Interpretation of the chest radiograph

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The traditional technique used in the acquisition and development of a chest radiograph uses methods similar to those discovered by Roentgen in 1895. The film is exposed, developed, coded, and placed in a packet, and stored for review. However, with the advent of digital radiography and the Picture Archiving and Communication System (PACS), the technique has significantly changed. This allows the images to be viewed remotely and manipulated via a workstation by clinicians in different locations, almost as soon as they are acquired. The radiation dose of a chest X-ray is very small (~0.2 mSv). We receive 13 times this dose (2.6 mSv) annually from natural background radiation emitted from trace radioactive minerals in rocks and building foundations, and cosmic radiation (Table 1).[1]

Today, the chest radiograph remains the most important method of chest imaging, providing an easily accessible, cheap, and effective diagnostic tool. However, it is important to appreciate the limitations and pitfalls of this technique. Studies have shown that 'routine' daily chest radiographs in critical care are neither beneficial nor cost-effective, and that the chest X-ray should be used to answer targeted and specific clinical questions.[2] Refining requests for chest X-rays will result in a higher probability of demonstrating an abnormality that will result in a change in patient management.[3 4]

How to assess a chest X-ray

Evaluation of a chest X-ray may appear to be simple, but is in fact a more complex task, requiring careful observation, sound understanding of chest anatomy and the principles of physiology and pathology. A systematic approach to chest X-ray review is essential to gain the optimum diagnostic information available from the film and to avoid potential errors in the interpretation. The film should be analysed using a light box with low ambient lighting to optimize viewing conditions. It is best to direct your search to specific areas rather than just simply gaze at the entire film, as you are unlikely to pick up abnormalities with your peripheral vision. Images should be viewed in date order to accurately assess changes over time.

Identification label

Verify the patient's identity: name, date of birth, hospital number, and sex. Ensure that you are looking at the correct film: check the date and time it was taken.

Technical considerations[5]

Side marker

Ensure that the orientation is correct. A misplaced marker is much more common than dextrocardia or situs inversus. There have been reports of chest drain insertion on the opposite side to a pneumothorax because of mislabelling.

Projection

Most departmental films are from posterior to anterior (PA), i.e. with the X-ray source situated 1.5–1.8 m posterior to the patient and the X-ray plate positioned immediately anterior to the patient's chest. Where there is difficulty in positioning the patient because of acute illness or general immobility, the film may be taken anterior to posterior (AP); this should be noted on the radiograph. If in doubt, look at the scapulae: in a PA view, the scapulae should be clear of the lungs. Due to divergence of the X-ray beam, the heart and mediastinal structures appear magnified on an AP view, making heart size difficult to assess. If on an AP film the cardiothoracic ratio is $\leq$50%, then the heart size can be considered to be normal; no other accurate comment can be made regarding heart size on an AP film.

Patient positioning

The erect position is optimal for chest radiography. All PA films will be obtained with the patient in standing position, and most AP films with the patient in either standing or sitting position. All supine films are obtained AP, and

Key points

The chest radiograph is an easily accessible, cheap, and effective diagnostic tool. However, it is important to appreciate its limitations and pitfalls.

Studies have shown that 'routine' daily chest radiographs in critical care are neither beneficial nor cost-effective; the chest X-ray should be used to answer specific clinical questions.

Basic knowledge of normal thoracic anatomy is essential when interpreting the chest X-ray.

A systematic approach to chest X-ray review is necessary to gain the optimum diagnostic information and to avoid potential errors in interpretation.

There are five basic Roentgen densities that are distinguishable on any radiograph: gas, fat, soft tissue, bone, and metal.

