Thoracic imaging

THE CHEST RADIOGRAPH

The chest radiograph (X-ray) is the cornerstone of thoracic imaging and should be considered an integral part of the respiratory examination. The chest radiograph is the most frequently requested radiological investigation worldwide.

To optimize the information obtained from a chest radiograph the patient should be standing erect with the anterior chest wall against the film cassette. The arms are abducted to rotate the scapulae away from the chest. The film is taken at maximal inspiration. The X-ray beam traverses the chest from back to front and is thus called the posteroanterior (PA) chest radiograph. If the patient is too ill to stand for a PA chest radiograph an anterior/posterior (AP) radiograph can be taken with the film cassette positioned behind the patient's back. In certain circumstances, where a third dimension is required to elucidate an abnormality on a PA radiograph, a lateral film can be obtained.

THE EVALUATION OF A CHEST RADIOGRAPH

The order in which a chest radiograph is scrutinized is unimportant. It is important, however, to have a fail-safe system that systematically examines all areas thoroughly. If there is a gross abnormality on a chest radiograph it is still important to carry out a thorough inspection to avoid missing other more subtle abnormalities. It is useful to know whether the patient has any old radiographs for comparison.

To aid interpretation it is important to note the age and racial origin of the patient when studying a chest radiograph. Hansell suggests the following order in which to scrutinize the film:

- Position of trachea.
- Mediastinal contour.
- Hilar shadows (position, outline, and density).
- Lungs (size, transradiancy, and collapse).
- Diaphragm (position and clarity).
- Ribs and soft tissues.

NORMAL ANATOMY ON A PLAIN RADIOGRAPH

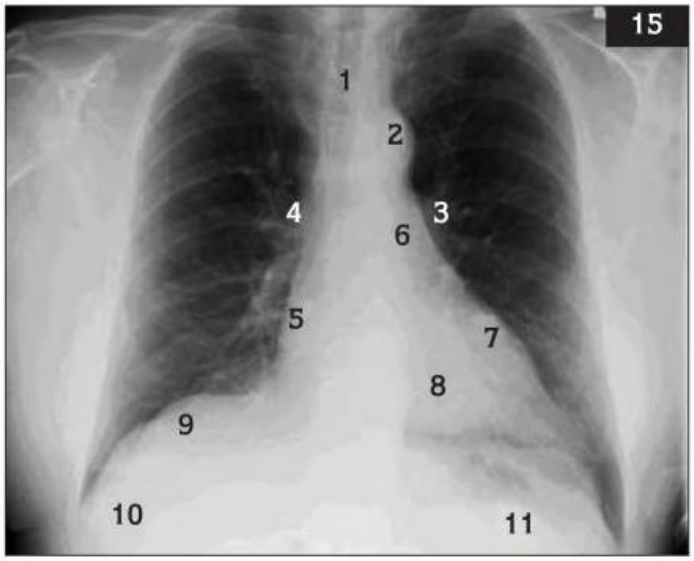
Figure 15 shows a normal PA radiograph with labelling of the important structures. The mediastinal structures are superimposed on each other and are seen together as a unit. Further definition of the mediastinum can be seen on a CT scan and will be discussed later.

The cardiac silhouette should be clear and well defined. A loss of clarity to either border may suggest the presence of adjacent consolidation or collapse of the surrounding lung.

