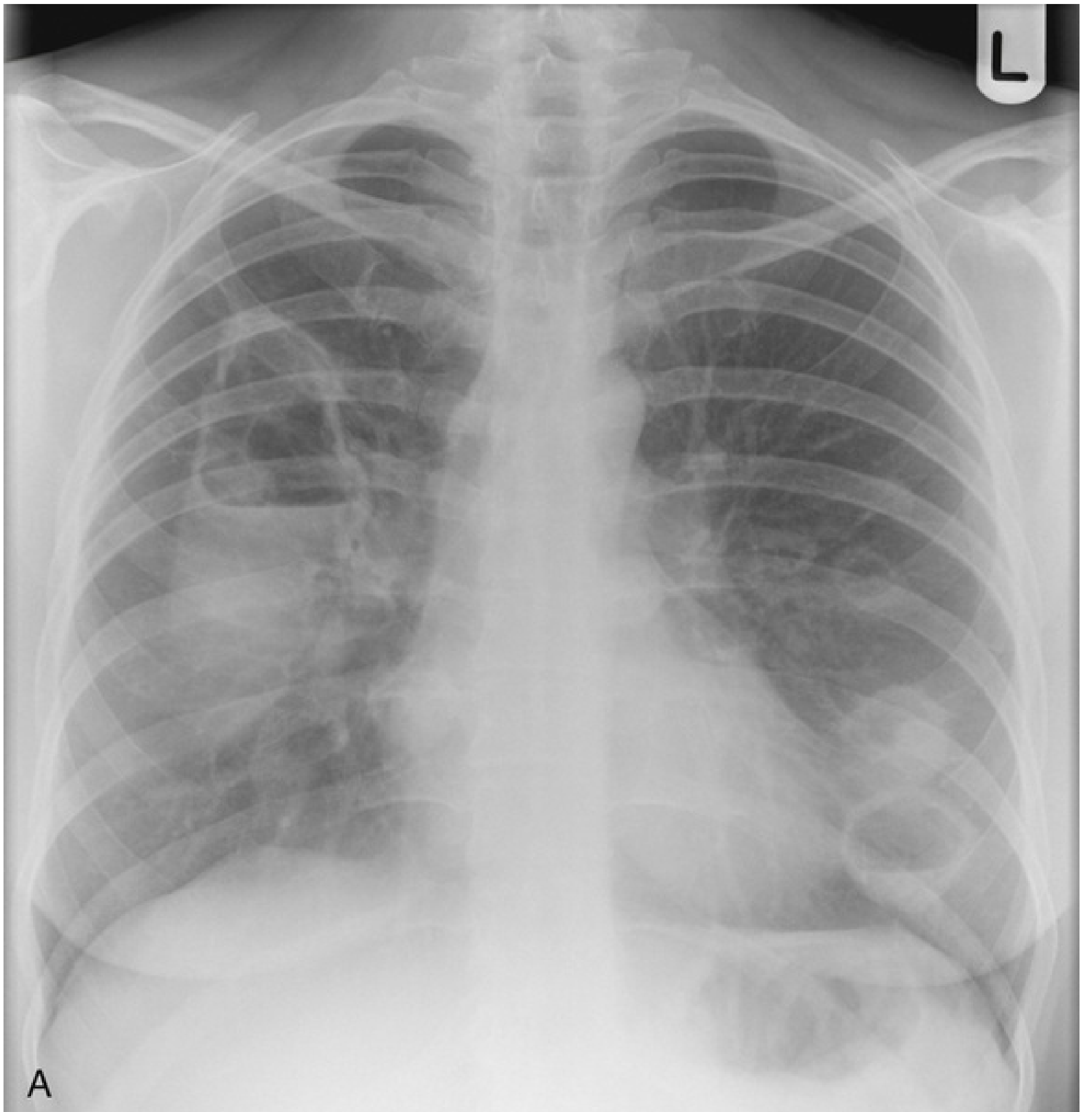


**FIGURE 4.28** Shown here is a nodule with a black centre indicating that it has cavitated. This was proven to be a squamous cell carcinoma.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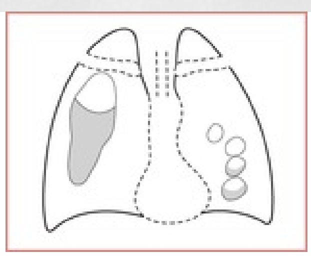


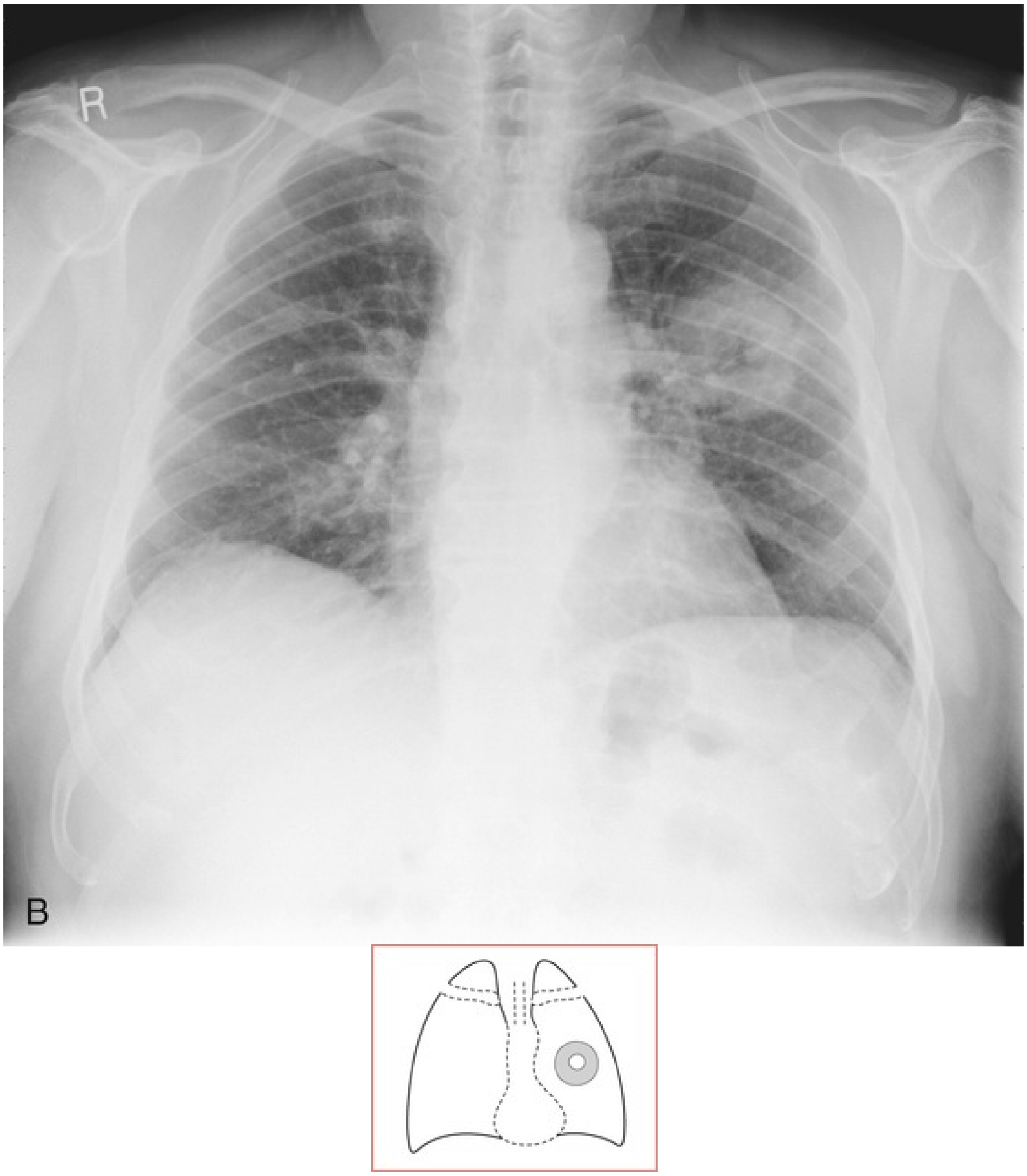
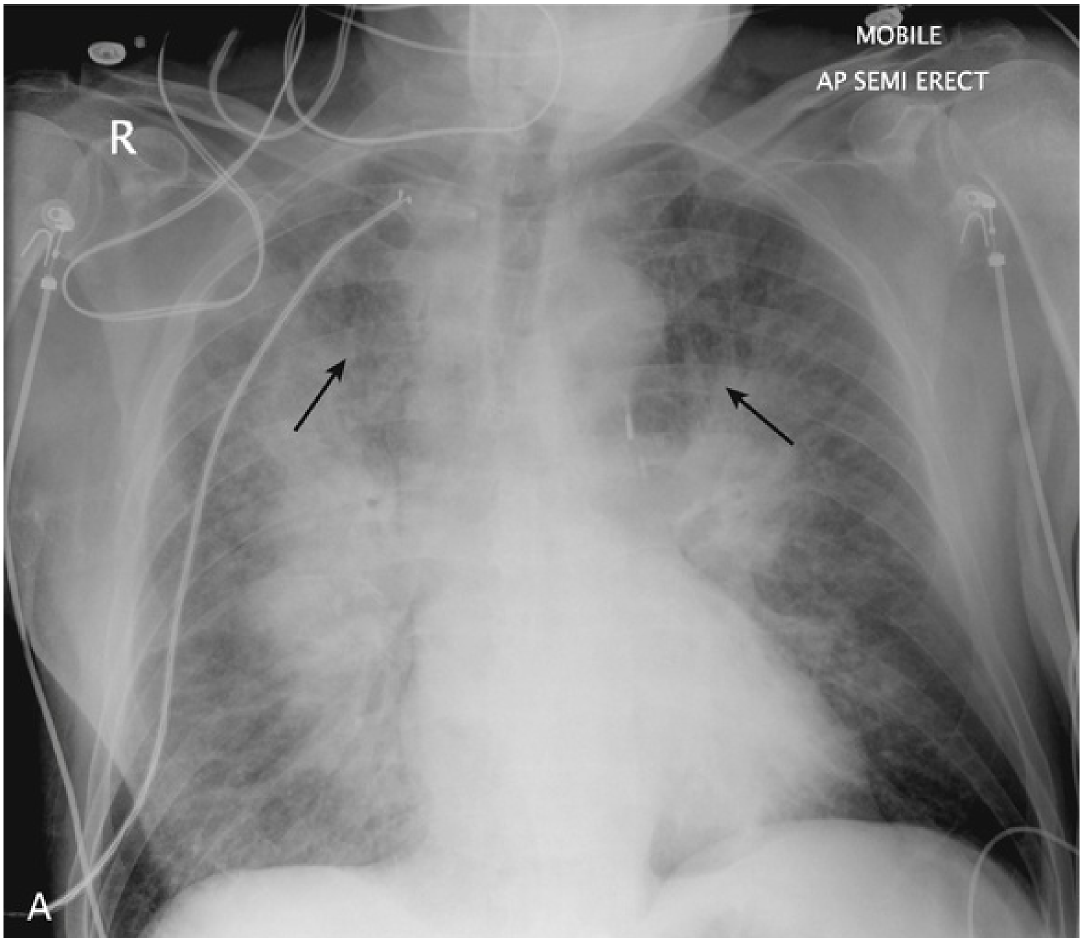



**FIGURE 4.29** Cavitating lung lesions. **(A)** Bilateral thin-walled cavities, some with air–fluid levels. This was due to granulomatosis with polyangiitis (GPA), formerly termed Wegener's granulomatosis. **(B)** A single cavitating mass lesion in the left mid zone. This has a much thicker wall. This lesion was found to be due to a cavitating tumour. The thickness of the wall makes this a more likely diagnosis.

## Left Ventricular Failure (LVF)

If you suspect heart failure as a cause of a generalised, or localised, area of shadowing (Fig. 4.30A,B) then:

1. Look at the size of the heart. The presence of left ventricular dilatation is strongly suggestive of heart failure. In a PA film the maximum diameter of the heart should be less than half that of the maximum diameter of the thorax (the cardiothoracic ratio). If it exceeds this, then there is a cardiac abnormality, such as left ventricular enlargement, and this suggests that the associated shadowing is due to left ventricular failure (LVF) (see Chapter 7 for other causes of an enlarged cardiac shadow). You cannot comment on the size of the heart on an anterior-posterior (AP) portable film since the heart is anterior and will appear magnified. Note also that in acute-onset LVF you may not get cardiac enlargement.
2. Look for Kerley B lines. These are caused by oedema of the interlobular septa. They are horizontal, nonbranching, white lines best seen at the periphery of the lung just above the costophrenic angle.
3. Compare the size of the upper lobe and lower lobe blood vessels. Take an upper lobe and a lower lobe blood vessel at similar distances from the hilum and compare their widths. The upper should be narrower than the lower. If they are the same size or the upper is wider there is upper lobe blood diversion – the first sign of heart failure. Note that this only applies to an erect film. Upper lobe blood diversion is normal on a supine film and not suggestive of heart failure – a common mistake. Upper lobe blood diversion is due to lower zone arteriolar vasoconstriction secondary to alveolar hypoxia.
4. Look for whiteness that spreads out from the hilum giving a ‘bat’s wing’ appearance. This is what you see in severe heart failure. To confirm severe heart failure as the cause of this more generalised whiteness look again for upper lobe blood diversion and Kerley B lines. Look also at the hilum. In pulmonary oedema it may appear distended and the vessels close to the hilum may be blurred.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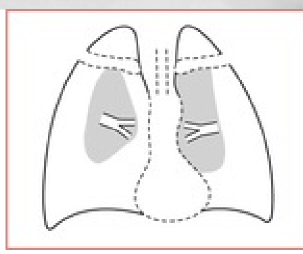


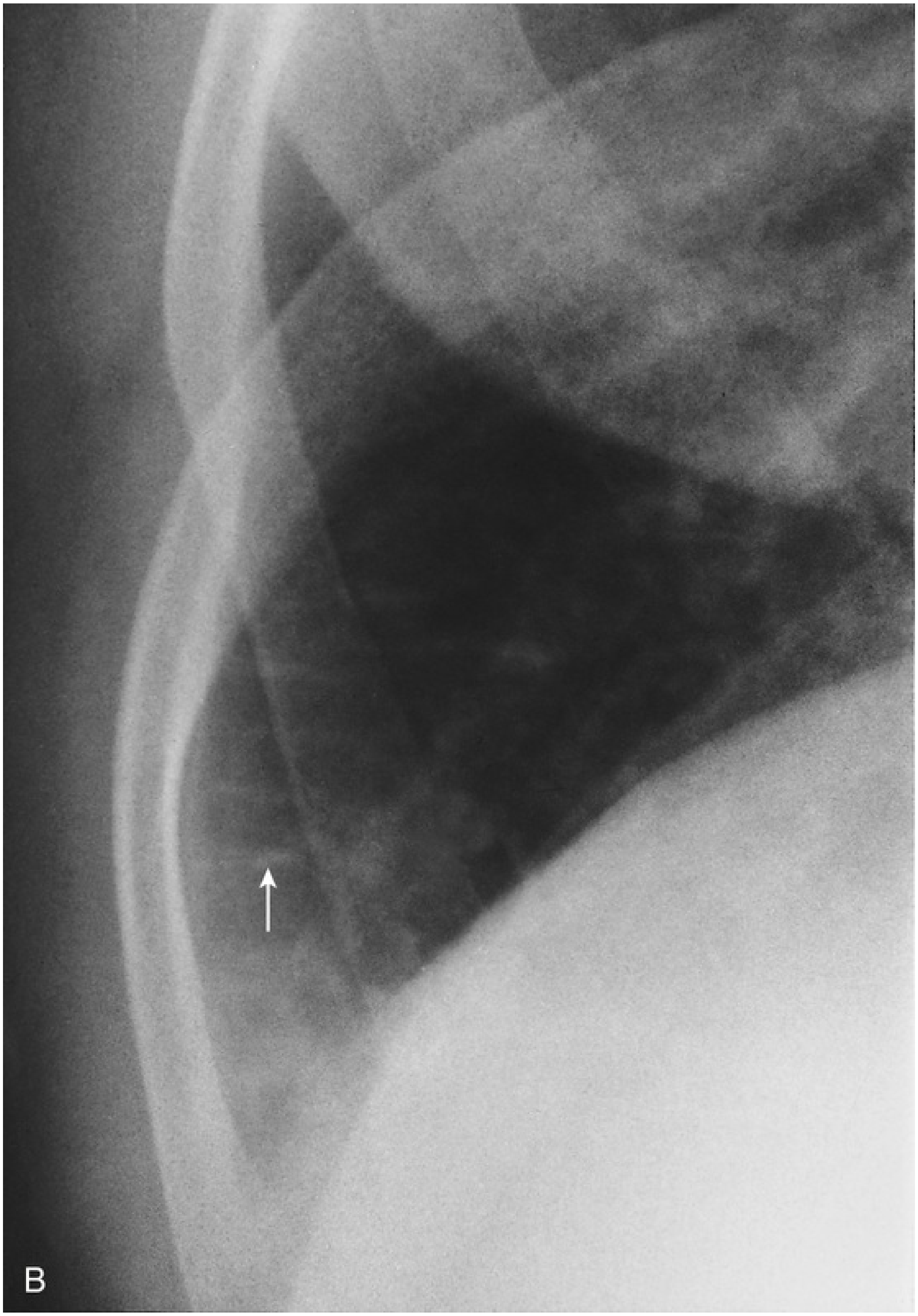



**FIGURE 4.30** **(A)** Patient presented with an acute cardiac event. This patient's scan clearly shows 'bat's wing' hilar shadows characteristic of pulmonary oedema. At present the pleural spaces are clear but it is common in pulmonary oedema to develop pleural effusions. These are often larger on the right than on the left. Pulmonary upper zone blood

vessels are also often dilated **(arrows)**. **(B)** The magnified image of the right lower zone shows the horizontal septal lines more clearly **(arrow)**.

## LVF and CT

To diagnose pulmonary oedema secondary to LVF on a CT you need to look for the same features such as a large heart and evidence of interstitial oedema that you looked for in the plain CXR (Fig. 4.31). Therefore:

1. Look at the heart size and, just as you did with the plain CXR, compare the diameter of the heart to the diameter of the thorax. Just as with the plain CXR, the heart should be less than half the diameter of the thorax. On a CT scan you can differentiate between the left and right ventricle. The left ventricle should be larger than the right and this difference will be exaggerated in LVF.
2. Look for septal lines. Normally the interlobular septae are not visible on CT images. In LVF and pulmonary oedema, the interlobular septae and the venules become oedematous, making them visible on CT images. These can be seen as hexagonal white lines within the lungs.
3. Look for ground glass shadowing, which is a sign of pulmonary oedema. This will appear in the dependent part of the lungs, which, on a CT scan, with the patient lying on their back, will be posterior. Look at the posterior and anterior parts of the lung fields. If the posterior part is subtly whiter than the anterior part, then pulmonary oedema is a possible cause.
4. Look for pleural effusion, which will usually (but not always) be bilateral. On the lung windows this will appear as an area of whiteness with a distinct, usually curved border. With the patient lying on their back, this will occur posteriorly. On the mediastinal windows the effusion will be grey in colour since its density will be between that of air (black) and bone (white). The pleura itself should be normal so you should not see any signs of pleural thickening as would be the case with pleural disease.

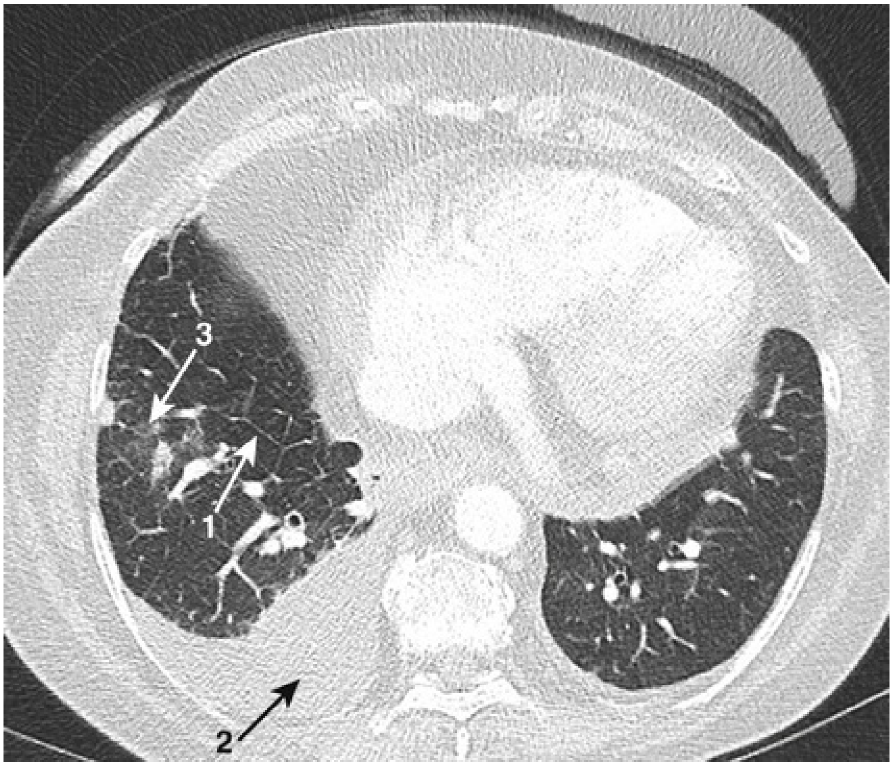


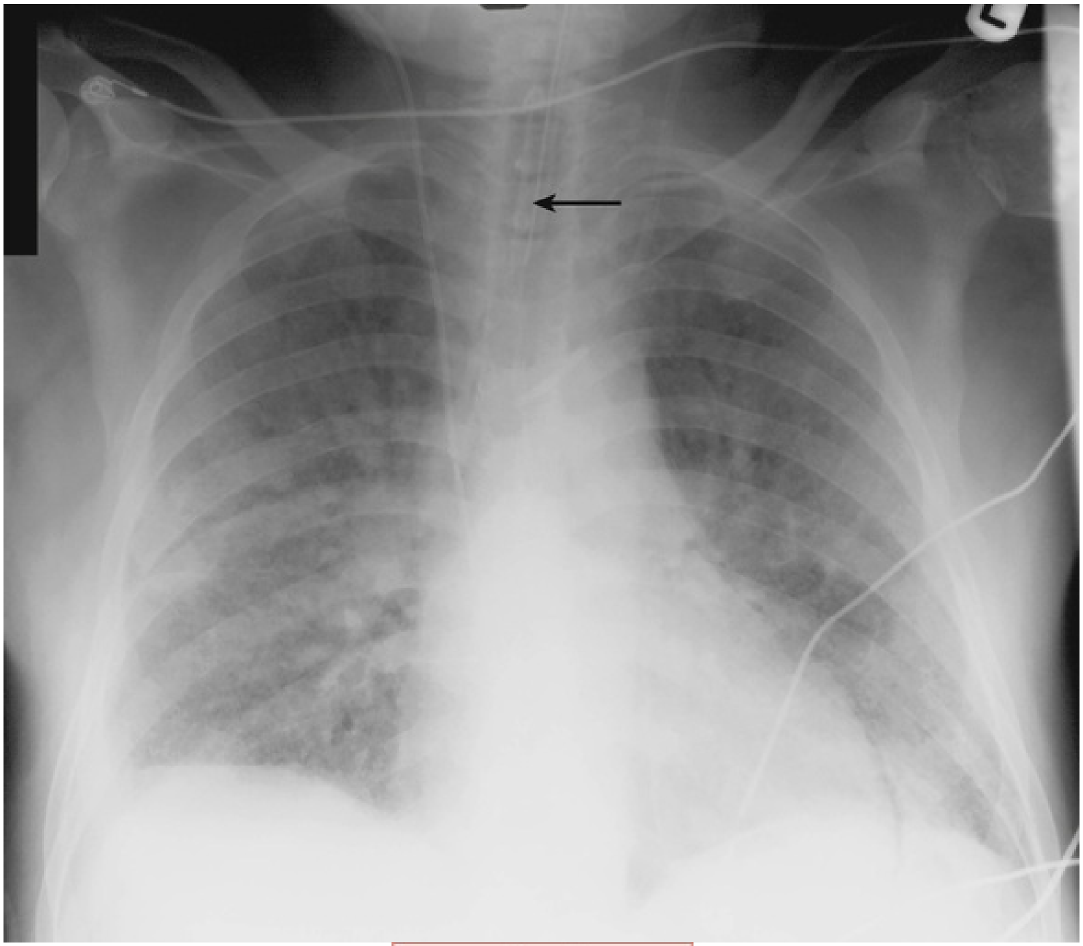

**FIGURE 4.31** CT lung window settings. Patient presented with increasing breathlessness and history of paroxysmal nocturnal dyspnoea (PND) and orthopnoea. The scan shows typical features of pulmonary oedema. Note the interlobular septae in the right lung base **(1)**, enlarged heart, right pleural effusion **(2)** and subtle ground glass change **(3)**.

## Acute Respiratory Distress Syndrome (ARDS)

ARDS is defined as respiratory failure in association with a CXR that shows confluent alveolar opacification (whitening) of the lungs that looks like pulmonary oedema.

The other (and far more common) cause of pulmonary oedema is LVF, which is also a cause of respiratory failure. Therefore, if you see a CXR that has bilateral white shadows in the lungs and you suspect ARDS look for the following clues:

1. Look at the distribution of the shadowing (Fig. 4.32). In ARDS it should be present in both lungs – that is part of the definition. Look also at the nature of the shadowing. It is usually fairly ill-defined, which means it is difficult to see a clear edge. It may also have the features of consolidation, which means that you may be able to see an air bronchogram within it.



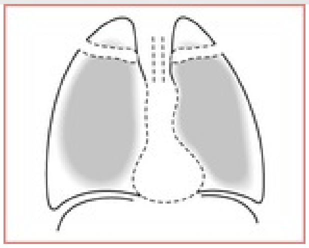


**FIGURE 4.32** This 36-year-old man presented with severe upper abdominal pain and was diagnosed as having pancreatitis. Whilst in hospital he became acutely short of breath and required intubation and ventilation. Note the ET tube **(arrow)**. A CXR was taken which suggested that he had developed the complication of acute respiratory distress syndrome (ARDS). Note that the x-ray shows multiple bilateral white shadows but does not have any signs of left ventricular failure. Unfortunately this man died after 3 weeks of mechanical ventilation on the intensive care unit.

2. To distinguish ARDS from LVF:
    a. Look at the heart size. In LVF you would expect the heart to be big. In ARDS it may be normal size.
    b. Look again at the distribution of the shadowing. In LVF it tends to be

more central whereas in ARDS it is more peripheral.

c. Look for Kerley B lines. Although these do occur in ARDS they are far more common in LVF.

d. Look for the presence of a pleural effusion. These may be small so look carefully at the edge of the diaphragm for loss of the normal costophrenic angle. Pleural effusions can occur in ARDS but they are much more common in LVF.

e. Look at old films. A large heart and pleural effusion may have shown on earlier films and may point to left ventricular failure as a more likely diagnosis.

If you are certain that the CXR suggests a diagnosis of ARDS then look for clues as to the cause. There are many causes of ARDS (see Box 4.6) and most can only be picked up by history and examination. However, an asymmetrical distribution of the shadowing, i.e. significantly more shadowing in one lung than the other, may point to lung injury as a cause. CXRs taken just before the development of ARDS may show an obvious pneumonia. (See Box 4.7 for complications of ARDS.)

**Box 4.6**

## Some causes of ARDS

ARDS is caused by any insult to either the alveolar or endothelial cells that results in a loss of integrity of the junction between those cells, allowing fluid to leak into the alveoli. Causes include:

Aspiration including toxic gas inhalation
Lung trauma
Pneumonia
Radiation
Sepsis
Drugs, including drugs of abuse
Drowning
Fat embolism after trauma
Hypersensitivity reactions
Transfusion reactions

**Box 4.7**

**Complications of ARDS**

A patient with ARDS should have their CXR repeated daily. Look for signs of disease progression or resolution. Look also for the development of a pneumothorax or lung cysts due to barotraumas caused by the use of positive pressure ventilation in the treatment of ARDS.

## ARDS and CT

A CT scan can confirm the diagnosis of ARDS and also give useful information about the aetiology and prognosis (Fig. 4.33).

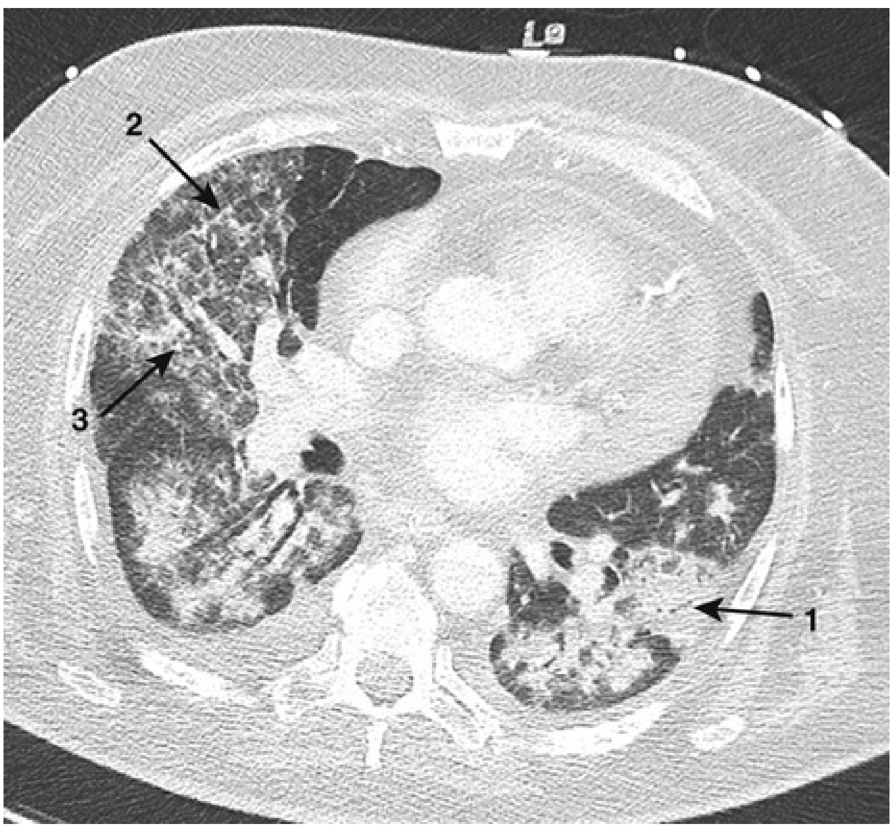



**FIGURE 4.33** CT lung window settings. This 54-year-old man developed type I respiratory failure as a complication of Gram-negative sepsis. The CT scan shows typical features of ARDS. Notice the bilateral shadowing which includes areas of consolidation **(1)**, ground glass shadowing **(2)** and interstitial thickening **(3)**. Note that these changes are asymmetric in keeping with a nonpulmonary cause of ARDS.

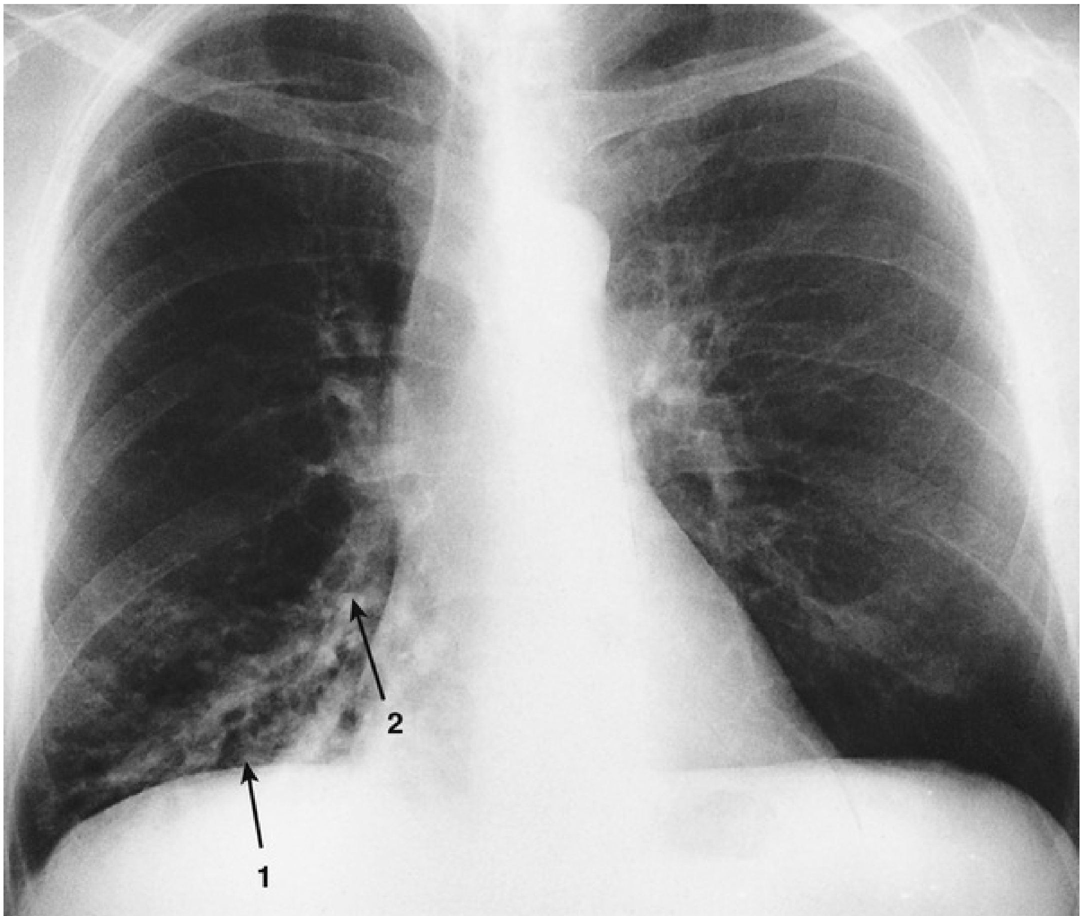
When looking at the CT:

1. Check that the white abnormalities are present in both lungs. ARDS is always bilateral.
2. Look at the nature of the abnormalities. The commonest abnormalities are ground glass shadowing and consolidation.
3. Look for interstitial thickening. This will appear as linear opacities.
4. Check the distribution of the shadows. This can give a clue to the aetiology. A general rule is that an asymmetrical distribution of shadows is more likely to be due to pulmonary disease and a symmetrical distribution due to extra-pulmonary disease. Diffuse shadowing is associated with a worse prognosis than shadowing confined to the lower zones.

## Bronchiectasis

Bronchiectasis can be difficult to diagnose on a plain CXR (Fig. 4.34). If you suspect it as a cause of increased shadowing then look for the following features:

1. *Ring shadows.* These look like rings and are any size up to 1 cm in diameter. They can be single but usually occur in groups giving a 'bunches of grapes' appearance. Ring shadows represent diseased bronchi seen end on.
2. *Tramline shadows.* Look for these towards the periphery of the lung. They consist of two thick white parallel lines separated by black. It is common to get parallel lines close to the hilum in the normal CXR but these lines are hairline in nature. True tramline shadowing is thicker and is not necessarily close to the hilum. Tramline shadows are diseased bronchi seen side on.
3. *Tubular shadows.* These are solid thick white shadows up to 8 mm wide. They represent bronchi filled with secretions seen side on. They are not common but their presence suggests bronchiectasis.
4. *Glove finger shadows.* These represent a group of tubular shadows seen head on and look like the fingers of a glove – hence the name!



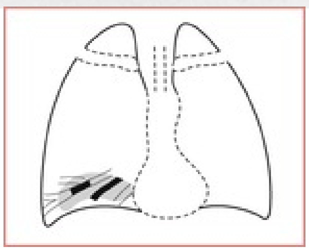



**FIGURE 4.34** A localised area of bronchiectasis in the right lower lobe which has resulted from an earlier pertussis infection. In the lower lobe you can see a cluster of typical ring shadows giving a 'bunches of grapes' appearance **(1)** together with bronchial wall thickening seen side-on, which gives two thick parallel lines, known as tramline shadows **(2)**.

The presence of any of these features suggests the possibility of bronchiectasis. A normal CXR does not, however, exclude the diagnosis and CT scanning is the most sensitive diagnostic test available.

## The HRCT scan and bronchiectasis

Although bronchiectasis can be diagnosed on a plain CXR, in half the patients the x-ray is normal. Therefore, if you suspect bronchiectasis and the CXR is normal, you will need to undertake a high-resolution CT (HRCT) scan (Fig. 4.35). An HRCT scan may also give you clues as to the cause of the bronchiectasis and will give you a much more accurate picture of the extent of disease.