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Table 1 Comparative radiation doses and risk of fatal cancer of chest X-ray compared with other investigations

	Chest X-ray	Head CT	Abdominal CT
Typical effective dose (mSv)	0.2	2	10
Equivalent period of background 'natural' radiation	28 days	280 days	4 yr
Risk of fatal cancer per examination	1:100 000	1:10 000	1:2000

reserved for sick patients receiving intensive therapy. Again, all films other than those taken PA erect should be labelled with the position. Positioning has a significant influence on the appearance of air, fluid, and blood vessels within the chest:

Air: air tends to rise to the highest point within the chest cavity, which means that a pneumothorax is most commonly seen at the lung apex in an erect position. On a supine film, the highest point in the chest lies adjacent to the heart and mediastinum. A pneumothorax may cause increased lucency adjacent to these structures, which appear to have a better-defined outline than normal, often with no lung edge visible. If a pneumothorax is suspected on a supine view, this may be confirmed by a decubitus view. When the patient lies on the side opposite to the suspected pneumothorax, any air in the pleural cavity will rise to be situated along the lateral chest wall.

Fluid: on an erect film, pleural fluid usually collects at the lung base and appears as dense opacification obscuring adjacent structures. The fluid usually reaches a higher point along the lateral chest wall than along the mediastinum; this is the meniscus sign. On a supine film, the fluid will accumulate along the posterior chest wall, which may produce more diffuse opacification throughout the affected hemithorax. Vascular markings are usually visible within the lung situated anterior to the effusion, which may be confused with consolidation within the lung.

Pulmonary vessels: on a supine film, the upper lobe vessels are normally similar in calibre in both the upper and lower lobes, compared with an erect film where the upper lobe vessels are normally smaller because of gravity.

Attempts to obtain an AP erect film may result in a lordotic positioning; this is where the patient leans backwards slightly so that the shoulders lie closer to the X-ray plate than the lower chest. Normally, the clavicles are projected over the lung apices and overlap the anterior first ribs. With a lordotic film, the clavicles are projected higher than normal and may be seen to lie above the lung apices; the ribs also appear more horizontal. This also has the effect of magnifying the heart and mediastinum. In addition, it may cause hazy opacification at the lung bases as a result of increased overlying soft tissues (Fig. 1A).

