Chest imaging in the intensive care unit

Rakesh Bhandary

Abstract
Radiological imaging is an indispensable investigation for critically ill patients. Newer modalities (e.g. ultrasound, magnetic imaging) are also increasing in usefulness. This article looks at the commonly employed imaging investigations in critically ill patients, their indications and problems associated with them.

Keywords Angiography; computed tomography; intravenous contrast; radiation; radiology; ultrasound

Digital radiography

Digital radiography has largely replaced conventional radiological imaging in many healthcare systems. In digital radiography, a digital screen replaces the X-ray film. The tissue absorption characteristics are computer analysed and the image visualized on a monitor. With this method, radiological departments are now filmless and images can be viewed using the Picture Archiving and Communications System (PACS). The principal advantages of digital over traditional radiography are:

- significant reduction in radiation exposure
- adequate quality of images due to digital enhancement
- easy transfer of images out of radiology department
- easy and rapid retrieval of previous images and report
- reduction in storage space requirement compared to conventional image films
- no degradation in quality of images over time compared to conventional films.

Radiological modalities

Chest X-ray

Chest X-ray (CXR) is the most common ITU imaging modality and is frequently the first radiological investigation requested. Although the standard postero-anterior projection (P-A) view produces the best quality images, this is frequently impractical in the critically ill. Other views include lateral, antero-posterior (A-P) and supine. A-P or supine views are commonly used for ill patients in the ICU, although with these views, it is difficult to assess heart size or a 'widened mediastinum'. They also show less of the lung fields.

Indications for chest X-ray: chest X-rays can be performed easily on the ICU, but unnecessary requests and consequent radiation exposure should be avoided. The Ionising Radiation (Medical Exposure) Regulation 2000 (IRMER), with subsequent amendment in 2006 and 2011, requires that all medical exposures to ionizing radiation must go through a referral and justification process prior to the exposure, and a clinical evaluation of the results must be made and recorded after the exposure.

Chest X-rays are indicated for:

- Diagnosing commonly encountered pulmonary parenchymal and pleural space abnormalities (e. g. pneumonia, pulmonary oedema, pleural effusion, pneumothorax).
- Monitoring the progress of disease process in the ICU, e. g. acute respiratory distress syndrome. However, there is no evidence for requesting routine daily chest X-rays in ICU patients.[1]
- Confirming correct placement of tubes and invasive lines, e.g. central venous catheter, feeding tube, chest drains, endotracheal tubes, tracheostomy tube, and pulmonary artery catheter. Informing the radiographer of this indication means they can often adjust the technique in acquiring the film, or repeat the film automatically if the line position is not clear.
- Ruling out complications from invasive procedures, e.g. pneumothorax following central venous catheter insertion.

Viewing the chest X-ray: as a routine practice, the chest X-ray should be viewed in a systematic manner, looking at the lung parenchyma, hila, cardiac shadow, mediastinum, diaphragm, skeletal and soft tissues.

The individual may decide their own system. Whichever system one uses should be logical, sequential and comprehensive to ensure subtle defects are not overlooked, particularly in the presence of obvious, distracting abnormalities.

The five basic Roentgen densities distinguishable on any radiograph are: gas, fat, soft tissue, bone, and metal. Gas or air has poor absorption and appears dark (almost black) while bone and metal absorbs more energy and appears white. Commonly encountered radiological patterns on the CXR can be seen in Table 1.

After checking the identifying information on the film to ensure the film relates to the correct patient, correct image, side marker, and whether P-A or A-P, the chest X-ray is checked for the following:

- Film quality — How likely is the information you acquire from the film to be precise. The challenges of the critical care unit film can be exacerbated by patients' condition such as poorly compliant lungs or their inability to cooperate.

Penetration (exposure) is adequate when the lower thoracic spine is just visible.

- Rotation — The upper thoracic spinous processes are midway between the clavicular heads. The mediastinum and trachea move in the same direction as the clavicles in the rotated film. Rotation of the image may give the impression of mediastinal shift or lobar collapse.
- Inspiration — On an inspired image, 5–6 ribs can be counted anteriorly on the right side
- Soft tissues. The trachea lies in the midline and bifurcates at the level of T6. It deviates slightly to the right at the level of aortic knuckle.
- Mediastinum. The challenges of the ICU film in determining abnormally sized structures have been mentioned.

__Rakesh Bhandary__ MB BS FRCA EDICM is a Consultant in Critical Care Medicine and Anaesthesia at University Hospital of North Tees, Stockton-on-Tees, UK. Conflicts of interest: none declared.