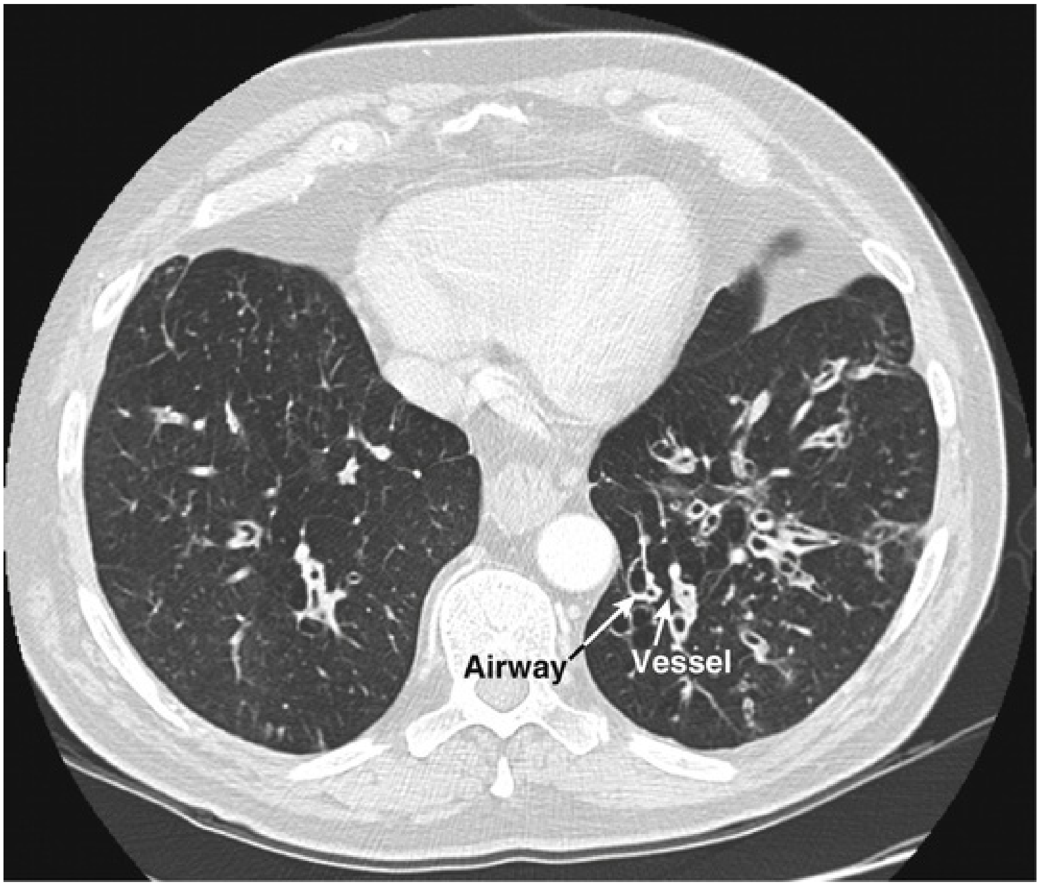



**FIGURE 4.35** The HRCT scan and bronchiectasis. The airways and vessels are indicated with the arrows.

To diagnose bronchiectasis on HRCT scanning you need to identify areas in which the bronchi are dilated. There are a number of ways of doing this. Look at the lung windows:

1. Look in the periphery of the lung, where the airways are round. Compare the airway diameter here to that of the neighbouring blood vessels. If the diameter of the airway is larger than that of the neighbouring blood vessel, then it is dilated. The airway is usually patent so will have a black hole in the middle whereas the blood vessel is solid white.

2. Look in the middle third of the lung fields. The airways here can be seen along their long axis, and the airway walls should normally taper over 2 cm. If there is no tapering, this is a sign of more proximal airway dilatation.
3. Look for areas of mucus plugging. These are airways in which the lumen has been blocked by mucus. The normal airway has the appearance of a white ring (the airway wall) surrounding a black hole (the air within the airway). When the airway is plugged it has a solid appearance – the plug, being mucus, may have a lower density (be darker) than the airway wall when you look at the mediastinal windows. Occasionally it is not clear whether these structures are impacted airways or blood vessels since both may appear white.
4. Look at the lung parenchyma around the airways, since changes in the lung occur around bronchiectatic airways. These changes include:
   - areas of collapse, known as atelectasis
   - areas of very small airway plugging, known as 'tree in bud'
   - larger patches of consolidation.

The HRCT scan may also give some clues as to the cause of the bronchiectasis (Box 4.8). The radiologist will look at the distribution of the changes to give an indication of the possible aetiology. For example:

- If it is localised to one lobe or one segment of lung it could be due to an obstructive lesion which would require further investigation by a contiguous CT scan and a bronchoscopy to find the cause.
- Proximal bronchiectasis is often seen in allergic bronchopulmonary aspergillosis (ABPA).
- Cystic fibrosis causes widespread bronchiectasis often more marked in the upper zones, with some sparing of the lung bases.

**Box 4.8**

### Some causes of bronchiectasis

Structural, e.g. obstruction (carcinoma, foreign body)
Infection, e.g. childhood pertussis or measles, tuberculosis, pneumonia
Immune, e.g. hypogammaglobulinaemia, allergic bronchopulmonary aspergillosis
Congenital, e.g. cystic fibrosis
Idiopathic

Finally, when looking at the scan, you should note the extent of the disease. Mild bronchiectasis is a relatively common finding on HRCT and may not necessarily be the cause of the patient's symptoms. Interpret the scan in the context of the clinical history and make sure that you discuss the images with a radiologist.

## Fibrosis

Fibrosis is one of the rarer causes of white lung (Box 4.9) and you need to differentiate it from consolidation or oedema which is far more common (Fig. 4.36). If you suspect fibrosis:

1. Look at old x-rays if possible. Fibrosis is a fairly chronic process so if present previously it is more likely to be fibrosis than consolidation or oedema.
2. Look at the distribution of the shadowing. This may help differentiate fibrosis from oedema since the latter is more likely to be bilateral, basal and peripheral. Therefore shadowing that is mid zone or apical is more likely to be fibrosis.
3. Look at the size of the lungs. Fibrosis may cause shrinkage of the lungs which will not be caused by consolidation or oedema. The presence of small lungs points strongly to fibrosis.
4. Look at the shape of the mediastinum. Since fibrosis causes shrinkage of the lungs it will pull the mediastinum and distort the outline.
5. Look at the nature of the shadowing. Pulmonary fibrosis gives reticular-nodular shadowing which simply means a meshwork of lines that combine to form nodules and ring shadows of about 5 mm in diameter. Sometimes the meshwork is very fine, giving a ground-glass appearance, said to look like a thin veil over the lung. Later it gives a more coarse appearance and is said to look like a honeycomb. Compare this appearance to that of pulmonary oedema (Fig. 4.31) or consolidation (Fig. 4.14) and you will see that it is quite distinctive, although in fact it is the other features of fibrosis outlined above that are often the most useful in making the diagnosis.
6. Look at the heart border and diaphragm. Both of these may appear blurred if fibrosis is present.
7. Look at the vascular markings. These become less distinct in areas of fibrosis. This is due to the development of numerous small areas of lung collapse.

**Box 4.9**

## Causes of fibrosis

Idiopathic
External/occupational, e.g. extrinsic allergic alveolitis, asbestosis
Infection, e.g. tuberculosis, psittacosis, aspiration pneumonia
Collagen vascular, e.g. rheumatoid arthritis, systemic lupus erythematosus (SLE)
Sarcoid
Iatrogenic, e.g. amiodarone, busulfan, radiotherapy

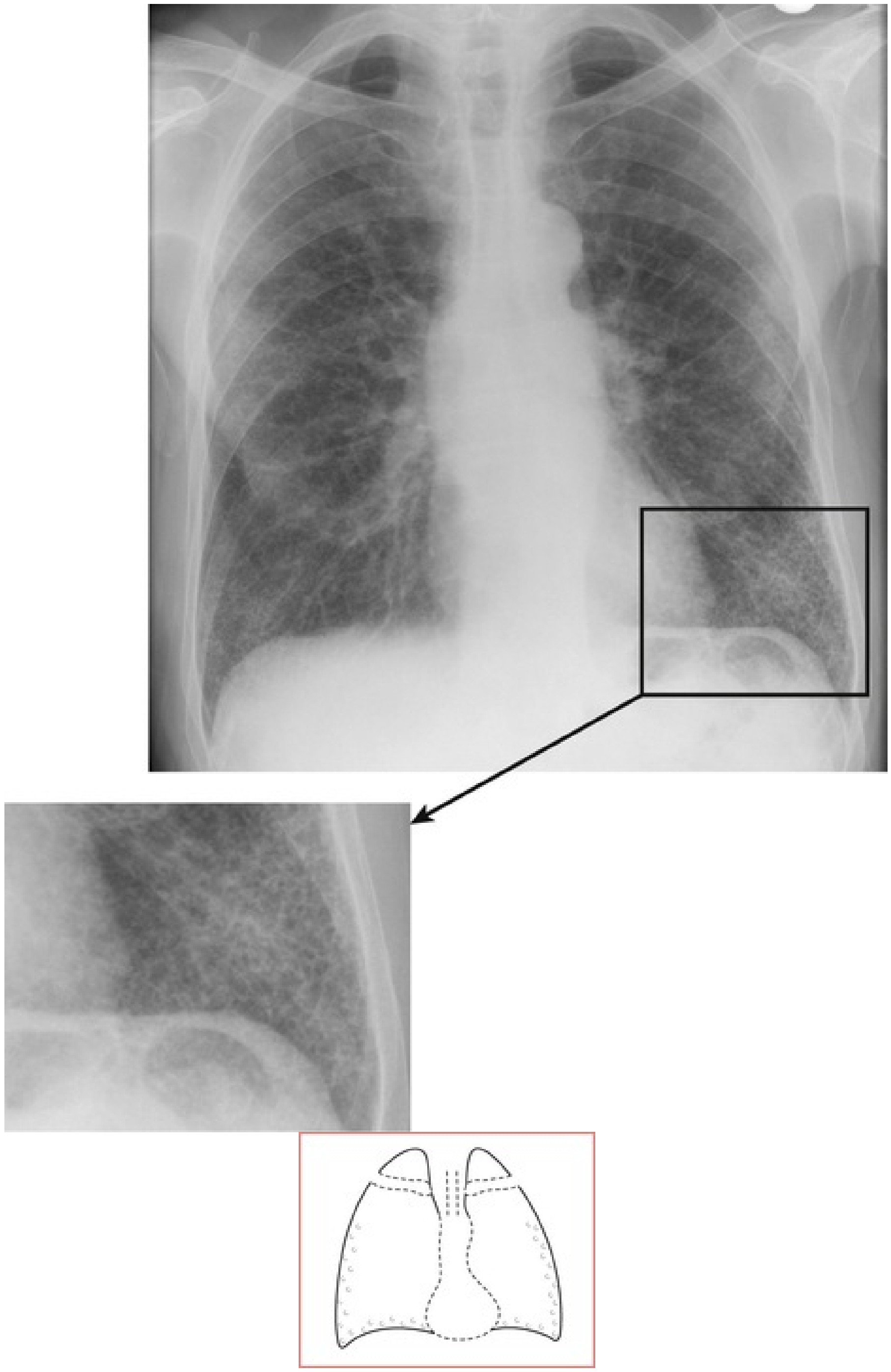


**FIGURE 4.36** A patient with usual interstitial pneumonia, a fibrotic lung disease. The scan demonstrates a fine meshwork pattern over the lungs which is worse in the periphery of the lungs, especially at the lung bases. In very severely affected areas a denser meshwork produces a ‘honeycomb’ appearance.

## The HRCT scan and pulmonary fibrosis

HRCT is the established test for patients with pulmonary fibrosis. It is a more sensitive and specific test than a plain CXR. If there is clinical suspicion and the patient has a normal x-ray you should still order a HRCT. The scan will demonstrate the distribution and characteristics of fibrosis. This can give valuable clues as to its aetiology and is a sensitive way to follow disease progression.

You will be ordering the scan to give you details of any lung parenchymal changes. Therefore you will need to order a HRCT scan so that you can see the fine detail of the lung architecture (Fig. 4.37).

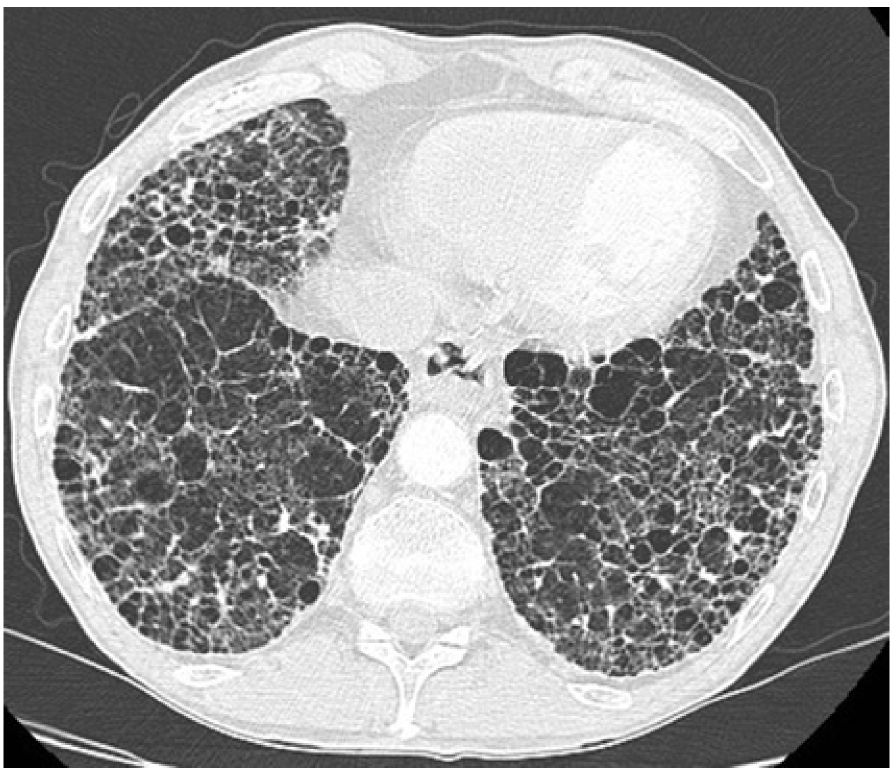


**FIGURE 4.37** HRCT lung window settings. HRCT of a 76-year-old man with an 8-month history of increasing breathlessness and dry cough. Spirometry showed a restrictive deficit with reduced transfer factor. The HRCT shows typical honeycombing.

### Confirming fibrosis

1. Look at the lung edges along the pleura. In early cases of fibrosis you will see fine lines along the edges coming into the lung that have a sawtoothed

appearance.
2. The meshwork of lines in the lung periphery may give rise to a ‘honeycomb’ appearance. This occurs late on in the fibrotic process and consists of areas of black air surrounded by a thicker white border.
3. Look at the bronchi. In pulmonary fibrosis owing to architectural distortion and loss of volume, the airway walls are pulled apart. Unlike in bronchiectasis, the walls do not appear thickened. This is known as traction airway change.
4. Look for a ground glass density in the lung. This has a very specific appearance. There is abnormal increased whiteness in the lung. Look at the blood vessels – with ground glass shadowing the blood vessels must still be visible. If they cannot be seen then that area of lung is said to be consolidated (another cause of increased whiteness in the lung). Ground glass density tends to be unevenly distributed through the lung – it may affect particular zones of the lung or occur in smaller discrete areas. Ground glass density may represent very fine fibrotic change which is below the resolution of the scanner to demonstrate more clearly or conversely be due to transient abnormalities such as infection or fluid within the lung. If seen in isolation it is difficult to be certain of its significance, but if seen with the other features described above it is consistent with an interstitial fibrosis.

## Determining aetiology

Radiologists may be able to determine the aetiology of pulmonary fibrosis by careful examination of the HRCT images. They will look for a number of clues, for example:

1. *The distribution of the fibrotic changes*.
    a. Idiopathic pulmonary fibrosis, fibrosis secondary to connective tissue disease, and asbestosis are characterised by their patchy distribution and by the presence of subpleural, predominantly basal, fibrotic changes.
    b. Sarcoidosis causes changes predominantly in the upper and mid zones and around the hila.
2. *The appearance of the interlobular septa*. In lymphangitis carcinomatosis there is irregular thickening of the interlobular septa. Some nodular deposits can also be seen on the pleura, but the distribution is not usually the same as that of sarcoidosis.
3. *The appearance of the pleura*. In asbestos lung diseases the pulmonary fibrosis is often accompanied by changes to the pleura, notably pleural

thickening and calcified pleural plaques.

4. *Mediastinal changes*. In sarcoidosis the scan may demonstrate mediastinal lymphadenopathy.

The HRCT scan can accurately determine the aetiology of interstitial lung disease. However, this accuracy is highly dependent on the skill of the interpreter and so it is vital that these scans are assessed by experienced radiologists. Take care to ensure the radiologist is provided with full clinical information to aid interpretation.

## Focus on Ground Glass Shadowing

Ground glass shadowing is a common finding on high-resolution CT (HRCT) scans (see Fig. 4.38). It is seen on the lung windows and is a subtle increase in whiteness of the lung parenchyma. To distinguish it from consolidation, look for blood vessels. In ground glass shadowing you will still be able to see the blood vessels unlike in consolidation where these are obscured. Look also at the airways. In consolidation the airway wall is obscured leaving only the air within the lumen visible as a black structure within the white shadowing (the air bronchogram). In ground glass shadowing both the airway lumen and wall remain visible though will be slightly less distinct than normal.


**FIGURE 4.38** CT lung window settings. A CT of a patient who presented with what was presumed to be a viral chest infection. Note the area of ground glass shadowing **(1)** which appears as an area of haziness in the

left lung anteriorly with visible blood vessels **(2)** and no air bronchograms.

Ground glass shadowing occurs when the ratio of air to tissue changes, either due to a reduction in the amount of alveolar air or an increase in a thickness of the alveolar walls. A reduction in alveolar air will be caused by partial collapse of alveoli or small airways, and an increase in thickness of alveolar walls can be due to oedema or inflammation. The differential diagnosis of ground glass shadowing is therefore very wide and includes airways diseases, interstitial lung disease and vascular diseases.

Clues as to the cause can be gained by looking at the distribution of the shadowing. Table 4.1 shows some of the causes of ground glass shadowing and the associated distribution of the changes.

## Table 4.1

## Causes of ground glass shadowing

| Cause | Distribution of ground glass shadowing on CT | Other features |
|---|---|---|
| *Pneumocystis carinii* pneumonia (PCP) | Perihilar, mid zone | Septal thickening, lung cysts |
| Simple eosinophilic pneumonia | Peripheral, mid and upper zones | Tends to clear spontaneously |
| Acute eosinophilic pneumonia | Bilateral, no predominant zonal distribution | |
| Usual interstitial pneumonia (UIP) | Peripheral and basal, not a prominent feature | CT appearance usually dominated by fibrosis and honeycombing |
| Nonspecific interstitial pneumonia (NSIP) | Subpleural and asymmetrical | Reticular and linear opacities |
| Cryptogenic organising pneumonia (COP) | No predominant distribution | Associated with nodules and consolidation |
| Acute interstitial pneumonia (AIP) | Bilateral and symmetrical, usually widespread though more predominant in lower zones | Consolidation and fibrosis in later stages |
| Respiratory bronchiolitis-associated interstitial lung disease (RBILD) | Upper zone preference | Patchy areas of fibrosis and bronchial wall thickening |
| Pulmonary oedema | Posteriorly (the dependent area with the patient lying flat) | Large heart and prominent septal lines |
| Hypersensitivity pneumonitis | Bilateral, mid and lower zones | |
| Drug reactions | More commonly peripheral | Overlap with hypersensitivity pneumonitis features |
| Vasculitis, Wegener's | Patchy distribution | Often discrete nodules and cavitation |
| Idiopathic pulmonary haemorrhage | Often upper zone, can be patchy | Clinical presentation remarkable |

## Chickenpox Pneumonia

Chickenpox pneumonia in adulthood can cause the development of numerous calcified nodules (Fig. 4.39; see Box 4.10 for other causes of calcified nodules). To determine whether this is a likely diagnosis:

1. Look at the distribution of the nodules. In chickenpox pneumonia they tend to be in the lower and mid zones.
2. Look at the density of the nodules. They are calcified and so should be very white in appearance.
3. Look at their size. They are usually less than 3 mm in diameter.

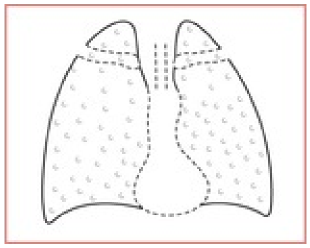


**FIGURE 4.39** A woman admitted with an acute abdomen shows the typical appearance of old chickenpox pneumonia. Numerous bilateral calcified intrapulmonary nodules can be seen.

**Box 4.10**

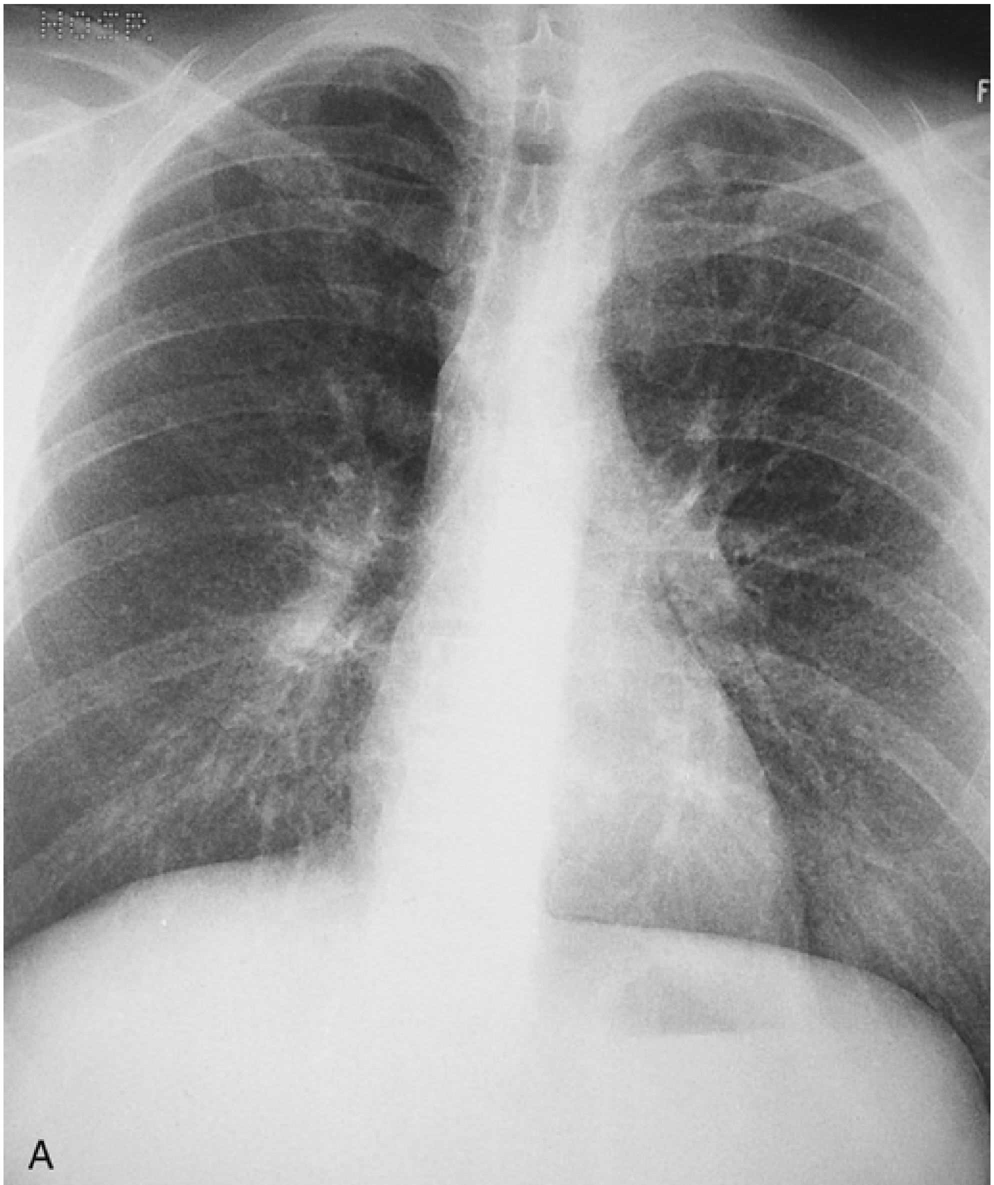
**Causes of numerous calcified nodules**

Infection, e.g. TB, histoplasmosis, chickenpox
Inhalation, e.g. silicosis
Chronic renal failure
Lymphoma following radiotherapy
Chronic pulmonary venous hypertension in mitral stenosis

## Miliary Shadowing

A number of abnormalities cause a spotted or miliary appearance of the lung (Fig. 4.40) but normal lung can also have a spotty or mottled appearance, especially in obese patients. If you think the lung looks spotty you must first determine whether it is miliary shadowing or normal lung:

1. Look at the distribution of the shadowing. Look carefully at the periphery. If the shadowing is present in the periphery it is far more likely to be pathological. Sometimes normal vasculature can mimic interstitial shadowing but this usually occurs only towards the centre of the lung fields.
2. Carefully examine the shadowing. With miliary shadowing the opacities should be discrete. Noise from overlying soft tissue can appear more fuzzy.
3. Compare a few of the opacities with one another. If the shadowing is miliary they should be of a similar density and size.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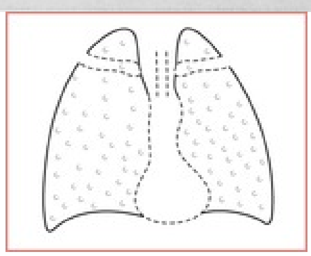


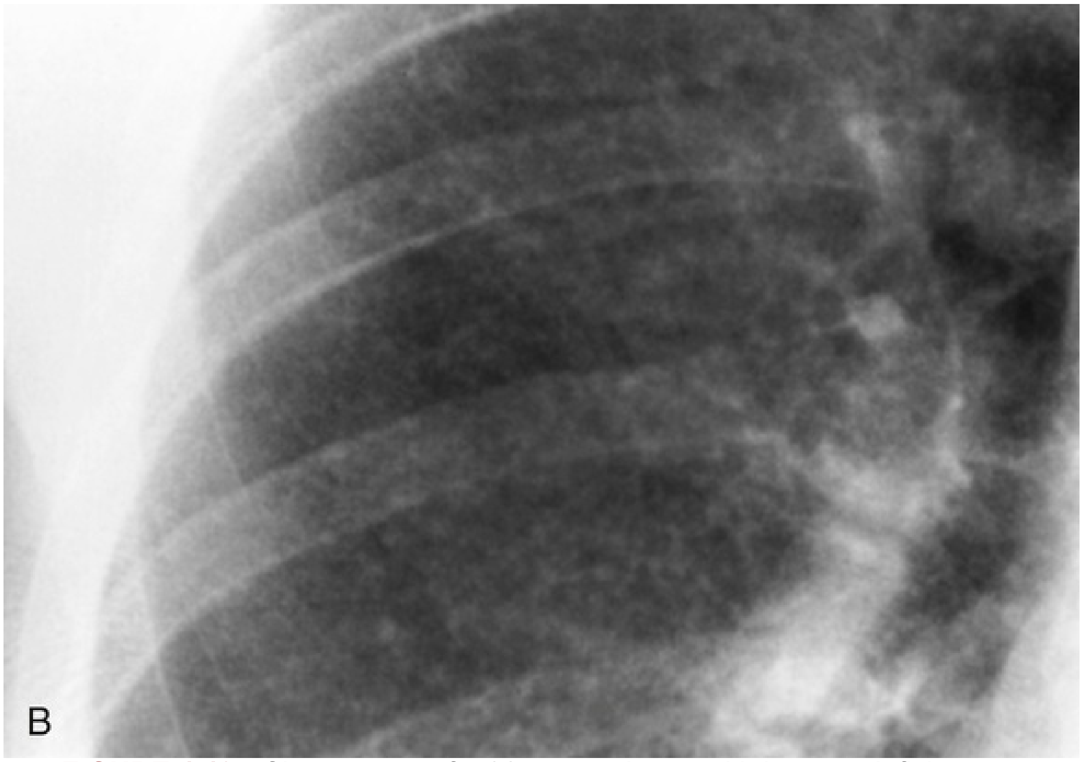



**FIGURE 4.40** Chest x-rays of a 32-year-old man with immunodeficiency. **(A)** The typical miliary shadowing characteristic of tuberculosis (TB) is shown. **(B)** There is also soft shadowing in the left apex consistent with TB.

If you feel the shadowing is miliary then look for clues as to its cause. Likely possibilities are miliary TB, sarcoid or malignant miliary metastasis:

1. Look again at the distribution. With miliary TB the opacities are most profuse in the upper zone, with sarcoid they are most profuse in the perihilar and mid zones, and with miliary metastases there may be more opacities in the lower zone.
2. Look at the density. High density, very white shadows are likely to be dust-related industrial disease or calcified TB. Less dense changes could be multiple secondaries, sarcoid or any of the other causes of miliary mottling.
3. Look at the rest of the x-ray for signs of other disease processes. Look at the hilum. Unilateral hilar enlargement suggests TB, and bilateral hilar enlargement sarcoidosis. Look at the upper part of the mediastinum for thyroid enlargement which could suggest secondaries from a thyroid carcinoma. Look at the apices for subtle cavitating lesions suggestive of TB. Note, however, that the presence of apical shadowing, although suggestive of TB, is in fact very rare in patients with miliary spread.

## Focus on Tuberculosis

Tuberculosis can cause a large number of changes on the CXR. It is a diagnosis that can often be missed and you should always think about including it in your differential diagnosis of any CXR change.

Primary pulmonary TB is usually a self-limiting disease which is often asymptomatic. Infection leads to the development of a primary complex in the lung which over the years will calcify, forming a granuloma. Figure 4.41 shows an example of such a granuloma. On occasions the primary infection is not limited and the patient goes on to develop the complications seen in reactiva ted disease.

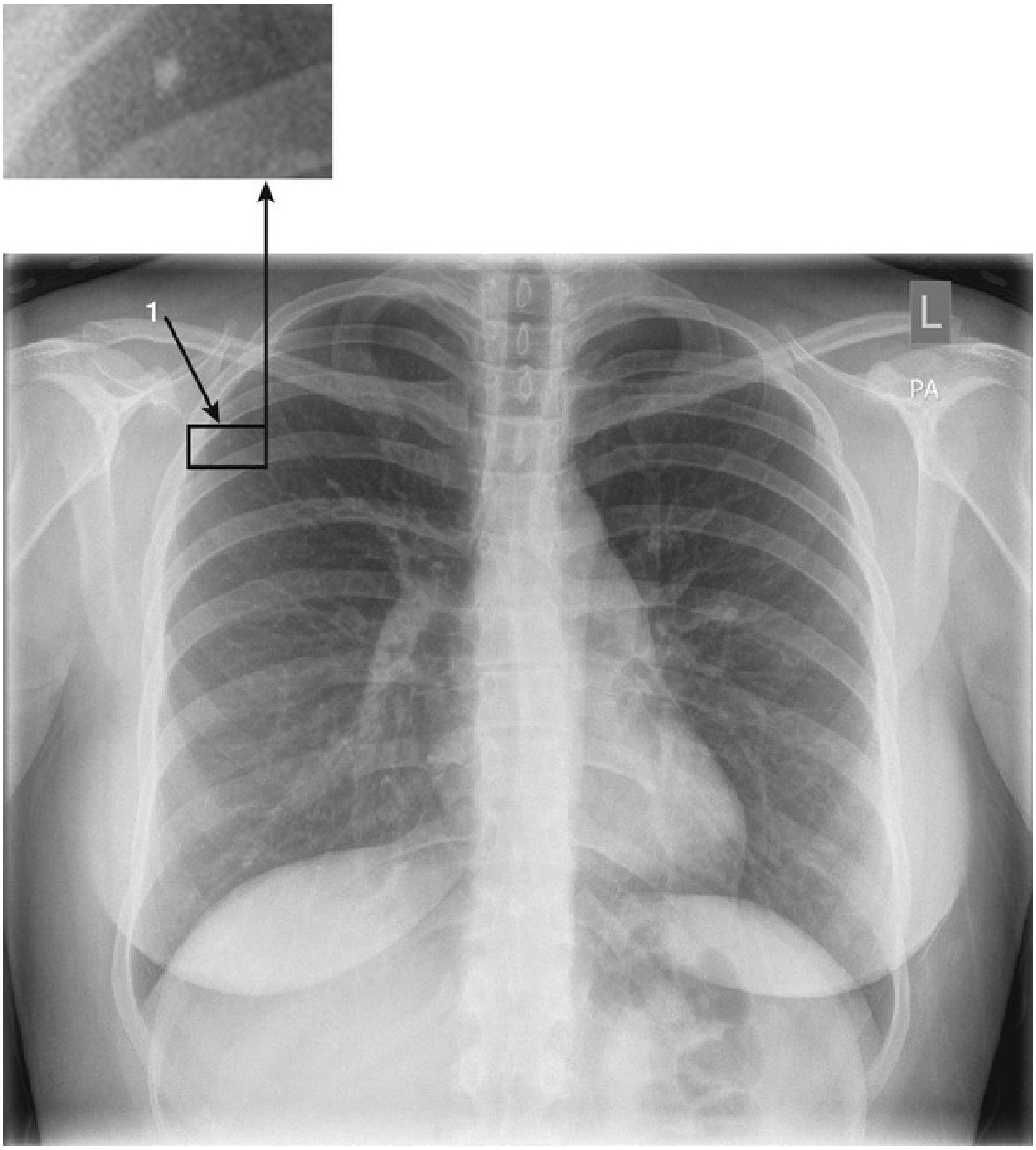



**FIGURE 4.41** This is the chest x-ray of a 27-year-old lady with asthma. There is an incidental finding of a small granuloma **(1)** in the right apex. This is likely to result from previous tuberculosis infection, which, in this patient, as with many, was subclinical.

In later life, if the immune response becomes less effective due to disease, old age, or reinfection, the primary infection can reactivate and the patient will usually develop symptoms. These may include cough, haemoptysis or fever, or can be more indolent such as chronic weight loss or loss of appetite. Reactivated TB can cause a multitude of CXR changes. It is a cause of pleural effusions or lung collapse. Other changes that should make you think specifically of TB are upper lobe consolidation (Fig. 4.42), single or multiple cavitating lesions (Figs

4.43 and 4.44), enlarged hilar lymph nodes (Fig. 4.45) or miliary TB (Fig. 4.40).

