Chest radiograph interpretation for critical care nurses

Heleen Hanekom, MBChB(Pret), FC Rad Diag(SA), MMed Rad D(Wits)
University of Pretoria, Faculty of Health Sciences, School of Clinical Medicine, Department of Diagnostic Radiology
Correspondence to: Dr Heleen Hanekom, e-mail: heleen.hanekom@yahoo.com

Abstract

Chest radiographs are one of the most common radiological investigations performed in a critical care setting and play a fundamental role in patient evaluation. Basic understanding of radiographic technique, anatomy and major pathologies is therefore essential for critical care nurses.

Prof Nurs Today 2018;22(3):25-33

Introduction

Chest radiographs are one of the most common radiological investigations performed in a critical care setting and play a fundamental role in patient evaluation. The uses are almost limitless and range from confirming line and tube placements to evaluating possible causes for deteriorating patients. In many intensive care units chest radiographs are performed routinely or even daily on certain patients within the unit.

The critical care nursing staff are often the first to review the images and may be able to prevent delays in patient care by interpreting major abnormalities before the managing physician has reviewed the image, or the radiologist's report becomes available.

Basic understanding of radiographic technique, anatomy and major pathologies is therefore essential for critical care nurses.

Indications for routine chest radiography

The American College of Radiology recommends routine portable chest radiographs in the following situations[1]:

- patients that are newly admitted to the intensive care unit (ICU)
- after insertion of a new line, tube or catheter to confirm positioning
- in stable or mechanically ventilated patients a chest radiograph is only appropriate for a clinical indication
- patients that are clinically deteriorating

Radiation safety

Radiographic images are obtained with the use of ionising radiation. During the acquisition of a radiograph, scattered radiation is produced. In ideal circumstances patients are imaged in the radiological unit where shielding is routine. In the ICU, where shielding is limited, all healthcare providers, including the nursing staff, should be vigilant about protecting themselves as well as other patients from unnecessary radiation exposure. Any staff member that is required to be in close proximity to the patient during image acquisition should wear lead shielding and pregnant staff should avoid all radiation exposure.

One of the most practical methods to reduce radiation exposure is by increasing the distance between the radiation source and the staff member. By doubling the distance between the staff member and the radiation source, the radiation dose is reduced four-fold i.e. standing further away from the X-ray machine has a marked impact on radiation exposure.

Technical considerations

The first and most important consideration is to always confirm that the correct patient is being imaged and subsequently that the correct radiograph is reviewed for the patient in question.

Objects such as jewellery, ECG leads, oxygen tubing, clothing and even hair or hair extensions can result in prominent artefacts on the radiograph and should be removed if possible to improve image quality.