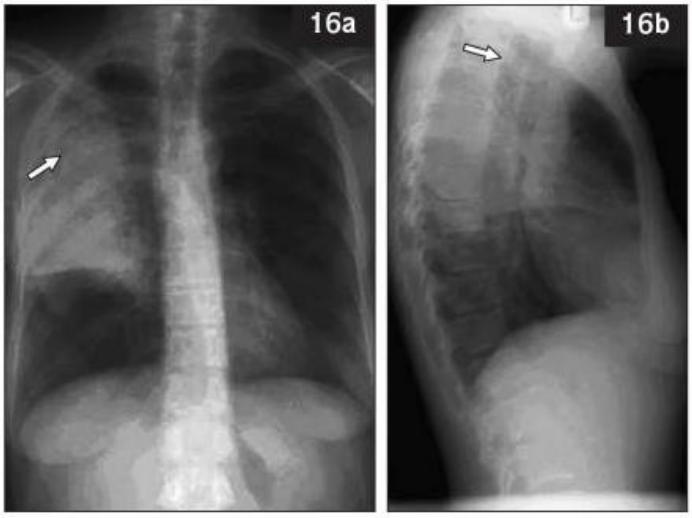
The trachea and main bronchi can be seen. The carina should be sharp. Splaying of the carina may indicate a subcarinal lymph node mass or an enlarged left atrium. The origins of the lobar bronchi can usually be seen through the mediastinal shadow.

The hila are composed of pulmonary arteries and veins. They should be the same size and density but the left hilum should lie between 0.5 and 1.5 cm above the right hilum.

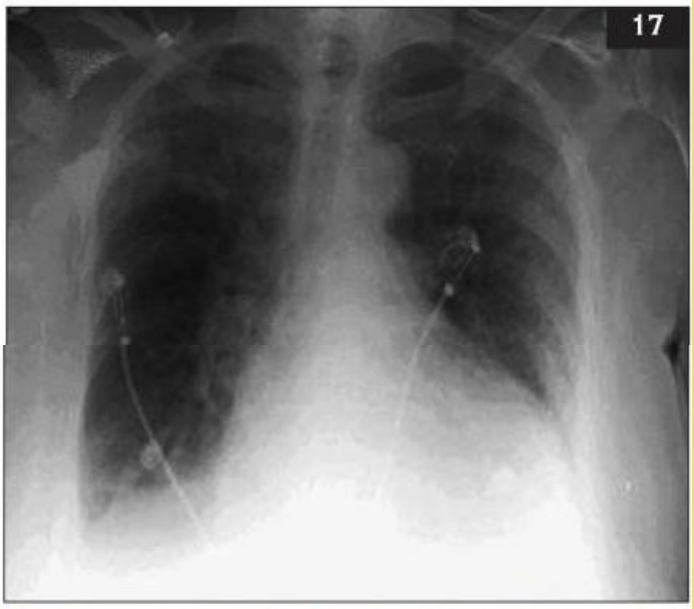
The horizontal and oblique fissures separate the upper, middle, and lower lobes of the right lung. The oblique fissue is visible in 60% of individuals and is a useful landmark to assess for volume loss or collapse. The oblique fissure separates the upper and lower lobes of the left lung.



15 Normal PA chest radiograph. **1**, Trachea; **2**, Aortic arch; **3**, Left main pulmonary artery; **4**, Right main pulmonary artery; **5**, Right atrial border; **6**, Left atrial appendage; **7**, Left ventricular border; **8**, Right ventricle; **9**, Right dome diaphragm; **10**, Costophrenic angle; **11**, Gastric bubble



16 Air bronchograms in right upper lobe pneumonia: (**a**) PA and (**b**) lateral view



17 Pulmonary oedema; large heart, bilateral effusions, and perihilar shadowing

There should be a sharp line between the domes of the diaphragm and aerated lung. The diaphragm falls off sharply laterally to make an acute costophrenic angle. The right diaphragm is usually 2 cm higher than the left because of the presence of the liver below it.

Signs of disease on the chest radiograph

Consolidation

This is where the distal air spaces – normally filled with air – are filled with something else, such as pus, water or blood. The abnormality commonly manifests as an area of increased shadowing that often contains an 'air bronchogram' and does not have a defined margin (**16**).