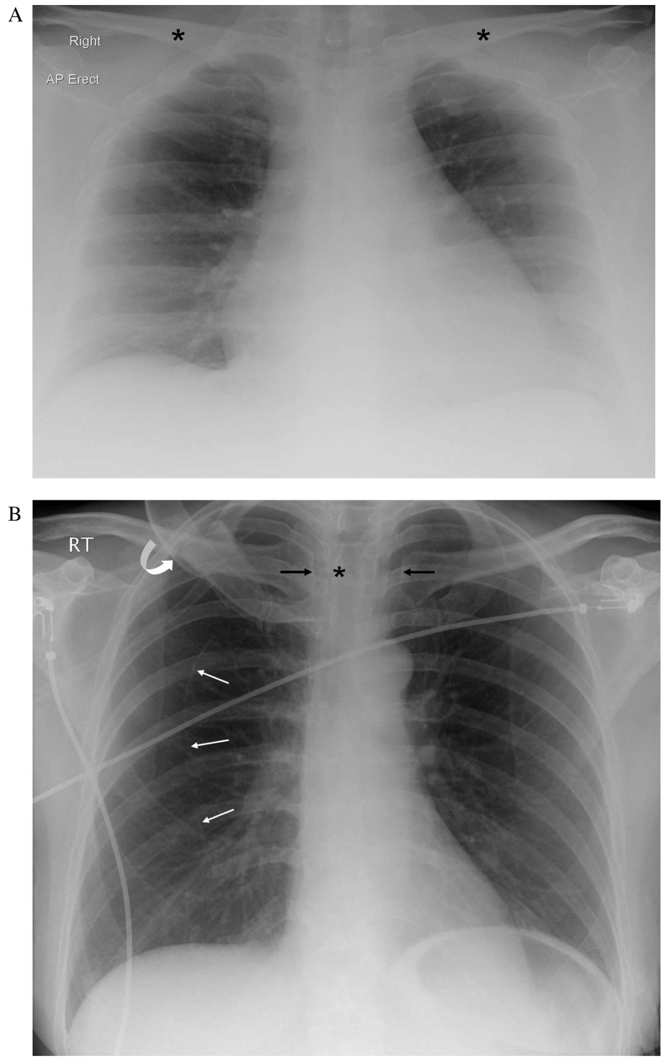

Fig. 1 (A) Lordotic AP film: note the position of the clavicles (*) that are projected higher than normal over the lung apices. The right clavicle is superimposed on a coincidental cervical rib. There is apparent mediastinal widening and enlargement of the heart. The hazy shadowing in both lower zones is because of the overlying soft tissues. (B) Rotated AP film: the spinous processes (*) lie closer to the medial end of the right clavicle than the left (black arrows); the patient is rotated to the left. In this case, the heart size still appears within normal limits and the lungs bases clear. Note the presence of artefacts because of an oxygen mask and tubing in the right upper zone (curved white arrow), and ECG leads. There is also a curvilinear line projected over the right lung because of a hospital sheet (straight white arrows); note that the pulmonary vessels traverse this line to reach the lung periphery, excluding the possibility of a pneumothorax.

Rotation

This should be minimal and can be assessed by looking at the medial ends of the clavicles; these should be equidistant from the thoracic spinous processes. Rotation may cause a spurious increase in cardiac size and increased opacification at the lung bases because of the overlying soft tissues.

Penetration

With the correct exposure factors, the end plates of the lower thoracic vertebral bodies should be just visible through the cardiac shadow. An under-penetrated film looks diffusely opaque (too white), structures behind the heart are obscured, and left lower lobe pathology may be easily missed. An over-penetrated film looks diffusely lucent, the lungs appear blacker than usual and the vascular markings and lung detail are poorly seen.

Lung volume

Full inspiration is required to detect intrapulmonary abnormalities. The diaphragm should be seen at the level of the 8th–10th posterior ribs or the right 6th anterior rib with good inspiration. Poor inspiration may cause increased opacification of the lungs because of atelectasis, most commonly affecting the lung bases.

Artefacts

Not all opacities on chest films originate in the lungs. Common artefacts include ECG stickers, the patient's hair and clothing, and hospital bedding. The presence of an opacity with a very well defined margin, or one that is projected over both the lung and adjacent soft tissues should prompt a visual examination of the chest wall (Fig. 1B).

Systematic search[6]

Various systems may be used. The illustrative approach we have chosen is an A B C review, similar to the method taught in Advanced Trauma Life Support (ATLS).

A: airway—large airways, lung, and pleura

Check whether the trachea is midline or deviated. The carina lies at the T4 level on expiration and will move inferiorly to T6 on inspiration. In adults, the right main bronchus has a steeper angle than the left, but the angles are symmetrical in children.

The lungs are divided into lobes by fissures; the right lung has three lobes and left has two lobes. The oblique fissures, separating the upper from the lower lobes, are not usually seen as they are positioned facing the toward X-ray beam. Part of the horizontal fissure, separating the right upper and middle lobes and lying tangential to the beam, is seen in about 50–60% of patients. Most commonly, the lateral portion is seen in contact with the chest wall at the level of the right 6th rib.

B: bones—clavicles, ribs, and spine

Review of the ribs, clavicles, scapulae, and spine is needed to look for fractures and bone destruction. The ribs and intercostal spaces should be symmetrical.

C: circulation—heart, mediastinum, and vascular markings

Knowledge of the normal anatomical structures that form the mediastinal and cardiac outline is essential to detect abnormality. On the left, the outline is formed from superiorly to inferiorly by the left brachiocephalic vein, the aortic knuckle, the left main pulmonary artery, the left atrial appendage, and left ventricle. Similarly, the right is formed by the right brachiocephalic vein, the superior vena cava and right pulmonary artery, and the right atrium and inferior vena cava.

