Tutorial 8: The Chest Radiograph

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Aims and Guidance for Tutors

The chest radiograph is the most commonly performed radiological investigation. While its ubiquity may lead some to believe that it is easy to interpret, there is a wealth of information that can be garnered from this simple test. This chapter aims to familiarise students with basic chest radiograph anatomy and techniques. It also aims to help students understand the appropriate indications for this test. There are a number of emergent diagnoses which students must be able to recongise on a chest radiograph and then know how to act accordingly, e.g. tension pneumothorax. After completion of this tutorial, students should be able to accurately diagnose common and important clinical conditions on the chest radiograph.

Introduction

- The chest radiograph is the most common imaging test ordered within a hospital.
- Although it is easy to focus on the lungs, there are many other structures visible on the radiograph, including the mediastinum, bones and upper abdomen.
- Each of these has a different radiological density on the image; the lungs are normally dark or 'lucent' as they are composed of air containing alveoli, the mediastinum, vessels within the lung and upper abdomen appear whiter,

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'denser' or 'more opaque' due to their soft-tissue composition, while the bones are the most dense (whitest) structures visible due to their calcification and mineralization.

- A vast range of pathologies can be seen on the chest radiograph as alterations in these normal anatomic densities. Pulmonary infections, malignancies and oedema result in increased densities or opacities in the usually dark lungs. Alternatively abnormal free air in the abdomen (pneumoperitoneum) leads to the usually white upper abdomen appearing darker or more lucent due the accumulation of air density.
- There are also a plethora of instruments and devices that may be visible on the chest radiograph in various patient populations. It is important to be familiar with the more common devices and to be able to discern if their positioning is adequate.
- Posteroanterior (PA), anteroposterior (AP) and lateral chest radiographs all convey different information and it is important to be aware of the strength and limitations of each technique.

Chest Radiograph Anatomy and Technical Principles

PA chest radiograph:

- The term 'PA' or posteroanterior refers to the direction the x-ray beam passes through the patient before it reaches the detector. In this case the patient stands with the front of their chest in contact with the detector and the source of the x-ray beam is positioned at a distance behind the patient.
- This position is the most desirable and is the default position. It may not be possible in certain instances, for example, if a patient is bedbound or immobile. If this is the case, an AP study is performed.

AP chest radiograph:

- This is the technique used for portable chest radiographs, frequently performed in critically ill patients in the intensive care unit. In this case, the patient remains in bed and the detector is placed behind the patient's back, while the x-ray machine is positioned in front of the patient.
- This technique has certain limitations and potential pitfalls for interpretation; for example, a normal sized heart may appear falsely enlarged due to magnification by the image technique (Fig. 1). Also the patient's scapulae are not retracted on an AP film, as they are on a PA film, which can partially obscure the lungs or creasing of the bed-bound patient's skin folds can occasionally be confused for a pneumothorax.

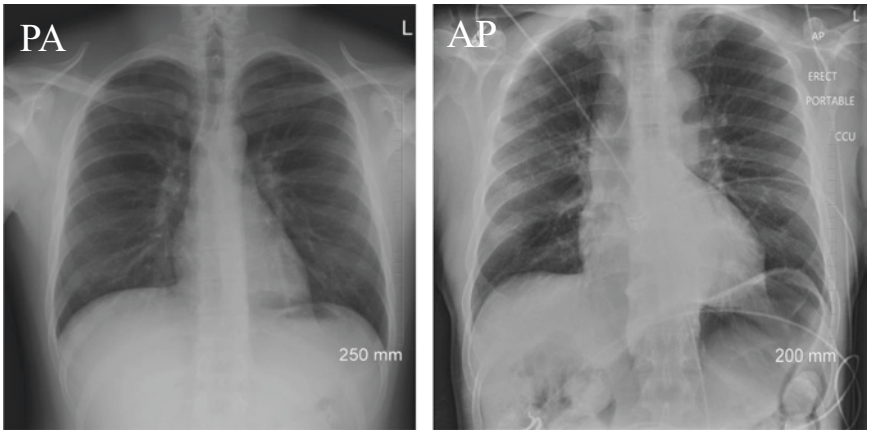


Fig. 1 PA and AP chest radiograph side by side for comparison. Note how the cardiac and mediastinal silhouettes are magnified on the AP view (right), and the scapulae are less retracted

Lateral chest radiograph:

- Although this technique has become less relevant with the advent of CT, it may still be a useful test in certain instances, for example, confirming the position of pacemaker leads or further evaluating abnormalities suspected on PA studies.

Erect chest radiograph:

- Chest radiographs are preferably performed in this position, with the patient upright, when clinically feasible. This is useful for detecting pneumoperitoneum in a patient with a suspected perforated abdominal viscus, which will be seen as free air under the diaphragm. Note the patient should be in the erect position for at least 10 min prior to taking the radiograph.

