Interpreting a chest X-ray

The chest X-ray is the most commonly performed plain film in medicine (Beese and Wasan, 2000). It is used frequently to diagnose disease that may affect organs within the thoracic cavity. Owing to the vast number of chest X-rays being performed, films are often not reported immediately and junior doctors may be left to identify serious abnormalities without radiology opinion. It is therefore essential that all junior doctors are competent at assessing the chest X-ray in a clinical context, to allow for early diagnosis and early intervention as required.

What are we doing?

The principle behind the chest X-ray is simple. X-rays pass through the body and are absorbed by tissues of different densities. Tissues of greatest density, i.e. bone, absorb the most radiation appearing white whereas tissues absorbing the least, i.e. air within the lung, appear black. Where tissue density lies between these two extremes a grey image results. The final image is therefore a result of the interaction between normal anatomy and pathology which alters the film (*Table 1*). A solid understanding of these two areas forms the basis of interpreting the chest X-ray.

What makes a good chest X-ray?

A poorly taken chest X-ray can be impossible to interpret and can cause medicolegal problems. All films must include patient name, date of birth and projection. A well-taken film should show adequate penetration (vertebral bodies should be seen behind the heart to T7), rotation (medial ends of clavicles should be equidistant from the spinous process) and inspiration (five to seven anterior ribs).

The projection of a film is the beam direction in relation to the patient (*Figure 1*). The beam is a point source and divergent. In a posterior anterior (PA) chest X-ray the beam enters the chest posteriorly and the plate is anterior to the patient. The patient is usually standing and this is the best possible attainable chest X-ray. As the heart is an anterior structure, there is minimal magnification of the heart size. In an anterior posterior (AP) film the beam enters

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Table 1. Pathology and findings seen on chest X-ray

Pathology	Chest X-ray finding
Consolidation	Air bronchogram, loss of silhouette sign, poorly demarcated opacification with loss of lung markings
Pulmonary oedema (non-cardiogenic)	Diffuse alveolar shadowing (bat wing appearance)
Pulmonary oedema (cardiogenic)	Cardiomegaly, diffuse alveolar shadowing (bat wing appearance), upper lobe blood diversion, Kerley B lines, pleural effusions
Pleural effusion	Blunting of costophrenic angle, meniscus sign, white out of lung (if large)
Collapse	Loss of lung volume, mediastinal shift towards side, raised hemidiaphragm
■ Left upper lobe	■ Silhouette sign lost over aortic knuckle
■ Left upper lobe (lingular)	■ Silhouette sign lost over left heart border
■ Left lower lobe	■ Silhouette sign lost over left hemidiaphragm
■ Right upper lobe	■ Silhouette sign lost over right paratracheal stripe, superiorly displaced horizontal fissure
■ Right middle lobe	■ Silhouette sign lost over right heart border
■ Right lower lobe	■ Silhouette sign lost over right hemidiaphragm
Pneumothorax	Lung edge visible, absent lung markings, mediastinal shift away from side (if tension pneumothorax)
Soft tissue mass	Discrete lesion within lung field, associated consolidation, collapse or effusion
Hilar lymphadenopathy	Enlarged lobulated soft tissue masses in hilar region, maybe unilateral or bilateral

Figure 1. There is minimal magnification of the heart size in a posterior anterior film compared to an anterior posterior film because the heart is an anterior structure within the thorax.

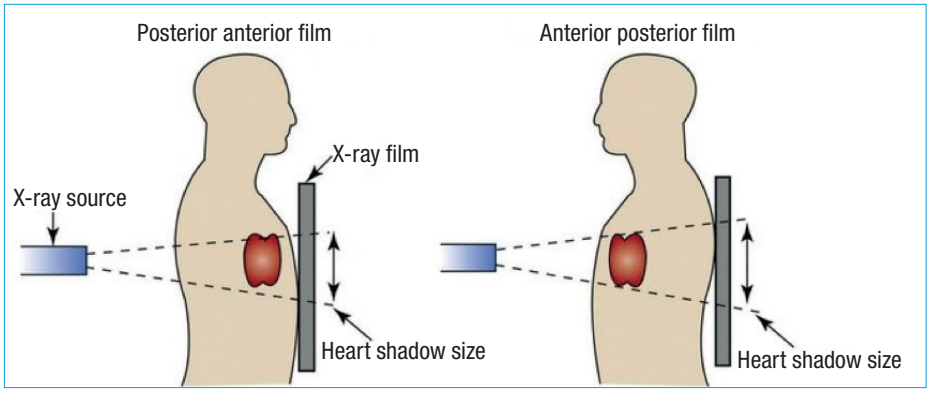


Table 2. Location of loss of silhouette sign and its corresponding likely site of pathology