Examples commonly encountered radiological patterns on CXR

Reticular shadow	Produced by thickening of the interstitial tissue around the alveoli as in pulmonary fibrosis (Figures 1 and 2)
Consolidation	Air in the alveoli is replaced by fluid or tissue resulting in homogenous shadowing e.g. pneumonia. Patent airways may be seen as linear lucent streaks, referred to as bronchograms
Nodular shadowing	Discrete rounded opacities measuring 1—5 mm in diameter seen in pneumoconiosis, sarcoidosis, or miliary tuberculosis
Mediastinal shift	Seen with lobar collapse; mediastinum is pulled towards the side of the lesion. With significant pleural pathology, the mediastinum is pushed to the opposite side
Raised hemidiaphragm	Seen with basal pulmonary atelectasis, phrenic nerve injury or abdominal pathology
Obliteration of costophrenic angle	Seen with intra-pleural fluid accumulation e.g. pleural effusion, haemothorax (Figure 3)
Signs of cardiac failure	Appearances vary from upper lobe vein diversion, to interstitial fluid accumulation (Kerley A and B lines) and fluid in the right horizontal fissure; to frank alveolar oedema spreading outwards from the hilum (Bat's wing appearance)

Table 1

- Cardiac shadow: The right atrium is just to the right of the thoracic spine, the inferior border is formed by the right ventricle and left border by the left ventricle. Heart chamber size is always best assessed by echocardiography. The hila are central mediastinal structures, predominantly formed by pulmonary arteries. The left hilum is smaller and slightly higher than the right. If they are the same height it is suggestive of some lung collapse.
- Diaphragm. The right leaf is usually higher than the left, though occasionally the converse may be true. In the event that it appears thicker than 3 mm, any gas demarcating its edge is likely in the gut rather than suggestive of pneumoperitoneum.
- Lung fields. The two sides should be of similar lucency. The intrapulmonary arteries radiate from the hila and taper towards the periphery. This contributes to the majority of the lung markings, with a smaller component from the pulmonary veins. The lung fields are divided into three lobes (upper, middle and lower lobe) on the right and two lobes (upper lobe including the lingula and lower lobe) on the left. Note the position and thickness of the horizontal fissure.

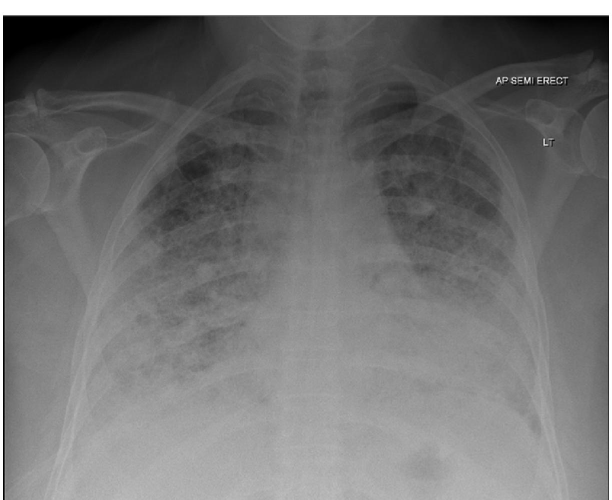

Figure 1 AP view of chest in patient with bilateral reticular shadowing — the patient had idiopathic pulmonary fibrosis. The CXR shows added areas of superimposed infection.

Abnormal pathologies may be distinguished by the pattern of shadowing within the lung fields, although in critical care they may coexist such as in adult respiratory distress syndrome (ARDS). Table 1 outlines some commonly encountered appearances. Clear knowledge of the patient's history will help in interpreting the X-ray appearance. Repeated films over time may help clarify pathology such as in ARDS where a progression from central pulmonary alveolar shadowing to a more generalized appearance is seen.

Pulmonary pathology may be obscured by bony or soft tissue elements leading to 'blind spots' such as masking of basal segments of the left lower lobe by the left ventricle, the lungs apices or behind the hila. Pneumothoraces can be easily missed on the supine film and the large bullae seen in severe emphysema may be misinterpreted as a pneumothorax.

Further attention should be given to the presence of fluid blunting the costophrenic angle. This rarely has the clear meniscus of the erect chest film and can be difficult to distinguish from other causes of increased density, especially given that those pathologies, such as basal pneumonia, can often coexist.

Any masses should be noted, whether they are cavitating or homogenous, regular or irregular, or indeed multiple, as in the case of septic emboli or pulmonary metastases.

- Skeletal structures. It is often beneficial to compare both sides repeatedly to clarify any perceived abnormalities.

Pitfalls in chest X-ray interpretation:

- The image may be under-exposed or over-exposed.
- Rotation of the image may give an impression of mediastinal shift/lobar collapse.
- The cardiac shadow is magnified on the A-P view and it may cause difficulty in identifying true cardiomegaly.
- Large emphysematous bullae or occasionally a hiatus hernia may be misinterpreted as pneumothorax.
- Pulmonary pathology may be obscured by bony or soft tissue elements leading to 'blind spots' on frontal view X-rays (e.g. masking of basal segments of left lower lobe by the left ventricle.

Ultrasound

Ultrasound employs high frequency (typically 2—7 MHz) sound waves, produced by a piezo-electric crystal in a transducer. The