D: diaphragm

Check the shape, height, and angles. The right diaphragm should be ~1–3 cm higher than the left. Look through the diaphragmatic shadow for pathology in the lung bases and the pleural reflections for evidence of pleural fluid.

E: review areas

Lines and tubes: check position and look for complications, e.g. pneumothorax (Fig. 2A).

Central lines should pass to the lower superior vena cava, and should not enter the right atrium.

Pulmonary artery catheters should not be wedged into small branches.

Endotracheal tubes should have the tip at least 3 cm above the carina, optimally midway between the carina and thoracic inlet.

Gastric tubes should pass below the diaphragm and into the stomach.

Chest drains—check the position. The tip of the tube should lie in an effective position, and not be misplaced or displaced into lung tissue.

Areas where pathology is commonly missed:

Apices: avoid missing masses, consolidation, or a small pneumothorax.

Behind the heart: look for lobar collapse and hiatus hernia (Fig. 3).

Hila: look for masses or lymphadenopathy. The left hilum will be 1–2 cm higher than the right.

Below the diaphragm: look specifically for tubes and free gas.

Soft tissues: look specifically for breast shadows or mastectomy, and surgical emphysema.

Useful signs and hints

Silhouette sign

This is one of the most useful signs in chest radiology, first described and published in 1950 by Dr Ben Felson.[7] The silhouette sign describes the loss of a normal lung/soft tissue interface or "silhouette", caused by any pathology which either replaces or displaces normal air filled lung. This sign is commonly applied to heart, mediastinum, chest wall and diaphragm. For example, right lower lobe consolidation may obliterate part or all of the right hemidiaphragm, but the right cardiac border would still be clearly defined due to normal aeration of the adjacent middle lobe.

Air bronchogram

This commonly signifies alveolar disease (any cause of consolidation, see below), but may be seen in atelectasis. On a normal