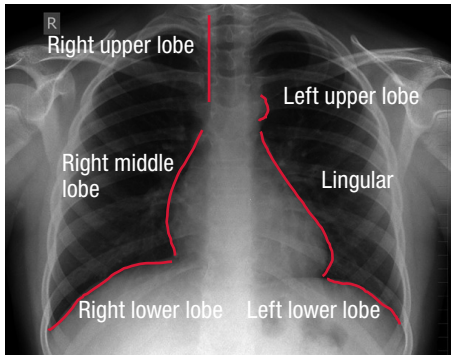
Loss of silhouette sign location	Site of pathology
Right paratracheal stripe	Right upper lobe
Right heart border	Right middle lobe
Right hemidiaphragm	Right lower lobe
Aortic knuckle	Left upper lobe
Left heart border	Lingular segment of left upper lobe
Left hemidiaphragm	Left lower lobe

the chest anteriorly with the plate posterior to the patient, usually semi-erect in bed. Given the heart's position anteriorly, the heart size is magnified and hence comments cannot be made about its size and the cardiothoracic ratio (maximum cardiac diameter divided by maximum thoracic diameter). AP films are portable chest films, reserved for patients who are ill and unable to stand.

The silhouette sign

The thoracic structures in a normal chest X-ray are clearly demonstrated because there is an air–soft tissue interface – referred to as the silhouette sign. Where there is a loss of the clearly demarcated air–soft tissue interface, pathology may be implicated. The position where the well-demarcated interface is lost can indicate where the pathology most probably exists (*Table 2*, *Figure 2*).

Figure 2. The location where the silhouette sign is lost (red) can tell us the likely location of pathology.



Anatomy

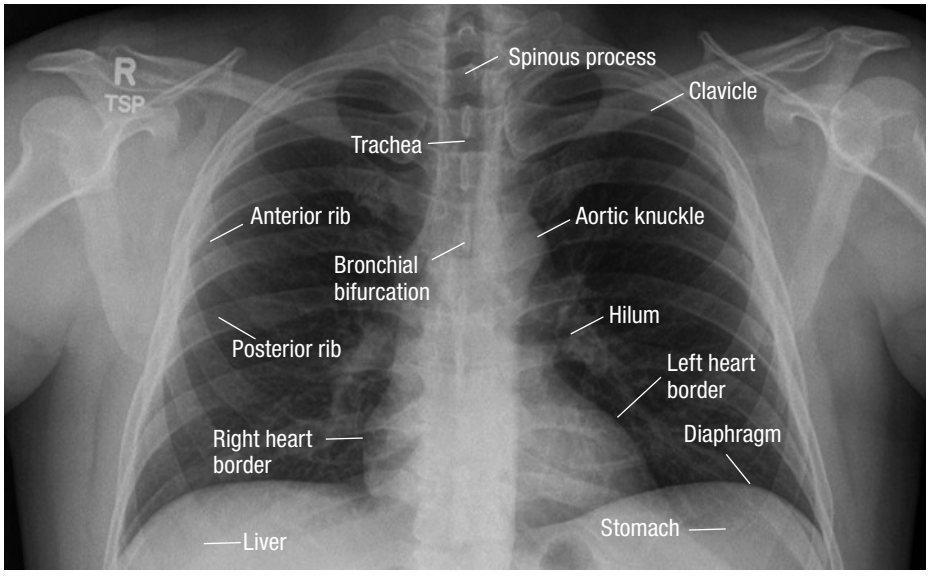
Understanding the anatomy of the normal chest increases the possibility of identifying an abnormality even when the exact discrepancy may not be immediately identifiable. *Figure 3* shows a normal chest X-ray with key anatomy labelled. The anatomy is difficult because the X-ray gives a two-dimensional image of a three-dimensional structure.