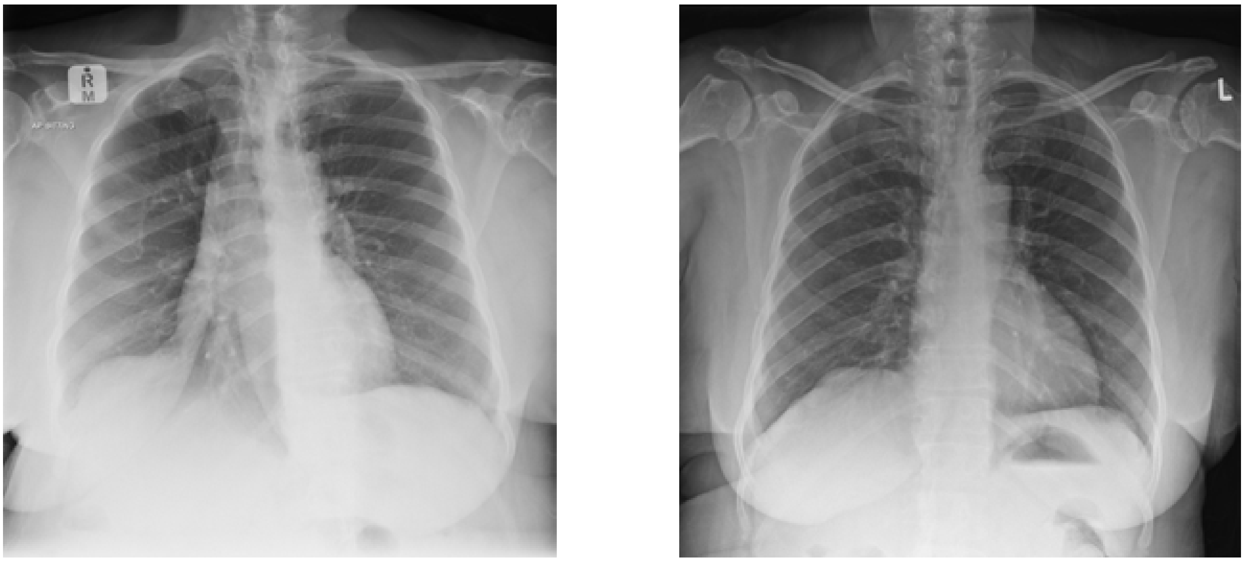

Figure 1. Chest radiographs of an adult female patient demonstrating the effect of rotation on the image quality. Figure 1a – rotated image, Figure 1b – straightened image.

Patient positioning is of importance as it dictates the image quality and the diagnostic value of the radiograph.

The patient should be aligned with the film at the time of image acquisition. Patient rotation should be limited and can be evaluated in an adult patient by comparing the distances between the medial ends of the clavicles and the spinous processes, which should be equal if the patient is adequately aligned. A rotated view results in distortion of the mediastinum, cardiac silhouette as well as the lungs and reduces image quality (Figure 1).

A standard chest radiograph is taken in a postero-anterior (PA) projection with the patient in a standing position and at maximum inspiratory effort. This is, however, rarely possible in a critically ill patient. The patient's condition usually necessitates that the radiograph is taken using a mobile unit with the patient in a supine or sitting position with an antero-posterior (AP) projection.

The suboptimal AP projection results in magnification of the cardiac silhouette and mediastinum and may result in apparent cardiomegaly. Supine positioning further alters the pulmonary vasculature physiology resulting in the diversion of blood to the lung apices. This appearance would have been regarded as pathological in a standard erect PA radiograph but is considered normal in a supine AP radiograph.

Further challenges with supine AP radiographs are that pleural effusions and pneumothoraces layer in the posterior and anterior aspects of the thoracic cavity respectively and are consequently difficult to differentiate from air-space disease (Figure 2) .