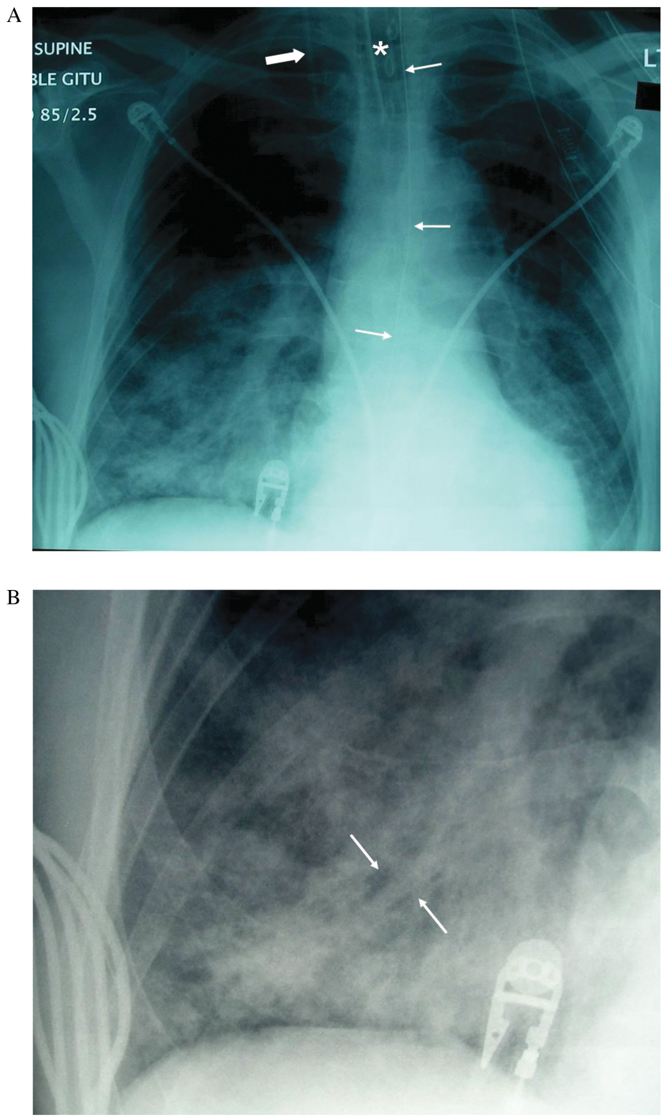

Fig. 2 (A) Portable supine film: with a tracheal tube (*) and right internal jugular line (large arrow) in situ in satisfactory positions. A nasogastric tube (thin arrows) is also present, the distal portion of which is poorly seen through the cardiac shadow. Note the opacification in both mid and lower zones, in this case because of fluid overload. (B) Magnified view of the right lung base: The opacification appears 'fluffy', indicating alveolar consolidation. Within the consolidation, there are several linear lucencies representing air bronchograms.

radiograph, the bronchi are not normally visible unless seen end on, or if there is bronchial wall thickening. When the alveoli no longer contain air and opacify, the air-filled bronchi passing through the same area may be visible as branching linear lucencies, or air bronchograms (Fig. 2B).

Consolidation

Consolidation is the result of filling of the alveoli by any cause, e.g. fluid (e.g. pulmonary oedema), pus, blood (e.g. pulmonary

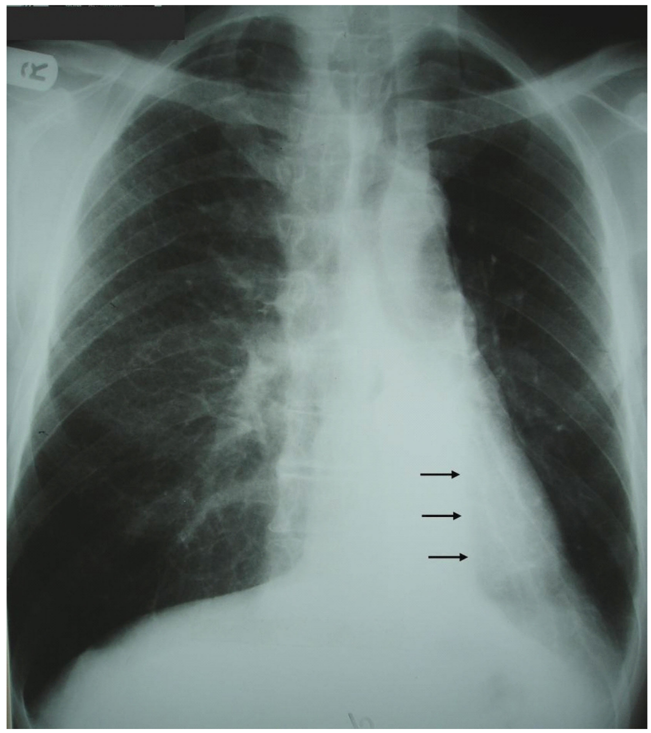

Fig. 3 Left lower lobe collapse: even allowing for patient rotation, there is volume loss within the left hemithorax. The edge of the collapsed, left lower lobe is visible through the cardiac shadow (black arrows). Note the paucity of pulmonary vessels on the left compared with the right, because of hyperinflation of the left upper lobe.

haemorrhage), and tumour (especially bronchioloalveolar cell carcinoma). Clinical correlation is therefore essential to make the diagnosis. For example, if a patient has a cough and fever, then infection is the likely cause, whereas aspiration should be suspected in patients with a known predisposing factor such as a recent seizure or episode of unconsciousness.

Pleural effusion

On average, >150 ml must be present for a pleural effusion to be detected on an erect chest X-ray. Smaller volumes (>75 ml) may be detected on a decubitus view, with the patient lying on the side of the suspected effusion.

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Please see multiple choice questions 1–4