Lungs

The right and left lung should always be compared, looking in particular for:

- Opacification – this can be categorized into unilateral *vs* bilateral, and focal *vs* diffuse. Examples of focal unilateral opacities include infection and malignancy. Bilateral diffuse opacification can be caused by pulmonary oedema, pneumonia and parenchymal disease.
- Lung borders – the lung is surrounded by visceral and parietal pleura. Thickening of the pleura may suggest mesothelioma, adenocarcinoma or post-infective changes. Lung markings are always visualized in the healthy lung and their absence may suggest an underlying pneumothorax.
- Lung volumes – five to seven anterior ribs should normally be visualized. More than seven ribs suggests hyper expansion (i.e. chronic obstructive pulmonary disease) whereas fewer than five suggests inadequate inspiration.

Figure 3. Key anatomy labelled on a normal chest X-ray.



Mediastinum

The mediastinum refers to the central compartment of the chest between the lungs. Owing to the similar density of its soft tissue structures, individual identification is unlikely within the mediastinum, but the border between the aorta, trachea and heart should be well demarcated. Similarly to the trachea, the mediastinum can be drawn towards the affected side (i.e. lobar collapse, fibrosis or pneumonectomy) or away from the affected side (i.e. pneumothorax or a large pleural effusion). It may also be widened secondary to lymphadenopathy or an aortic aneurysm.

Heart

The heart is a soft density structure which should occupy less than half of the cardiothoracic ratio. Should the ratio be greater than 50%, cardiomegaly may be assumed, although this assumption should not be made on an AP film. The right and left heart borders should be traced to ensure there is no possible underlying pathology.

Hemidiaphragms

The right hemidiaphragm should be superior to the left and the contours well defined. An elevated hemidiaphragm may be the result of lung or lobar collapse, phrenic nerve palsy or hepatomegaly.

Bones

Ensure there are no fractures, inconsistencies in density or metastases. If there are rib fractures, check the lung fields again for a missed pneumothorax.

Review areas are areas where pathology can be missed:

- Lung apices – a pneumothorax can easily be missed. Check for a Pancoast's tumour and lung fibrosis secondary to tuberculosis.
- Costophrenic angle – this should be well defined. Fluid seen may be secondary to a pleural effusion or a haemothorax.

- Soft tissues – check for symmetrical breast shadows (i.e. tumour or mastectomy) and for irregular subcutaneous gas (i.e. surgical emphysema).

Pathology

Consolidation

Consolidation is the consequence of fluid within the alveoli giving a grey, poorly demarcated opacification (*Figures 4–6*). The causes of consolidation are broad and should be thought of categorically:

- Exudative – typically unilateral, i.e. pneumonia, malignancy
- Transudative – typically bilateral pulmonary oedema, i.e. cardiac failure, liver failure, nephrotic syndrome, drug reactions and bilateral systemic processes.

Pneumonia is by far the most common cause of consolidation but it is important to correlate radiological and clinical findings to elucidate the most likely pathology. Infective causes can be divided into:

- Bacterial, e.g. Streptococcus pneumonia
- Viral, e.g. adenovirus
- Mycobacterial, e.g. *Mycobacterium tuberculosis*
- Fungal, e.g. Aspergillus.

The key findings suggestive of consolidation on the chest X-ray are:

- Air bronchograms – these are the outlines of an airway which are made visible because of the presence of surrounding fluid or debris. Identification of an air bronchogram is highly suggestive of lung consolidation rather than collapse.
- Loss of lung markings – the opacification from fluid or debris accumulation within the alveoli causes lung markings to be lost within the lobe affected. Unaffected areas will have normal lung markings.
- Loss of silhouette sign – the exact location where the silhouette sign is lost can identify the location of pathology, e.g. if consolidation obscures the right hemidiaphragm, the right lower lobe is implicated. There is loss of the normal air–soft tissue interface and a new abnormal soft tissue–soft tissue interface is seen.