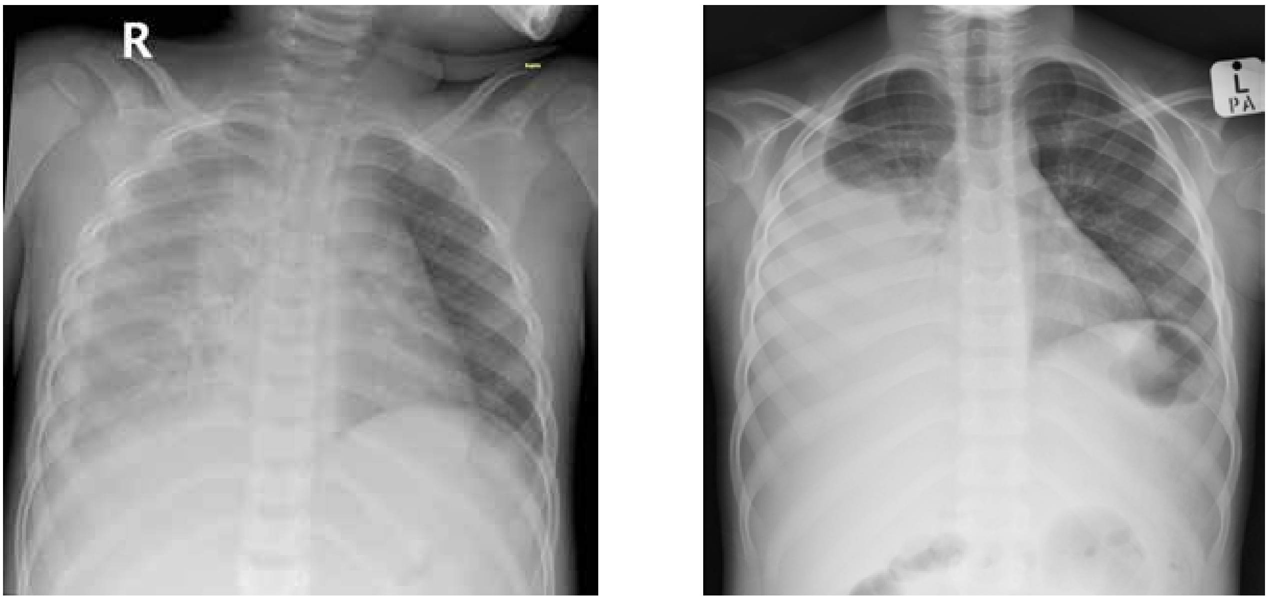

Figure 2. Chest radiographs of an infant demonstrating a right pleural effusion on a supine (a) and erect (b) radiograph of the same patient.

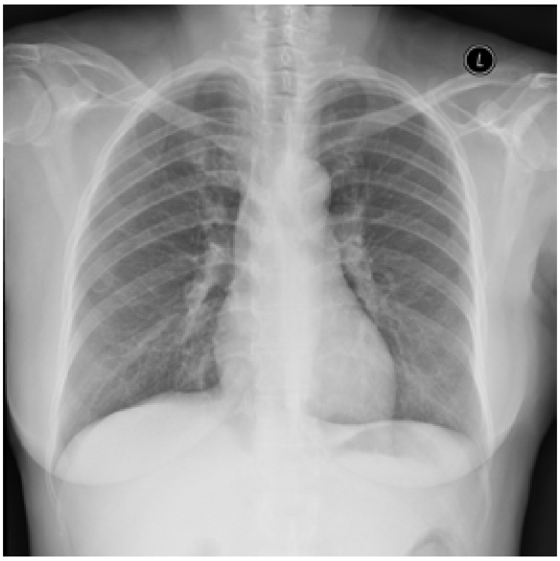

Figure 3a. Chest radiograph of an adult female patient demonstrating normal radiographic anatomy.

Another technical limitation is that an adequate inspiratory effort is often not possible in critically ill patients due to altered mental status or pain. Inadequate inspiration results in crowding of the vascular markings as well as a hazy appearance to the lungs, limiting assessment of basal atelectasis and pulmonary oedema. The appearance of the heart and mediastinum is also altered resulting in apparent cardiomegaly. Inspiratory effort is evaluated by counting the number of ribs visualised above the diaphragm. The inspiratory effort is deemed to be adequate if the sixth anterior rib intersects the diaphragm or if nine posterior ribs are visible above the diaphragm.

Normal radiographic anatomy (Figure 3)

Radiographic appearance is dependent on the density of the imaged tissue or structures. Low density structures such as the lungs comprised predominantly of air, appear black (radiolucent), whereas dense structures, such as bone, appear white (radiopaque).

A well-known system used to evaluate a chest radiograph is the 'ABCDE' system:

A. Airways (trachea and main bronchi)

The trachea should be in the midline and patent. A tension pneumothorax or large pleural effusion may cause the trachea to deviate away from the side of the pathology. In the case of a collapsed lung the trachea may be pulled towards the side of the pathology.

B. Breathing (lungs)

Evaluate the lungs by comparing the apices, mid zones and lower zones of the lungs with one another. Carefully trace the borders of the lungs to ensure the lung markings extend to the periphery and to evaluate for the presence of pneumothoraces.