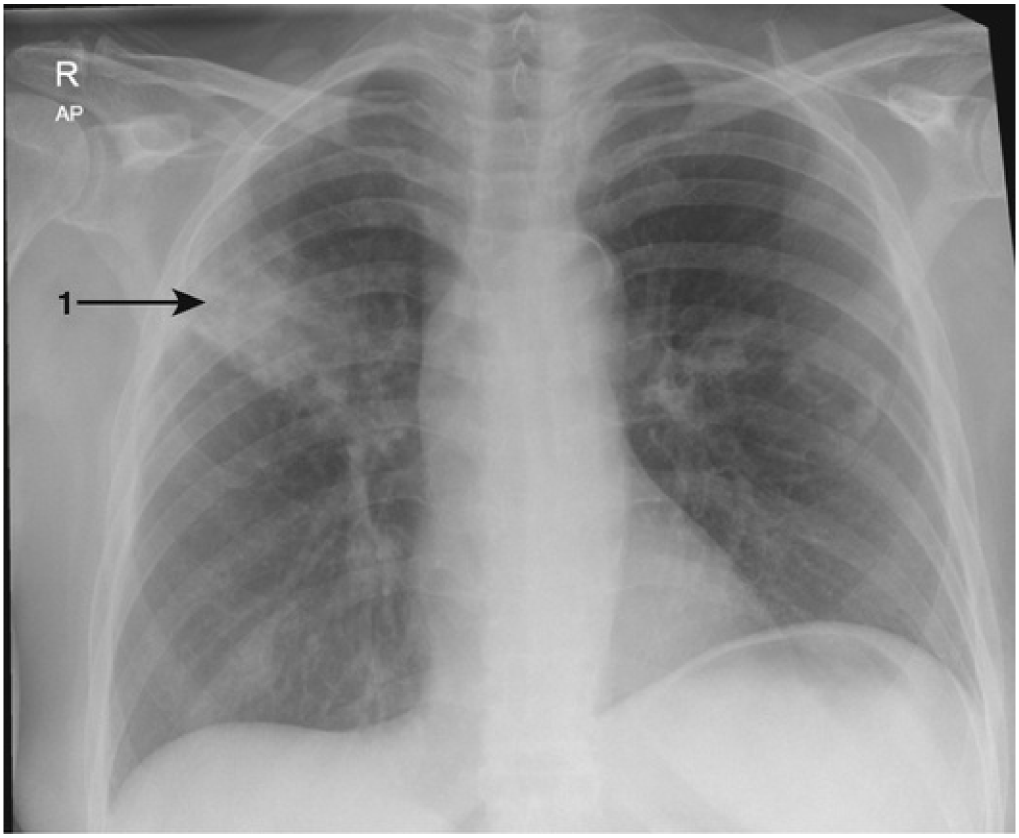



**FIGURE 4.42** CXR showing an area of upper lobe consolidation **(1)** in patient with pulmonary tuberculosis.

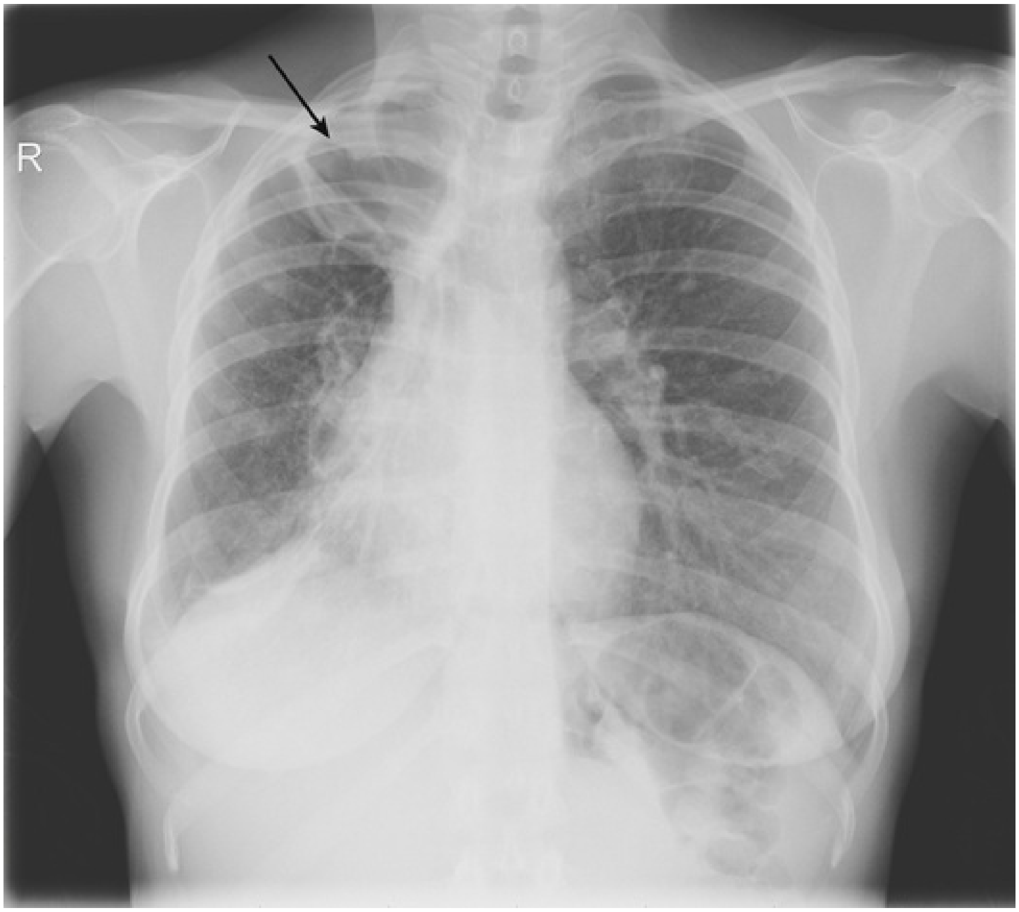



**FIGURE 4.43** This is the CXR of a 26-year-old lady who has been fully treated for tuberculosis. You can see a fairly thick-walled cavity **(arrow)** in the right apex.

**FIGURE 4.44** Multiple cavities in tuberculosis (arrows).

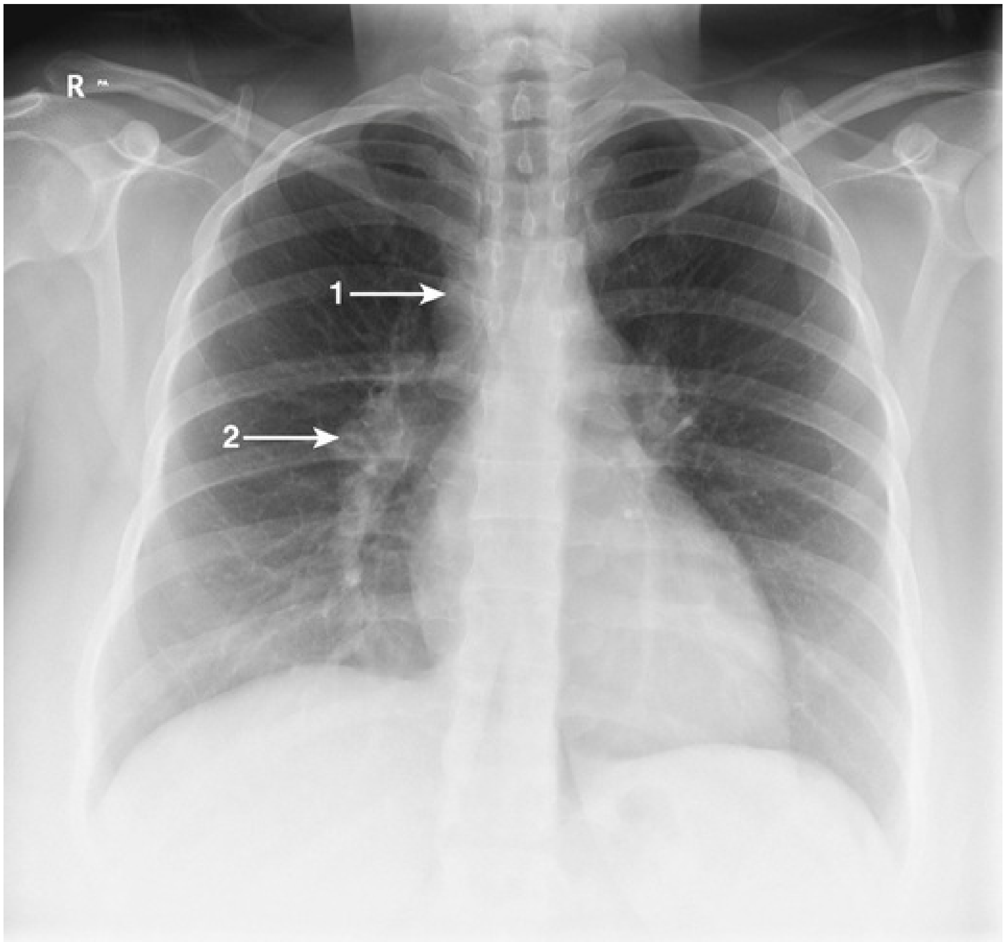



**FIGURE 4.45** Tuberculosis in hilar nodes. This CXR shows right paratracheal lymphadenopathy **(1)** and right hilar lymphadenopathy **(2)** due to active tuberculosis.

Tuberculosis can lead to chronic fibrotic changes in the lung. Typically these are in the upper zones, as shown in Figure 4.46.

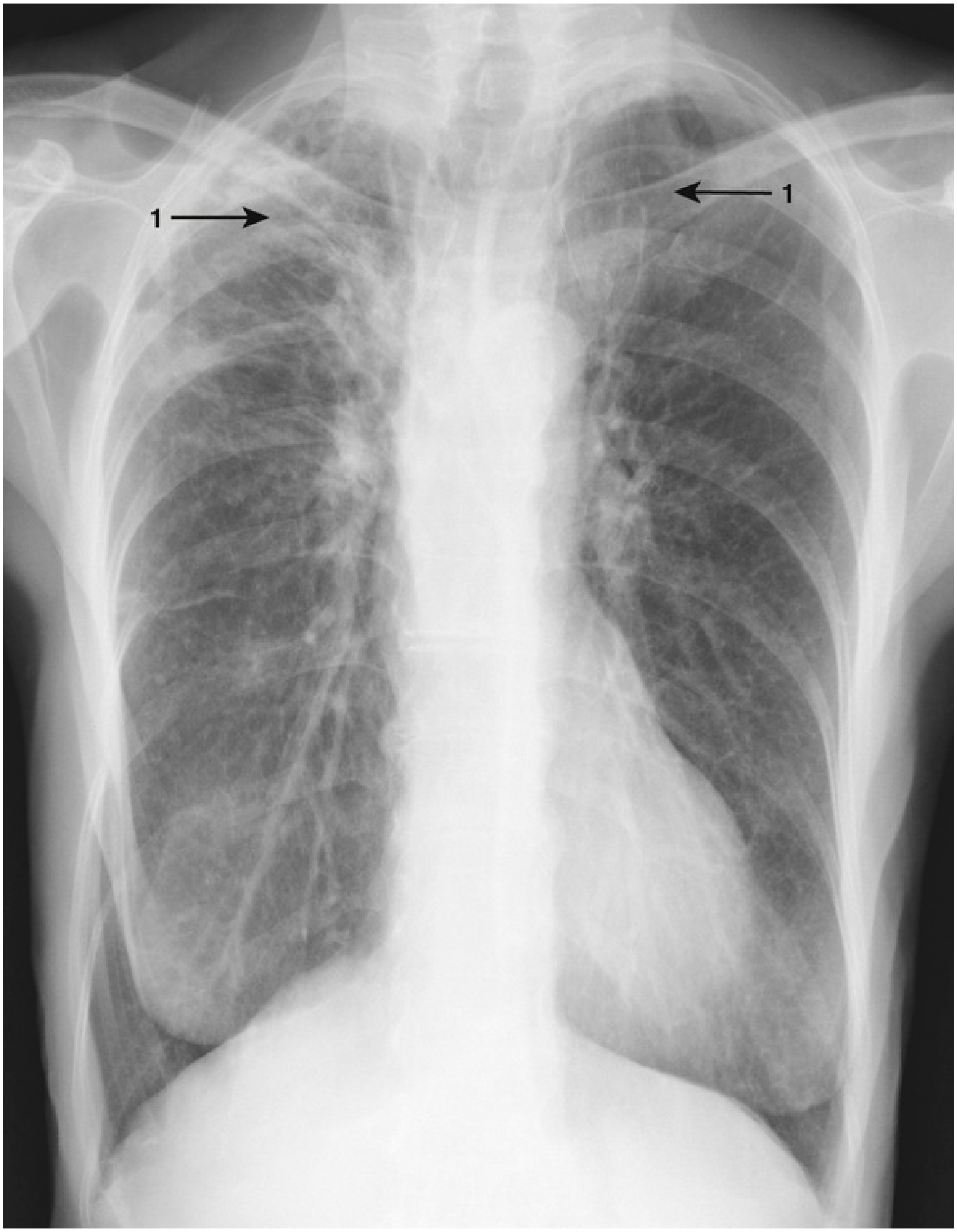



**FIGURE 4.46** CXR showing chronic upper lobe fibrotic changes **(1)** in patient with old pulmonary tuberculosis.

5

# The black lung field



## Chronic Obstructive Pulmonary Disease (COPD)

When trying to decide the cause of *bilateral* black lungs (Fig. 5.1) you need to:

1. Check the penetration. Look at the vertebral bodies behind the heart. Remember that in a good-quality x-ray the vertebral bodies become harder to see behind the heart shadow. If they are too clearly seen the film is over-penetrated, making the lungs appear black.

**FIGURE 5.1** Chest film of a patient with chronic obstructive pulmonary disease. The lungs look larger in volume than normal. The diaphragms are rather flattened. The right upper zone and many areas of the left lung are abnormally black. In these areas the blood vessels are difficult to see or are very thinned. This is because these regions of lung have developed emphysema.

If you are satisfied with the technical quality of the film then the most likely cause is COPD. COPD is associated with large lungs due to air trapping and the development of bullae. You therefore need to:

1. Look at the shape of the diaphragm. In COPD the diaphragms are flat or even scallop shaped instead of concave upwards. This is a more reliable sign of hyperexpansion than rib counting.
2. Count the number of ribs you see anteriorly. If the lungs are enlarged you should be able to count more than seven. Be careful, however, because you can sometimes count more than seven ribs in normal patients if they are tall and slim.
3. Look at the shape of the heart. The enlarged thorax of COPD appears on the x-ray to elongate and narrow the heart, elevating the lower border. The heart, instead of sitting on the diaphragm, often appears to 'swing in the wind'. It will also appear small unless there is also an element of cardiac failure, in which case it will be normal in size or large.
4. Look for bullae. These are densely black areas of lung, usually round, surrounded by fine curvilinear shadows. Bullae distort the surrounding vasculature so to help find them look out for areas of distortion of vascular markings.
5. Look at the distribution of lung markings. The black lungs of COPD are due to reduced size of blood vessels. The lung markings are reduced bilaterally and fan out in straight lines from the hilum, starting off chunky but stopping two-thirds of the way out – peripheral pruning.

## The computed tomography (CT) scan and COPD

As with a chest x-ray (CXR), COPD can appear as black lungs on the CT scan (Fig. 5.2). Sometimes the picture is clear with obvious bullae but on other occasions the changes are more subtle. When interpreting black lungs on a CT:

1. Look for bullae. These are large, very obvious holes in the lung parenchyma which have a thin but obvious wall. Check the thickness of the wall – it should be less than 1 mm. Check also the rest of the lung fields. They should be darker than usual and you will often find other bullae. Figure 5.3 shows the appearance of lung bullae.
2. Look carefully at the lung fields. On careful inspection you may see small black areas with no obvious surrounding wall. Because of the anatomy of the lungs you can sometimes see blood vessels in these areas. These blood vessels are usually thinner than those you will see in non-affected lung. This is because the body will not perfuse areas of lung where there is no ventilation. This is the typical appearance of centrilobular emphysema.

3. The lung fields may appear generally darker than normal. If you look carefully, you will see many small holes distributed throughout the lungs with no obvious wall. This is the appearance of panlobular emphysema (Fig. 5.4).
4. Look at the distribution of the blackness. Cigarette smoke in a room floats upwards and likewise smoking-related lung damage tends to be worse in the upper zones. However this is not always the case and the emphysematous changes of COPD can be very diffuse.
5. Finally do not be surprised if the changes on CT do not reflect the patient's symptoms. There is little correlation between patients' symptoms and CT changes. The CT scan needs to be interpreted in conjunction with the clinical picture and lung function tests.

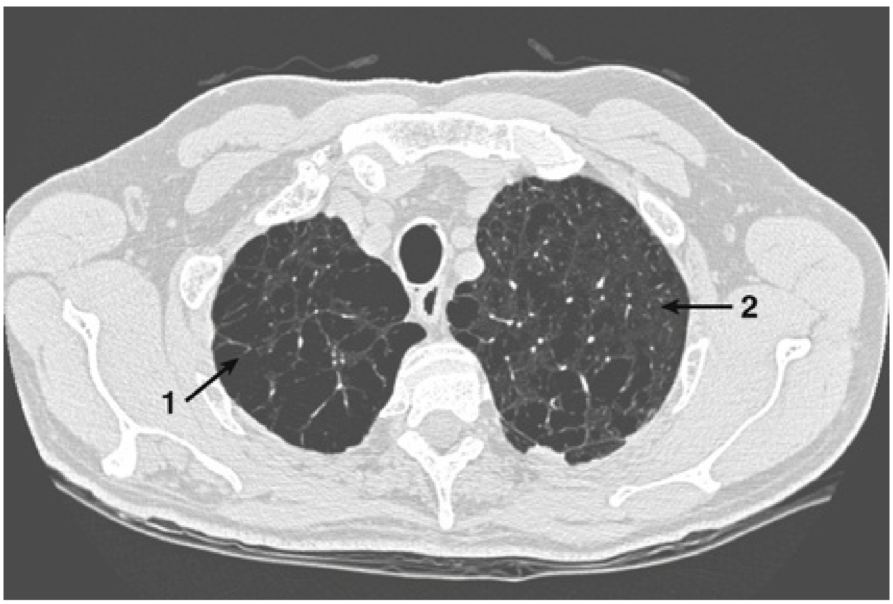



**FIGURE 5.2** CT section of a patient with chronic obstructive pulmonary disease, which shows how the lung contains black holes **(1)** and thin thready blood vessels **(2)**.

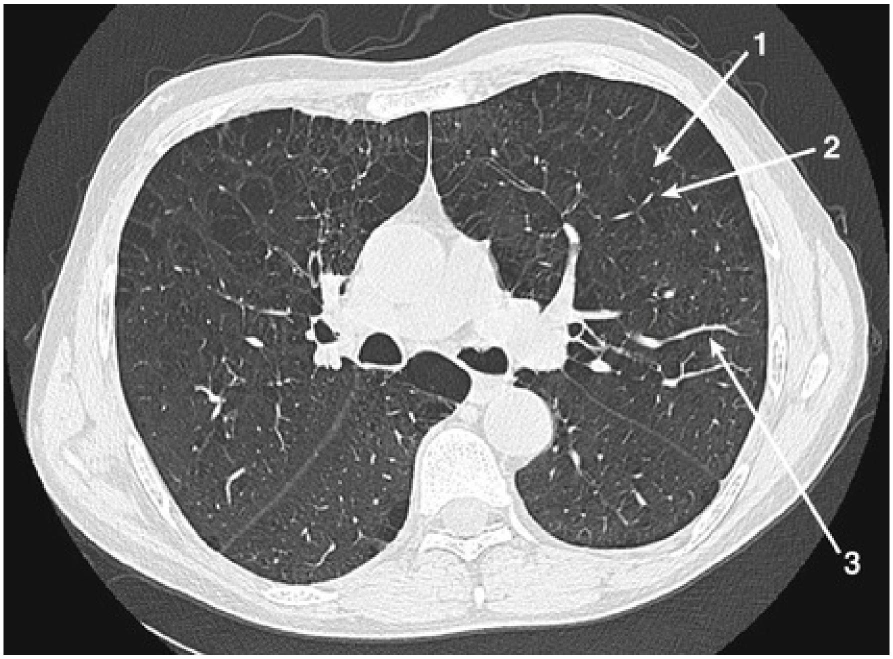



**FIGURE 5.3** CT lung window settings. CT of a 74-year-old man with a long history of COPD. The scan shows multiple bullae surrounded by thin walls **(1)**. Notice the blood vessels in the affected areas of the lung **(2)** which appear thinner than the normal blood vessels **(3)**.

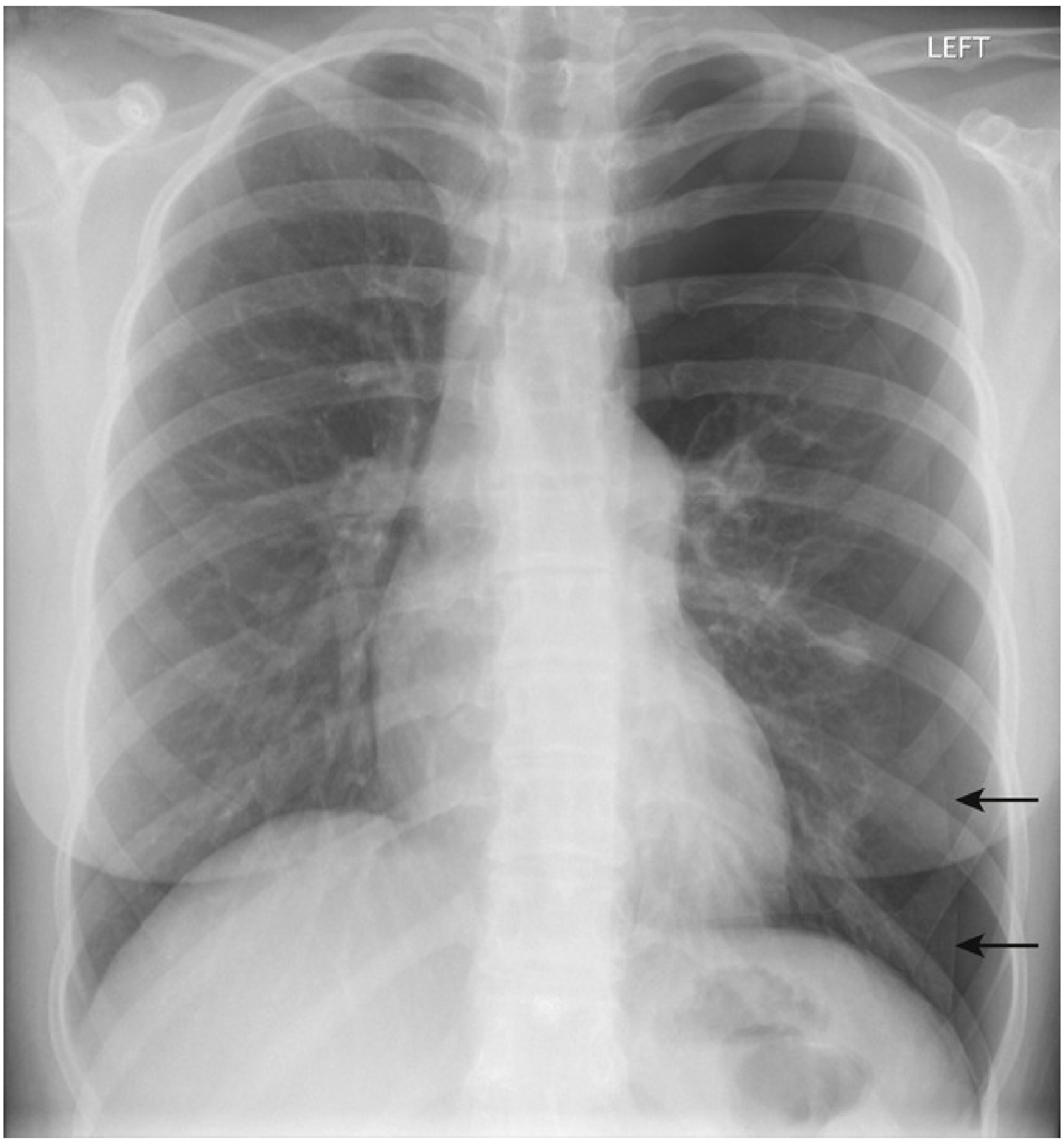

**FIGURE 5.4** CT lung window settings. Both lungs show numerous tiny

holes with no obvious walls **(1, 2)**. You can also see some obvious bullae **(3)**. This patient has a mixture of bullous and panlobular emphysema.

## Pneumothorax

When you see a *unilateral* black lung (Fig. 5.5) you need to:

1. Check the technical quality of the film. A rotated film may make one side less dense than the other.
2. Determine which side is abnormal. This is usually easy since the side with reduced lung markings will be the abnormal side.



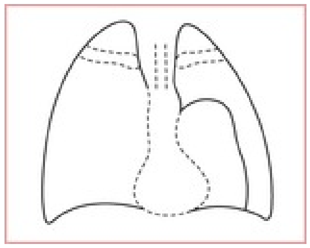


**FIGURE 5.5** This patient has a left-sided pneumothorax with partial collapse of the left lung. The outer left lung field is black. You can see the lung edge **(arrows)**.

You must now decide the cause of the blackness. Lung markings are made up of bronchi and blood vessels and it is their absence that makes the lung look black. Vascular shadows will disappear if the lung is replaced by air, which will occur with a pneumothorax, or bullous, or cystic lung disease, or if the vessels are deprived of blood as in a pulmonary embolus (PE). Therefore think pneumothorax, bullae/cyst or pulmonary embolism and:

1. Look for a lung edge. In a pneumothorax you will see the edge of lung which is not normally seen. Look carefully at the upper zone where air will accumulate first. Your eye is trained to see horizontal lines better than vertical so it is sometimes easier to detect the lung edge with the x-ray turned on its side.
2. Look at the mediastinum. Obvious mediastinal shift away from the black lung suggests that a tension pneumothorax is developing. This is a medical emergency and you need to urgently reassess the patient (see also p. 97).
3. Look at the rest of the lungs. Bullous disease is more likely if bullae or emphysematous changes are seen in the rest of the lung.
4. Differentiating between a pneumothorax and a bulla can be difficult and often impossible. Look at the distribution of the blackness. In a pneumothorax it will be peripheral and upper zone, or lateral and even underneath the lung. Bullae are within the lung and have curvilinear convex margins. In a pneumothorax the edge of the blackness will run parallel to the chest wall, which will not be the case with a bulla lying within the lung.
5. Look carefully for lung markings. If you see them crossing the area of blackness, you are probably looking at a bulla. If you see lung markings peripheral to the blackness, it is also probably a bulla.

Box 5.1 shows possible causes of a pneumothorax.

### Box 5.1

**Some causes of a pneumothorax**

Spontaneous

Iatrogenic/trauma, e.g. pleural tap, transbronchial biopsy, central venous line insertion, mechanical ventilation

Obstructive lung disease, e.g. asthma, COPD

Infection, e.g. pneumonia, tuberculosis

Cystic fibrosis

Connective tissue disorders, e.g. Marfan's, Ehlers–Danlos

## Tension Pneumothorax

If you suspect a pneumothorax (Fig. 5.6) as a cause of a black lung field you must consider carefully whether it may be under tension since this is a medical emergency.

1. Look at the size of the blackness. In a tension pneumothorax the black lung is usually very large.
2. Look at the position of the mediastinum. In a tension pneumothorax it will be shifted away from the affected lung.
3. Look at the shape of the mediastinum. Look at the edge on the side of the blackness. If it is concave to the side of the blackness you should suspect a tension pneumothorax.
4. Always remember the patient. A tension pneumothorax can develop at any time and if the patient suddenly becomes distressed the absence of tension on a previous x-ray does not exclude the diagnosis.

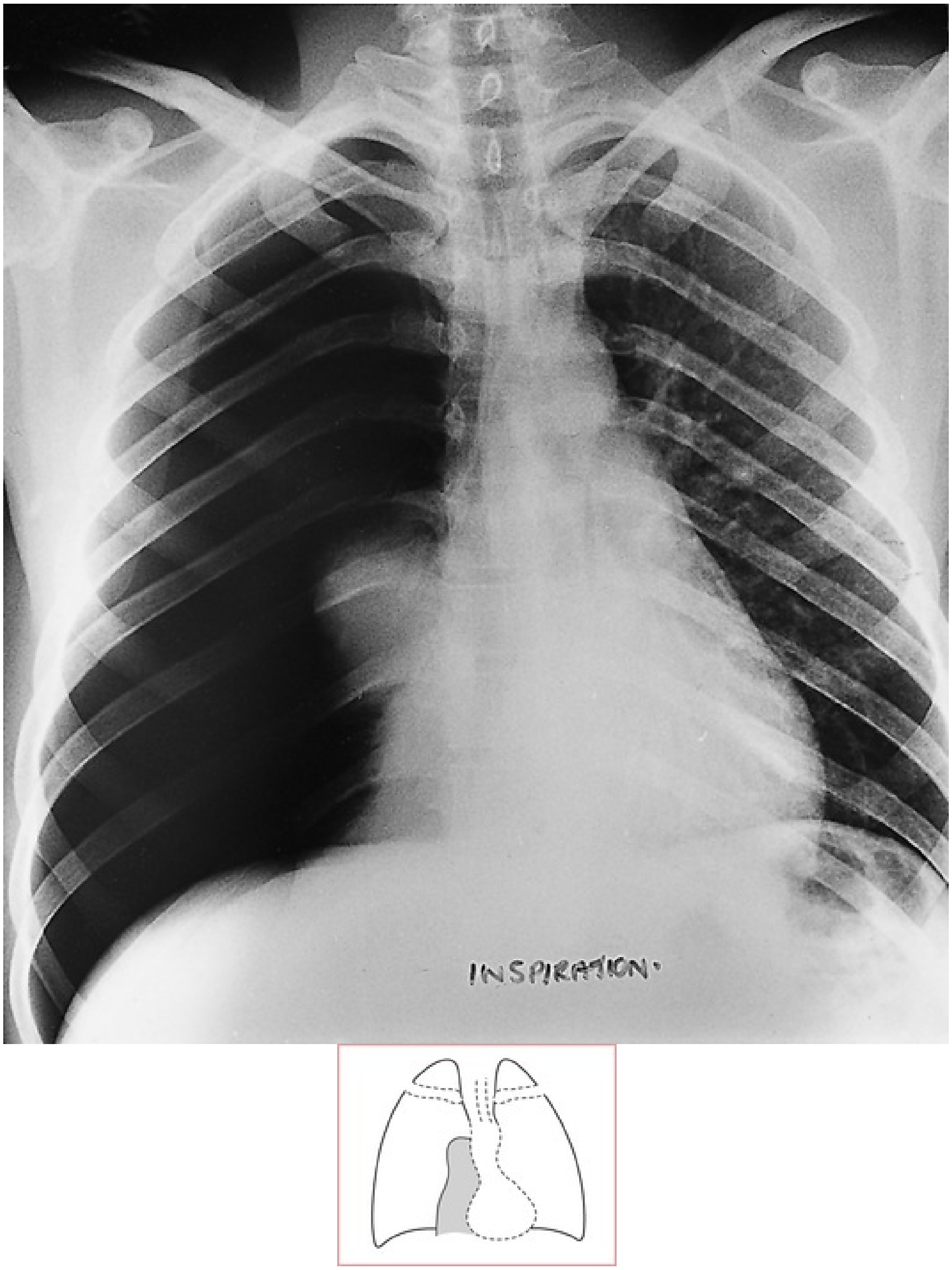



**FIGURE 5.6** This chest film shows the potentially fatal condition of a tension pneumothorax. The build-up of pressure in the thorax on the side of the air leak can obstruct cardiac venous return. This can be potentially fatal if the pleural cavity is not urgently drained.

## Pulmonary Embolus (PE)

A large PE is a cause of black lung. However, a pulmonary embolism is very rarely detected on a plain CXR and the main reason for doing a plain film is to exclude other causes of shortness of breath, such as pneumonia or pulmonary oedema. Of far more use for the detection of pulmonary emboli are CT pulmonary angiogram (CTPA) and ventilation/perfusion ( $\dot{V}/\dot{Q}$ ) scanning.

## CT pulmonary angiogram (CTPA)

A CTPA is essentially a contrast enhanced spiral CT scan in which the administration of contrast is timed to highlight the pulmonary arteries (Fig. 5.7). Vessels blocked by clots will appear darker. It is a sensitive means of detecting emboli within central or segmental arteries, although it will not necessarily detect more minor peripheral emboli. Any pulmonary embolus that causes significant breathlessness should be detectable on a CTPA.

**FIGURE 5.7** **This patient became suddenly short of breath. CTPA showed a PE. Clots can be seen in both the right pulmonary artery and the left lower lobe pulmonary artery (arrows). A plain film diagnosis of a PE is very rare.**

Think before you order a CTPA. These scans are often undertaken in young people and involve significant amounts of radiation. Make sure that you have stratified the clinical risk by taking an appropriate history and reviewing the Ddimer result, and consider whether a $\dot{V}/\dot{Q}$ scan or ultrasound imaging of the peripheral veins to look for a deep vein thrombosis would be a reasonable alternative.

In order to interpret a spiral CT scan you need to:

1. Look at the contrast enhanced scans, usually labelled as such.
2. Look at the main pulmonary artery and then follow your way through the scans to examine the major pulmonary vessels. With the spiral CT scan you will be able to visualise the clot, which will appear as a filling defect – a dark area surrounded by whiter contrast. Clot tends to lodge across bifurcations in the vessels and may be seen extending down the vessel towards the periphery. The vessel may be expanded by acute clot compared to the equivalent vessel in the other lung.
3. Look for accompanying features of an embolus. Look on the lung windows for areas of consolidation, which may be wedge shaped, and also look for small pleural effusions.
4. Remember that even if the CTPA does not show a PE it may show another cause for the patient's symptoms.

## V/Q scanning

The $\dot{V}/\dot{Q}$ scan is a nuclear medicine test. This uses small low-dose radioactive particles to compare the pattern of perfusion with that of ventilation (Fig. 5.8). For the ventilation part of the test the particles are suspended in a gas, which is then inhaled, and stick to the walls of the airways to show airflow. For the perfusion part of the study the particles are injected intravenously and lodge in the very small blood vessels in the lungs. The distribution of radioactivity within the lung is then monitored using a gamma camera. Normally four views are taken (anterior, posterior, and right and left posterior oblique).

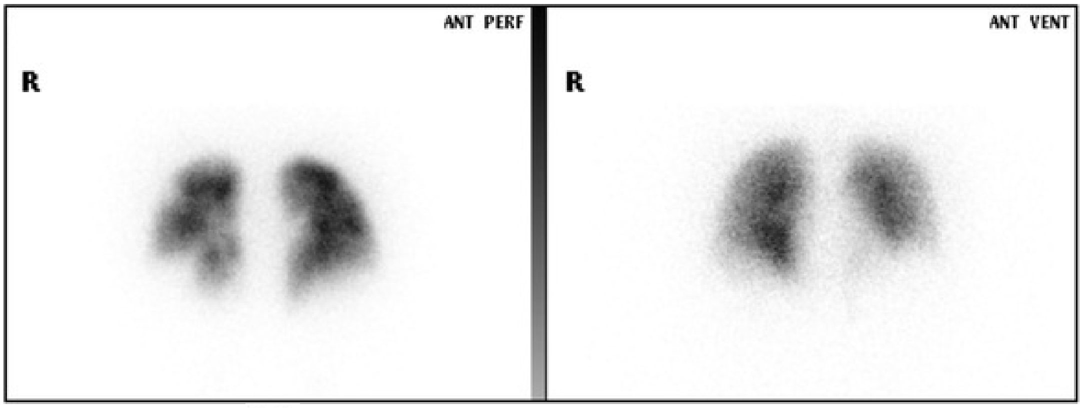



**FIGURE 5.8** $\dot{V}/\dot{Q}$ scan in patient with pulmonary emboli. Note how the perfusion image is more patchy than the smoother texture of the ventilation scan.

In the normal lung ventilation and perfusion should match. In a pulmonary embolism the blood supply to a region of lung is reduced but the ventilation maintained, so-called ‘ventilation/perfusion mismatch’. In some lung diseases, for example pneumonia, the ventilation and perfusion may both be reduced, giving a so-called ‘matched defect’. Other lung diseases, for example COPD, can result in a mismatch between ventilation and perfusion. In practise with a PE it is very common to see a mixture of both matched and mismatched defects. A $\dot{V}/\dot{Q}$ scan is therefore only of value in a patient with otherwise normal lungs.

The $\dot{V}/\dot{Q}$ scan does not give a definite diagnosis of PE. Instead it gives you the probability of the patient having a PE. As such, it must be interpreted alongside the clinical situation. A normal scan will virtually exclude a PE, certainly one of clinical significance.

In order to interpret a $\dot{V}/\dot{Q}$ scan:

1. Look at the plain CXR. Abnormalities on the CXR may affect ventilation and perfusion and so may make interpretation of the scan difficult. A scan can be interpreted with much more confidence in the presence of a normal CXR. Someone with multiple areas of lung pathology on their chest film, e.g. consolidation or extensive COPD, is likely to have an inconclusive $\dot{V}/\dot{Q}$ scan, and may be better investigated by CTPA.
2. Look at the perfusion scan (labelled Q). A dark speckled pattern is seen over the well-perfused areas, with under-perfused areas appearing as lighter holes. Compare these areas to the ventilation scan (marked V). If they also appear light then they are classified as matched defects. If ventilation is normal they are classed as mismatched defects.

3. Make sure that you have looked at both lungs. In the presence of a massive PE it is possible for a whole lung to be obliterated on the perfusion scan.
4. The test needs to be carefully interpreted by a radiologist who will determine the number and size of matched, and mismatched, defects to work out the radiological probability of a PE.

Although a PE is a cause of black lung, the findings on x-ray following a PE are those due to subsequent infarction of the lung, leading to haemorrhage or lung necrosis, see Box 5.2.

**Box 5.2**

**Changes of infarction**

Raised hemidiaphragm
Collapse and linear atelectasis
Pleural effusion
Wedge-shaped shadowing

## Mastectomy

It is important to remember that problems outside the lung can sometimes cause the lung fields to look too black (or too white). This is why it is important always to examine the CXR for soft tissue markings (Fig. 5.9).