The causes of an air bronchogram are listed in *Table 7*. Consolidation is most commonly localized with infections such as pneumonia – 'lobar pneumonia'. A more diffuse pattern of air space infiltration is seen with water in the context of pulmonary oedema. Other features seen in pulmonary oedema to strengthen the diagnosis include pleural effusion (often bilateral), fluid in the fissures, and Kerly 'B' lines leading to the pleura (**17**). The cardiothoracic ratio may be increased (normally < 50%). In cases of pulmonary oedema the shadowing can often be seen to start at both hila and increase towards the periphery of the lung, the so-called 'bat's wing' shadowing.

While pulmonary oedema is the commonest cause

Table 7 Causes of an air bronchogram on a plain chest radiograph

- ❑ Consolidation
- ❑ Pulmonary oedema
- ❑ Blood
  - Pulmonary haemorrhage
  - Infarction
- ❑ Compression atelectasis (pleural effusion, pneumothorax)
- ❑ Fibrotic scarring (radiation fibrosis, bronchiectasis)
- ❑ Severe interstitial lung disease
- ❑ Neoplasms (bronchoalveolar cell carcinoma, lymphoma)

If a SPN is detected it is important to look at old radiographs to assess its possible growth. Features such as spiculation (a ragged edge), rapid growth, and cavitation suggest malignancy. Features such as calcification, slow growth, smooth edges, and a draining vein suggest a benign cause. The further investigation and management of the SPN is discussed in Chapter 5. Many of the features used to characterize malignancy in a SPN can also be applied to the assessment of a pulmonary mass, most of which are malignant. Their specific characteristics and management are discussed in Chapter 5.

Cavitation of a mass could indicate a squamous carcinoma. Cavitation is also known to occur in bacterial pneumonias such as those caused by *Staphylococcus* spp. and *Klebsiella* spp. Cavitation occurring in a mass can also rarely be seen with a resolving pulmonary infarct, especially in those occurring in the upper lobes. Long-standing cavities can be colonized by *Aspergillus* to give 'fungal balls' within an area of scarred lung.

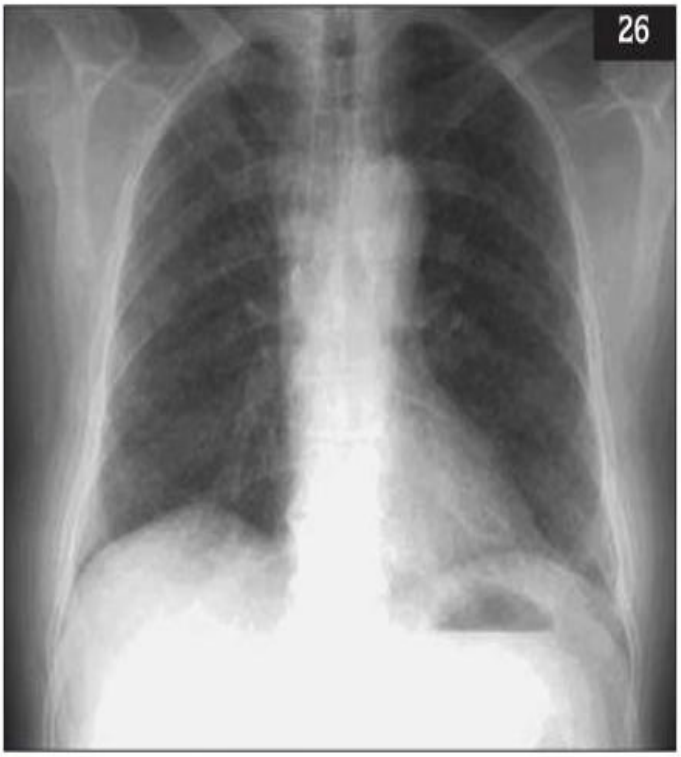
Miliary pulmonary nodules

Miliary pulmonary nodules are usually < 2–5 mm in size. Classically on a chest radiograph these small nodules can be picked out individually with a pin. The commonest cause of miliary shadowing is tuberculosis (**26**). In this case the nodules are spread evenly from apex to base. Causes of miliary nodular shadowing are listed in *Box 4*.