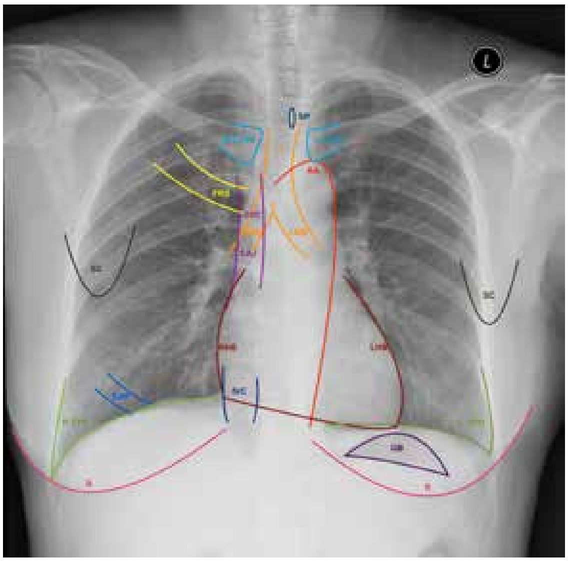

Figure 3b. An annotated chest radiograph of an adult female. AA – aortic arch, B – breast shadows, C – carina, CAJ – cavo-atrial junction, CPR – costophrenic recess (Left and Right), CLAV – medial ends of the clavicles (Left and Right), FRS – first anterior rib space, IVC – inferior vena cava, GB – gastric bubble, LHB – left heart border, LMB – left main bronchus, RHB – right heart border, RMB – right main bronchus, SAR – sixth anterior rib intersecting the diaphragm, SC – inferior tip of scapula blade, SP – spinous process of vertebral body, SVC – superior vena cava, T -trachea.

*Note that the patient is slightly rotated, as the medial ends of the clavicles are not equidistant from the spinous process of the vertebra.

C. Circulation (heart and mediastinum)

Evaluate the cardiac silhouette and mediastinum. A cardiac silhouette larger than 50% of the chest diameter indicates cardiomegaly (Figure 4) and a mediastinal diameter larger than 8 cm is consistent with mediastinal widening. An important caveat is that this is only accurate in an erect PA radiograph. In an AP supine radiograph, commonly done in a critical care setting, there may be

Figure 4. Chest radiograph of an adult female patient demonstrating cardiomegaly (markedly increased cardiothoracic ratio).

apparent widening of the mediastinum and cardiac silhouette due to technical factors.

Also evaluate for abnormal lucency within the mediastinum or surrounding the cardiac silhouette that may suggest pneumomediastinum or pneumopericardium.

D. Diaphragms (above and below)

The right hemidiaphragm is usually slightly higher than the left. Outline both hemidiaphragms as well as the costophrenic recesses. If the diaphragms are obscured or the costophrenic recesses are blunted it may indicate lower lobe pathology or pleural effusions.

Inspect the area below the hemidiaphragms by evaluating for abnormal lucency (pneumoperitoneum).

E. Everything else (foreign bodies, bony skeleton and soft tissues)

Evaluate the lines, tubes and monitoring devices. Even though this is the last step in the approach, it is usually the first aspect of the film that is evaluated.

Inspect the bony skeleton. Look for fractures in a trauma patient or bone lesions (lucent or sclerotic) in a patient with possible malignancy. The bony structures outside the chest, e.g. the shoulders, are often overlooked. Evaluate the soft tissues for lucency (soft tissue emphysema), foreign bodies or other masses.

Correct positioning of lines and tubes[2]

Knowledge of the correct placement of indwelling catheters and monitoring devices is vital. Not only are these catheters and devices key in the management of patients but the incorrect placement can lead to dire complications (Figure 5).

- Nasogastric tube (NGT): the tip should be within the stomach (below the left hemidiaphragm), at least 10 cm distal to the gastro-oesophageal junction. A naso-enteric tube should be placed with the tip at least 10 cm into the small bowel (Figure 5).
- Endotracheal tube (ETT): the tip should be 5 cm above the carina*, approximately at the level of the medial ends of the clavicles. The minimum distance between the tip of the tube and the carina should not be less than 2 cm (Figures 5, 6).
- Central venous catheter (CVP): the tip should be in the superior vena cava (SVC) or at the cavo-atrial junction**. This correlates to approximately the first anterior intercostal space or the tip of the catheter lying at or immediately above the level of the carina (Figures 5, 7).
- Pulmonary artery (Swan Ganz) catheter: during measurements the catheter tip should be placed within the right or left pulmonary artery. On chest radiograph the tip should not extend more than 1 cm lateral to the mediastinal margin or past the pulmonary hilum.
- Thoracostomy tube/intercostal drain: the drain is placed to treat a pneumothorax or drain pleural fluid and the positioning depends on the indication. The drain is usually placed anterosuperiorly to drain a pneumothorax and posteroinferiorly to drain pleural fluid. The tube should be inserted such that the last side hole (marked by an interruption in the radiopaque line on the tube) is within the thoracic cavity (Figure 5).
- Cardiac pacemakers and defibrillators: many different devices exist and the placement depends on the device used. AP and lateral radiographs are required to definitively confirm placement. There should be no sharp angulation in the course of the wires (Figure 8).
    - Single-lead pacemaker: tip in the right ventricular apex.