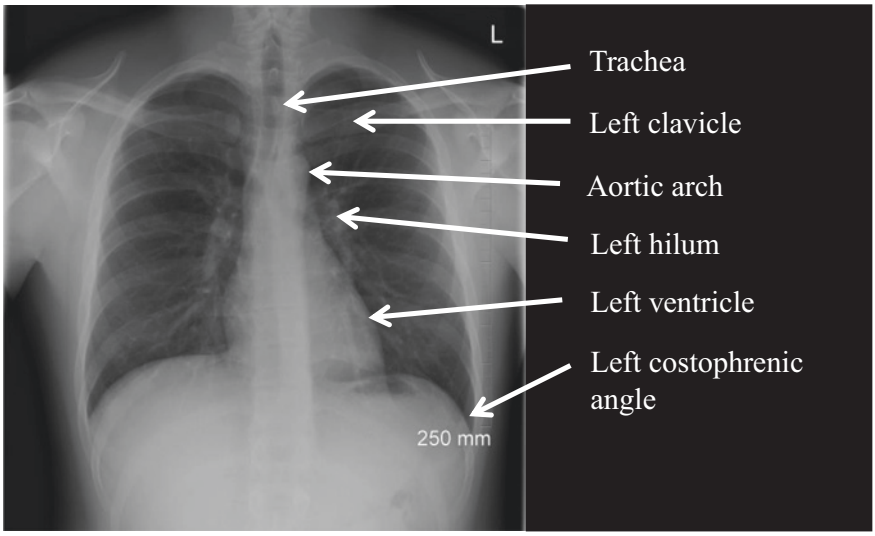
Indications for Imaging

- The need for imaging is determined by clinical assessment.
- In the inpatient or emergency department setting, the chest radiograph can be a useful initial diagnostic screening tool in a generally unwell patient.
- Indications in an outpatient or community setting would include, but are not limited to:
  - Haemoptysis
  - Persistent cough or chest pain
  - Unintended weight loss
  - Night sweats

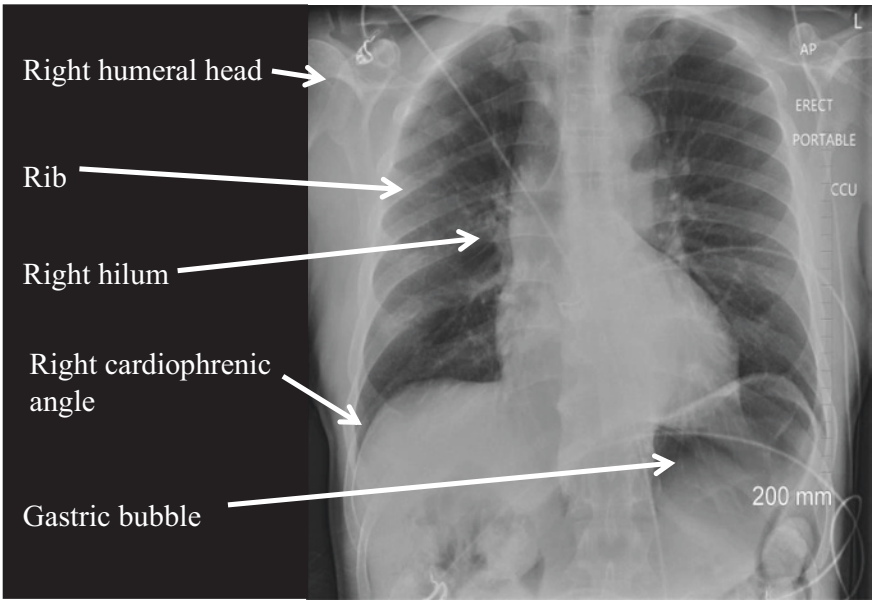
Radiologist's tips

- Develop a system for interpreting chest radiographs. The 'ABCDEFGH' approach is widely used and will capture the vast majority of abnormalities if employed correctly. It is denoted as follows:
  - Airway—central or deviated?
  - Bones—any fractures or lesions?
  - Cardiac silhouette—normal or enlarged?
  - Diaphragm—elevated? Is there pneumoperitoneum? Are the costophrenic angles blunted?
  - Extras—any devices present? Are they in the correct position?
  - Fields—are the lung fields clear?
  - Gastric bubble—is it normally located?
  - Hila—are they enlarged or obscured by a mass?
- Other key review areas include the lung apices, the lower lung fields behind the cardiac silhouette and the hemidiaphragms and breast shadows
- Don't be fooled by nipple shadows, they can mimic lesions in the lower lungs. If in doubt, repeat the radiograph with nipple markers.
- ALWAYS compare the current chest radiograph to any previous chest radiographs available, as an interval change in appearance can help to identify new pathologies.