OTHER TECHNIQUES IN THORACIC IMAGING

COMPUTED TOMOGRAPHY

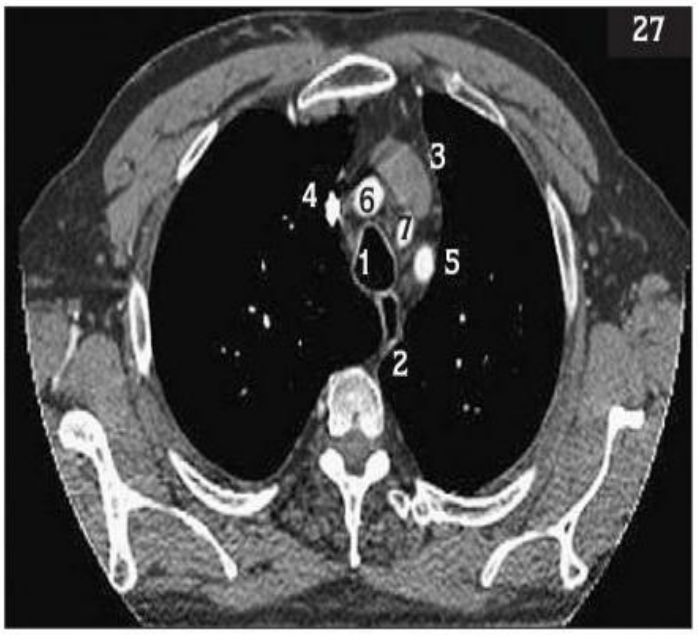
Computed tomography (CT) is now established as an integral part of the work-up for specific patients with respiratory disease. CT generates cross-sectional images of the thorax that can be reconstructed in different planes to give a three-dimensional image of the chest (**27**). Newer CT scans are 'spiral' in nature meaning that the image is acquired in a spiral contiguous fashion. This significantly shortens the time taken to perform the scan and the radiation dosage is utilized to best effect. Indeed, the most recent CT scanners are able to acquire an image of the whole thorax within a single



26 Miliary tuberculosis

BOX 4 Causes of miliary nodular shadowing (< 2–5 mm)

- Miliary tuberculosis.
- Fungal disease.
- Viral infection.
- Pneumoconiosis:
  - Coal workers.
  - Silicosis.
  - Berylliosis.
- Sarcoidosis.
- Acute extrinsic allergic alveolitis.
- Metastases (carcinoma of the prostate).
- Histiocytosis X.

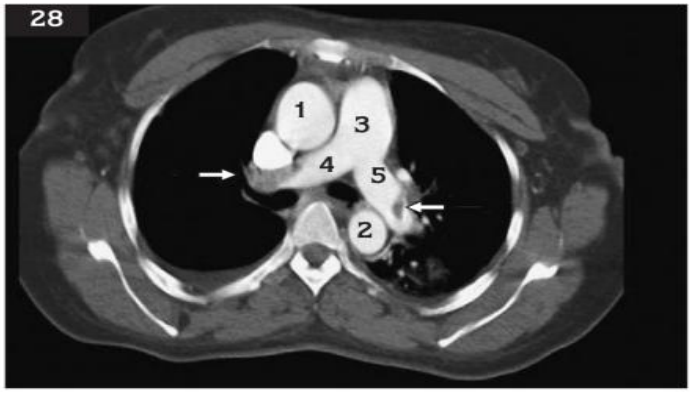


27 CT images of upper mediastinum: **1**, Trachea; **2**, Oesophagus; **3**, Lymphadenopathy; **4**, Superior vena cava; **5**, Left subclavian artery; **6**, Brachiocephalic artery; **7**, Left common carotid artery

breath-hold. CT can further image difficult areas, such as the mediastinum, to help with the staging of lung cancer and characterization of mediastinal masses. A CT pulmonary angiogram (CT-PA) can be used to detect central and segmental pulmonary emboli without the need for more invasive angiography (**28**). The use of CT for the staging of a SPN and in lung cancer has already been described. Finer CT cuts of 1 mm (vs. 10 mm for lung cancer staging) are used to assess for diffuse parenchymal lung disease (see Chapter 8, page 80). Indications for a CT scan of the thorax are listed in *Box 5*.