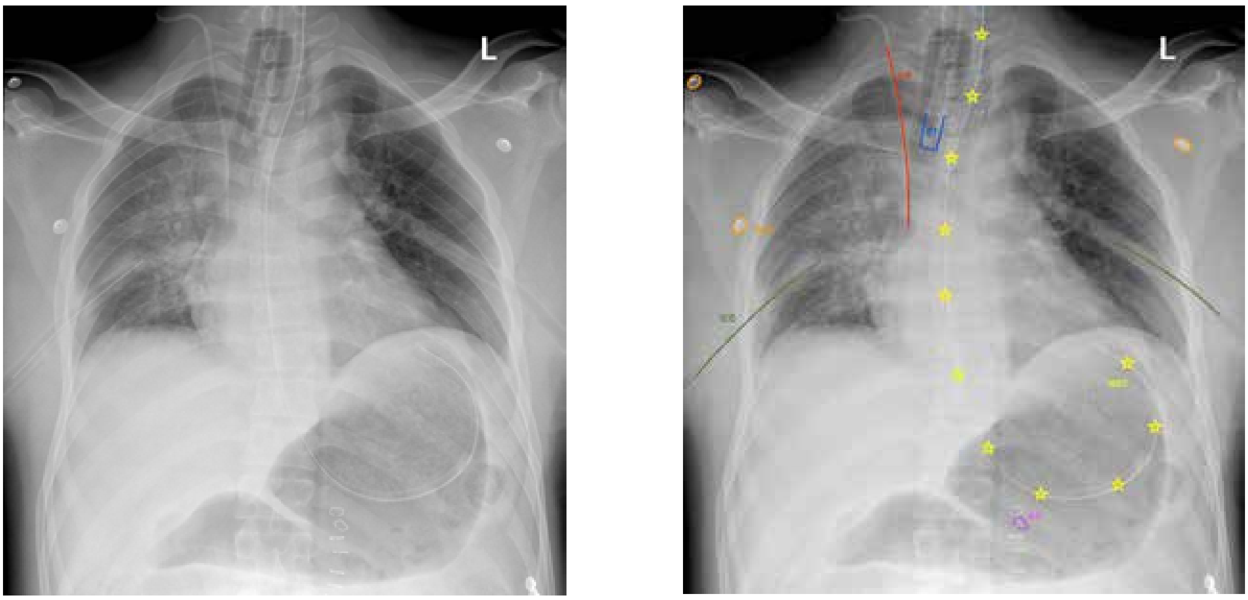

Figure 5. Chest radiograph of an adult patient demonstrating an endotracheal tube (ETT), nasogastric tube (NGT), central venous line (CVL) and bilateral thoracostomy tubes in the correct positions. Also note the presence of ECG leads (ECG) and abdominal surgical clips (SC).

* carina – bifurcation of the trachea

** cavo-atrial junction – the area where the SVC joins the right atrium

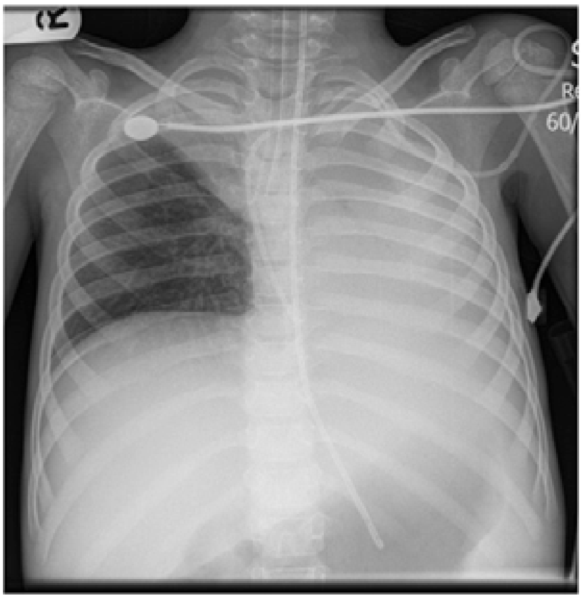

Figure 6. Chest radiograph of a child demonstrating a malpositioned endotracheal tube with the tip in the right main bronchus with resultant collapse of the right upper lobe and left lung. Also appreciate the left subclavian central venous line with the tip extending into the right atrium (too deep).