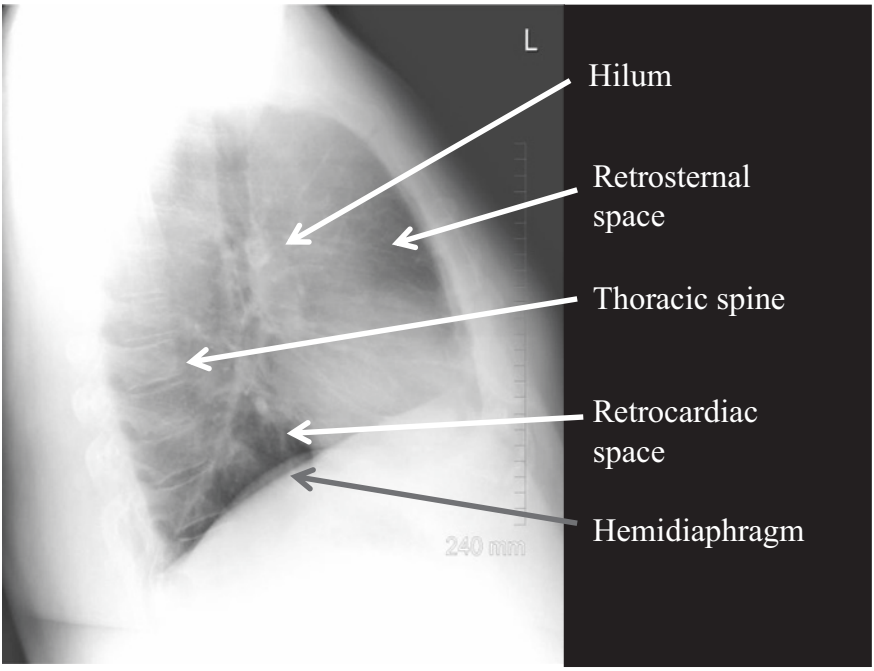
Review of Relevant Radiological Anatomy: PA Chest Radiograph



Review of Relevant Radiological Anatomy: AP Chest Radiograph



Review of Relevant Radiological Anatomy: Lateral Chest Radiograph



Common Pathologies

Pneumonia:

- A variety of pathogens may be responsible, most commonly the bacteria streptococcus pneumoniae in community acquired pneumonia.
- The alveolar sacs fill with pus, limiting oxygen exchange.

Clinical features:

– Productive cough with green sputum.
– Fever.
– Pleuritic chest pain and dyspnoea.
– May progress to sepsis and cardiovascular instability if untreated.

Key imaging appearances:

– Usually presents as pulmonary consolidation (Fig. 2).
– This is seen as an abnormal patchy or confluent area of increased opacification/density in the lung. This can lead to loss of normal interfaces between the usually dark lungs and adjacent denser structures including the heart borders or diaphragms. This is referred to as 'silhouetting'.

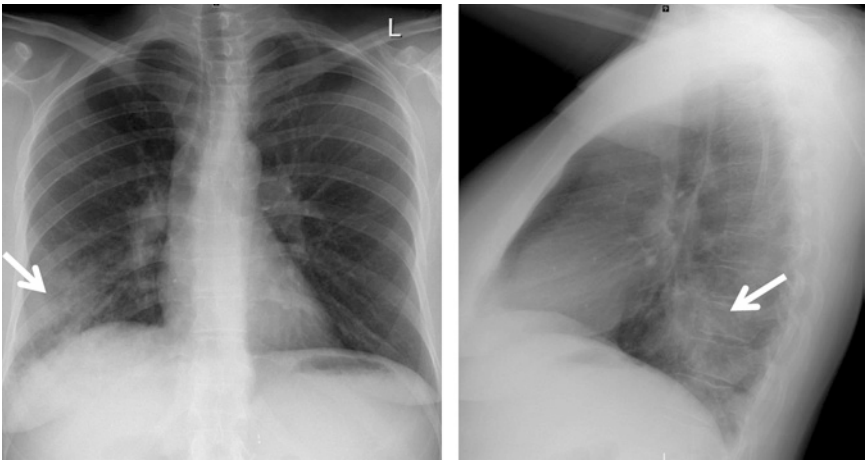


Fig. 2 Right lower lobe pneumonia on PA and lateral chest radiograph. Note the asymmetric patchy increased density in the right lateral lower lung on the PA image. On the lateral view there is abnormal increased opacification overlying the lower thoracic vertebrae, which usually appear darker than upper thoracic vertebral bodies on a normal lateral radiograph, this is known as the Spine Sign

– In severe cases, cavitation may be seen within the infected lung, particularly when the pathogen is Klebsiella pneumoniae or Staphylococcus aureus. This is evidenced by focal air collections within the consolidation.

Radiologist's tip

- It is advisable to obtain a repeat chest radiograph in six weeks following antibiotic therapy in cases of lobar pneumonia to ensure resolution. Failure of the consolidation to resolve could indicate an underlying malignancy requiring respiratory referral and further investigation with CT thorax.

Lobar collapse/atelectasis:

- This refers to loss of air from the lung alveoli leading to volume loss and collapse of the affected lung lobes.
- There are many potential underlying causes including internal airway obstruction from mucus plugging or an endobronchial tumour, or extrinsic compression for example by a pleural effusion.