Ultrasound

The main use for ultrasound of the chest is in the localization and characterization of a pleural effusion. It can also be used to guide percutaneous drainage of effusions and needle biopsies of abnormal pleural or lung masses abutting the pleura.



28 Pulmonary emboli (arrowed) in main pulmonary arteries in a CT pulmonary angiogram: **1**, Ascending aorta; **2**, Descending aorta; **3**, Main pulmonary artery; **4**, Right pulmonary artery; **5**, Left pulmonary artery

Ventilation–perfusion (VQ) scanning

The patient inhales an inert gas with an ultra-short half-life (e.g. Krypton) to assess ventilation and this is compared to images obtained from the injection of radiolabelled technetium. The thorax is scanned using gamma rays. Areas of unmatched perfusion compared to ventilation may be suggestive of pulmonary embolic disease (**29**). In patients with lung disease, such as asthma or COPD, the perfusion scan similarly shows perfusion defects. However, in these cases the perfusion defects reflect hypoxic vasoconstriction in an area of diminished ventilation – so-called matched ventilation/perfusion defects. A VQ scan must be interpreted in the light of a recent chest radiograph and the clinical history. VQ scanning can also be used to assess patients with COPD before lung cancer surgery.

Magnetic resonance imaging (MRI)

In magnetic resonance imaging (MRI) a powerful magnet generates a magnetic field and a very small percentage of hydrogen atoms within the body will align with this field. Radio wave pulses are broadcast towards the aligned hydrogen atoms in tissues of interest, which return a signal of their own. The subtly differing characteristics of that signal from different tissues enable MRI to differentiate between various organs. There is no ionizing radiation involved in MRI, and there have been no documented significant side-effects of the magnetic fields and radio waves used on the human body to date.

MRI has become the modality of choice in many diagnostic studies of the head, spine, and joints. It can also provide detailed pictures of tissues within the chest cavity, without obstruction by overlying bone. It is most commonly used to clarify findings from previous radiographs or CT scans where cystic/mass-like lesions need further delineation. MRI can show the structures of the chest from multiple planes and can, therefore, be

BOX 5 Indications for a computed tomography (CT) scan of the thorax

10 mm spiral CT

- ❑ Suspected or proven lung cancer for staging (must include liver and adrenal glands and IV contrast to assess lymph nodes).
- ❑ Evaluation of a solitary nodule.
- ❑ Further evaluation of an abnormal hilum or mediastinal shadow.
- ❑ Pleural disease.

High-resolution CT (HRCT)

- ❑ Patients with suspected diffuse parenchymal lung disease.
- ❑ Staging patients with COPD/emphysema.

CT-PA

- ❑ Suspected pulmonary embolism.

Intervention

- ❑ Percutaneous needle biopsy.
- ❑ Positioning of a difficult chest drain.

very useful for assessing tumour invasion into the chest wall or mediastinum and providing information for the more accurate staging of tumours in the chest cavity.

Currently, MRI is not routinely valuable in the evaluation of subtle changes of the lung tissue since the lungs contain mostly air and are difficult to image. However, inhaled radiolabelled helium has been used to assess functional regional lung diffusion in research studies. This may be an exciting tool in the future to give a more accurate early assessment of emphysema.