Figure 4. Right upper lobe consolidation with air bronchograms noted by arrows. There is loss of the right paratracheal stripe or silhouette sign implicating pathology in the right upper lobe. Note loss of lung markings within the opacification. The inferior aspect of the consolidation is limited by the horizontal fissure.

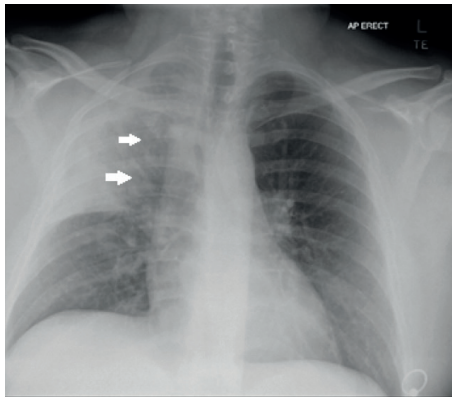


Figure 5. Right middle lobe consolidation. Note how there is loss of the right heart border implicating the right middle lobe. The opacification can be clearly seen and confined beneath the horizontal fissure. The right hemidiaphragm is clearly seen as a result of normal air in the right lower lobe.

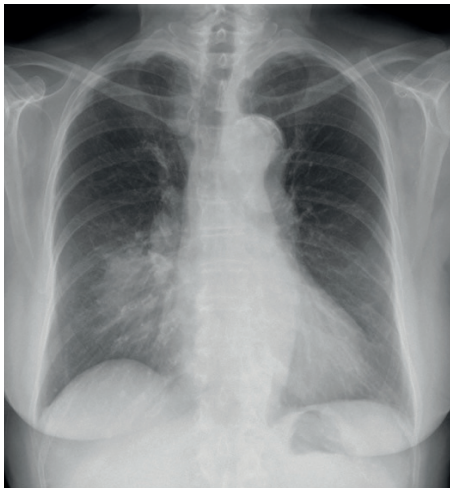
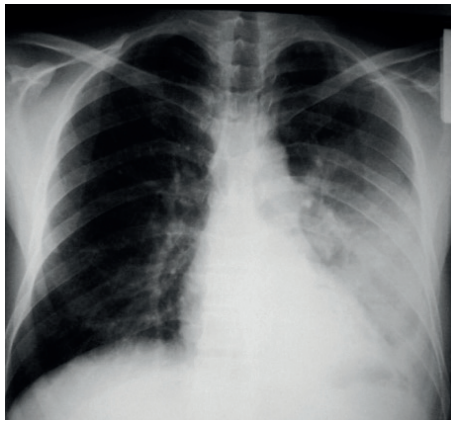


Figure 6. Left lower lobe consolidation with loss of the silhouette sign of the left hemidiaphragm indicating no air in the left lower lobe. There is increased soft tissue density behind the heart and loss of normal lung markings. All these signs indicate the left lower lobe is solid, airless and consolidated. The left heart border is clearly seen, indicating air in the lingular.



Heart failure

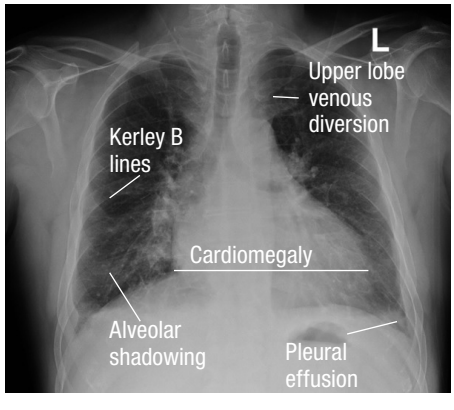
Heart failure refers to the inability of the heart to meet the body's requirement for adequate blood supply. It may cause a wide variety of features on the chest X-ray, but the presence of cardiomegaly and pulmonary oedema together suggest heart failure as a possible diagnosis (*Figure 7*).

Pulmonary oedema alone may be the result of causes other than heart failure. It may be a consequence of either an increase in vascular hydrostatic pressure (i.e. heart failure or intravascular volume overload), a decrease in plasma oncotic pressure (i.e. liver or renal failure) or damage to the lung parenchyma (i.e. adult respiratory distress syndrome).