Clinical features:

– Symptoms include dyspnoea, productive cough or secretions
– There may be ancillary signs of the underlying cause, such as weight loss or hemoptysis in a patient with malignancy

Key imaging appearances:

– Without air in the alveoli the affected part of the lung becomes relatively smaller and more dense/opaque on the chest radiograph
– Typical appearances depend on the lobe involved, however in all cases there will be volume loss +/− associated deviation of the trachea and hilum towards the affected side (Fig. 3). There may also be ipsilateral deviation of the lung fissures or hemidiaphragm.
– In right upper lobe collapse, there is increased opacification in the right upper lung zone and upward deviation of the transverse fissure. In cases due to a central obstructing bronchial tumour, the classic 'Golden S' is observed due to hilar enlargement.
– In left upper lobe collapse, a veil-like opacity is typically seen projected over the left hemithorax. The 'Luftsichel' sign may be appreciated and refers to the compensatory hyperinflation of the superior left lower lobe.
– In right lower lobe collapse the right hemidiaphragm is obscured/silhouetted, and if the right middle lobe is involved, the right heart border is also obscured.

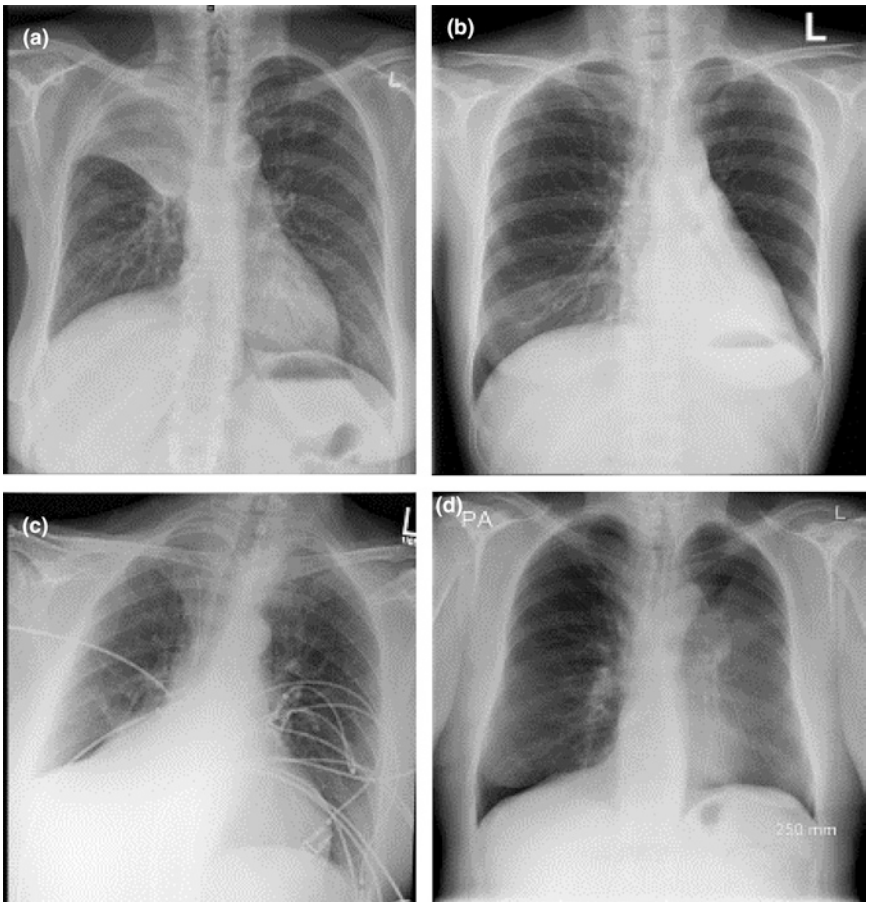


Fig. 3 **a**–**d** Panel of images showing various lobar collapses. **a** Right upper lobe collapse due to right hilar tumour exhibiting S Sign of Golden. **b** Left lower lobe collapse secondary to mucus plugging demonstrating the sail sign. **c** There is relatively increased right-sided retrocardiac density and elevation of the right hemidiaphragm due to right lower lobe collapse. A right subclavian central venous line with tip in the lower SVC is also present. **d** Note the veil-like opacity projected over the left hemithorax. This is the collapsed left upper lobe projected over the remainder of the inflated left lung

– In left lower lobe collapse the left hemidiaphragm is obscured and a retrocardiac 'sail' sign may be seen.
– Lingular collapse is uncommon, but presents with an obscured left heart border.
– Collapse of the entire lung will lead to a 'white-out' appearance with ipsilateral shift of the mediastinum (Fig. 4)

Radiologist's tip

- As lobar collapse may be the initial presentation of a more sinister underlying cause such as an endobronchial mass, it should prompt further investigations with either bronchoscopy or CT thorax or both.

Pleural effusion:

- This refers to the abnormal accumulation of fluid in the pleural space and can be composed of serous fluid, blood (hemothorax), pus (pyothorax/empyema) or chyle (chylothorax).
- Thus, effusions may be due to a variety of etiologies, including cardiac failure, trauma, malignancy, pulmonary infarcts, pneumonia or thoracic duct injury. They can be unilateral or bilateral.