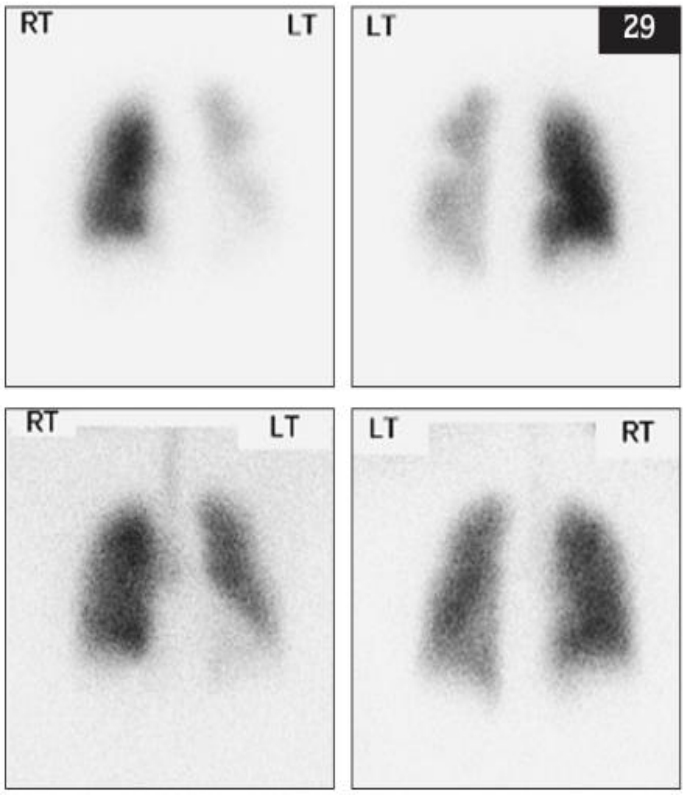
Positron emission tomography

Positron emission tomography (PET) measures glucose uptake into tissue following the administration of radiolabelled glucose (fluorodeoxyglucose, FDG) into the patient. Areas of high metabolic activity take up the glucose and release positrons which can be detected by a gamma camera. The radiation dose of a PET scan is equivalent to that from a CT scan. Organs, such as the heart and the brain, have a high metabolic state and therefore are very FDG-avid and appear black ('hot') on the scan. Most types of tumour and areas of acute inflammation in the body are also FDG-avid and will give a positive scan. Functional imaging by PET complements and enhances the staging and detection of tumours by imaging modalities (radiography, CT, and MRI) which demonstrate anatomical changes. More recent PET scanners are dual PET/CT scans and can co-register images so PET hot-spots can be correlated with the anatomical area simultaneously. normals it is difficult to identify primary or secondary brain tumours by this method. However, PET is very useful for detecting extrathoracic metastases in bone and adrenal glands. Inflammatory conditions which increase turnover of glucose will also be hot on PET scanning, e.g. tuberculosis and sarcoidosis. Therefore, PET has a low specificity but a very high sensitivity for cancers. PET cannot replace conventional imaging and tissue confirmation of primary tumours still needs to be made. Other investigational uses of PET scanning in respiratory medicine include the assessment of particle distribution throughout the lung following inhaled medication.

SUMMARY

- ❑ The PA chest radiograph is an excellent tool for respiratory imaging.
- ❑ A lateral radiograph can help to delineate lobar collapse.
- ❑ Always ask the patient about the availability of any previous radiographs for comparison.
- ❑ CT scanning of the thorax is essential in lung cancer staging and for further evaluation of difficult radiographs.
- ❑ MRI of the thorax is not routine.
- ❑ PET scanning is a further valuable tool in the staging of intrathoracic malignancy.

of tumours by imaging modalities (radiography, CT, and MRI) which demonstrate anatomical changes. More recent PET scanners are dual PET/CT scans and can co-register images so PET hot-spots can be correlated with the anatomical area simultaneously. Most tumours have an increased requirement for glucose compared to that of normal tissue. Therefore, PET scanning can allow detection of primary tumours and metastases. Tumours which grow slowly may be negative on PET scanning, for example bronchoalveolar cell carcinoma. As the brain has a high requirement for glucose and is positive in staging of intrathoracic malignancy.



29 Ventilation–perfusion scan showing reduced perfusion to left lung with preserved ventilation