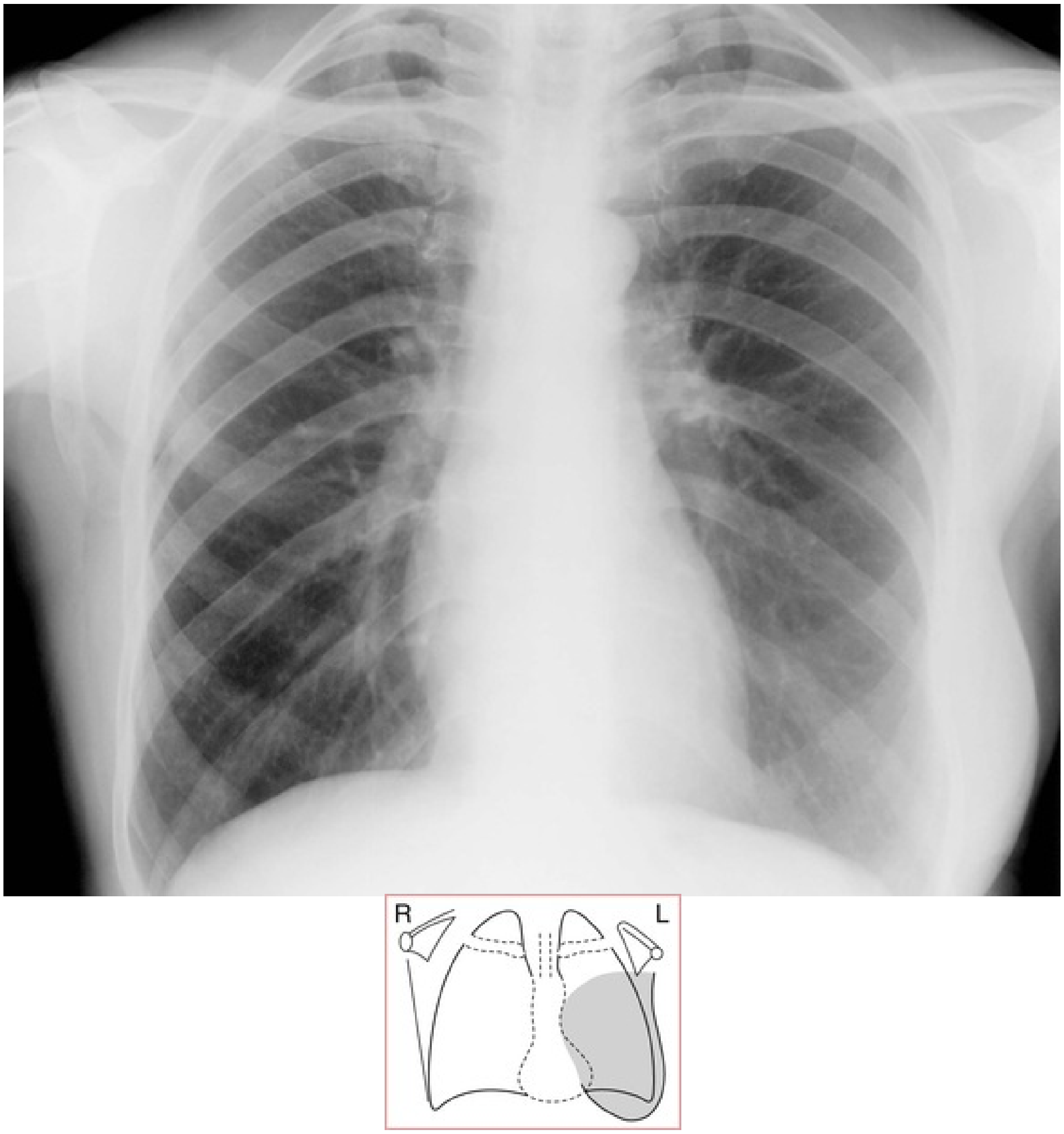



**FIGURE 5.9** Film of a patient who has undergone a unilateral mastectomy on the right side.

A mastectomy will make the underlying lung look too black since there will be less soft tissue overlying the lungs on the affected side, compared to the normal side (Fig. 5.8). Therefore, if one lung looks blacker than the other, look carefully for the breast shadows. There will be an absent breast shadow on the side of the mastectomy.

6

# The abnormal hilum



## Unilateral Hilar Enlargement

Hilar enlargement is difficult (Fig. 6.1). Suspect unilateral hilar enlargement if:

1. One hilum is bigger than the other (obviously – they should be the same size!).
2. One hilum is denser than the other.
3. There is a loss of the normal concave shape – the hila are usually concave in shape. This concavity may disappear and be the first sign of hilar enlargement.

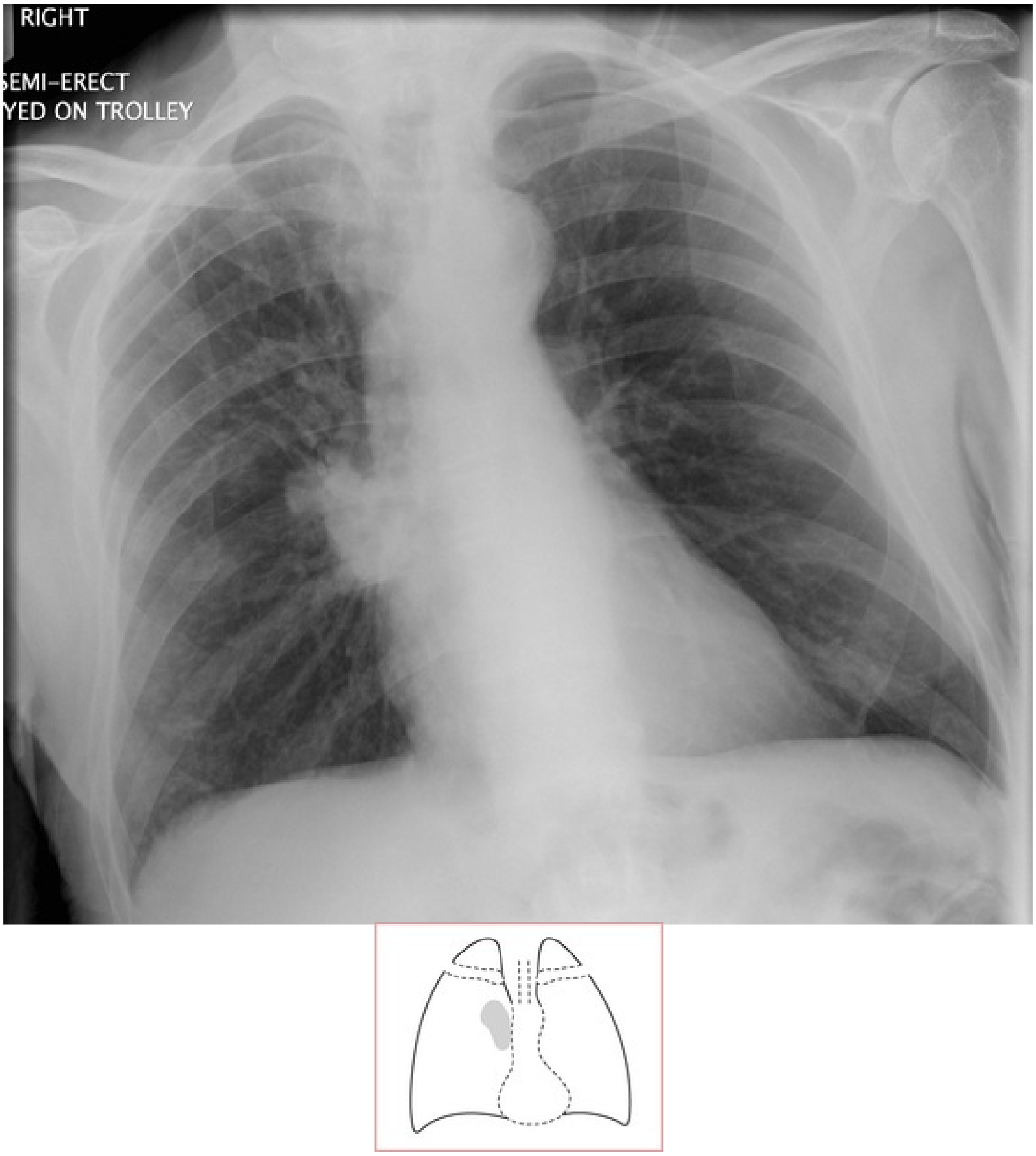



**FIGURE 6.1** This patient has a bulky right hilum. The contour of the right pulmonary artery is not seen separate to it.

If you suspect unilateral hilar enlargement (Box 6.1) then:

1. Check the technical quality of the film. A rotated film will make one hilum appear larger than another.
2. Look at the lateral film. An enlarged hilum may look abnormally dense on the lateral and sometimes this is easier to spot than on the posterior-anterior (PA).
3. Look at the old films. You will be less worried if the x-ray looked the same 15 years ago!

**Box 6.1**

### Causes of unilateral hilar enlargement

#### Causes of hilar lymphadenopathy

Neoplastic, e.g. spread from bronchial carcinoma, primary lymphoma
Infective, e.g. tuberculosis
Sarcoidosis (rarely unilateral)

#### Causes of hilar vascular enlargement

Pulmonary artery aneurysm
Poststenotic dilatation of the pulmonary artery

Now you need to decide whether the enlargement is due to (a) enlarged vascular shadows, (b) enlargement of the hilar lymph nodes, or (c) a central bronchial carcinoma superimposed over the hilar shadow. These are the likely possibilities.

1. Look at the edge of the hilum. Vascular margins are usually smooth in nature. Lymphadenopathy gives a smooth lobular appearance. Spiculated, irregular or indistinct margins suggest malignancy.
2. Look for the presence of calcium, which will appear as a very dense white. Its presence suggests lymphadenopathy.
3. Look at the rest of the x-ray. If you suspect hilar enlargement then look carefully at the periphery for lung lesions (tumour, tuberculosis), lung infiltration (carcinomatous lymphangitis) or bone lesions (metastases).
4. Look at the rest of the mediastinum. Malignant hilar enlargement may be associated with superior mediastinal lymphadenopathy.

Hilar enlargement always warrants further investigation.

## Computed tomography (CT) and hilar enlargement

Computed tomography is the best modality to assess hilar enlargement and determine its cause. Hilar enlargement may be due to lymph node enlargement, CT appearance of which is described in pages 26–28. The CT will also show vascular causes of hilar enlargement as described on pages 125–126.

Sometimes lesions in front or behind the hila can give the appearance of hilar enlargement on the chest x-ray (CXR). Figures 6.1 and 6.2 shows such an example.

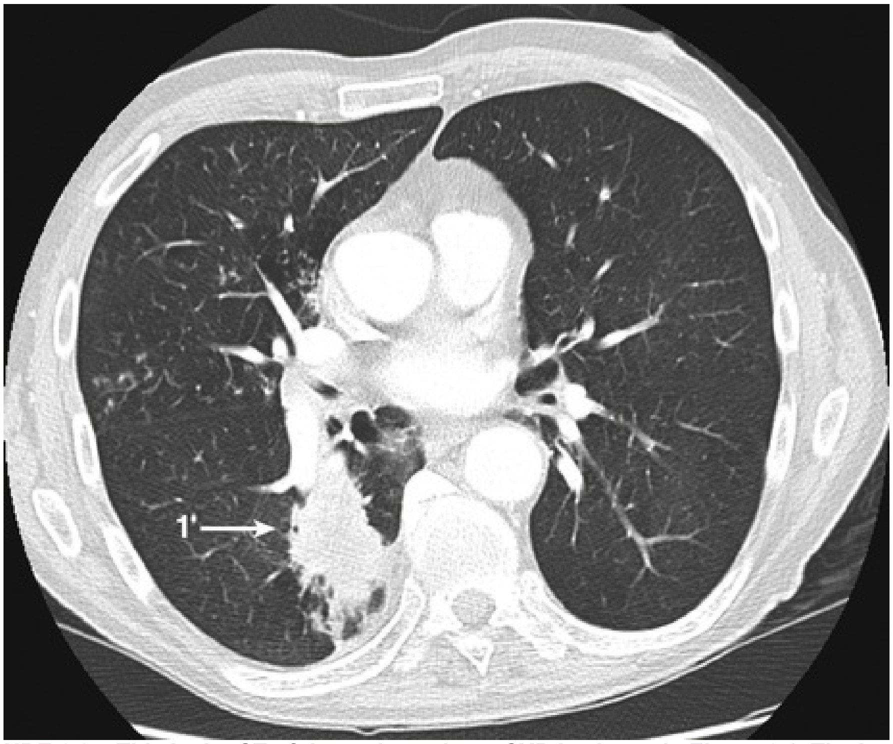



**FIGURE 6.2** This is the CT of the patient whose CXR is shown in Figure 6.1. The lung window settings show a lobulated mass posterior to the right hilum, seen as a dense white area (1). You can see how on a two-dimensional CXR this could give the impression of hilar enlargement.

## Bilateral Hilar Enlargement

As with unilateral hilar enlargement, bilateral hilar enlargement can be due to enlargement of pulmonary arteries, veins or lymph nodes (Box 6.2; Fig. 6.3). The features that suggest unilateral hilar enlargement are described on page 104–5. In bilateral enlargement these are present on both sides! The commonest causes of bilateral hilar enlargement are pulmonary hypertension and sarcoidosis. You should start off by looking for features of either of these. If you suspect pulmonary hypertension then:

1. Look at the periphery of the x-ray. Pulmonary hypertension is associated with peripheral pruning, which means that the blood vessels appear cut off before they reach the outer third of the lung. The edge of the lung fields are,

therefore, often darker than usual and the central area often whiter.

2. Look at the shape of the hila and lower lobe pulmonary arteries. The lower lobe pulmonary arteries will also be big in pulmonary hypertension but of normal size if hilar enlargement is due to lymphadenopathy. The hila are, therefore, convex in shape in pulmonary hypertension.
3. Look for a cause of pulmonary hypertension. Look for signs of lung disease such as chronic obstructive pulmonary disease (COPD) and look carefully at the shape of the heart for chamber enlargement, for signs of left to right shunts or mitral stenosis.

**Box 6.2**

## Causes of bilateral hilar enlargement

### Causes of bilateral hilar lymphadenopathy

Sarcoid
Tumours, e.g. lymphoma, bronchial carcinoma, metastatic tumours
Infection, e.g. tuberculosis, recurrent chest infections, AIDS
Berylliosis

### Causes of pulmonary hypertension

Obstructive lung disease, e.g. asthma, COPD
Left heart disease, e.g. mitral stenosis, left ventricular failure
Left to right shunts, e.g. atrial septal defect, ventricular septal defect
Recurrent pulmonary emboli
Primary pulmonary hypertension

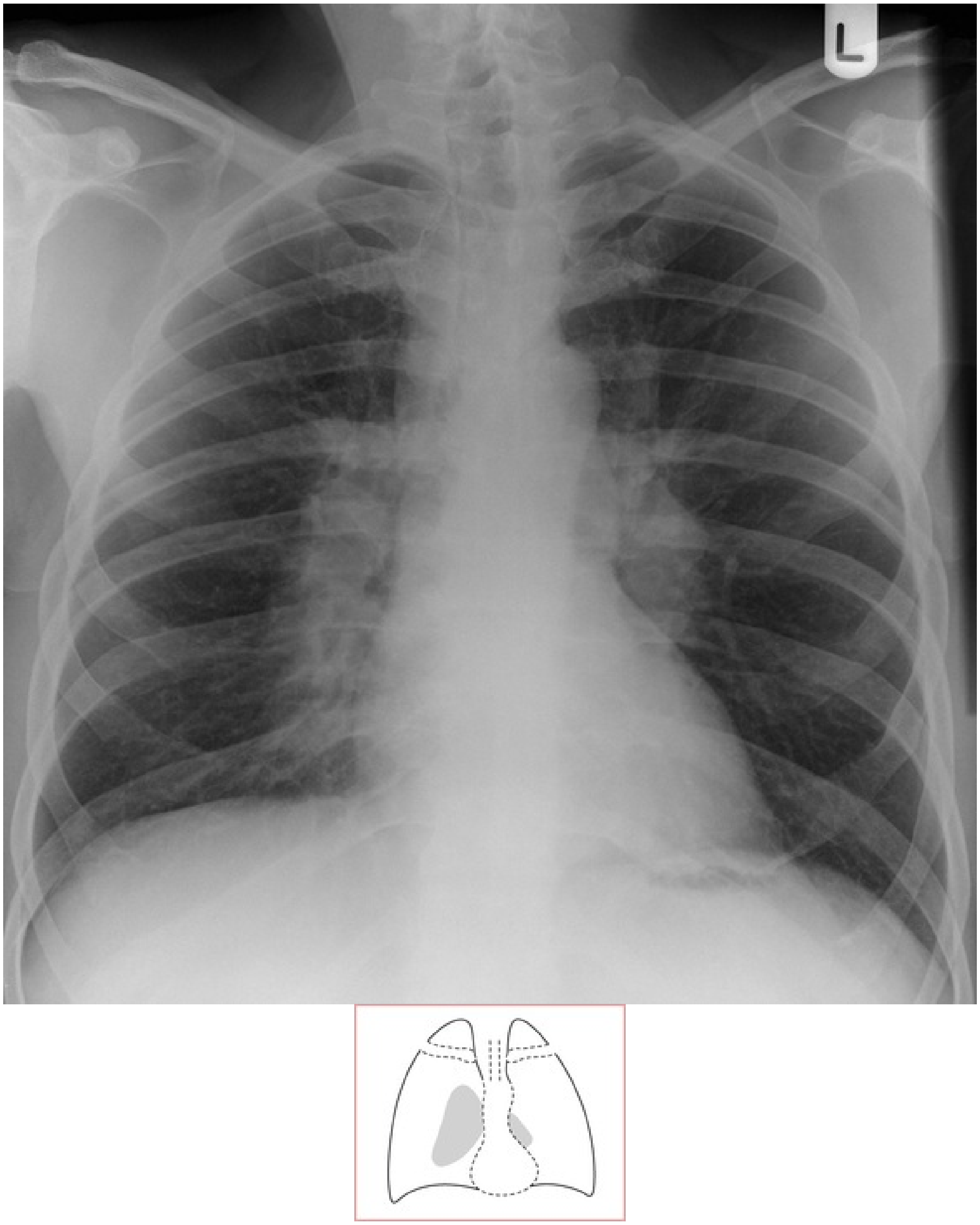


**FIGURE 6.3** In this patient both hilar regions are enlarged. The pulmonary arteries leading away from the hila are normal in size. This indicates that there is lymph node enlargement at both hila. This patient was a 30-year-old man with a skin rash, erythema nodosum, and his diagnosis was sarcoidosis.

If you suspect sarcoidosis then enlargement of the hilum may be the only finding. However, other features are often present and you should look for:

1. *Small nodules*. These are between 1.5 and 3 mm in diameter, are mostly found

in the perihilar and mid zones, are nonuniform in character, moderately well-defined and usually bilateral.

2. *Large nodules*. These are about 1 cm in diameter, have an ill-defined edge and sometimes coalesce to give larger opacities which may contain air bronchograms.
3. *Lines*. The x-ray may demonstrate a network of fine lines emanating from the hilar region.
4. *Honeycombing*. Features of fibrosis may be apparent. Look for these particularly in the upper zones where they are especially common.

7

# The abnormal heart shadow



## Atrial septal defect (ASD)

Always remember to study the heart and the pulmonary arteries. If the heart is enlarged or pulmonary hypertension is present then one possible cause is an atrial septal defect (ASD) (Fig. 7.1). If you suspect an ASD then look for the following:

1. The heart may be enlarged. Determine the cardiothoracic ratio by measuring the width of the thorax and the width of the heart. If the heart is more than half the diameter of the thorax it is enlarged.
2. Look at the shape of the heart. Look first at the apex, which is often rounded due to enlargement of the right ventricle and is sometimes lifted clear of the diaphragm. Next look at the right heart border. Because the right atrium enlarges, the right heart border looks much fuller than normal.
3. Look at the position of the heart by comparing it to the position of the vertebrae. With an ASD the heart is sometimes shifted to the left and so the right edge of the vertebral column is revealed.
4. Look at the aortic knuckle and arch of the aorta. It is often smaller if an ASD is present since blood is diverted to the right atrium rather than passing through the aorta.
5. Check for the signs of pulmonary hypertension (see page 108).
6. If you are suspicious, organise an echocardiogram. An ASD is difficult to distinguish from other left to right shunts and an echocardiogram is the most

appropriate means of making a diagnosis.

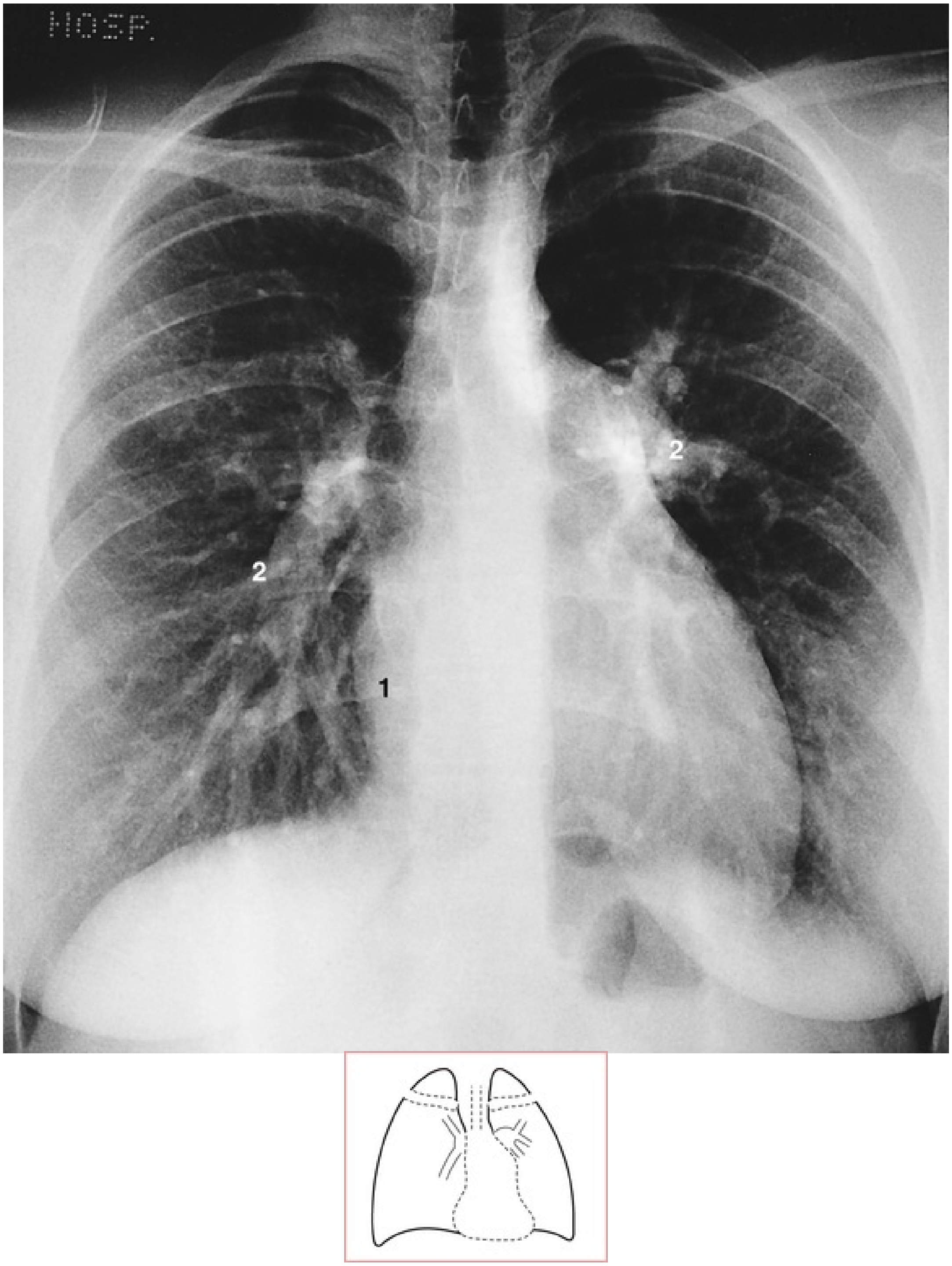



**FIGURE 7.1** This x-ray shows the typical appearance of an atrial septal defect. The heart is enlarged, the apex is rounded, the right atrium prominent **(1)** and the pulmonary arteries are dilated **(2)** due to increased pulmonary blood flow.

## Mitral stenosis

Mitral stenosis can cause changes in both the shape and size of the heart (Figs 7.2 and 7.3). It is a cause of pulmonary oedema (Box 7.1). If you suspect mitral stenosis review the following:

1. Look at the left heart border. Look just below the left hilum where the border of the heart is made up of the left atrium (see Chapter 2, page 18). This area is usually concave in shape but in mitral stenosis the left atrium is enlarged, causing a loss of this concavity and a straightening of the left heart border. Sometimes atrial enlargement is so great that this part of the heart bulges outwards.
2. Look at the right heart border. Look carefully for a double shadow, which you sometimes see in a well-penetrated film and which is due to left atrial dilatation.
3. Identify the trachea and follow it down until you see it split into right and left bronchi. This is the carina, and the angle between the bronchi should be less than 90 degrees. Measure this angle. If it is more than 90 degrees this may indicate left atrial enlargement, a feature of mitral stenosis. However, there is wide normal variation.
4. Look in the area of the mitral valve for signs of calcification, for example flecks of dense white around the valve. This would suggest mitral valve disease, but is a rare finding.

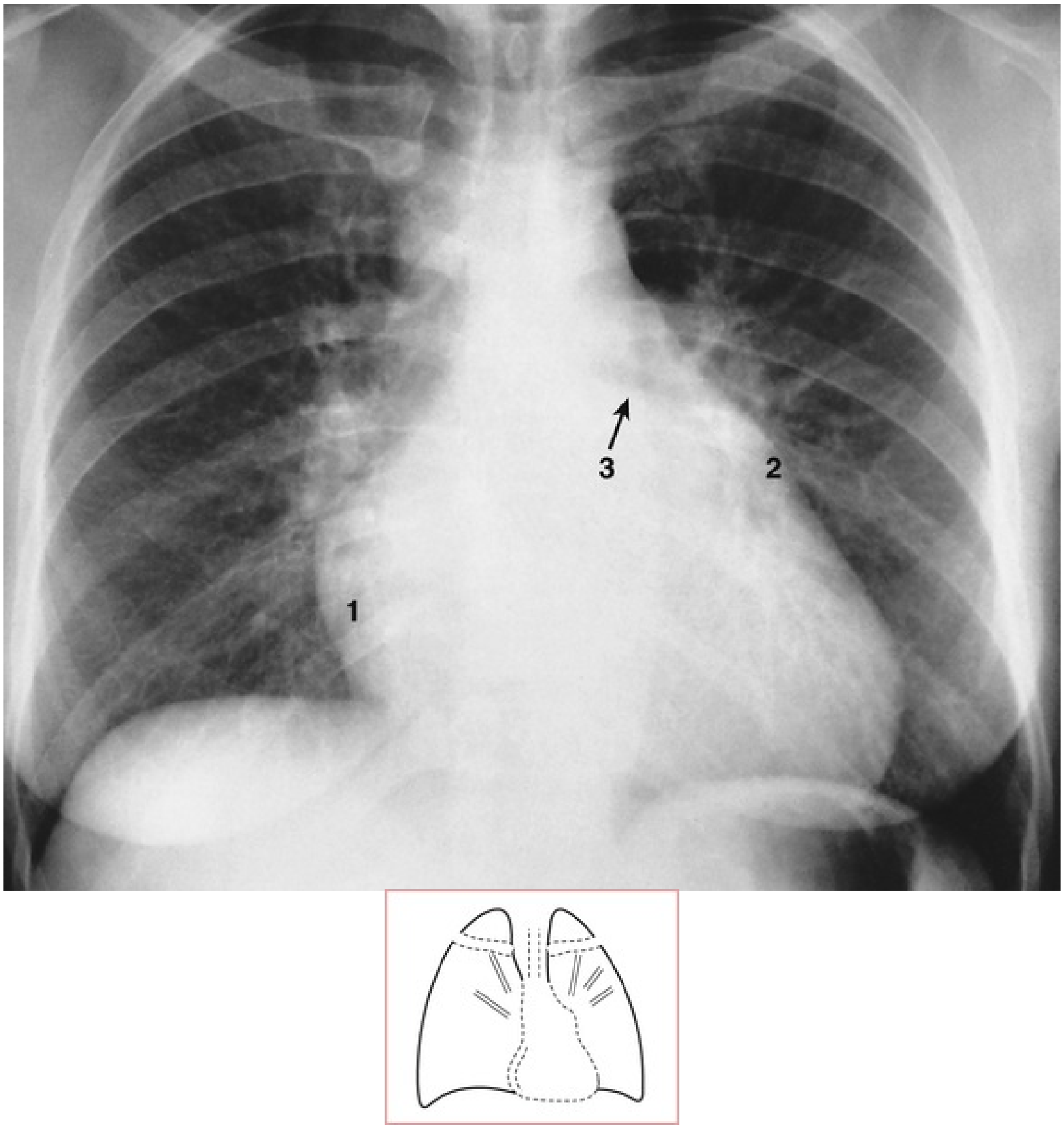



**FIGURE 7.2** This film is that of a patient who had rheumatic fever when younger. The cardiac contour is abnormal with bulging on the right giving a double right heart border **(1)**, prominence of the left atrial appendage **(2)** and elevation of the left main bronchus **(3)**, indicating left atrial enlargement. The left atrial pressure is elevated, producing increased pulmonary venous pressure with upper lobe diversion (prominence of the upper lobe veins) and basal septal lines of interstitial oedema.

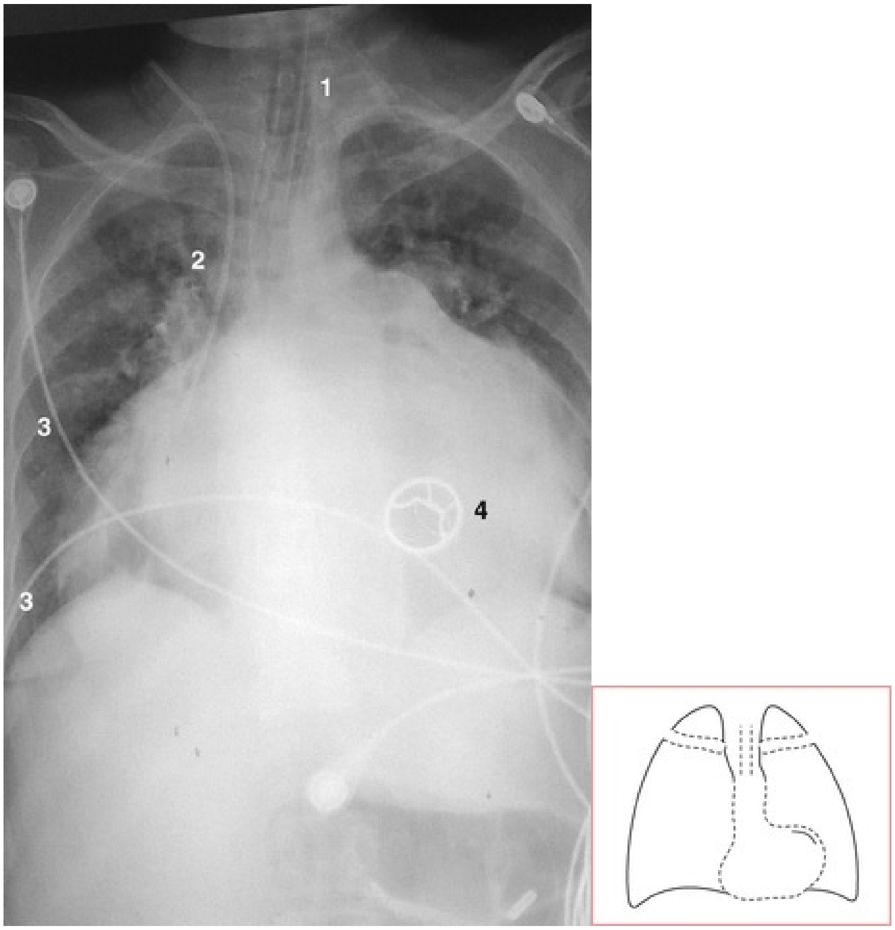



**FIGURE 7.3** This film shows features consistent with severe mitral stenosis. The patient is in the intensive care unit and you can see the endotracheal tube **(1)**, right internal jugular line **(2)** and electrocardiogram leads **(3)**. The heart is grossly enlarged and you can see the metallic mitral valve **(4)**. The lung fields appear whiter than they should and when you examine them closely, you can see prominent vasculature. This patient is from India, where rheumatic fever is common. Like other countries where rheumatic fever is endemic, patients often present late with severe cardiac complications.

**Box 7.1**

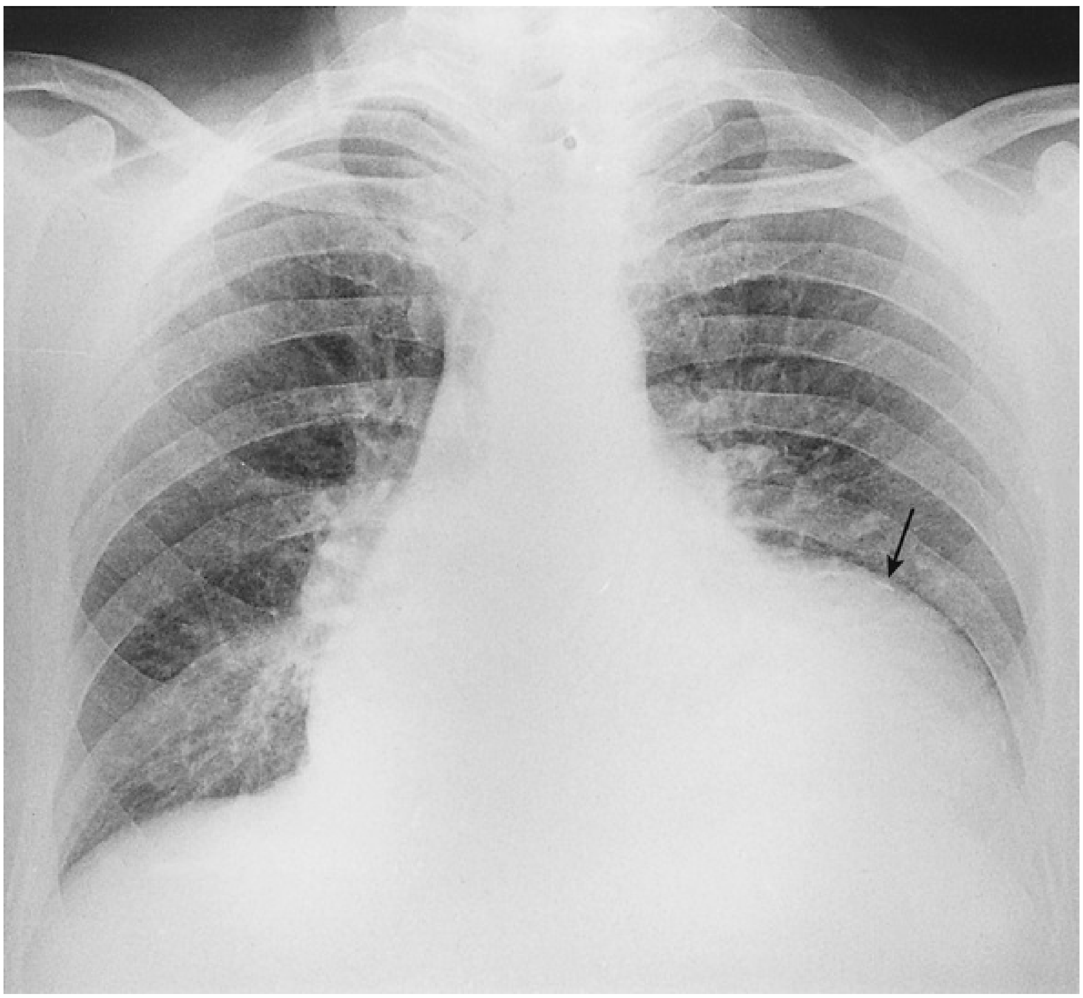
### Causes of mitral stenosis

Congenital
Rheumatic fever

## Left ventricular aneurysm

A left ventricular aneurysm is a cause of cardiac enlargement on the chest x-ray (CXR) (Fig. 7.4). It can often cause generalised enlargement of the left ventricle and be indistinguishable from left ventricular dilatation. If you suspect an aneurysm then look for the following:

1. A bulge in the left ventricle. Follow the left border of the heart. If a part bulges out then this is suggestive of an aneurysm.
2. Look for calcification. If the aneurysm is long-standing then it may have become calcified and you will see a rim of calcification along the heart border (see Box 7.2).



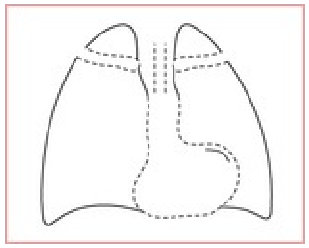


**FIGURE 7.4** This film is of a 57-year-old man with chest pain and shortness of breath. In addition to the signs of early pulmonary oedema, the film also shows a left ventricular aneurysm with an outward and upward bulge of the left ventricular apex. Calcification is also apparent **(arrow)**.