Clinical features:

– Symptoms may be due to the effusion itself causing shortness of breath and pleuritic chest pain, or be related to the underlying cause. On examination, there will be reduced breath sounds and dullness to percussion on the side of the effusion.
– Clinically, pleural effusions tend to be classified into transudative or exudative causes and can be distinguished using Light's criteria.

Key imaging appearances:

– Loss or blunting of the normal costophrenic angle, with a 'meniscus' sign, is indicative of a pleural effusion.

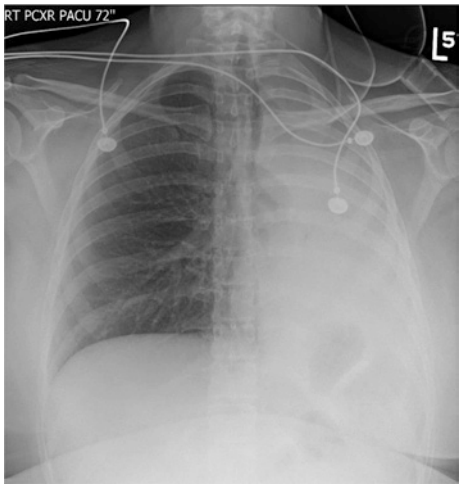


Fig. 4 White-out of the left hemi-thorax due to complete left lung collapse. Note the ipsilateral deviation of the trachea and cardiac silhouette due to the volume loss. There is also resultant elevation of the left hemidiaphragm and underlying bowel gas

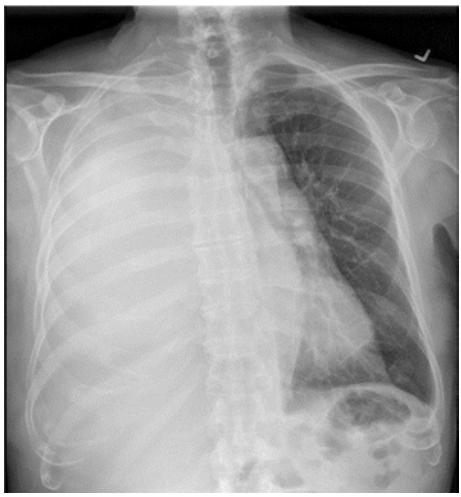


Fig. 5 White-out of the right hemi-thorax due to a very large right pleural effusion. In this case, note the contralateral deviation of the trachea and cardiac silhouette due to the mass effect of the pleural effusion pushing away and displacing these structures

– Very small effusions are first detected on a lateral chest radiograph as blunting of the posterior costophrenic sulcus
– With very large effusions the trachea can be deviated to the contralateral side as the effusion 'pushes' the mediastinum away (Fig. 5).
– Fluid may be seen within the fissures, and if loculated may be mistaken for a mass ('pseudotumour').

Radiologist's tip

- It is not possible to distinguish between a transudate or exudate or to determine the pleural fluid composition on chest radiographs

Heart failure:

- Consideration of the underlying pathophysiology of heart failure helps explain the chest radiographic appearances (Fig. 6).
- Loss of left ventricular function leads to increased pressure within the left atrium and pulmonary veins, causing them to enlarge and fluid to 'seep out', first into the pulmonary interstitium and then into the alveoli of the lung parenchyma and possibly the pleural spaces.

Clinical features:

– Symptoms include dyspnoea on exertion, orthopnoea, peripheral oedema.

Key imaging appearances:

– Air-space opacities represent fluid-filled '**A**lveoli'.
– Interstitial oedema is represented by peripheral Kerley '**B**' lines.

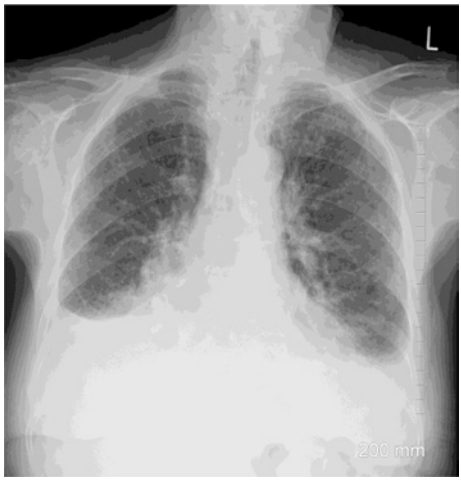


Fig. 6 This patient presented acutely short of breath with a history of prior myocardial infarction. There is cardiomegaly, bilateral pleural effusions, increased perihilar vasculature and increased bilateral interstitial markings compatible with pulmonary oedema

– **C**ardiomegaly—the width of the cardiac silhouette will be greater than 50% of the width of the thorax.
– **D**ilated hilar vessels represent enlarged pulmonary veins.
– Pleural **E**ffusion, usually bilateral but may be unilateral.

Radiologist's tip

- The imaging appearance of heart failure may be remembered by the 'ABCDE' mnemonic.

Pneumothorax:

- This refers to the abnormal accumulation of gas within the pleural space.
- Most commonly due to trauma, rupture of a bulla or iatrogenic (e.g. post pacemaker insertion or lung biopsy).