Key radiological features of heart failure include:

- Cardiomegaly – if there is a cardiogenic cause, an enlarged heart greater than 50% of the cardiothoracic ratio may be seen.
- Upper lobe pulmonary venous diversion – as a result of hypoxia in the lower lobes, blood flow is diverted to the upper lobes and hence upper lobe blood vessels appear wider in cardiogenic causes. Upper lobe diversion is indicative of a raised left atrial pressure.
- Alveolar shadowing – often bilateral and may appear in a bat wing distribution as a result of oedema spreading out from the hilum.
- Pleural effusions – accumulation of fluid between the pleura will cause blunting at the costophrenic angle (*Figure 8*).
- Kerley B lines – these are the result of fluid between the interlobular septa or interstitium or lymphatics. They are seen peripherally above the costophrenic angles running horizontally.

Figure 7. A chest X-ray showing characteristic findings of heart failure. It is unlikely that all these features will be seen in each patient.



Pleural effusion

A pleural effusion results when there is excessive fluid between the visceral and parietal pleura. Causes of a pleural effusion are either transudates (e.g. cardiac failure, renal failure, liver synthetic failure) or exudates (pneumonia, malignancy or chronic inflammatory conditions). Exudates are generally the result of local disease and hence appear unilateral, whereas transudates are commonly the result of systemic problems and hence often bilateral.

The differentiation is confirmed on pleural aspiration, but the presence of a pleural effusion is initially noted on the chest X-ray.

Chest X-ray findings include:

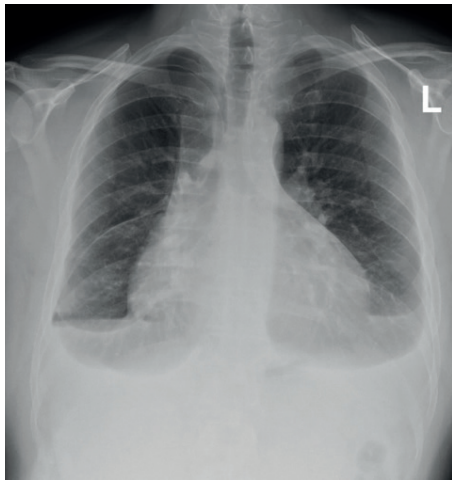
- Blunting of the costophrenic angles. The costophrenic angles should be well defined, but moderate pleural effusions will cause blunting. A meniscus may be visible. Small pleural effusions may not always be appreciated as a result of retro-diaphragmatic spaces.
- In moderate pleural effusions, there may be loss of the silhouette between the hemidiaphragms and the heart border.
- Very large pleural effusions can cause a 'white out of the lung' with lung collapse and mediastinal shift away from the pathological side.

Collapse

Collapse of a lung may be either partial or complete. Although this results in the lung being unable to fully expand, lung function does not often deteriorate acutely because of compensation from other lobar segments. The cause of collapse is bronchial obstruction of the lobe and may include malignant tumours, foreign bodies or mucus plugs.

The chest X-ray appearance is dependent on the lobe affected, but principles behind the silhouette sign can identify which lobe is involved. *Figures 9–11* show characteristic appearances of different lobar collapses.

Figure 8. Bilateral pleural effusions with an obvious fluid levels visible in the costophrenic angles. Note that the pleural effusion is bilateral suggesting a systemic underlying pathology. The heart is enlarged with increased cardiothoracic ratio. Heart failure should be considered.



Pneumothorax

A pneumothorax results when air enters the pleural space causing movement of the lung towards the hilum. The extent of the movement towards the hilum is dependent on the severity of the pneumothorax, and hence severity can vary from asymptomatic to life threatening. Pneumothoraces can be broadly categorized into primary and secondary:

- Primary pneumothoraces occur spontaneously, normally as a result of small pleural bleb rupture. These usually occur in tall, thin young males
- Secondary pneumothoraces arise as a result of an underlying disease or injury. Examples include emphysema, cystic fibrosis, trauma and iatrogenic causes (e.g. central line insertion, lung biopsy).