**Box 7.2**

### Cardiac-related calcification

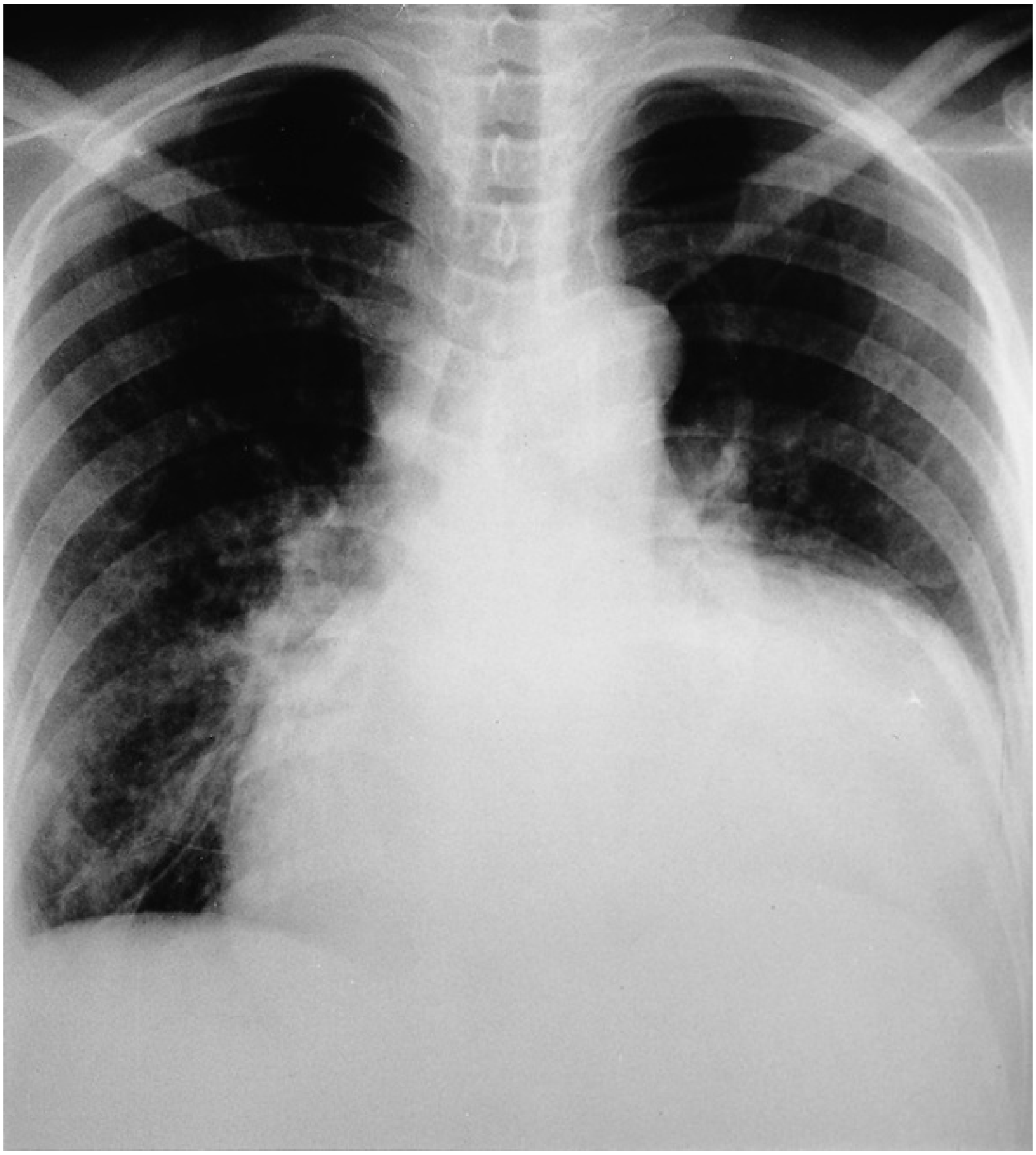
A left ventricular aneurysm is not the only cause of calcification within or around the heart. Calcification of the pericardium can occur as a result of tuberculosis, or asbestos-related pleural plaques on the mediastinal surface. Uraemic pericarditis may also calcify. Often no cause can be found.

## Pericardial effusion

A pericardial effusion is another cause of an enlarged heart shadow (Fig. 7.5). The causes of a pericardial effusion are indicated in Box 7.3. If you suspect it then carry out the following checks:

1. Confirm that the heart shadow is enlarged. Check that it is a posterior-anterior (PA) film and that the largest diameter of the heart shadow is more than half the largest diameter of the thorax.
2. Look carefully at the shape of the heart shadow. Enlargement due to an effusion is generalised, so if the enlargement appears to be due to a specific chamber enlarging then the cause is unlikely to be an effusion. The heart shadow is globular in shape if an effusion is present; though do not be put off by a bulge that you can sometimes see on the left heart border.
3. Look at the lung fields. If cardiac enlargement is due to left ventricular failure then the vascular markings should be increased, making the lung fields whiter than usual. In a pericardial effusion the vascular markings are usually normal.
4. Look at previous films. A sudden increase in heart size is suggestive of a pericardial effusion.

5. Look at the hilum. In a pericardial effusion the heart shadow may cover both hila. This will not occur with other forms of cardiac shadow enlargement.
6. Look at the white line on the edge of the right side of the trachea (the paratracheal density). This should be less than 2–3 mm wide on an *erect* CXR. If it is wider, one cause is enlargement of the superior vena cava (SVC). This would be consistent with a pericardial effusion (see Fig. 7.5).



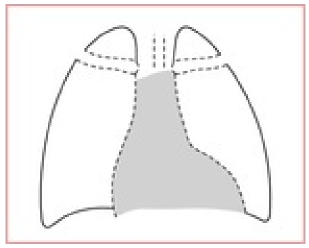


**FIGURE 7.5** This film shows a pericardial effusion. The heart shadow is enlarged and globular in shape and covers both hila.

**Box 7.3**

## Causes of pericardial effusions

Transudate
- Congestive cardiac failure

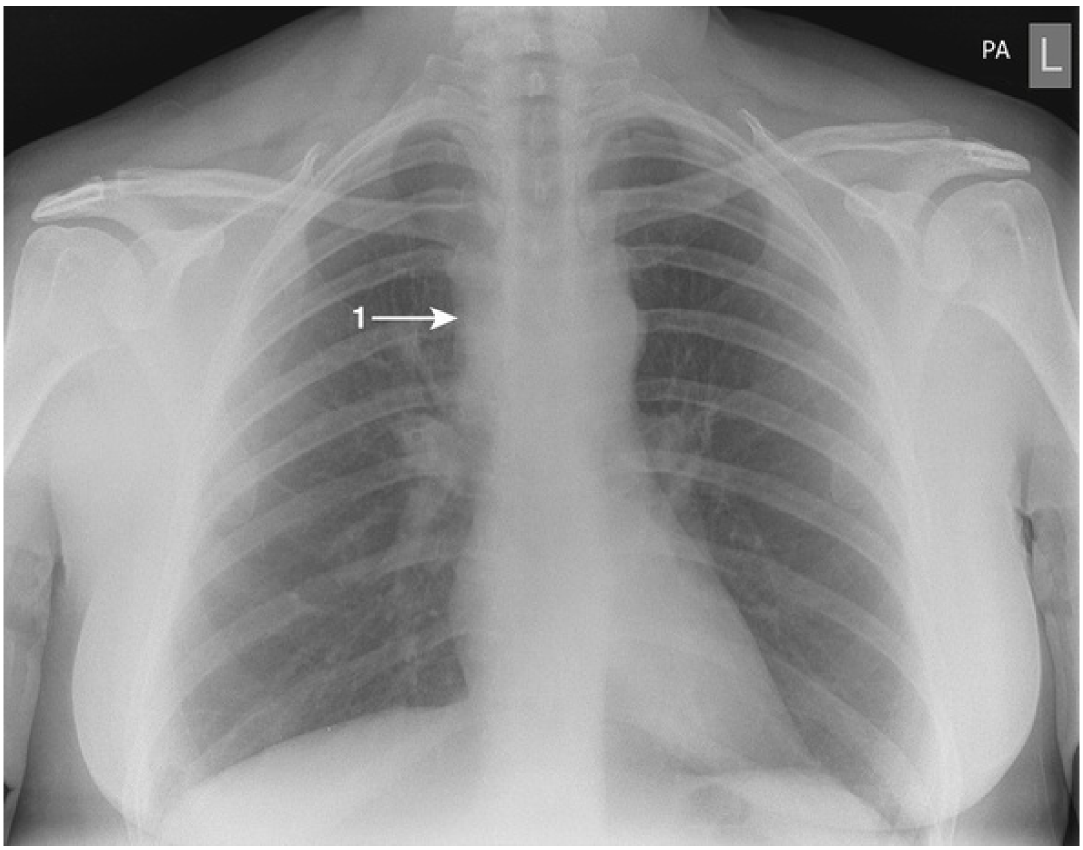
Exudate
- Post myocardial infarction
- Infection, e.g. tuberculosis, bacterial
- Neoplastic infiltration
- Collagen vascular, e.g. rheumatoid arthritis, systemic lupus erythematosus (SLE)
- Iatrogenic, e.g. post cardiac surgery
- Endocrine – myxoedema

Blood
- Trauma
- Neoplastic infiltration
- Aortic dissection/penetrating peptic ulcer
- Bleeding diathesis, e.g. anticoagulation, leukaemia

8

# The widened mediastinum

Always look carefully at the mediastinum (Fig. 8.1). If you think that it is widened then relate this finding to the clinical history. Try to find some old films and see if the mediastinum has got larger. Be aware that a normal chest x-ray (CXR) does not exclude a significant aortic event, such as a dissection, and in the presence of clinical suspicion an urgent computed tomography (CT) scan may be an appropriate investigation.



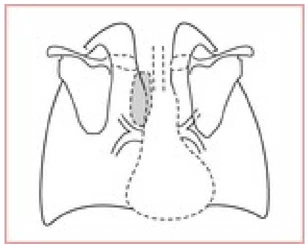


**FIGURE 8.1** This is the CXR of a 58-year-old lady with a known diagnosis of lymphoma. The x-ray shows widening of the middle part of the mediastinum. If you look at the right side of the trachea, above the right hilum you can see an increased white area which is larger than 2 mm in thickness **(1)**. This is due to enlarged right paratracheal lymph nodes.

Important causes of a widened mediastinum are thyroid enlargement, enlargement of mediastinal lymph nodes, aortic dilatation, dilatation of the oesophagus or thymic tumours (Fig. 8.2). In deciding a likely cause, go through the following process:

1. Check the rotation of the film. A badly rotated film can make the mediastinum appear widened.
2. Decide whether the enlargement is at the top, middle or bottom of the mediastinum. If at the top it is likely to be thyroid, thymus or innominate artery. If in the middle or bottom of the mediastinum it could be lymphadenopathy, aortic widening, dilatation of the oesophagus, or a hiatal hernia.
3. If the shadowing is at the top then look at the position of the trachea. An enlarged thyroid will displace or narrow the trachea. This will not happen with a tortuous innominate artery – a common finding in the elderly.
4. Look at the right side of the trachea. The white edge of the trachea should be less than 2–3 mm wide on an *erect* film. An increase in its width suggests either an enlarged superior vena cava (SVC) or a paratracheal mass. This rule does not apply to supine films.
5. If you suspect an enlarged thyroid then look at the outline of the shadow. A thyroid has a well-defined outline that tends to become less clear as one moves up the neck.
6. If you suspect widening of the aorta then try and follow its outline, remembering that the root of the aorta is not visible. You may be able to detect a continuous edge which widens to form the edge of the enlarged mediastinum. This would suggest that the widening is due to dilatation of the aorta.
7. The commonest cause of an abnormal widening of the mediastinum in the

elderly will be unfolding of the aorta. You may be able to trace the margin of the ascending aorta around the arch and to the descending aorta. Some calcification in the wall of the aortic knuckle is a common feature. If the line of calcium is separated from the edge of the aortic shadow this strongly suggests a dissection.

8. A widened, aneurysmal, aorta can sometimes be difficult to distinguish from the more common unfolded aorta. If you can follow both edges of the aorta and detect a widening this suggests an aneurysm (Fig. 8.3). CT is often used to assess aortic dimensions.

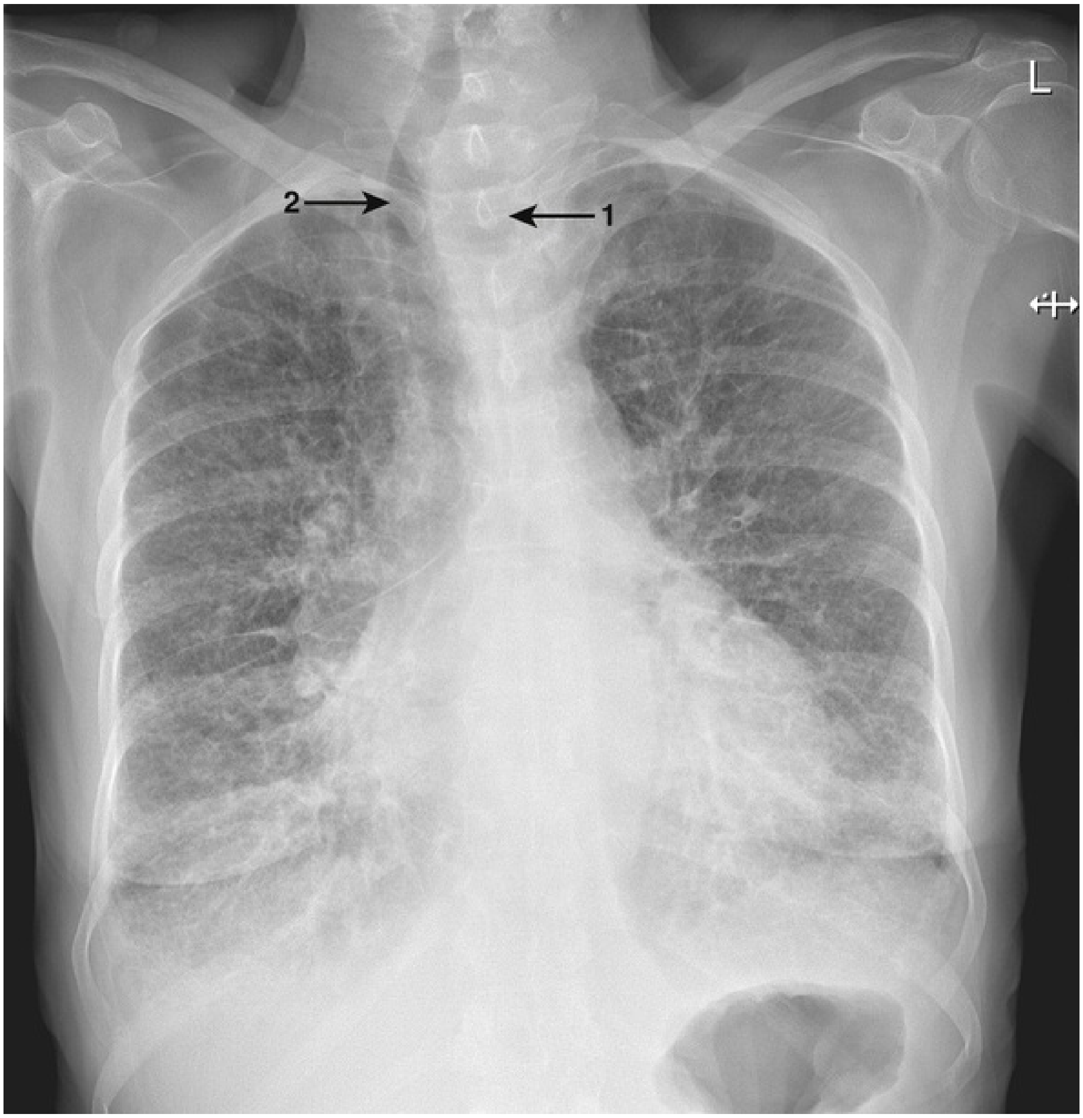



**FIGURE 8.2** **A CXR of thyromegaly with tracheal deviation. This patient had shortness of breath. As well as showing widespread pulmonary fibrosis, this image also demonstrates features of thyroid enlargement. The thyroid enlargement is seen as an abnormal white area at the top and left of the mediastinum (1). Notice how this enlarged**

thyroid is causing tracheal deviation to the right (2).

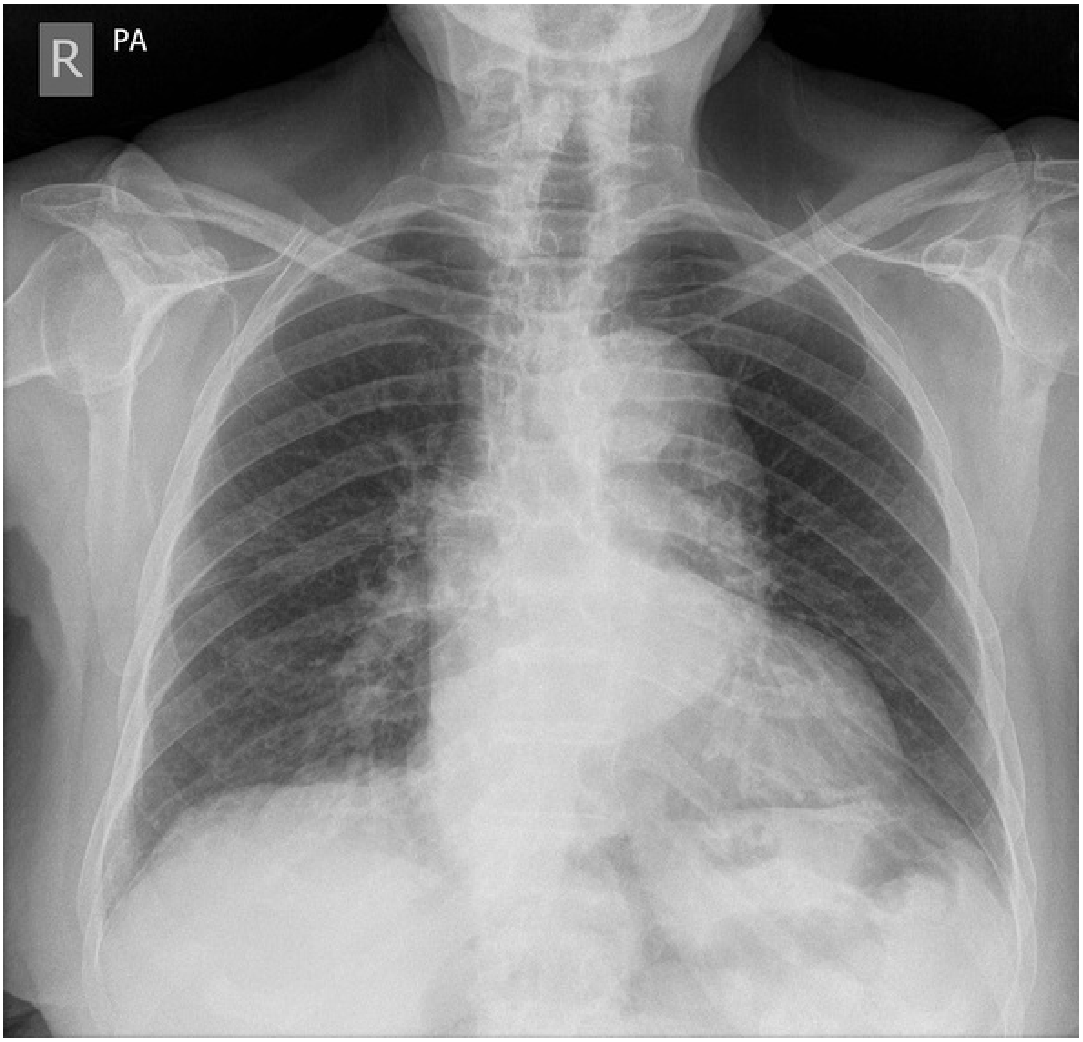



FIGURE 8.3 A CXR of a patient with a descending thoracic aortic aneurysm. The mediastinum is widened to the left of the midline throughout its length, with increased convexity around the aortic arch.

## CT and the widened mediastinum

CT is the best modality to assess the causes of mediastinal widening.

Even if the chest x-ray is normal, you can only exclude mediastinal pathology by performing a CT scan.

Because the mediastinal widening could be due to soft tissue or blood vessels, it is important that the scan is done with intravenous contrast. This will both distinguish soft tissue from blood vessels and also enable you to properly assess any vascular abnormality.

As with the chest x-ray, you need to methodically look at the top, middle and bottom of the mediastinum.

1. Look at the top of the mediastinum.

   Causes of mediastinal enlargement would include the thyroid and the thymus (Fig. 8.4).

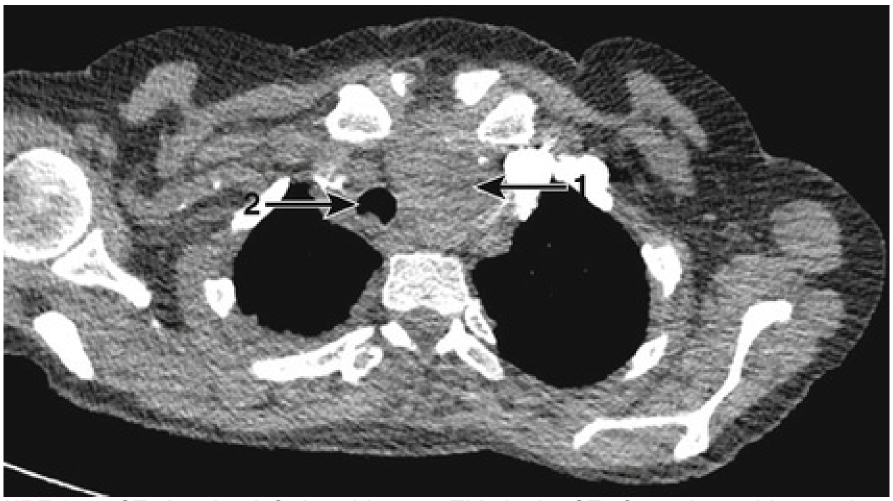



**FIGURE 8.4** CT showing left thyroid mass. This is the CT of a patient with an enlarged thyroid. Notice the enlarged thyroid which appears grey in appearance (1) with tracheal displacement to the right (2).

   The thyroid should normally be dense due to its high iodine content and not cause any tracheal displacement.

   An enlarged thyroid may appear less dense since the enlargement is due to nonfunctioning tissue.

   An enlarged thyroid would also push the trachea to the right or the left.

   Look for an enlarged thymus, which may appear as a well-defined soft tissue structure, which, if you follow slices downwards, may be seen to extend to the left in front of the heart.

2. Look at the middle of the mediastinum at the slices that cover the arch and the ascending and descending thoracic aorta.

   The aorta should be of uniform diameter with the ascending and descending aorta having roughly the same diameter.

   Enlargement of one of these indicates aortic aneurysm (Fig. 8.5).

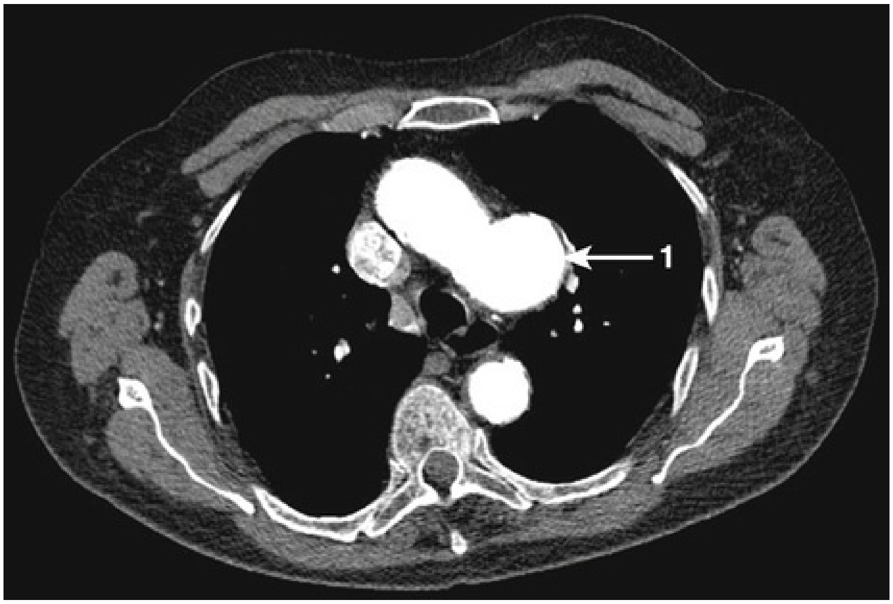



FIGURE 8.5 CT of a thoracic aortic aneurysm of a patient being investigated following an abnormal CXR. This slice has been taken at the level of the arch of the aorta. Notice how the arch has lost its normal oblong appearance and has a sac-like enlargement (1). This is an aneurysm of the arch of the aorta. All the contrast is contained in one lumen, suggesting there has been no dissection.

If the aorta is enlarged, check carefully that the contrast remains within a single lumen to exclude a dissection.

A dissection may require emergency treatment.

3. Look at the lymph nodes (as described in Chapter 3, Fig. 3.2–3.4).

   Significant lymphadenopathy can cause mediastinal widening.

9

# Abnormal ribs



## Rib Fractures

Your examination of the chest x-ray (CXR) is not completed until you have looked carefully at the ribs. They should be of a uniform density with smoothish, unbroken edges. The main abnormalities to look for are old and new fractures and metastases.

1. *New fractures*. Look along the edges of each rib. A new fracture will be seen as a break in the edge (Fig. 9.1). Once you have spotted a fracture look for more information. Look at the position of the fracture. A fracture of any of the first three ribs is unusual and implies tremendous force. Look for other fractures. A line of fractures suggests a traumatic injury whereas fractures scattered throughout the ribs may suggest repeated injury (as in an alcoholic) or underlying bony weakness (as in malignant disease). Look at the density of the ribs and compare them in your mind to other x-rays you have seen. If the ribs are less white than usual, this suggests underlying decrease in bone density. Finally look for the complications of rib fractures – surgical emphysema, pneumothorax and haemothorax. Remember also that damage to the lower three ribs may result in hepatic, splenic or renal injury.

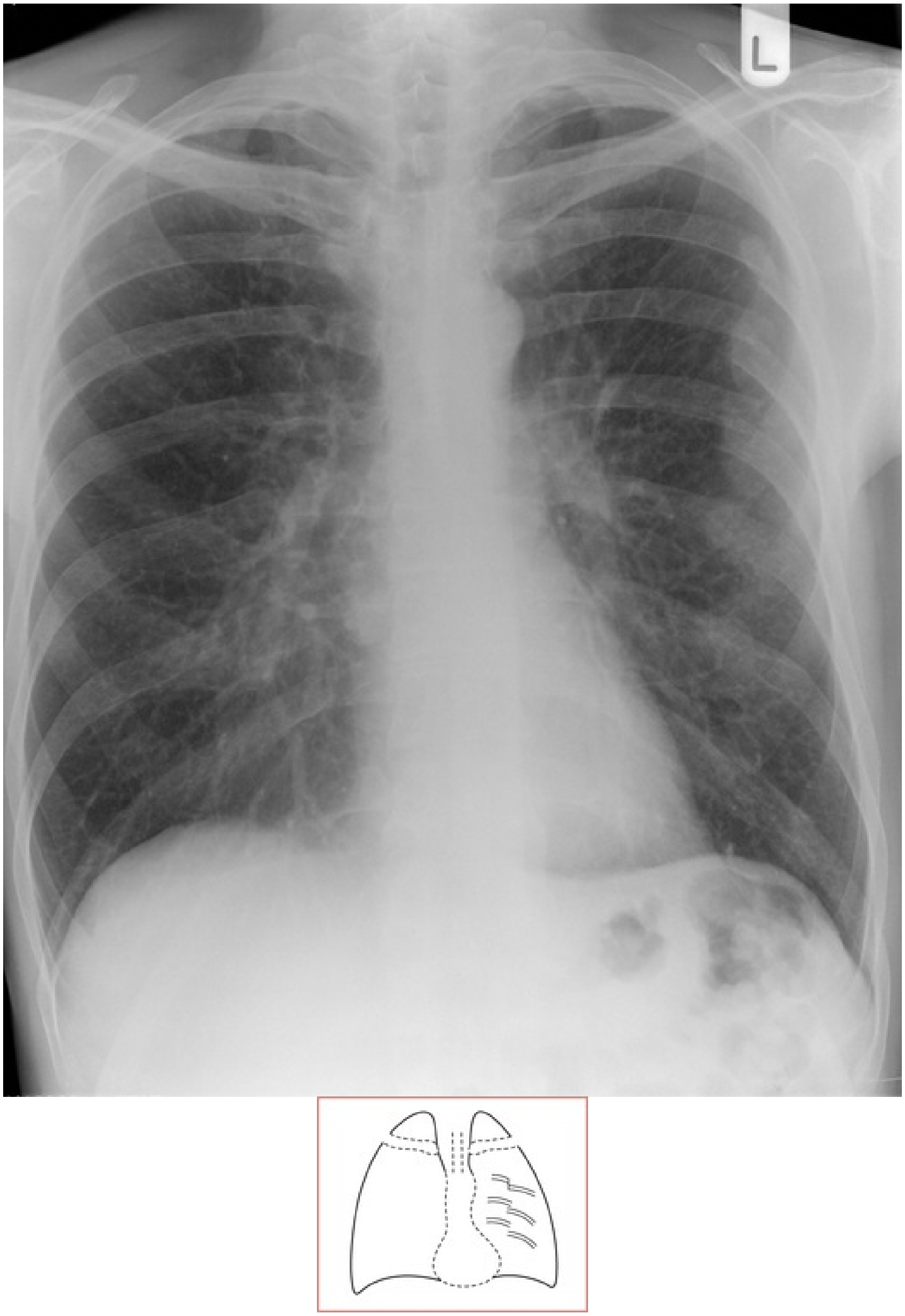


**FIGURE 9.1** Note how there is increased whiteness over the left side of the chest. On close inspection you can see that the posterior ribs have a step in their alignment – these are fractures affecting the 5th, 6th, 7th and 8th ribs.

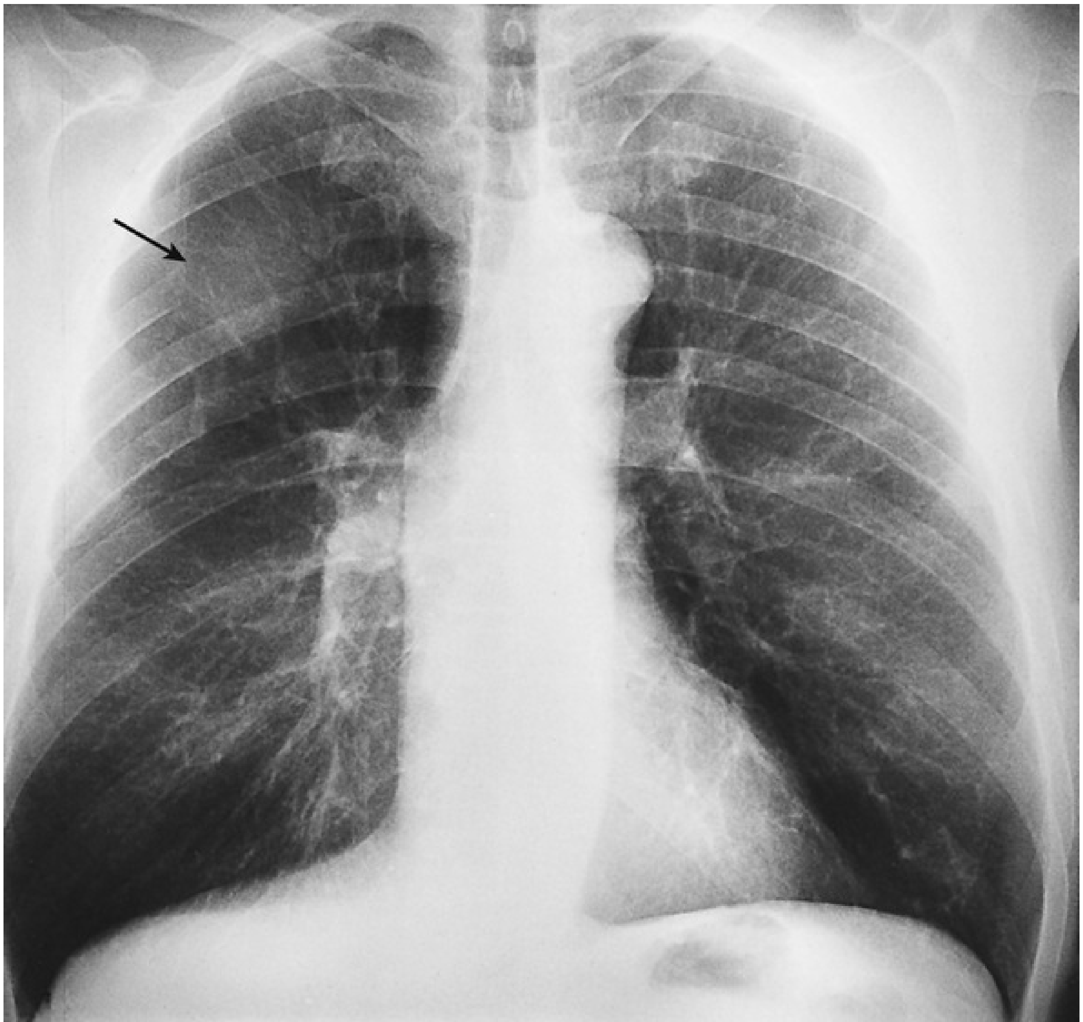
2. *Old fractures*. Again look along the edges. The callus formation that follows a

fracture will cause the rib to expand at this point. You need to look carefully – sometimes callus formation can simulate a lung mass.

If you suspect a rib fracture clinically but cannot see it on the CXR do not worry. Rib fractures can be missed easily on the x-ray and often cannot be seen at all. The CXR is usually performed to look for potential complications.

## Metastatic Deposits

Metastatic lesions in the ribs will tend to look like dark holes (Fig. 9.2). Scan the ribs carefully for evidence of metastasis. Secondaries start in the medulla and spread outwards with very little reaction around them so you are literally just looking for a dark hole. Sometimes the underlying lung markings create the impression of a metastasis in the overlying rib. If you spot a dark hole in the rib, then look carefully at its edge. Compare the outline to the underlying lung markings. If they overlap, then the metastasis may be deceptive. If you see bone metastases, check carefully to see whether there is an associated fracture.



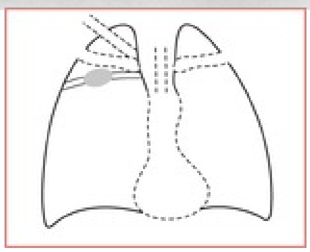


**FIGURE 9.2** Look carefully at this film. The lungs are over-expanded. Note the destruction of the posterior part of the cortex and the medulla of the right 5th rib with an associated ill-defined soft tissue mass **(arrow)**. This is a lytic metastasis.

Look carefully at the other bones, which may contain similar pathology.

10

# Abnormal soft tissues



## Surgical Emphysema

At first sight surgical emphysema gives a very messy appearance which is sometimes confined to the obvious soft tissue areas but may spread over the whole x-ray (Fig. 10.1). If you suspect surgical emphysema, the causes of which are shown in Box 10.1, then look for the following characteristics:

1. In mild cases look for lozenge-shaped areas of blackness (Fig. 10.1) which represent pockets of air in the soft tissue. These areas will all lie in the same plane, which will follow the plane of the soft tissue structures.
2. In severe cases the orientation of the planes is lost. Instead look for alternating dark and white lines which appear not to be confined to single structures and cross part or all of the film.

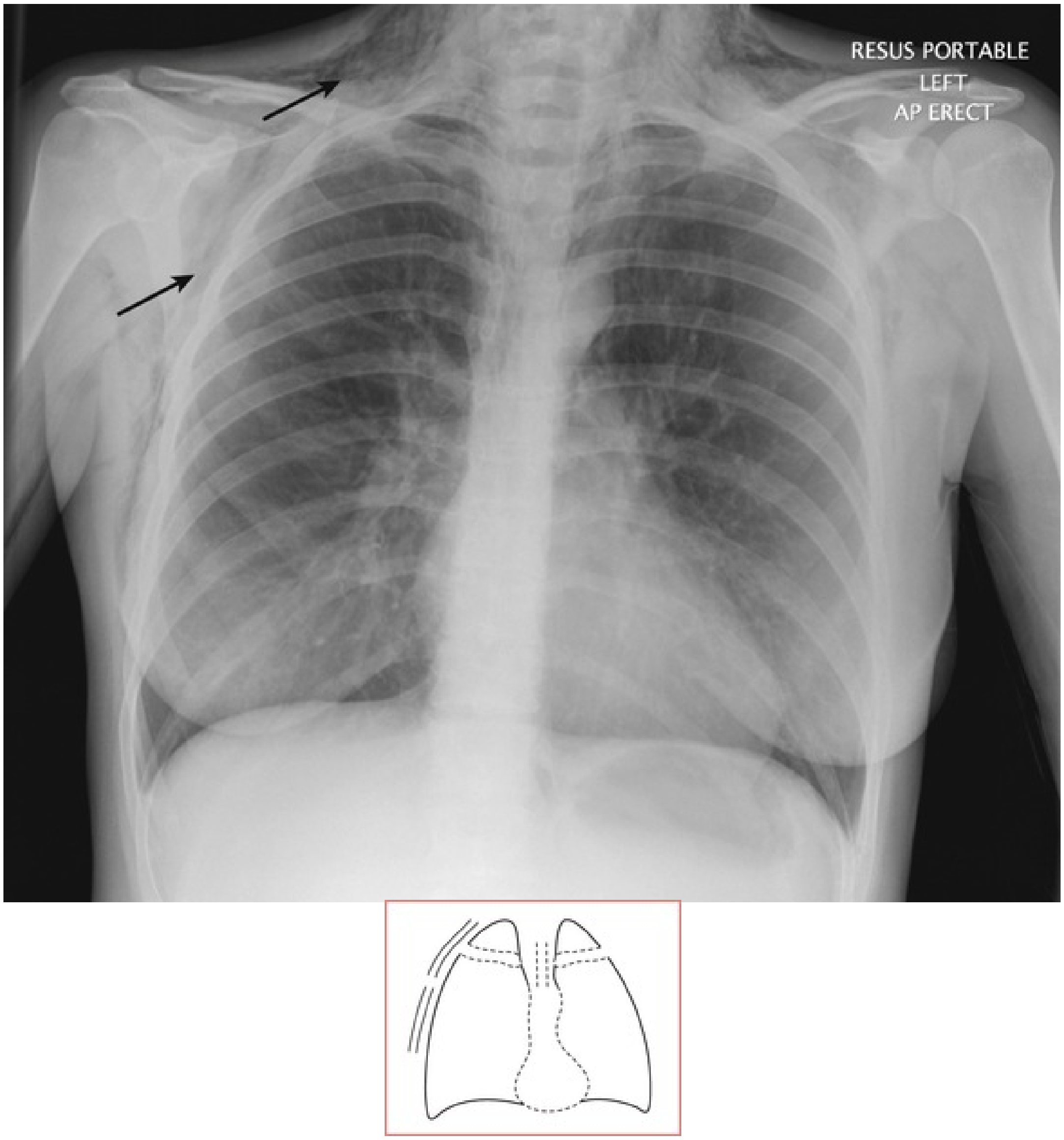



**FIGURE 10.1** This is the film of a young asthmatic patient who presented with chest pain. The film was taken to look for complications of asthma such as a pneumothorax or air in the mediastinum – pneumomediastinum. Neither can be seen, but there is extensive air in the soft tissues **(arrows)** over her shoulders and along the right chest wall, best seen in the axillary area. There probably is a small pneumothorax, but this cannot be seen on the film.