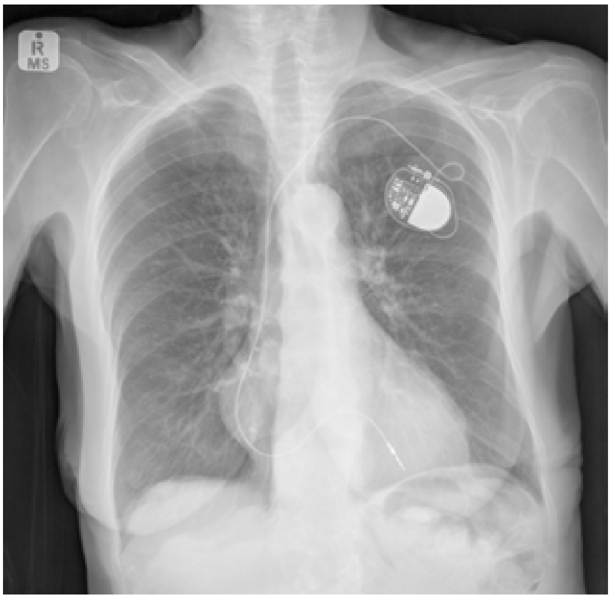

Figure 8. Chest radiograph of an adult patient with a single-lead pacemaker, the tip correctly sited in the right ventricle.

- Dual chamber/two-lead pacemaker: 2 leads, with the tips in the right atrium and right ventricular apex respectively.
- Biventricular pacemaker: tips in the right atrium, right ventricle and coronary sinus.
- Implantable defibrillator: the lead is wider than that of a pacemaker and the tip should be in the apex of the right ventricle.

- Paediatric lines (Figures 9, 10):
  - Umbilical vein catheter: courses superiorly (cephalad) to the right of the midline, overlies the liver, with the tip in the inferior vena cava (IVC) at the base of the right atrium (approximately level of T8-T9 vertebrae).
  - Umbilical artery catheter: extends inferiorly from the umbilicus, looping in the pelvis before extending superiorly (cephalad) to the left of the midline. The tip should either be in the preferred high position (T6-10 level) or low position (L3-4 level).

Figure 7. Chest radiograph demonstrating a malpositioned central venous catheter. The tip of the left subclavian central venous catheter is in the left internal jugular vein. The right subclavian central venous catheter is correctly sited.

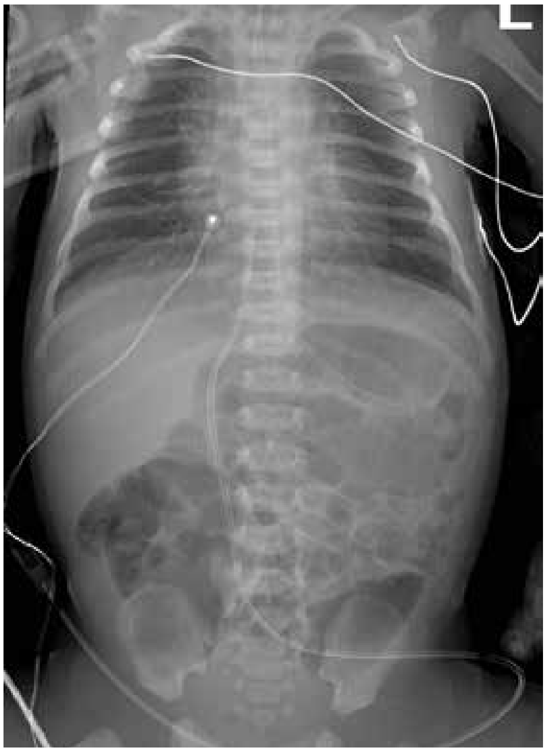

Figure 9. Radiograph of a neonate demonstrating an umbilical venous catheter, endotracheal tube and nasogastric tube in the correct positions.