A tension pneumothorax is a complication of a pneumothorax where a pleural flap acts as a one-way valve which allows air to enter but not escape. Accumulation of air in the pleural cavity causes a large shift of the mediastinum away from the affected side, resulting in kinking of the great vessels and haemodynamic compromise. This is a medical emergency and hence is treated urgently with decompression using a needle on the side of the pneumothorax. Bilateral pneumothoraces may also be seen in severe trauma and are a common cause of death.

Radiological findings of a pneumothorax include:

- A visible lung edge which demarcates the lung margin (*Figure 12*)
- No lung markings beyond the lung margin and the chest wall
- Mediastinal shift where a tension pneumothorax has resulted (*Figure 13*).

Figure 9. Right upper lobe collapse. Note obscuring of the right paratracheal stripe and increased density at the right apex. With elevation of the horizontal fissure and the trachea pulled to the side of collapse.

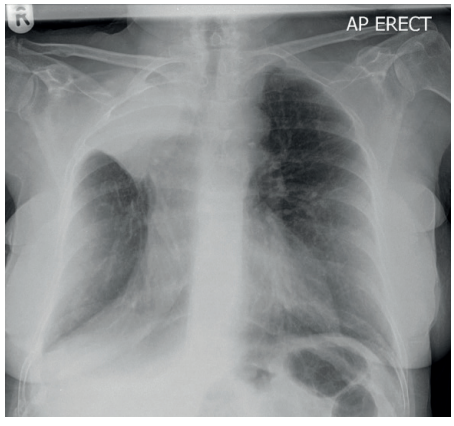
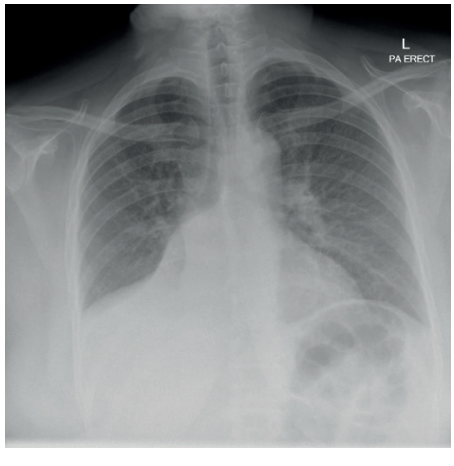


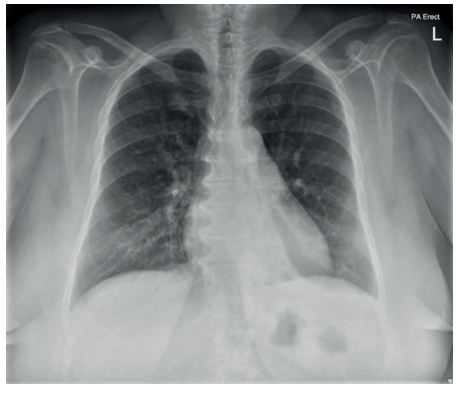
Figure 10. Right lower lobe collapse secondary to lung malignancy. The right hemidiaphragm silhouette is not visible as a result of collapsed right lower lobe adjacent to the diaphragm. There is an obvious bulge of the right heart border, which was found to be the tumour responsible. The right heart border is visible because of air in the right middle lobe.



Soft tissue mass

A soft tissue mass refers to a discrete area of opacification within the lung field. The appearance of a soft tissue mass can give

Figure 11. Left lower lobe collapse. Note the characteristic appearance where a triangular outline of the left lower lobe can be seen faintly projected through the cardiac shadow.



information about the likely underlying pathology. If its edges are irregular and poorly circumscribed, primary malignancy should be considered, but soft tissue masses have a large differential diagnosis and malignancy is a single possibility (*Figures 14–16*).

Differential diagnoses for a single soft tissue mass include:

- Neoplastic – either benign, e.g. hamartoma, calcified granuloma, or malignant (which can be primary, e.g. squamous cell carcinoma or secondary e.g. metastases)
- Infection, e.g. round pneumonia, tuberculosis, abscess.

Hilar lymphadenopathy

The hilar lymph nodes are responsible for drainage of the lungs, heart, thymus and oesophagus. Enlarged hilar lymph nodes can be seen on chest X-ray and their underlying pathology can be split into unilateral *vs* bilateral lymphadenopathy causes (*Figure 17*).