**Box 10.1**

## Causes of surgical emphysema

Trauma

Iatrogenic, e.g. surgery, chest drain insertion
Obstructive lung disease, e.g. asthma
Oesophageal injury
Gas gangrene

11

# The sick patient



## Lines, Tubes and Devices

Chest x-rays (CXR) are commonly used to check the position of lines, such as nasogastric tubes, central venous lines and chest drains (Figs 11.2–11.5). When checking the x-ray you need to look at (a) whether the line is in the correct position, (b) whether the line is smooth or kinked, and (c) whether any complications have occurred when the line was inserted. After checking the x-ray it is important to document your findings in the patient's notes and make a clear statement as to whether the line is safe to use.

To ensure that lines are positioned properly you need to understand the relevant anatomy. Figure 11.1 shows the position of the oesophagus and the subclavian and internal jugular veins. Remember these, since they will help you determine whether lines have been accurately placed.

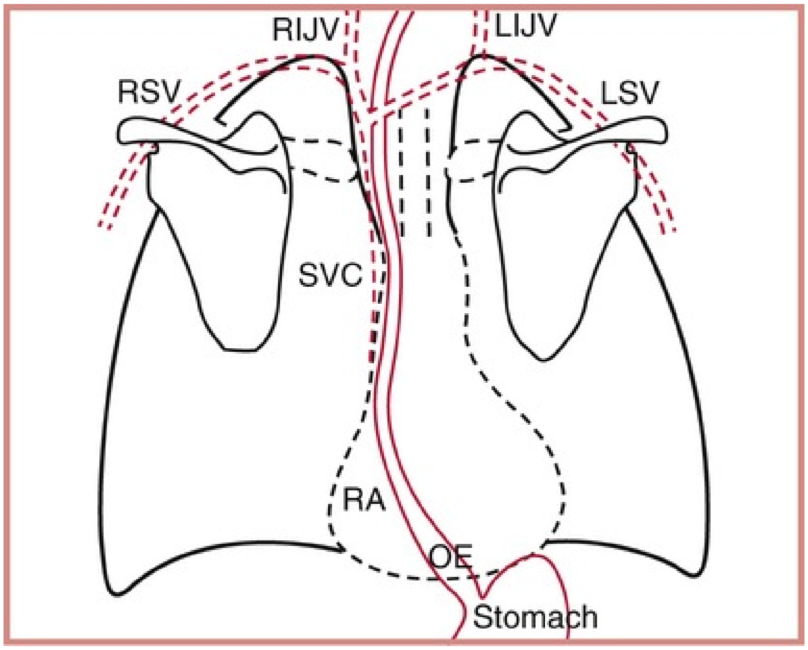



**FIGURE 11.1** This line diagram shows the course of the main veins used for central lines. These all drain into the superior vena cava (SVC). The position of the oesophagus (OE) and stomach is also shown. *LIJV*, left internal jugular vein; *LSV*, left subclavian vein; *RA,* right atrium; *RIJV*, right internal jugular vein; *RSV*, right subclavian vein.

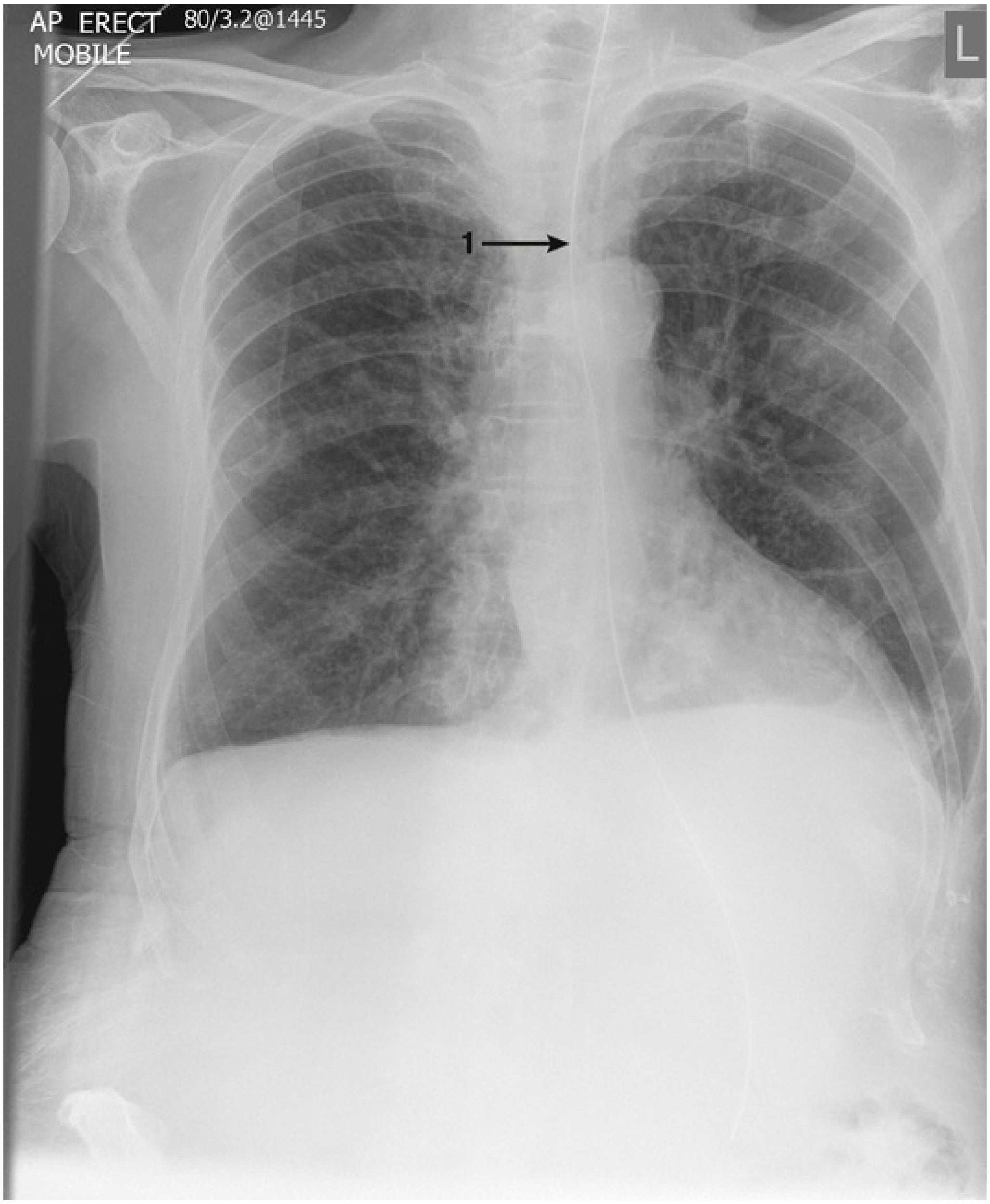



**FIGURE 11.2** A CXR of a 70-year-old man who had a protracted hospital stay following an episode of sepsis. A nasogastric tube has been inserted **(1)**. You can follow the tube from the top of the x-ray to its tip, which is below the diaphragm. The tube is smooth and not kinked and should function well.

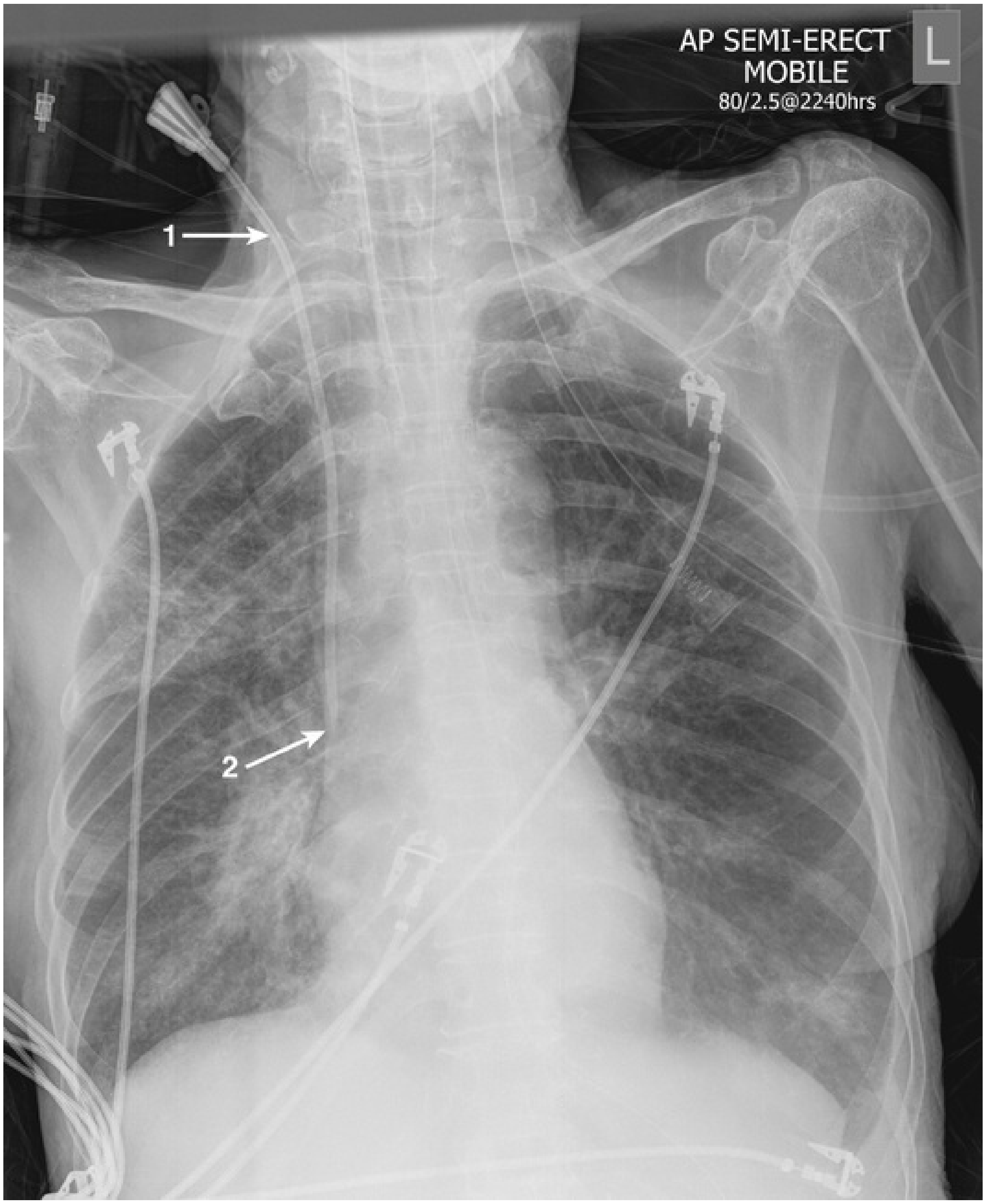



**FIGURE 11.3** A CXR of a 61-year-old lady admitted to intensive care unit with severe sepsis. You can see the right-sided central line which has been introduced into the right internal jugular vein **(1)** and follows the course of the right brachiocephalic vein. The tip of the line is seen in the superior vena cava **(2)**. You can see the patient has not sustained the complication of a pneumothorax.

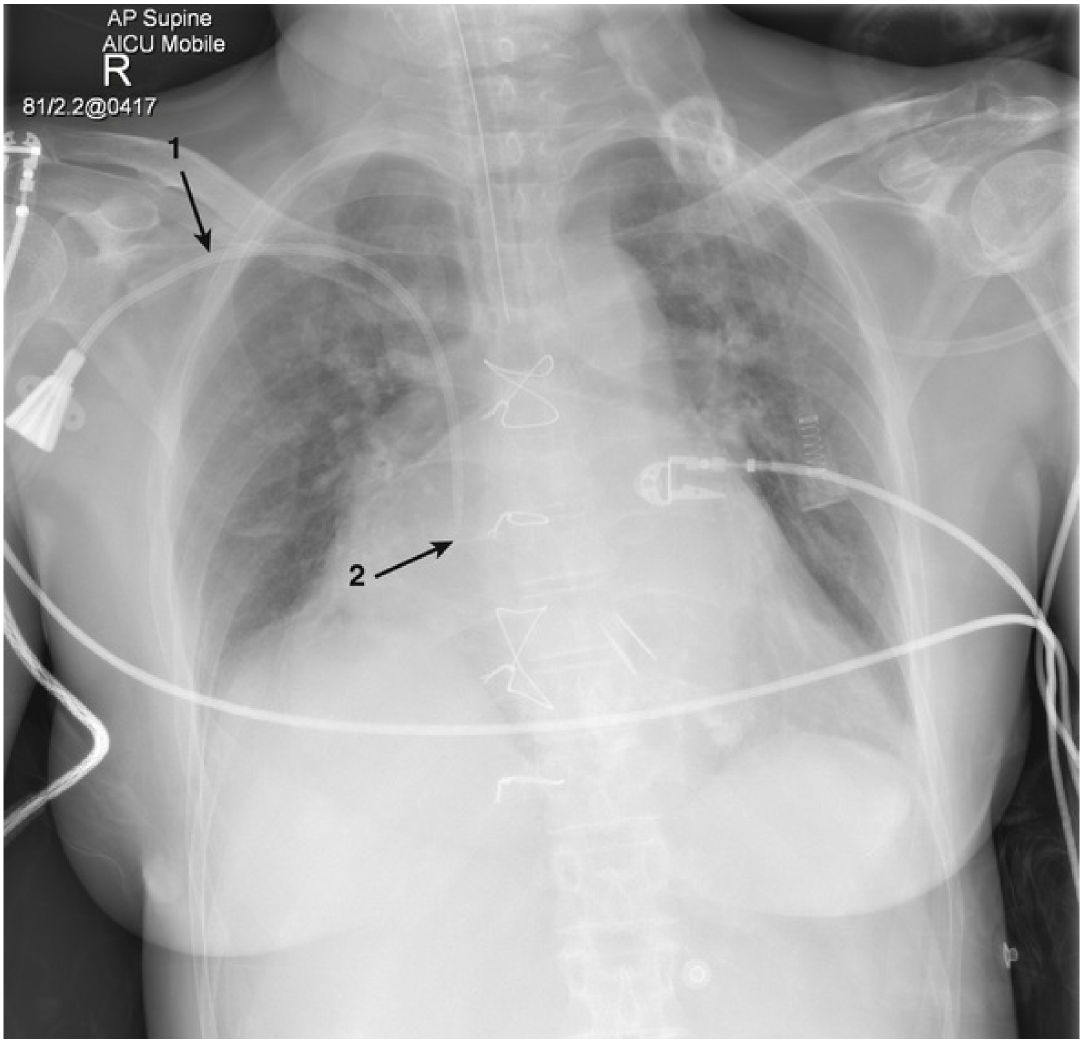



**FIGURE 11.4** In this x-ray the central line has been introduced through the right subclavian vein **(1)** and follows the course of the subclavian through to the right brachiocephalic vein. The tip can be seen in the superior vena cava **(2)**.

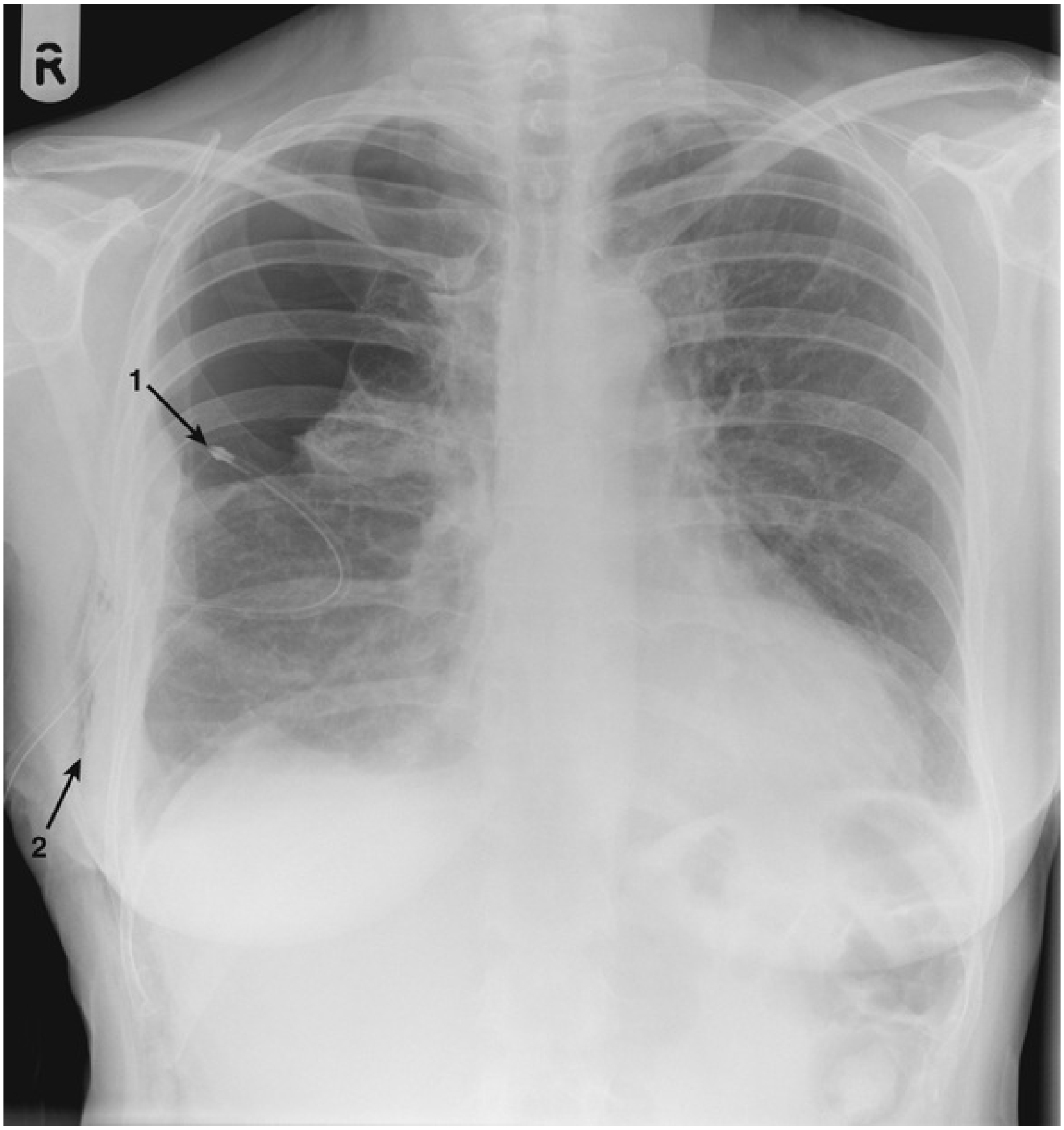



**FIGURE 11.5** A CXR of a 30-year-old woman with a primary pneumothorax. Note the right-sided chest drain. You can see the tip of the chest drain is within the pleural space **(1)** and although the line is curved, it is not kinked. Note the small amount of surgical emphysema at the insertion point **(2)**.

Finally, although the x-ray may have been ordered to check the position of the line it may still yield other information. Check the lung fields, soft tissue structures and bones in the same way as you would approach any CXR.

## Nasogastric tubes

You may need to look hard at the CXR to see the nasogastric tube clearly. If you are using a picture archiving (digital) system, change the contrast – this may make the tube easier to see.

Once you have identified a section of the line, follow the line up and down. Make sure you can confidently see the whole line. Follow the tube down to its lowest point. This should be beneath the diaphragm. Trace the line back up. It should follow the path of the oesophagus and so pass up centrally through the chest. A significant deviation to the left or the right may indicate the line is within a bronchus rather than the oesophagus.

Check that the line is not kinked.

A pneumothorax is unlikely to occur with the insertion of a nasogastric tube. However, it is a potential complication if the tube has entered an airway. If the tube appears to be in the lung, look for a possible pneumothorax.

## Central lines

Check that the line follows the anatomical boundaries shown in Figure 11.1.

Check the positioning of the end of the line. It should point towards the heart. Sometimes lines can turn back on themselves and occasionally enter other veins, turning away from the heart. It is not uncommon for example for a subclavian line to turn upwards into the brachiocephalic vein and point towards the head or shoulder. Check that the line is away from the cardiac shadow.

Check the line is smooth and not kinked.

Review the lung fields carefully and check that the patient has not sustained a pneumothorax. This is common complication of central line insertion.

## Chest drains

Check that the line enters the pleural cavity. Check that it is above the diaphragm and has passed through the subcutaneous tissues.

Check that the tip of the line is not resting on the chest wall or heart border.

Check the line is not kinked.

Following the insertion of a chest drain you may see surgical emphysema on the x-ray. This is not uncommon.

## Pacemakers

The position of a pacemaker needs to be checked by a cardiologist; however, it is useful to know the x-ray appearance of pacemakers and implantable defibrillators. In Chapter 2, Figure 2.2 shows a typical dual chamber pacemaker with leads going into the right atrium and right ventricle.

## The Patient on Intensive Care

The CXR of a sick patient is often more difficult to interpret since the x-ray is not taken in ideal conditions (Fig. 11.6).

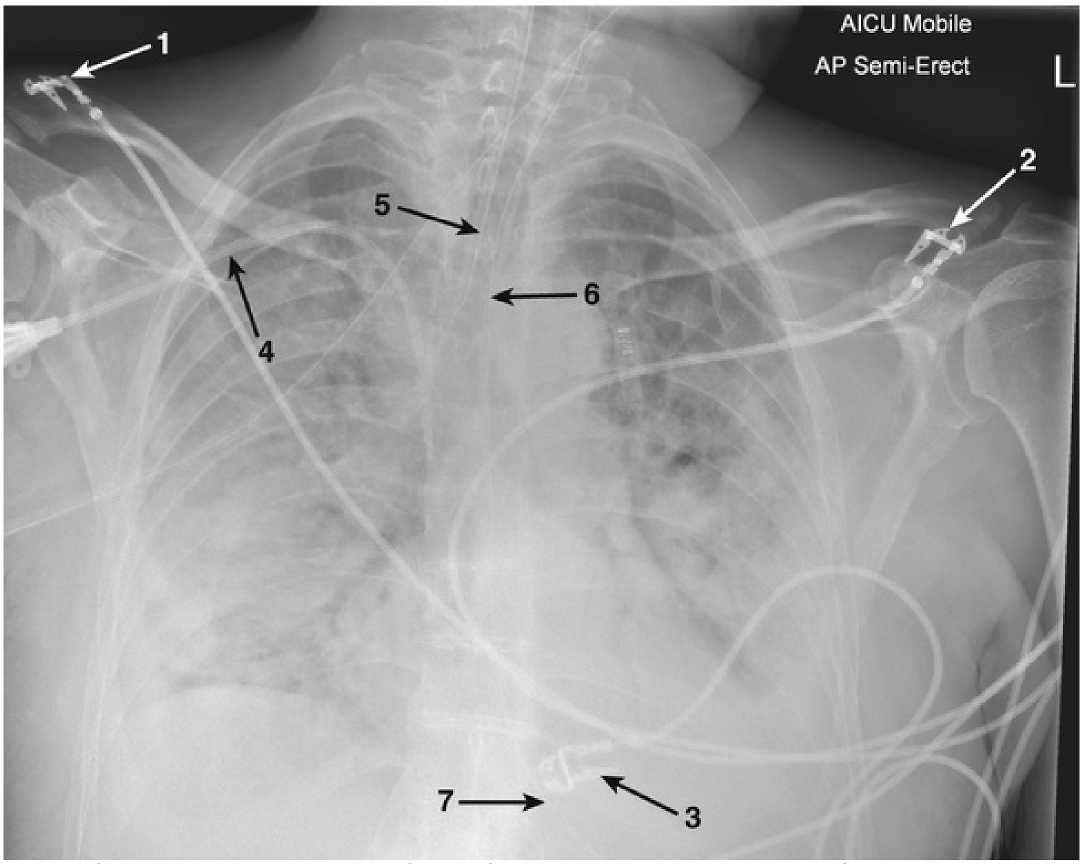



**FIGURE 11.6** This is the CXR of a 60-year-old lady on the ICU with severe ARDS. It is a difficult x-ray to interpret because of the technical limitations of performing an x-ray on the ICU. The x-ray is an AP projection and semi-erect. There are multiple lines crossing the image. You need to look carefully at each of these. Notice the three external ECG leads **(1,2,3)**. You can see the right subclavian line which appears to be in the correct position **(4)**. There is an endotracheal tube **(5)** that stops above the carina. There is also a nasogastric tube **(6)** which on the x-ray appears to the left of the endotracheal tube and courses down the oesophagus to below the diaphragm **(7)**.

The patient is likely to be semi-erect or supine since they will not be well enough to stand up. This will have a particular significant effect on the distribution of fluid. On an erect film, fluid will sink to the bottom of the lungs, obscuring the diaphragm and giving a well-defined upper border, usually with a meniscus. This will not be the case with a supine film where, instead, the fluid will appear less distinct with no clear upper border. A pleural effusion in a supine patient will give a general increase in whiteness across the lung fields.

The film is likely to be anterior-posterior (AP) rather than posterior-anterior (PA). It is therefore difficult to judge the size of the heart, which will appear larger than normal.

The patient may not have taken a deep breath and may have been unable to hold their breath. Not taking a deep breath will make the heart and mediastinum appear wider than normal and may make the lung fields appear whiter. If the patient has been unable to hold their breath the image may be blurred and subtle abnormalities may be missed.

The patient may have a number of lines and tubes. Remember that these lines are both inside and outside the patient. For example, an endotracheal tube will appear on the x-ray within the trachea but the line connecting it to the ventilator may pass over the patient's chest and so also appear on the film. This is important because these lines could obscure abnormalities. In addition sometimes seemingly abnormal areas on an x-ray are artefacts caused by the presence of lines.

Remember to look at the rest of x-ray for complications and underlying pathology. In this case (Fig. 11.6) you can see diffuse consolidation throughout the lung fields in keeping with acute respiratory distress syndrome (ARDS).

12

# The hidden abnormality



## Pancoast's Tumour

A number of abnormalities can be easily missed (Fig. 12.1). Before deciding an x-ray is normal:

1. Look carefully at the apices of both lungs. This is a common site for lung pathology, for example a Pancoast's tumour or chronic fibrosis. Lesions here can be easily missed because the apex of the lung is hidden by ribs and clavicles.
2. Look carefully at the heart shadow. Lesions behind the heart are often missed because they are obscured by the whiteness of the heart. Look carefully for any parts of the heart shadow that look whiter than the rest. Look also for the triangular shadow of the left lower lobe collapse and other subtle changes such as consolidation behind the heart.
3. Look carefully at the mediastinum. Changes in the shape of the mediastinum can be very subtle.
4. Look at the hilum. Changes in the shape or density of the hilum can be easily missed.
5. Obtain a lateral film – some abnormalities are more obvious on the lateral.
6. Read the radiologist's report!

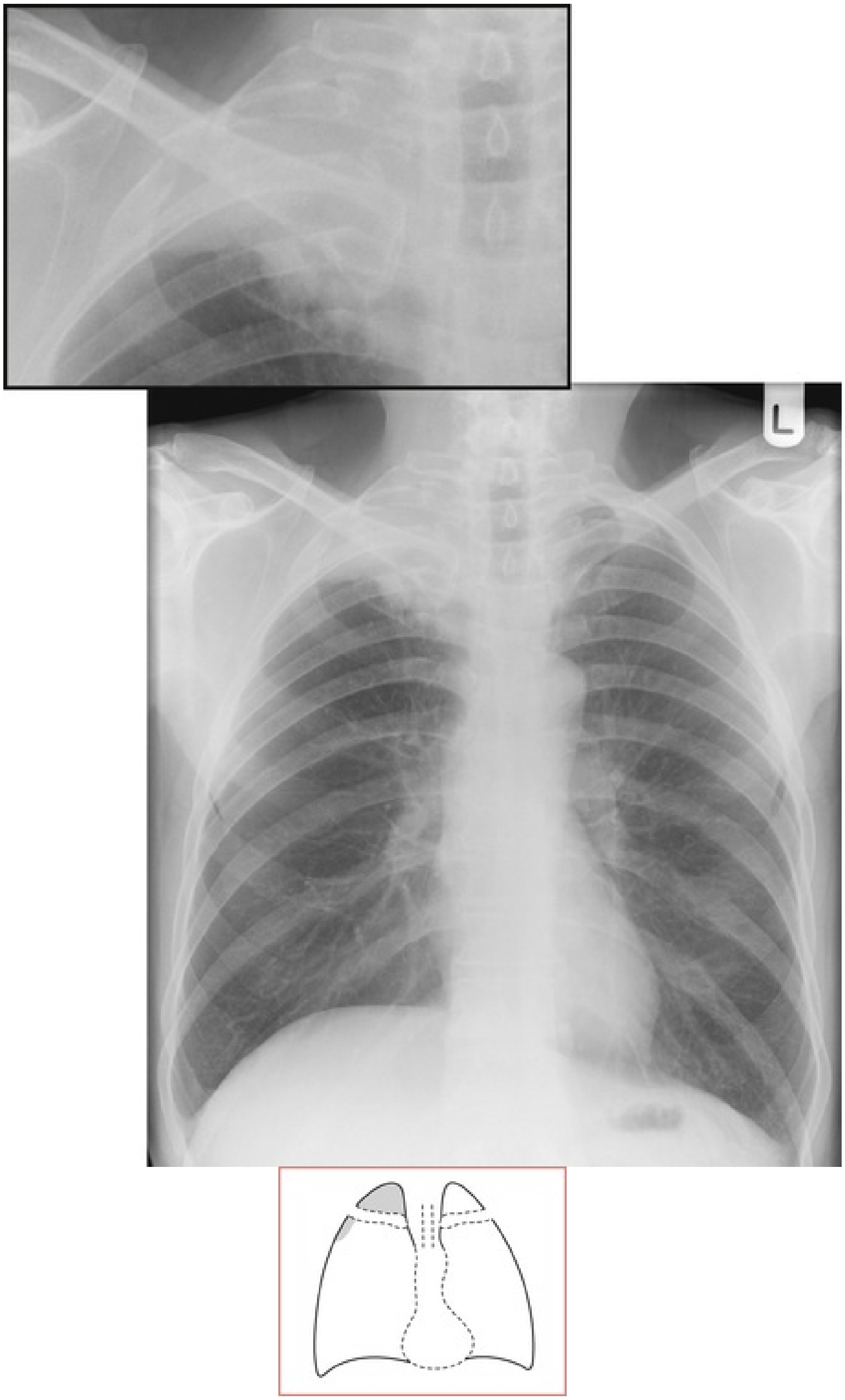



**FIGURE 12.1** At first glance it may be hard to spot that there is an abnormality on this film. Note, however, the increased whiteness at the right apex. On the magnified image you should also be able to see that the right second rib has fractured – a pathological fracture. This appearance is of a Pancoast's tumour with invasion into the chest wall.

Spotting the abnormality in an apparently normal chest x-ray (CXR) is a common question in postgraduate exams. If confronted with such an x-ray, then consider the information given in Box 12.1.

**Box 12.1**

### Exams and the normal x-ray

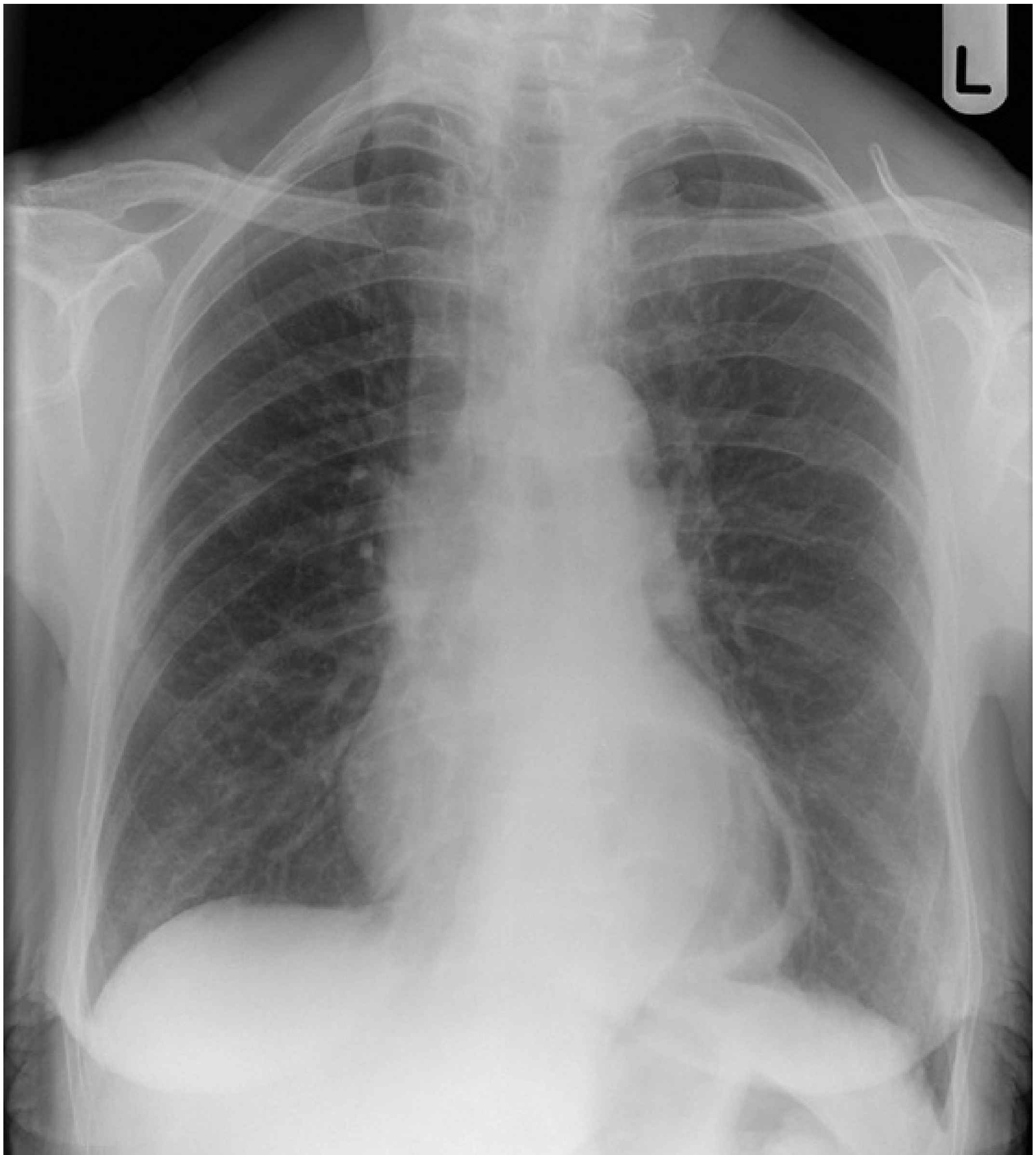
What you should be considering when reviewing an x-ray:

- Apical shadowing
- Left lower lobe collapse
- Hiatus hernia (fluid level behind the heart)
- Dextrocardia (with the x-ray shown the wrong way around)
- Mastectomy
- Air under the diaphragm
- Small pneumothorax

## Hiatus Hernia

When scanning an apparently normal x-ray it is important to look behind the heart (Fig. 12.2). The heart is usually a fairly uniform white colour and areas of increased whiteness can indicate possible pathology. Therefore if you see an area of increased whiteness behind the heart look for the following:

1. Decide whether it has any of the characteristics of the white lung field described previously. For example, can you see an air bronchogram which would suggest consolidation or the tramline or ring-like shadows which would suggest bronchiectasis?
2. Look carefully at the shadowing to see whether it has the appearance of left lower lobe collapse. This is described on page 43 and has the appearance of a dense white triangle behind the heart. It is easy to miss so you should look carefully for this.
3. Look to see whether the appearance is consistent with a hiatus hernia. Look for the outline of the stomach, which may appear as a rounded white line either behind the heart or next to the left heart border. Look for the flat line of a fluid level that you occasionally see and is caused by fluid within the stomach.