Clinical features:

– Typical symptoms include pleuritic chest pain and shortness of breath.
– If it continues to enlarge, a tension pneumothorax may develop which is a life-threatening condition and needs to be recognized and treated emergently by placing a large bore (14-G or 16-G) cannula into the ipsilateral 2nd intercostal space in the mid-clavicular line, followed by chest drain insertion.

Key imaging appearances:

– The typical feature is the presence of a thin white line (representing the pleural surface), peripheral to which there is only gas with no lung markings evident (Fig. 7).

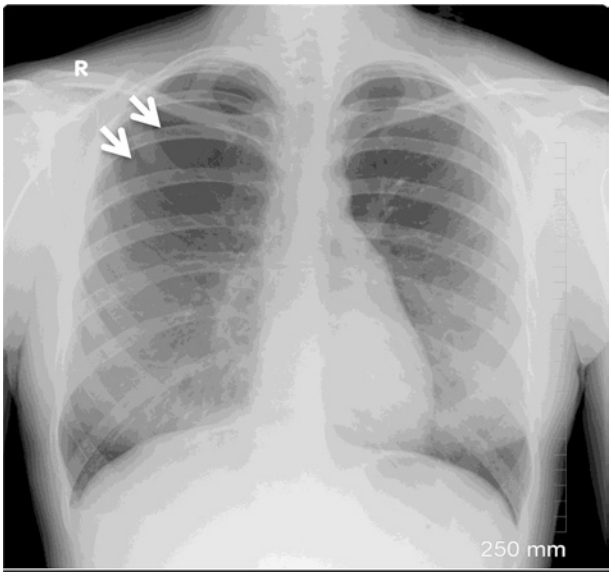


Fig. 7 Erect PA chest radiograph showing a spontaneous right-sided apical pneumothorax in a 32-year old patient. Arrows demonstrate the visceral pleural line. Note the absence of lung vascular markings peripheral to this line

- Usually this pleural line is seen in the apicolateral lung field on a chest radiograph performed with the patient upright.
- If there is uncertainty, an expiratory phase chest radiograph may be helpful to accentuate the pneumothorax
- When patients are semi-recumbent or in the supine position the air tends to accumulate in the non-dependent anteroinferior pleural space and can be seen as costophrenic angle lucency or 'deep sulcus sign'.
- Ancillary signs include subcutaneous emphysema and pneumomediastinum.

Radiologist's tip

- Signs of a tension pneumothorax include a large volume of air in the pleural space with collapse of the adjacent lung, flattening of the ipsilateral hemidiaphragm and contralateral deviation of the trachea and cardiomediastinal structures (Fig. 8). This requires urgent needle decompression as described.

Support Devices (Fig. 9):

- Nasogastric tubes—the tip of these should be visible below the diaphragm on chest radiograph before enteral feeding is commenced.
- The tip of an endotracheal tube should be within 3–7 cm of the carina in an adult patient.
- A PICC line should have its tip at the superior cavoatrial junction. Dialysis catheters, Hickmann lines and Port-A-Caths should have their tips in the right atrium.

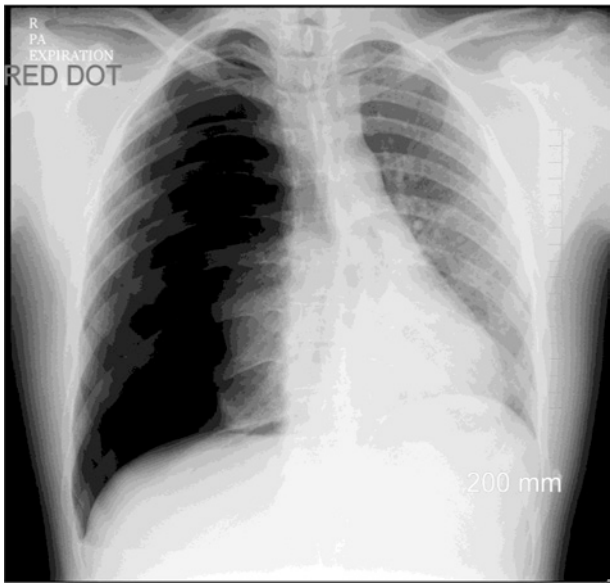


Fig. 8 Right-sided tension pneumothorax. Note the large volume of gas in the right pleural space with associated cardiomediastinal shift to the contralateral side, flattening and depression of the right hemidiaphragm and almost complete collapse of the right lung. This is an emergency and the patient needs to be decompressed immediately!

- Lead positions of cardiac devices are best assessed with PA and lateral views and typical placement can include right atrial, right ventricular and coronary sinus leads.
- A Swan-Ganz catheter should be positioned within the proximal right or left main pulmonary artery.
- The tip of an intra-aortic balloon pump should be positioned 2–3 cm distal to the origin of the left subclavian artery. A position of approximately 2 cm above the level of the carina or left main bronchus can be a helpful landmark on chest radiograph.

Important Differential Diagnoses

Nodules:

Solitary pulmonary nodule:

- Has an extremely broad differential which is often overlooked!
- Tumour is the main concern, this may be malignant such as a bronchogenic carcinoma or a solitary pulmonary metastasis. However, it could represent a low grade carcinoid, benign hamartoma or bronchocele.