Figure 12. Left-sided pneumothorax. Note the lung edge (arrows) and lack of lung markings beyond.

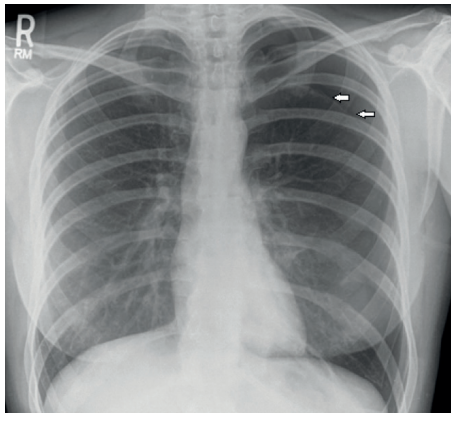
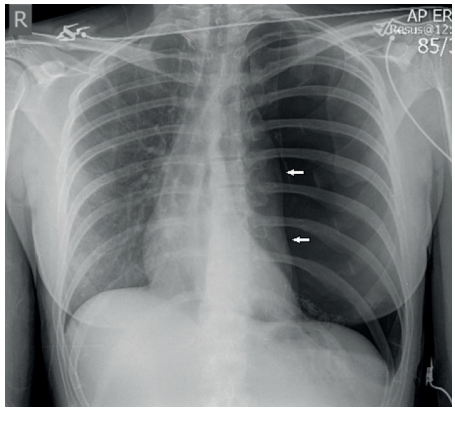


Figure 13. Tension pneumothorax. The left lung edge is clearly visible (arrows) with absent left markings beyond it. The trachea and mediastinum has been shifted to the right.



Causes of unilateral hilar lymphadenopathy include:

- Bronchial carcinoma
- Lymphoma
- Tuberculosis.

Causes of bilateral hilar lymphadenopathy include:

- Sarcoidosis – the commonest cause especially if asymptomatic (99%)
- Lymphoma
- Tuberculosis
- Metastases.

Conclusions

The chest X-ray is a fast and inexpensive investigation that allows doctors to detect the presence of underlying pathology. Junior doctors will often be left to interpret the chest X-ray alone and hence competence in interpretation must be attained. A solid understand of pathology, and its interaction with anatomy demonstrated on the film forms the foundation of this understanding. BJHM

Figure 14. Small soft tissue mass with a well-defined border in the left lung field. The mass is in silhouette with air in the surrounding lung. Appearances are keeping with a lung tumour which may be benign or malignant, but most likely malignant (primary or secondary).

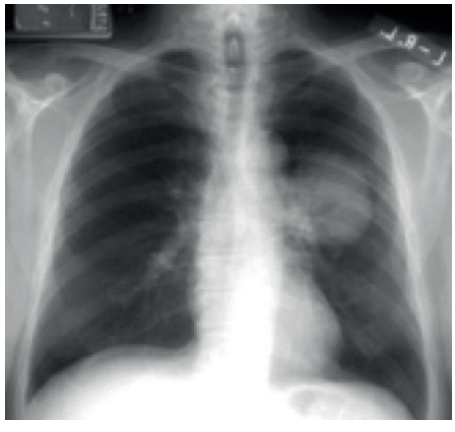


Figure 15. There is a well-defined soft tissue mass in the right upper zone with central calcification and popcorn configuration. Appearances are in keeping with a benign hamartoma.

KEY POINTS

- The chest X-ray can be difficult to interpret and requires an understanding of chest anatomy and pathology.
- The final image produced is a silhouette of the interaction of anatomy and pathology.
- Accurate diagnostic information can be gained about a range of pathologies which, when put into clinical context, can have great benefit to patient treatment.
- The chest X-ray demonstrates only 75% of the lung field and pathology can be missed.
- The chest X-ray is a valuable tool for diagnosis and all doctors should be competent in its interpretation.

Conflict of interest: none.

Beese R, Wasan R. 2000. Radiology Casebooks for Medical Students. Cheshire: Pastest.

Figure 16. There is a well-defined calcified lesion in the right lower zone in keeping with a calcified granuloma.

Figure 17. Bilateral hilar lymphadenopathy secondary to sarcoidosis.