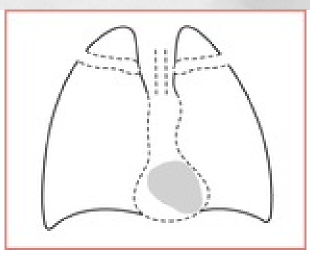
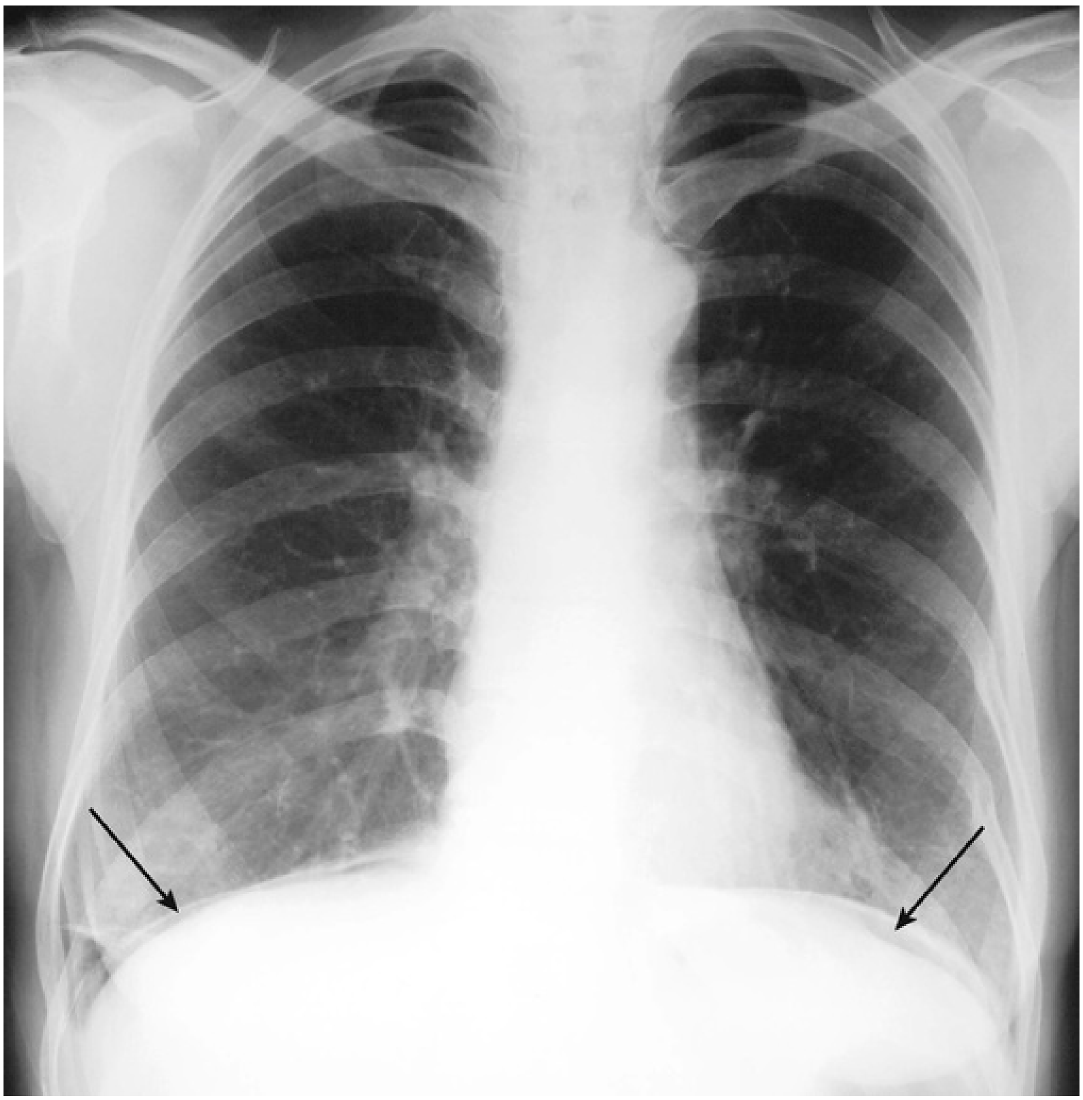



**FIGURE 12.2** This is the film of a 67-year-old patient who complained of a chronic cough. You can see a curved white line lying behind the heart. This is a hiatus hernia. When questioned, the patient complained of mild heartburn with no other symptoms.

## Air under the Diaphragm

Finish your examination of the CXR by looking at the area under the diaphragm (Fig. 12.3). The area immediately under the diaphragm will usually be white since the upper part of the abdomen contains the dense structures of the liver and spleen. Because of this you can usually only make out the upper surface of the diaphragm. You may see a darker round area under the left hemidiaphragm. This is the air bubble within the stomach.



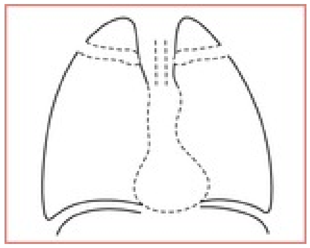


**FIGURE 12.3** An x-ray of a 72-year-old man who presented to casualty acutely unwell with abdominal and chest pain. Examination revealed a silent abdomen. Note the areas of blackness immediately under the hemidiaphragms **(arrowed)**. This represents air collecting under the diaphragm and confirms the clinical suspicion of abdominal perforation. Subsequent history-taking revealed that he had a 2-year history of recurrent upper abdominal pain and on surgery a perforated gastric ulcer was found.

One of the main reasons for looking under the diaphragm is to detect the presence of free air. This is an important sign since it indicates intra-abdominal perforation. Other intra-abdominal pathologies you might see include areas of calcification (small areas of increased whiteness) under the right diaphragm corresponding to gallstones, and dilated loops of bowel under the left diaphragm.

The CXR is a very sensitive investigation for the detection of free abdominal air since it can detect as little as 10 mL. It appears as a rim of blackness immediately under the diaphragm and you will recognise this since it may enable you to see both the upper and lower surface of the diaphragm.

It is sometimes difficult to differentiate air under the diaphragm from the normal stomach bubble. If in doubt then look at the following:

1. Look at the thickness of the diaphragm: that is, the line between the blacker area below and the lungs above. If there is free air immediately below the diaphragm, then the white line between the air and the chest will appear very thin since it will consist of the diaphragm only. If the air is in the stomach, then the white line created will consist of both stomach lining and diaphragm and appear thicker. In general, if the line is less than 5 mm, then free air is probably present.
2. Look at the length of the air bubble: that is, the distance from its medial to lateral aspect. If it is longer than half the length of the hemidiaphragm, it is likely to be free air, since air within the stomach is restricted by the anatomy of the stomach.
3. Look at both hemidiaphragms. If air is present below the right and left hemidiaphragms, it is likely to be free air in the abdomen.
4. If you are still in doubt, order a decubitus film. This is taken with the patient

lying on their left side. Free air will rise away from the diaphragm and come to lie lateral to the liver in the uppermost aspect of the abdomen whereas air within the stomach will remain in the same position. Remember that it takes over 10 minutes for these changes to occur so the patient needs to be on their side for 10 minutes before the x-ray is taken.

13

# The chest x-ray quiz



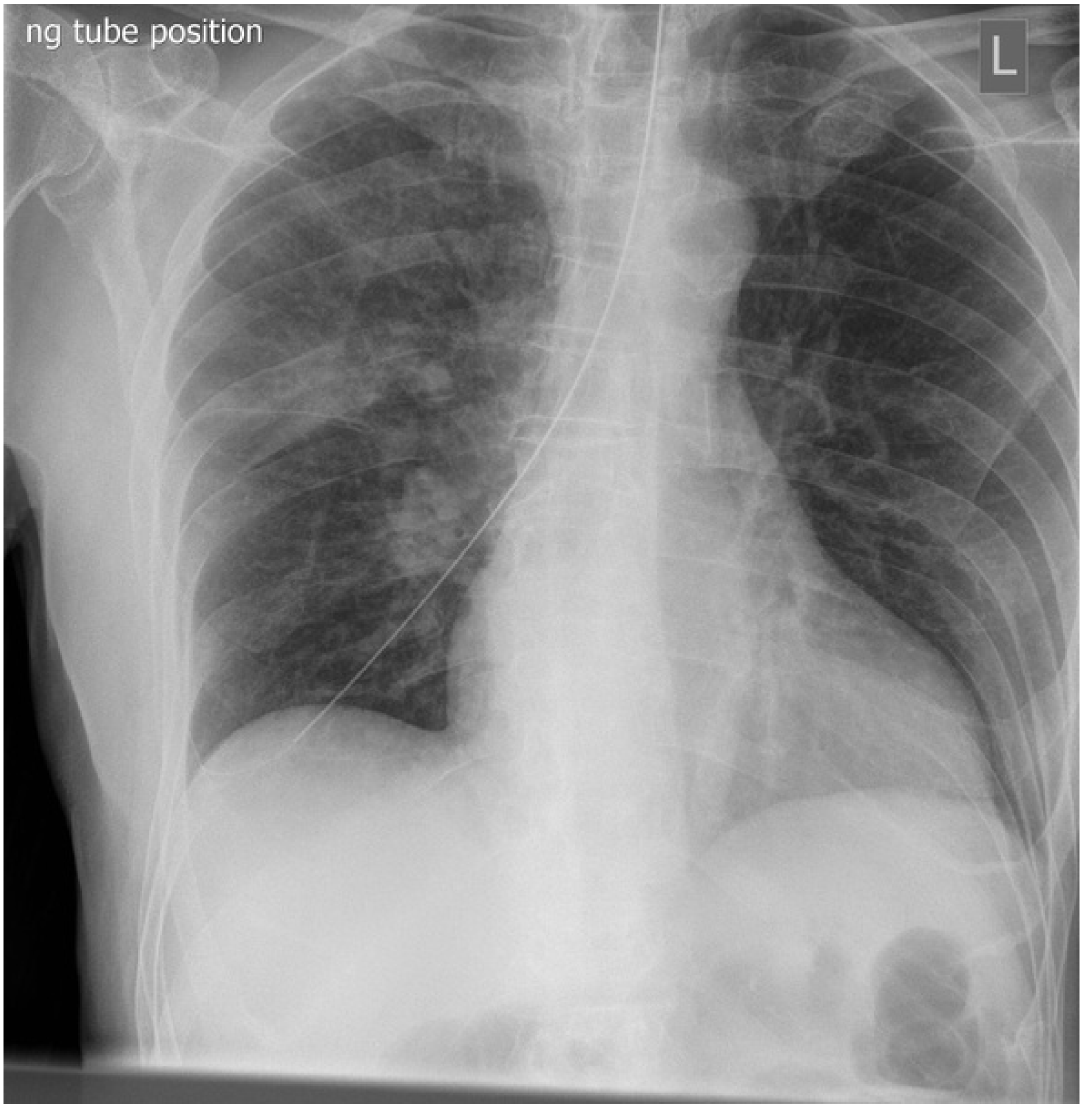
So far in this book we have chosen x-rays that clearly illustrate abnormalities. However, real life is not so simple and, whereas the abnormality may sometimes be obvious, on many x-rays it is not so straightforward. On the wards and in out-patient clinics you will see x-rays where there is more than one pathology and x-rays where the technical quality may make interpretation of the x-ray difficult.

Have a go at interpreting the following 10 chest x-rays. Some are simple but others are more complicated. They reflect the type of x-ray you will see in the real clinical situation. However difficult they are, the grounding you have gained by reading this book should be a good start.

Good luck.

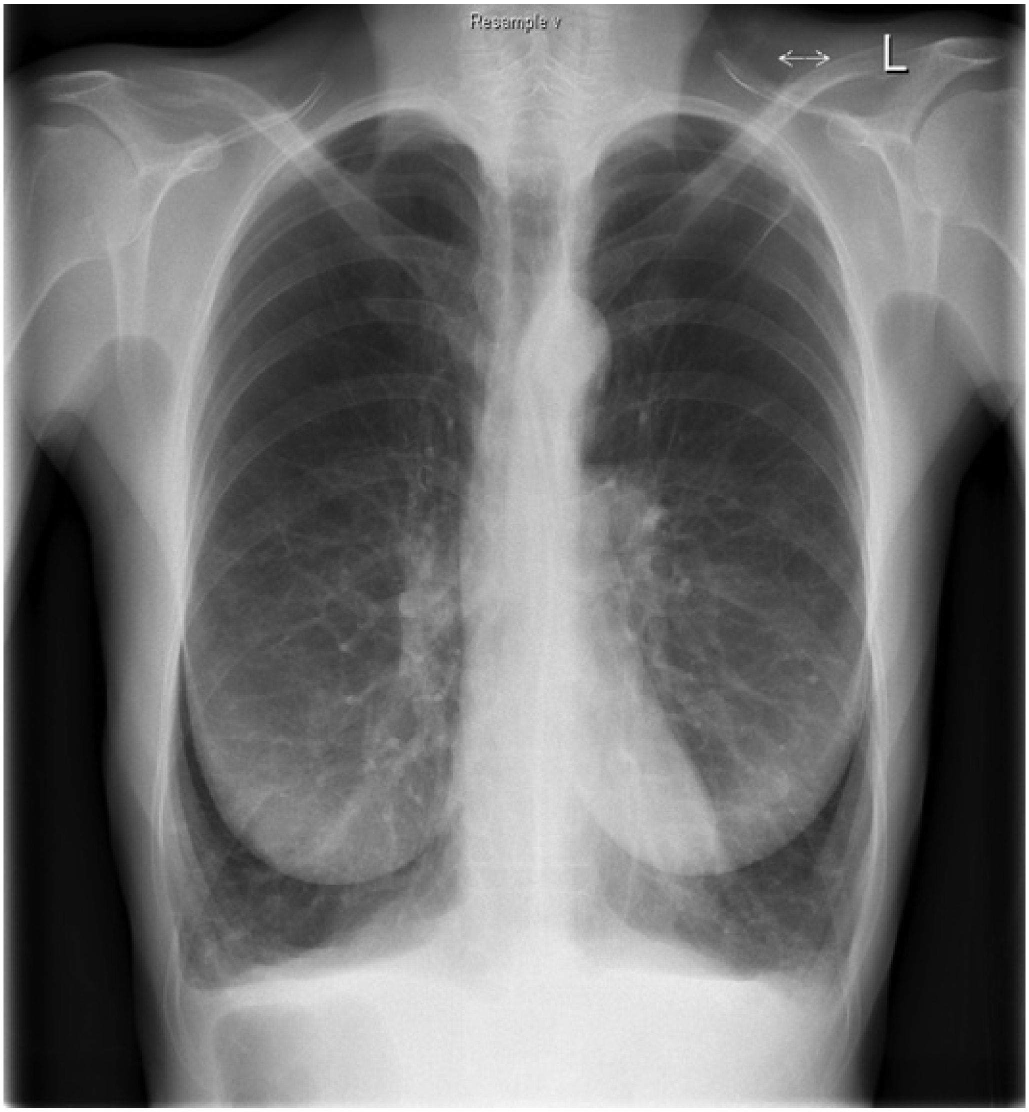
## Questions

### Question 1



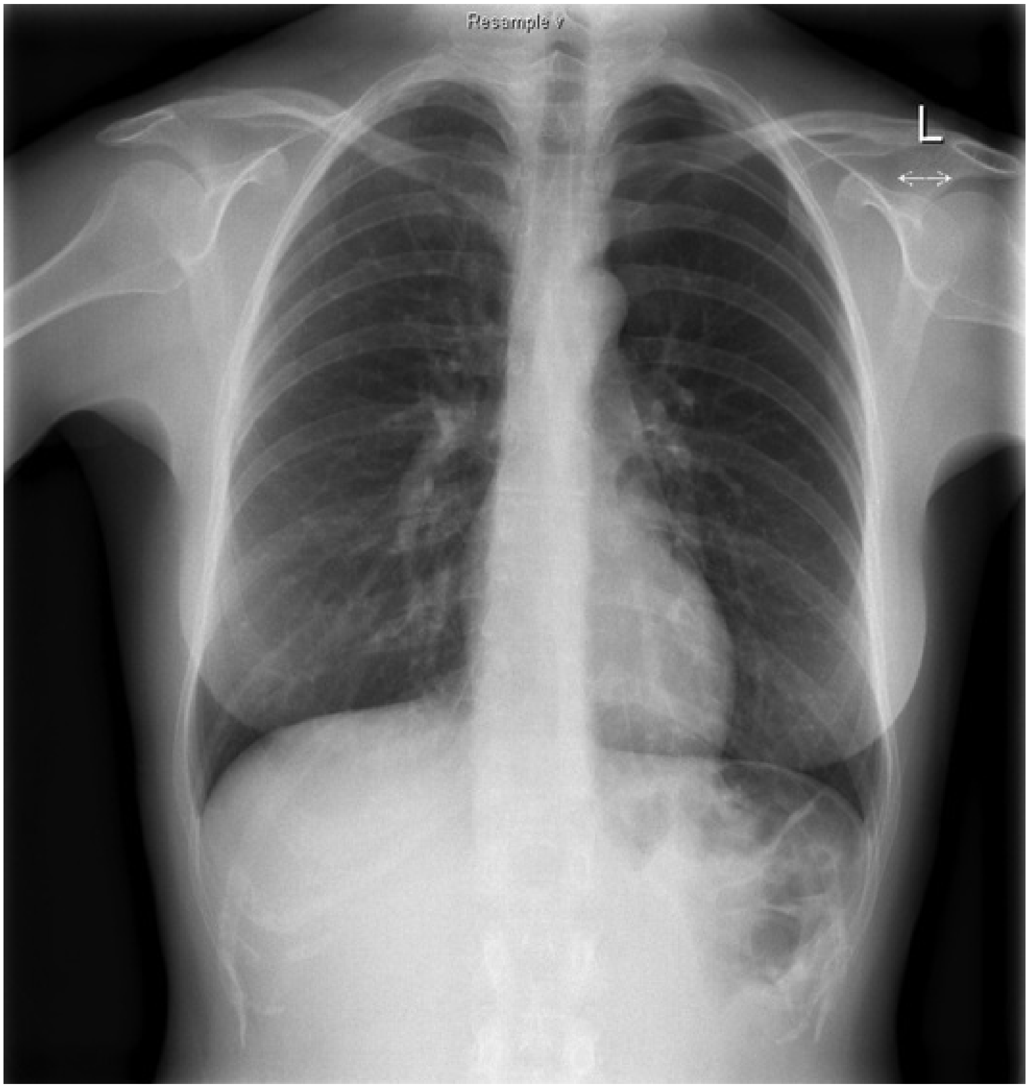

This 58-year-old male is currently an in-patient on your ward recovering from a stroke. He has been nil by mouth for three days since there is concern about his swallow. A nasogastric (NG) tube has been inserted. Is it safe to use?

## Question 2



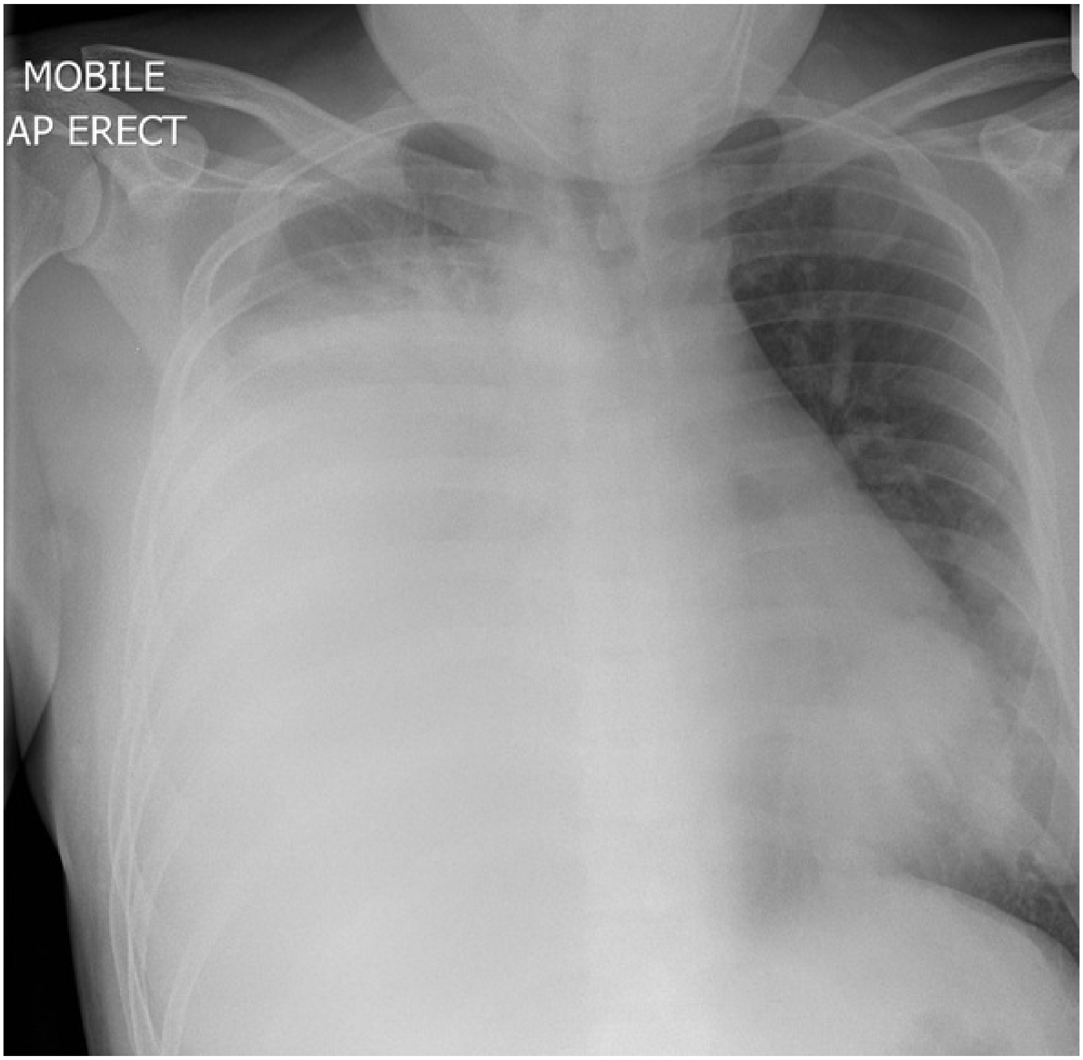

This 73-year-old female was admitted with a three-day history of a cough productive of thick green sputum and a deterioration of her breathing. What is the diagnosis?

## Question 3



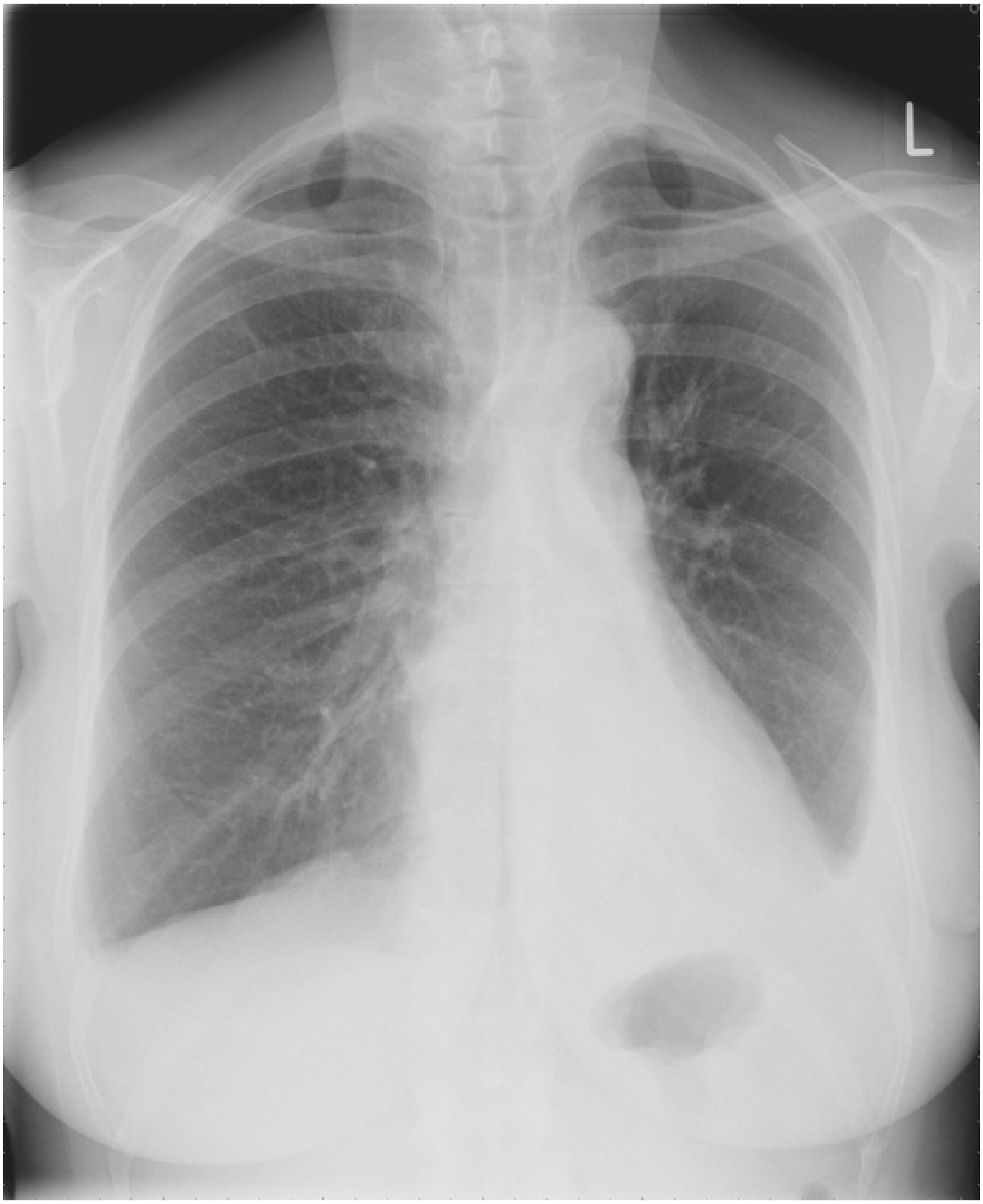

This 28-year-old male presented to the emergency department with a 1-day history of pleuritic chest pain. He was a smoker of 15 cigarettes per day and had a strong family history of heart disease. What is the cause of his pleuritic chest pain?

## Question 4



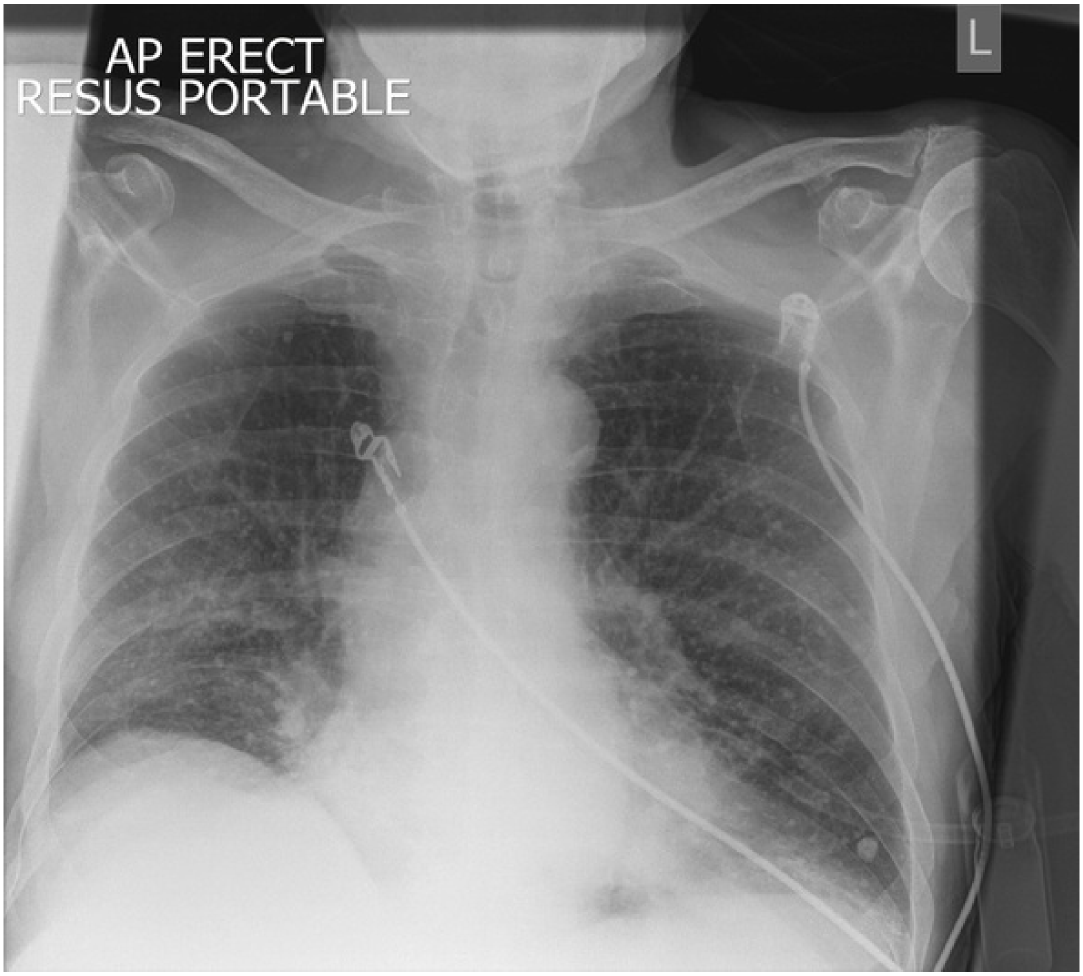

This 22-year-old male was admitted as an emergency, very short of breath and requiring 35% oxygen. This was the x-ray taken in the emergency department. Describe what you see on the chest x-ray. Why is the patient short of breath?

## Question 5




This is the x-ray of a 45-year-old teacher who presented to her GP following four episodes of haemoptysis. Are there any abnormalities on the CXR?

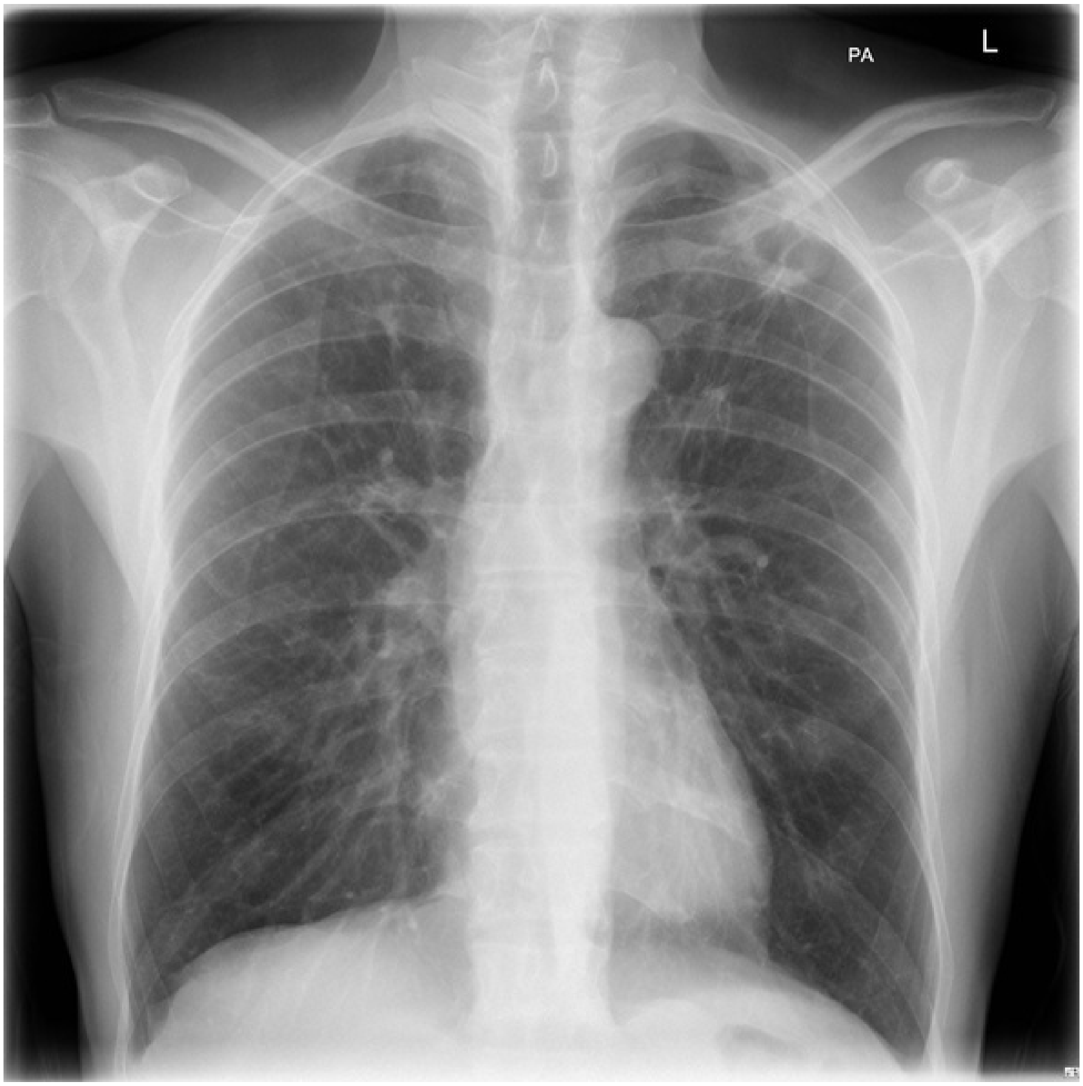
## Question 6




This is the CXR of a 60-year-old bus driver who presented with cough productive of green sputum and fever.

What abnormalities can you see on this x-ray?

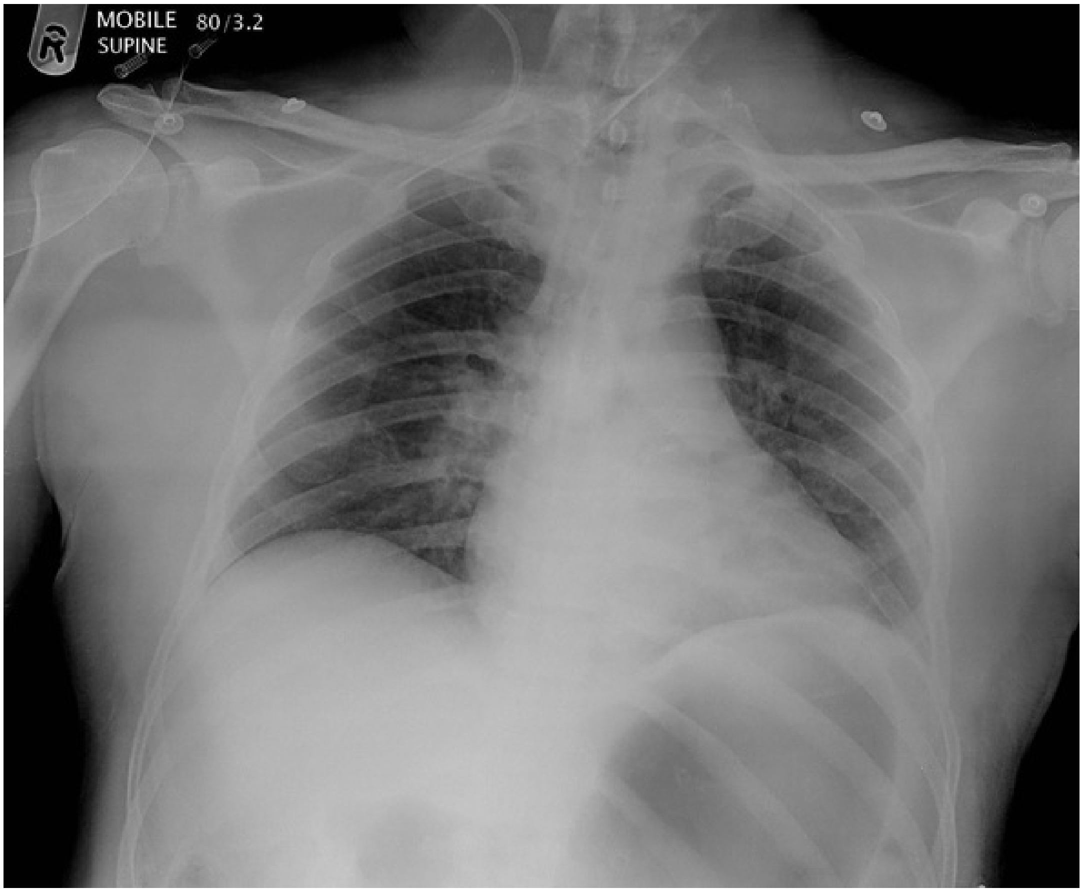
## Question 7




This is the CXR of a 71-year-old retired teacher who presented to his doctor with a 6-month history of gradually increasing shortness of breath.

What abnormalities do you see and why is the patient breathless?