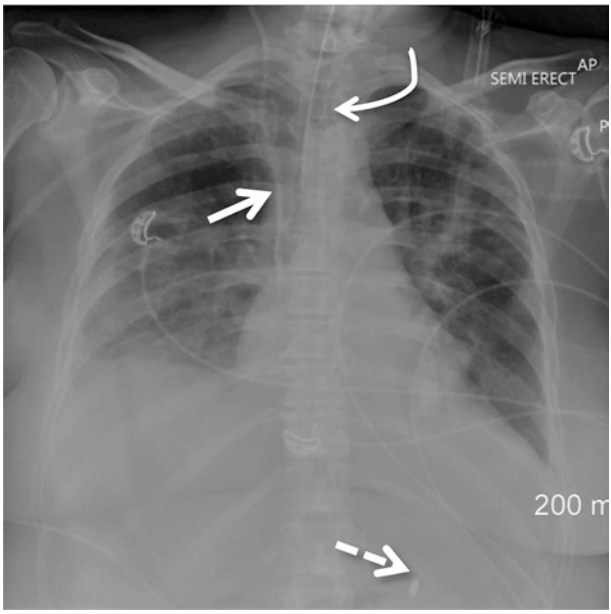


Fig. 9 This is an AP chest radiograph taken in an ICU patient. Support lines and tubes are in satisfactory positions. Note the central venous catheter in the right internal jugular vein with its tip at the superior cavo-atrial junction (solid arrow). An endotracheal tube is also visible with its tip approximately 4 cm from the carina (curved arrow). The tip of a naso-gastric tube is suitably placed within the stomach (dashed arrow). Numerous external cardiac monitoring leads are also visible. Other findings include left lower lobe consolidation and atelectasis, perihilar vascular congestion and oedema, and a small right pleural effusion that is layering dependently given the semi-erect position

- Inflammatory processes are the most common, ranging from a granuloma to a focus of pneumonia to abscess.
- Vascular causes such as pulmonary arteriovenous malformation, pulmonary infarction or septic embolus may present as a nodule.
- In cases of trauma, a pulmonary contusion can have this appearance.
- Congenital abnormalities such as cysts or CPAMs should also be considered.
- Always compare with a prior if available and bear in mind the clinical context.

Multiple pulmonary nodules:

- The worrying differential here is metastatic disease (Fig. 10). The most common malignancies to metastasise to the lung are breast, colorectal, renal, head and neck tumours and primary lung neoplasms.
- Infection is definitely a consideration, particularly in immunocompromised patients, including TB and fungal infection.

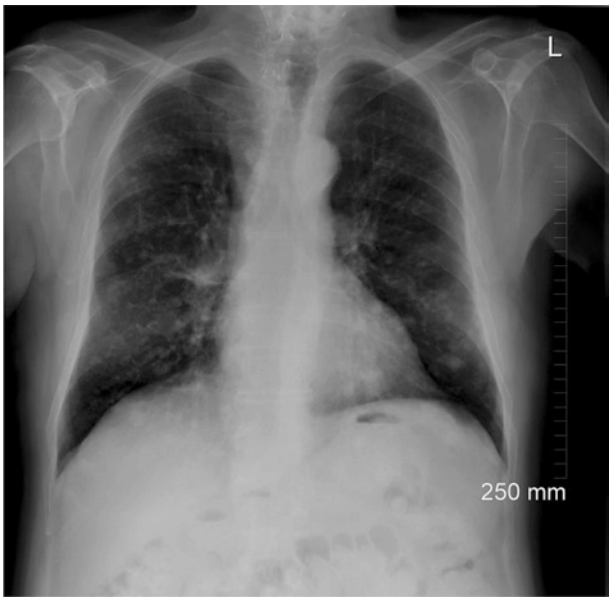


Fig. 10 This radiograph shows numerous small solid pulmonary nodules. There are very subtle surgical clips in the superior mediastinum/lower midline neck. This patient had a history of thyroidectomy for thyroid malignancy and represented with progressive shortness of breath. The diagnosis here was recurrent metastatic thyroid cancer

- Less common are granulomatosis with polyangiitis (formerly Wegener's granulomatosis, and usually cavitating but may appear solid on radiograph), hypersensitivity pneumonitis and sarcoidosis.
- Nodules may be long-standing or calcified in patients with a history of granulomatous disease (e.g. histoplasma) or varicella.

Cavitating nodules:

- Cavitating lesions may be due to diverse and severe pathologies; recognition of these is extremely important (Fig. 11). The mnemonic 'CAVITY' may be used:

  – Cancer—particularly primary squamous cell lung cancer, metastatic head and neck or cervical squamous cell carcinoma.
  – Autoimmune—granulomatosis with polyangiitis (formerly Wegener's).
  – Vascular—septic emboli.
  – Infection—seen in Staph aureus, Klebsiella pneumoniae and TB. This includes pulmonary abscess, which may have an air-fluid level.
  – Trauma—also known as a pneumatocele, these usually spontaneously regress.