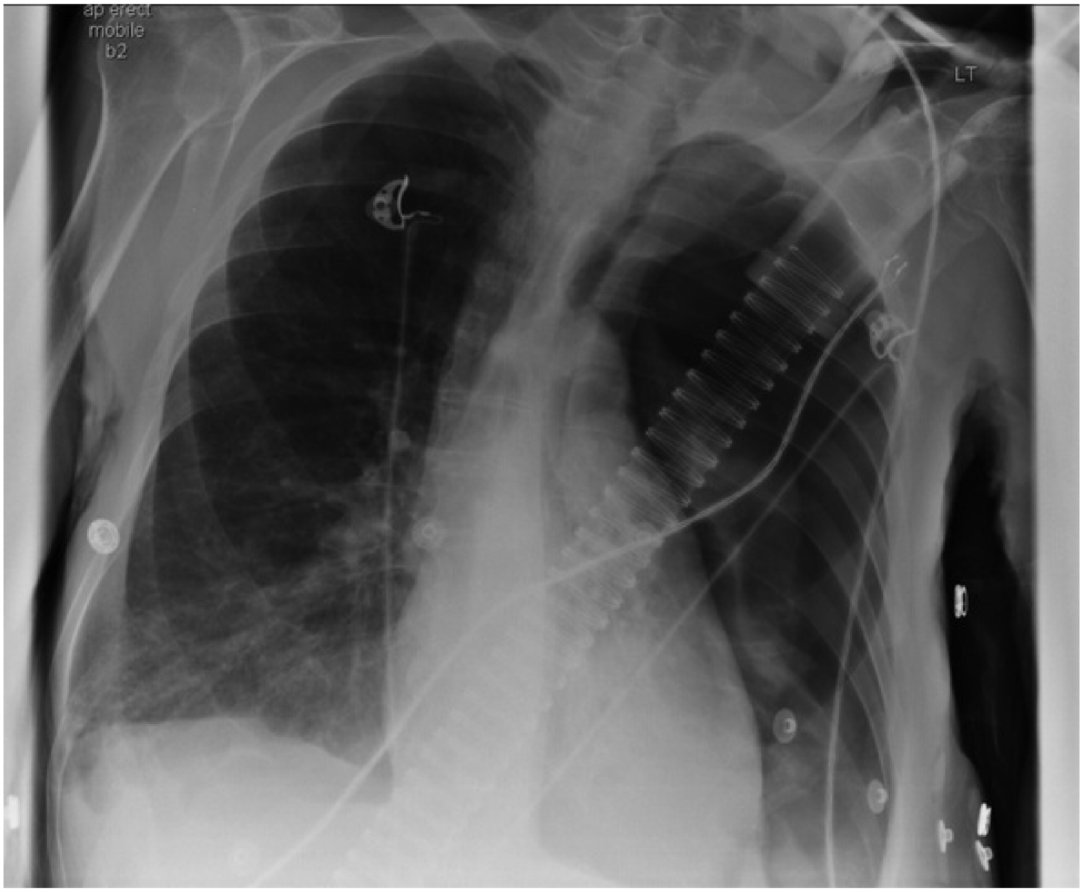
## Question 8




This is the CXR of a 68-year-old retired postman. He presented with abdominal pain and was found to be in acute renal failure. He failed to make recovery with aggressive intravenous fluid and was transferred to the intensive care unit (ICU). On arrival on the ICU, a central line was inserted.

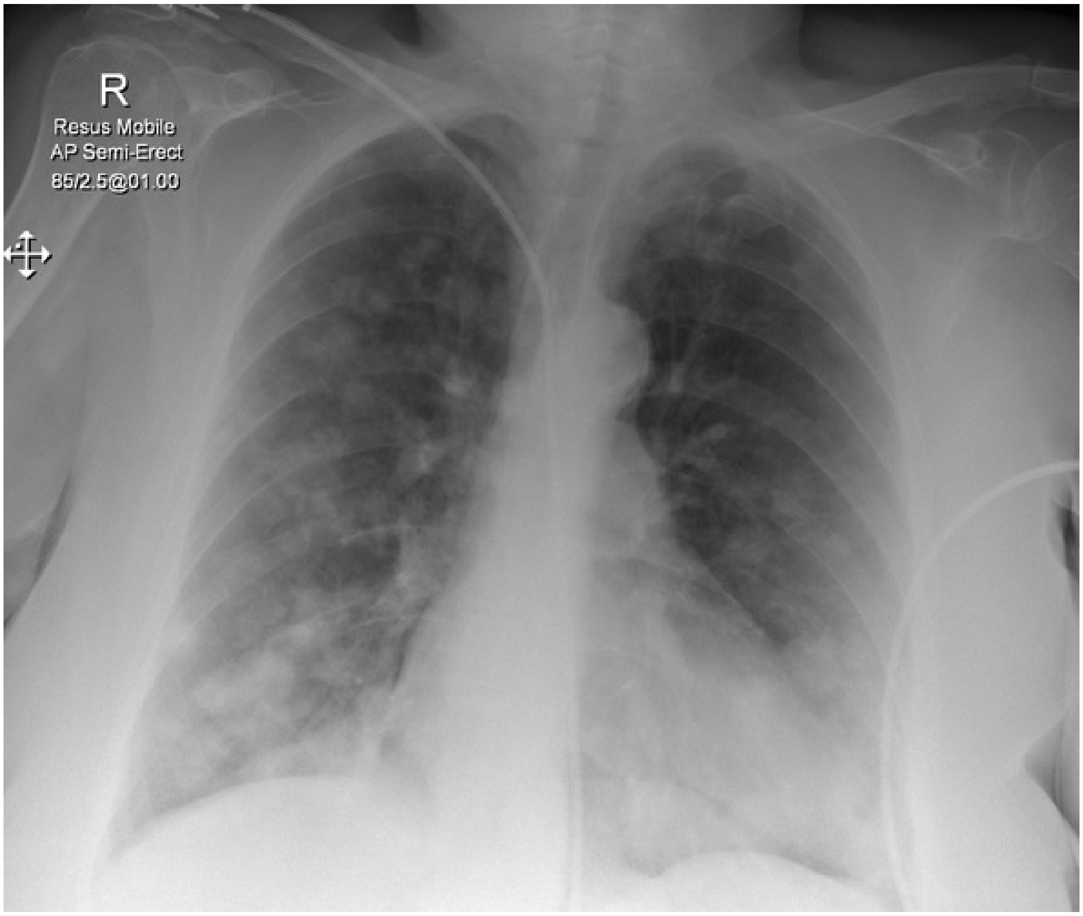
Comment of the position of the line. Is there any other abnormality on the CXR?

## Question 9




This 78-year-old male was admitted to the high dependency unit with an infective exacerbation of COPD and was found to be in type 2 respiratory failure with a respiratory acidosis. Despite noninvasive ventilation (NIV), his condition worsened and he developed increasing breathlessness. What is the cause of his deterioration?

## Question 10




This is the x-ray of a 59-year-old librarian with a history of breast cancer. She was admitted to hospital with a fever.

What abnormality can you see on this x-ray and what is the most likely cause?

# Answers

## Answer 1

This is definitely not safe to use. The tube does not follow the course of the oesophagus but instead points to the patient's right. It is in fact passing down the right main bronchus and ending up in the right lower lobe.

At first sight the end of the tube may appear to be below the diaphragm. However, this is not the case. Remember the CXR is a two-dimensional image and the diaphragm is a humped structure. In this case the tube is lying above the diaphragm either anteriorly or posteriorly. The hump of the diaphragm will be situated either in front or behind the tube and gives the appearance of the diaphragm being above the level of the tube's tip.

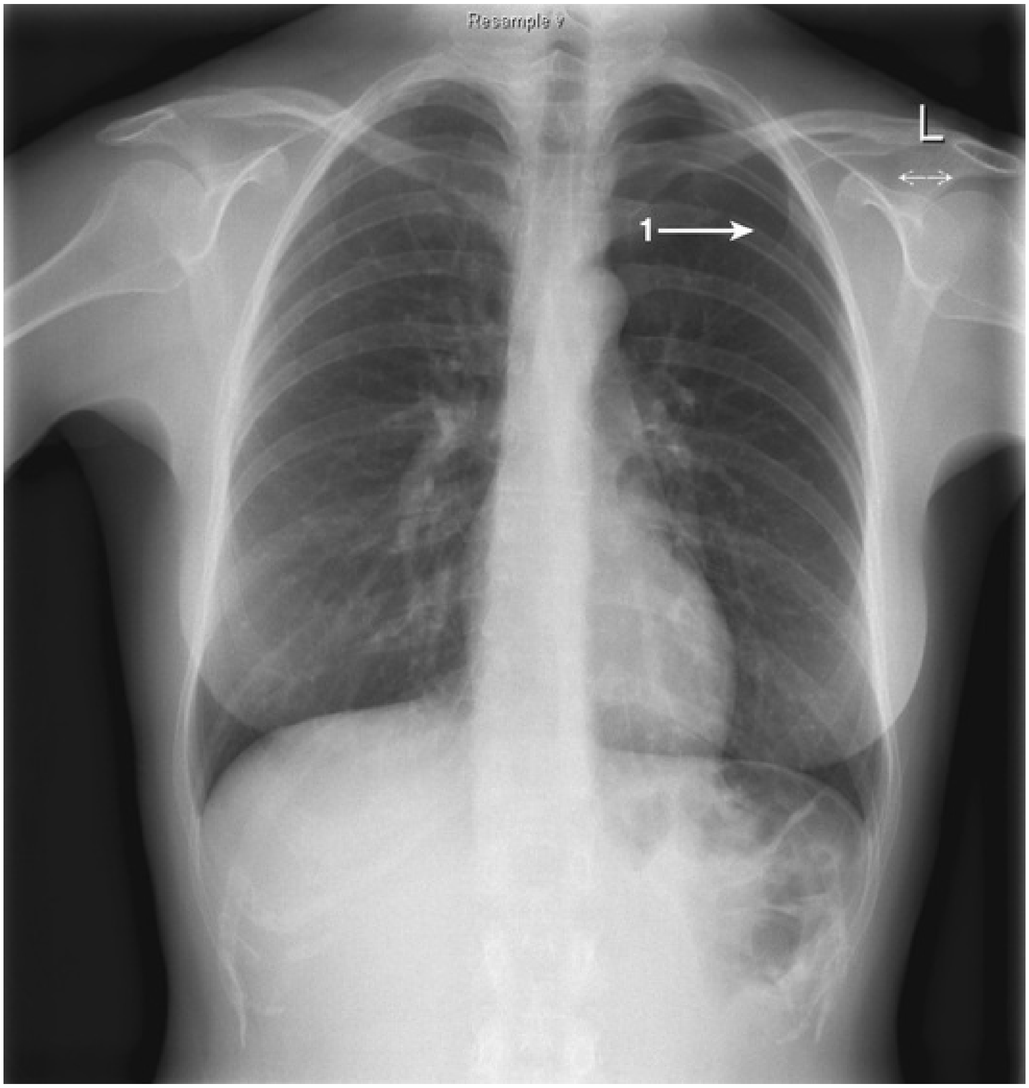
Remember when checking an NG tube to check both the course of the tube, ensuring that it follows the course of the oesophagus, and the position of the tip (which would usually be on the patient's left, pointing towards or in the stomach).

Very rarely these may be reversed in *situs inversus*.

## Answer 2

The patient has an infective exacerbation of chronic obstructive pulmonary disease (COPD). She has hyperexpanded lung fields with flat diaphragms and the lack of soft tissue shows that she is thin. The lungs are whiter at the bases because the apical hyperexpansion squashes the lower zones, pushing the blood vessels closer together and due to overlying breast tissues. There are, however, no signs of consolidation, so she has infective bronchitis rather than pneumonia.

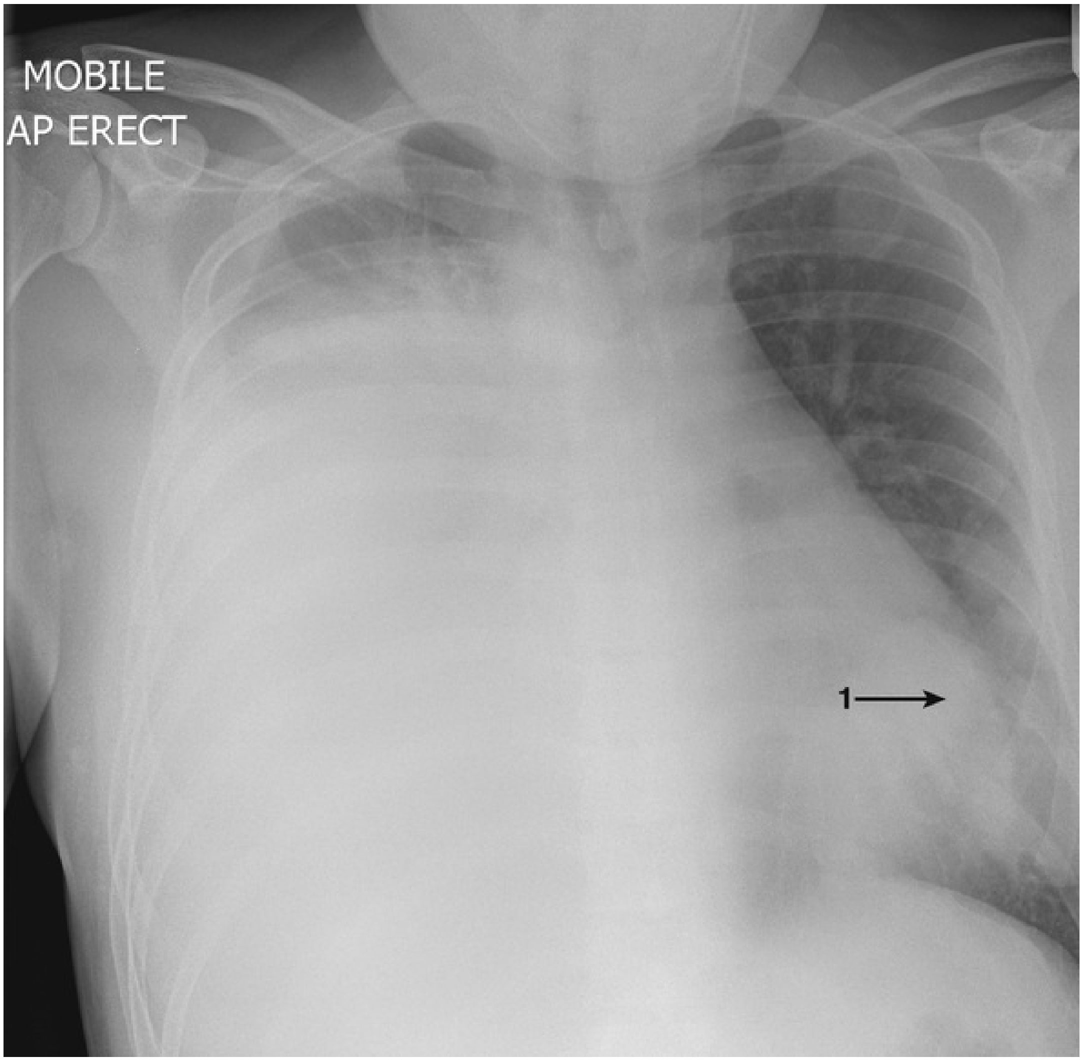
## Answer 3




The chest x-ray shows a small left apical pneumothorax. This is difficult to spot but if you look carefully you will see that the lung field at the left apex appears darker than that on the right. This could be due to increased shadowing on the right or lack of lung markings on the left. If you look very closely you can just about see the lung edge on the left side **(1)**. This confirms that the left apex is darker because of lack of lung markings beyond the lung edge and presence of air in the pleural space.

A small pneumothorax can be difficult to spot. If the clinical history is suggestive, look carefully at the image, especially at the apices. On a digital system the lung edge can be made more obvious by inverting or adjusting the contrast.

# Answer 4

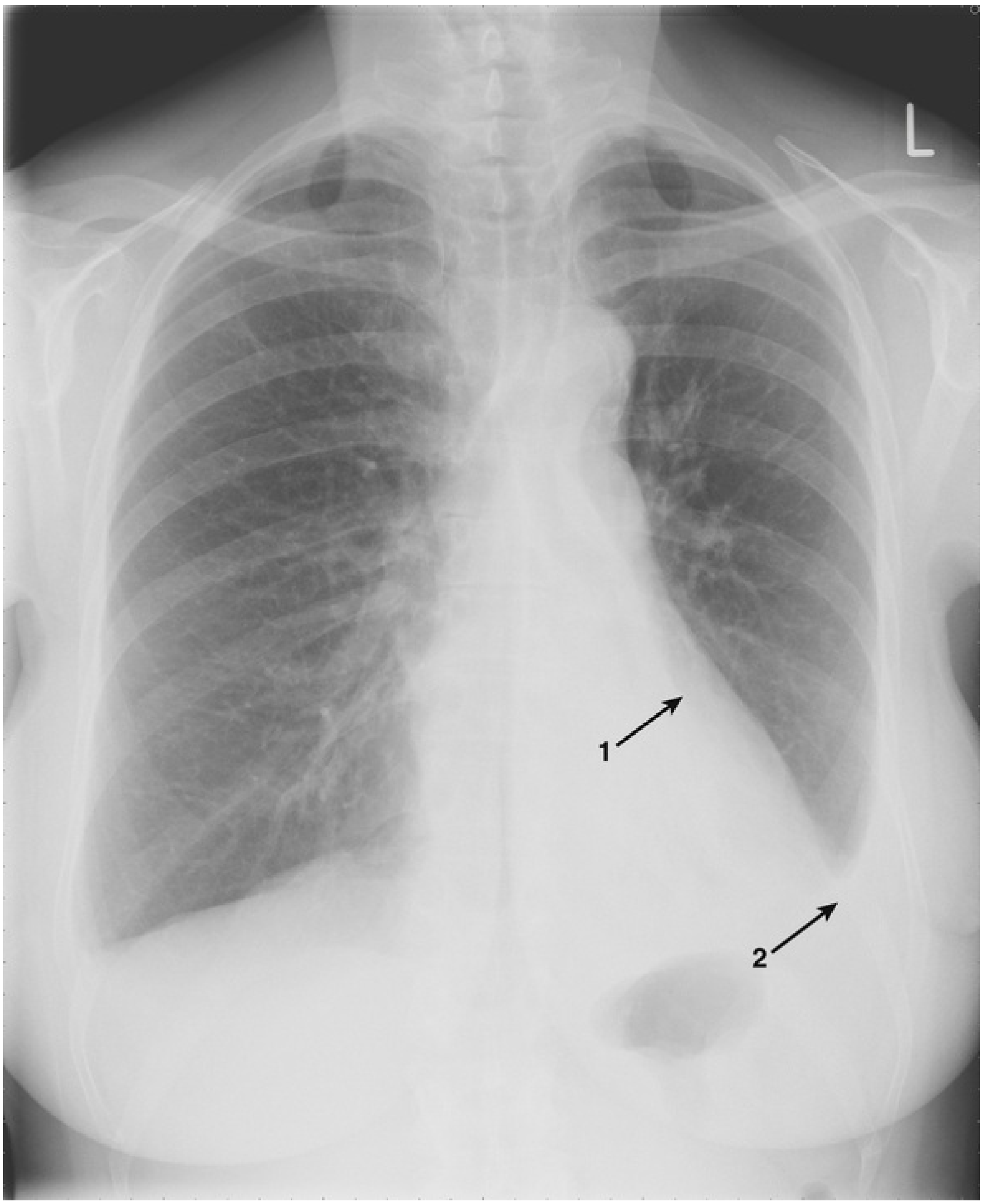



The patient is short of breath because he has a right pleural effusion. You can see that right lung field is almost completely white and the trachea and carina have been pushed to the left. There is no air bronchogram. Although there is no obvious meniscus, the combination of the dense whiteness with no air bronchogram, and the displacement of the trachea and carina to the left (pushed across by the build-up of pleural fluid), are very suggestive of a pleural effusion.

Careful examination of the x-ray will reveal another abnormality. On the left lung, behind the heart, you can see an area of increased whiteness **(1)**. You can see that it has a definite edge and a slightly rounded appearance, and appears separate to the diaphragm. This is a metastatic lung deposit.

Unfortunately, this patient had a germ-cell carcinoma with pulmonary metastases. The x-ray shows the importance of scanning the image thoroughly and not stopping when you find the most obvious abnormality.

## Answer 5

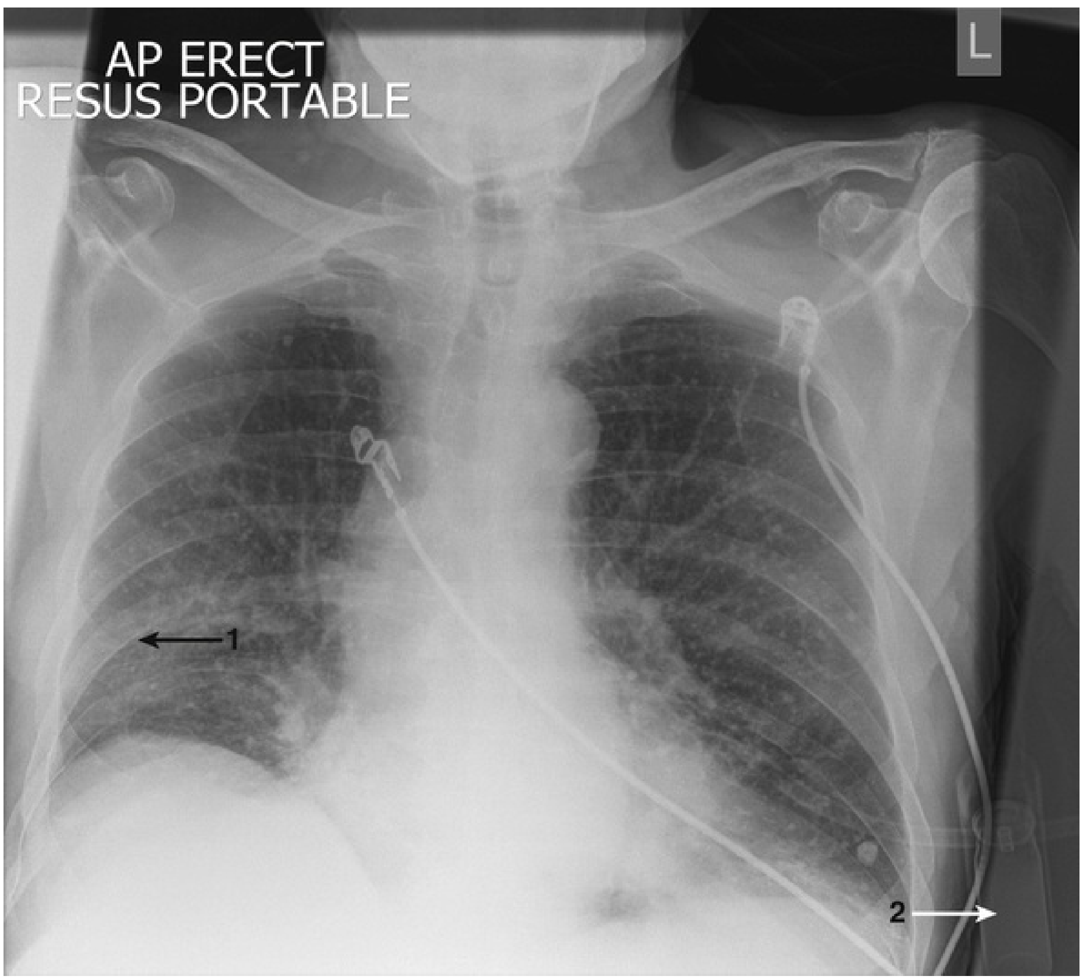


This CXR shows left lower lobe collapse.

Left lower lobe collapse can give rise to subtle changes that can easily be missed. In this x-ray, notice that the left lung field appears smaller than normal and you can no longer clearly see the diaphragm. Look carefully behind the heart where you can see the line of a collapsed left lung **(1)**, the so-called 'sail sign'. There is also a small left pleural effusion with a meniscus **(2)**.

This is an important sign to pick up since left lower lobe bronchial obstruction can be due to tumour. In this case, a CT scan and bronchoscopy showed no tumour and the changes were due to infection with thick mucus occluding the airway.

## Answer 6



The x-ray shows a patchy area of consolidation in the right lower zone on a background of old varicella zoster pneumonitis.

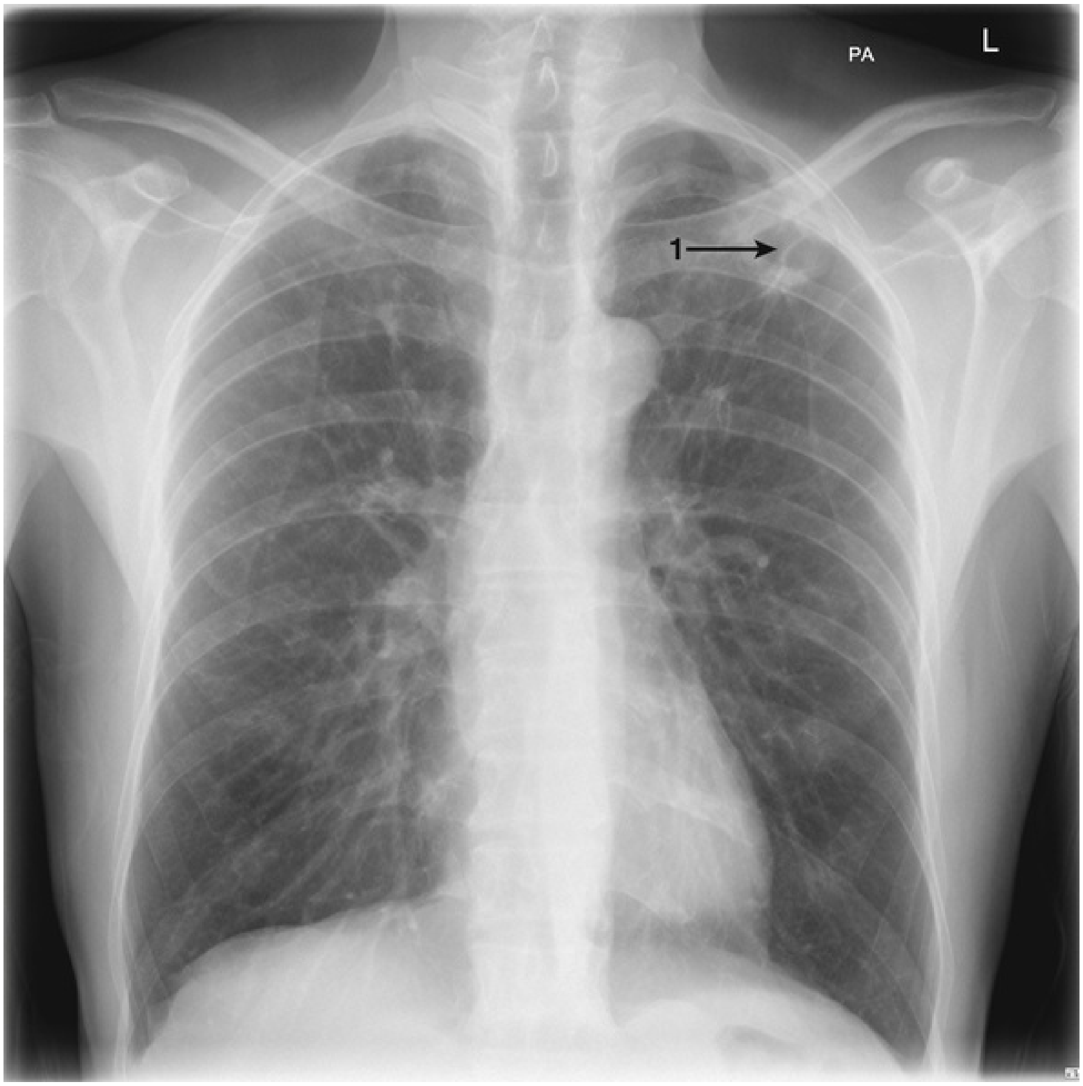
The x-ray is obviously abnormal, with the lung fields appearing much whiter that they should. Looking closely at the lung fields, you can see numerous small discrete nodules. These appear white because of calcification and they are all about the same size and less than 3 mm in diameter. These nodules are from old varicella zoster pneumonitis. These nodules are an incidental finding and would not be causing the patient any symptoms.

If you now take an overview of the lungs, you can see a subtle increase in shadowing the right lower zone **(1)**. This is an area of patchy consolidation. A subsequent CT scan confirmed this to be an area of consolidation.

This patient had pneumonia and responded well to treatment.

Notice the inhaler on the patient's left side **(2)**, probably situated in his pyjama pocket. The patient was known to have asthma.

## Answer 7




The most worrying abnormality is a cavitating lesion in the left apex **(1)**.

The lungs are hyperexpanded and the patient is breathless because he has COPD.

Initially the most obvious abnormality is the hyperexpanded lung fields. You can count up to 10 posterior ribs and the heart is long and elongated and appears to ‘swing in the wind’. When you scan the lung fields, look carefully at all zones of the lungs, comparing the left and the right. Be especially careful at the apex where abnormalities can be missed, often because they are hidden by overlying bones.

In this case, there is an increased area of whiteness in the left apex. When you look carefully at this, there is a circular area of white surrounding a dark hole. This is a lung cavity. The concern would be that this is a lung cancer. Fortunately, in this case, the cavity disappeared with antibiotics and turned out to be a lung abscess.

This x-ray shows the importance of scanning the lung fields in detail to look for subtle abnormalities.

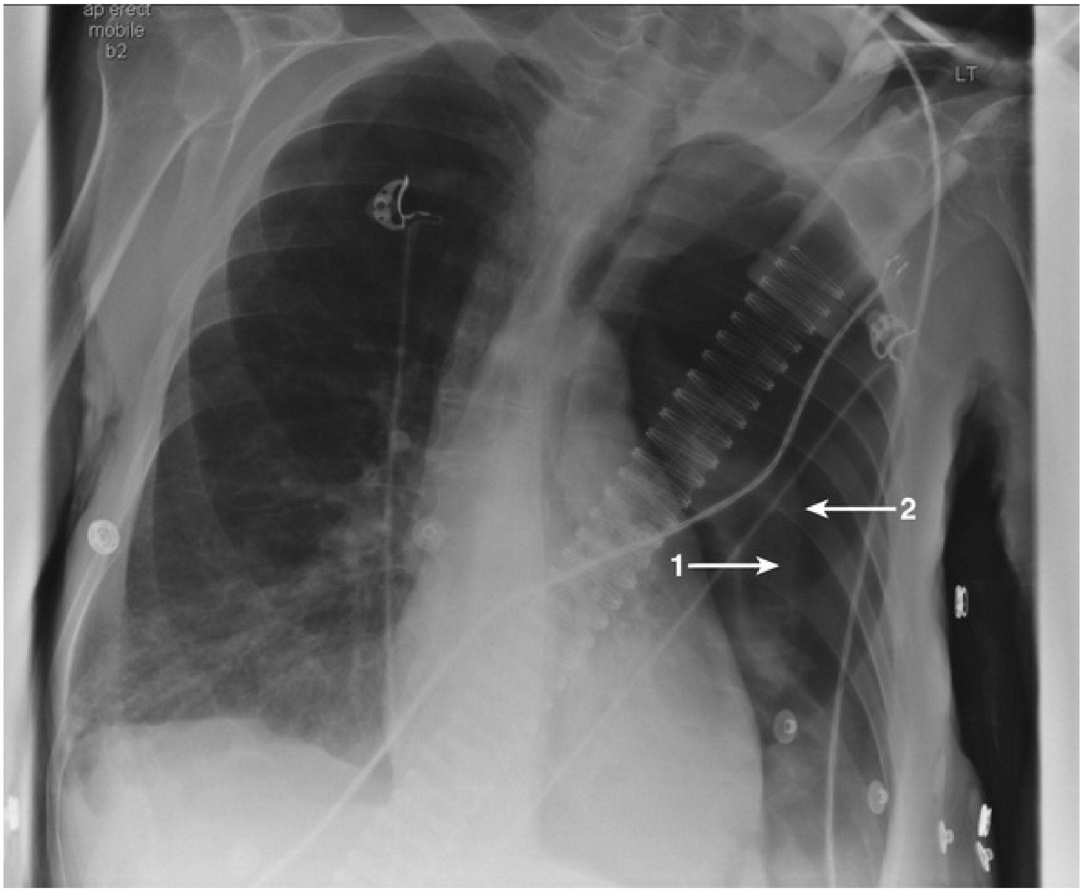
## Answer 8

A right-sided internal jugular line has been inserted, but the tip is positioned in the right subclavian vein. You can see a grossly distended stomach beneath the left hemidiaphragm.

This is a mobile supine image, typical for an x-ray on the ICU. If you look above the right clavicle, you can see the right line, which initially follows the course of the right internal jugular vein. However, instead of following the course of the vein towards the heart, this turns towards the patient's right and in the right subclavian vein. This should be repositioned.

Remember to survey the whole x-ray and not stop when you find the misplaced line. Your survey should include areas outside the chest and, in this case, you can see a large black area underneath the diaphragm: this is a distended stomach.

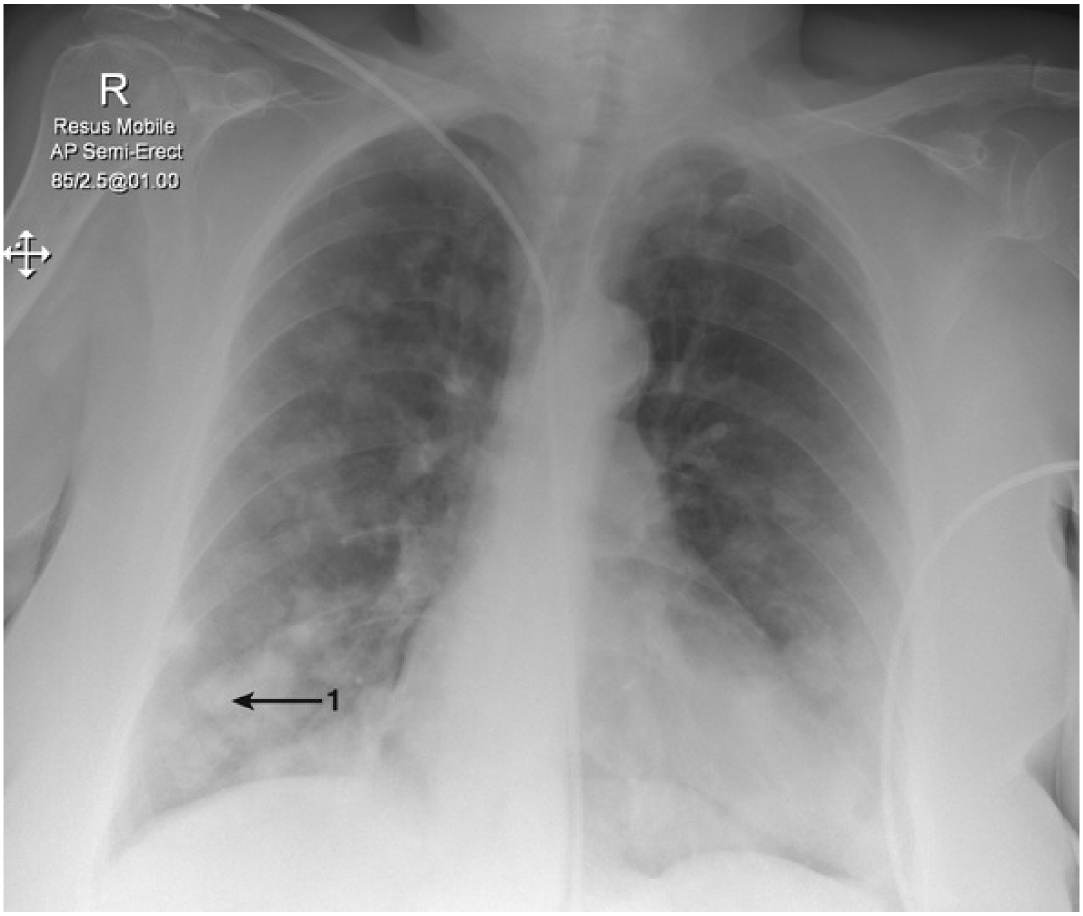
## Answer 9




This is a poor-quality x-ray because the patient is very unwell and you can see the tubing leading to the NIV mask. Do not let this distract you, and look carefully at the lung fields. Both lung fields appear black but the left lung field looks blacker than the white. Careful inspection of the left lung field shows a small whiter area **(1)**. This patient has a pneumothorax, which may have been caused by or worsened by the positive pressure ventilation. The small white area is the compressed lung, with the lung edge visible on careful inspection **(2)**. The rest of the left hemithorax is devoid of lung markings because the lung has been compressed by the pneumothorax.

The right lung field also looks blacker than normal but you cannot see a lung edge. This lung is black because the patient has emphysema and has destruction of lung tissue with a reduction in soft tissue markings.

## Answer 10




This x-ray shows multiple lung metastases.

The patient is obviously unwell since the x-ray has been taken in the resuscitation room and is an anterior-posterior (AP) and semi-erect image.

The most obvious abnormality is white shadows in both lungs. When you look at these closely, there are multiple areas of discrete shadows, rounded or oval in appearance with distinct borders **(1)**. The most likely explanation is that these are secondaries from her previously known breast cancer. Unfortunately this was confirmed following a lung biopsy.

The patient's fever turned out to be secondary to a urinary tract infection.

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Note: Page numbers in italic denote material in question and answer section.

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