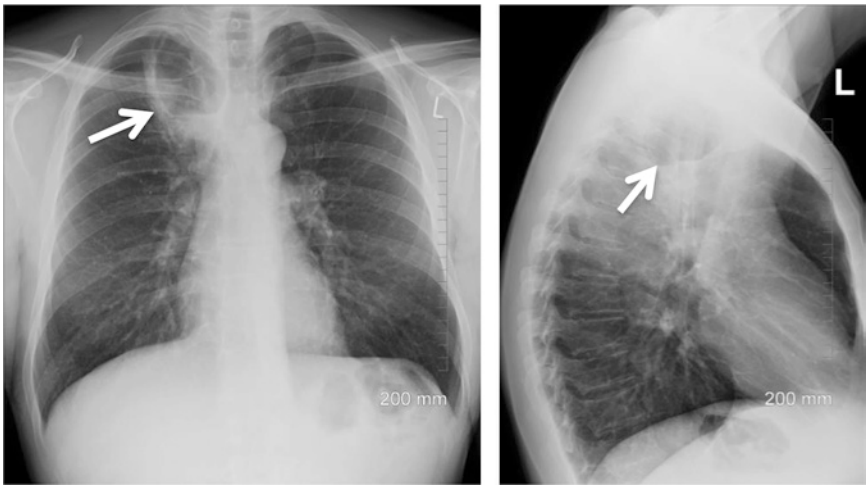


Fig. 11 Here we have a right upper lobe cavitating lesion in a 36-year old intravenous drug user. This patient presented with purulent sputum, weight loss and fevers. The diagnosis was a pulmonary abscess. Note the internal air-fluid level (arrows). Given the location and appearance, TB is a consideration, and the patient may need to be initially isolated

– Young—congenital pulmonary airway malformations (CPAMs) may present as a cavitating lesion on chest radiograph. Seen in newborns and infants.

Radiologist's tip: Managing the solitary pulmonary nodule

- It is important to keep the broad differential in mind, however, this may be the first presentation of a malignancy. As such, it is essential that appropriate follow-up is made to ensure the nodule resolves. A follow-up chest radiograph 4–6 weeks after treatment should be performed in all cases. If the nodule persists, referral to a Respiratory Rapid Access Clinic with a view to performing CT Thorax for further evaluation is advised.

Bihilar lymphadenopathy:

- This may be the presenting feature of sarcoidosis (Fig. 12). As this condition may progress to pulmonary fibrosis, which is irreversible, it is important to recognize it at this stage.
- The other main differential is malignancy, particularly lymphoma. Although any malignancy may metastasise to mediastinal nodes, if the abnormality is symmetrical, lymphoma is considered more likely.

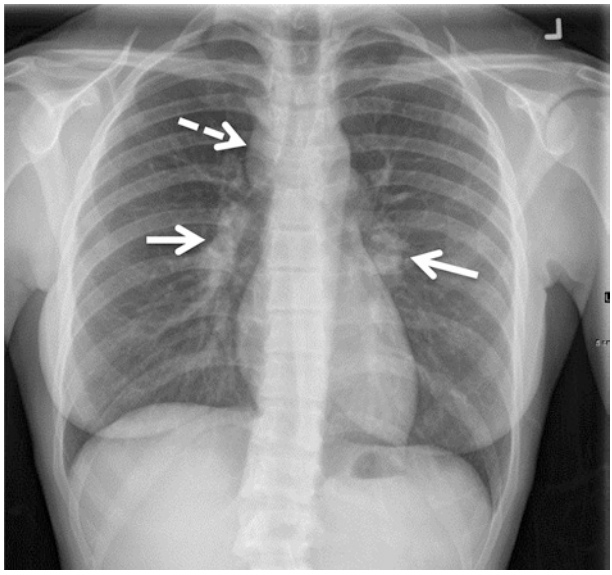


Fig. 12 In this patient with sarcoidosis, the characteristic mediastinal and bilateral hilar lymphadenopathy is present. This is evidenced by widening of the right paratracheal region (dashed arrow) and increased density and lobular contour of the hila bilaterally (solid arrows). No pulmonary parenchymal features of sarcoidosis are demonstrated

Tuberculosis (TB):

- No chapter on the chest radiograph would be complete without mentioning TB. It may present in a variety of ways, and the appearances on chest radiograph are dependent on whether it is primary or post primary infection.
- In **primary TB** (i.e. the time of initial infection), the most common appearances are a patchy area of consolidation (usually apical) with ipsilateral hilar or mediastinal lymphadenopathy. Pleural effusions, particularly large volume effusions, may also occur.
- In **post-primary TB** (i.e. reactivation occurring years later), there may also be patchy consolidation, however cavitation is more likely to occur. Again, the upper lobes are most commonly affected.
- **Miliary TB** is an important consideration and represents hematogenous dissemination of mycobacterium tuberculosis infection. This appears as innumerable nodules measuring 1–3 mm throughout the lung parenchyma.

Suggested Reading

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