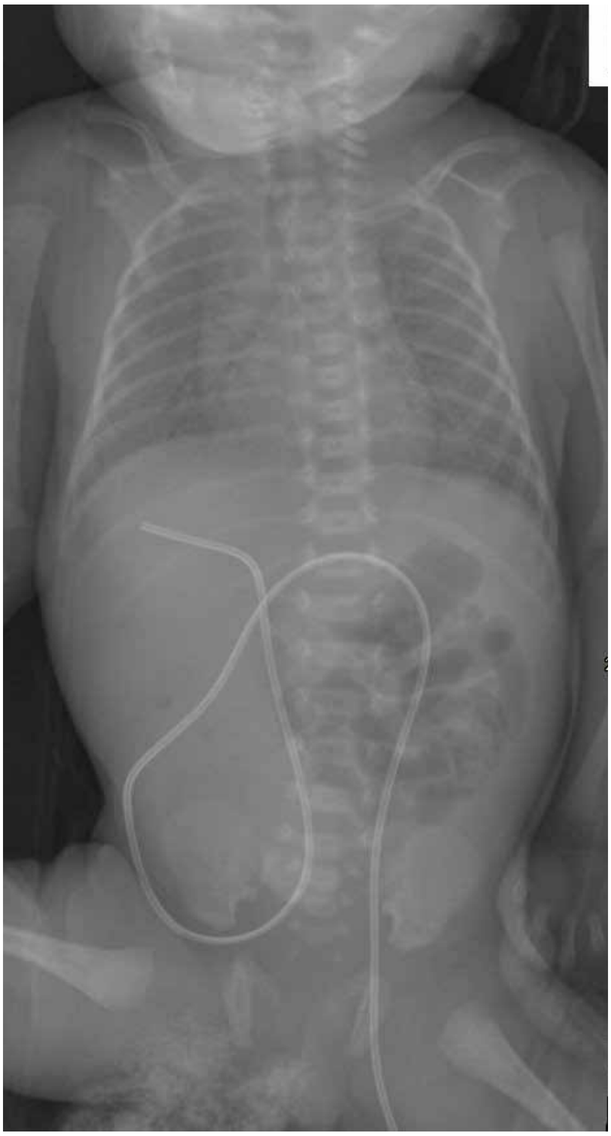

Figure 10. Radiograph of a neonate demonstrating a malpositioned umbilical venous catheter with the tip in a hepatic vein.

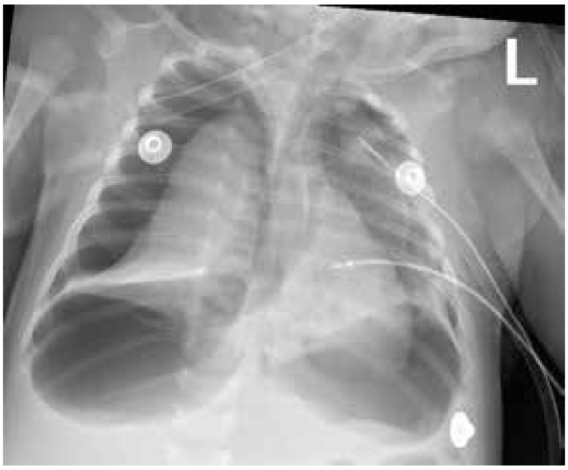

Figure 12. Chest radiograph of a neonate demonstrating bilateral tension pneumothoraces as evidenced by the depression of bilateral hemidiaphragms. The mediastinum remains central due to bilateral pathology.

Major pathology

The possible pathologies visualised on a chest radiograph in a critically ill patient are vast and the possible combinations of pathologies further complicate evaluation and interpretation. There are, however, certain main concepts that are more frequently encountered and knowledge of these is essential.

- Air in abnormal places:
  - Pneumothorax (Figures 11, 12):

    A pneumothorax describes the presence of air within the pleural space. This may occur spontaneously, secondary to trauma or as a result of parenchymal lung disease.

    Air within the pleural space usually displaces to the non-dependent position and the radiographic

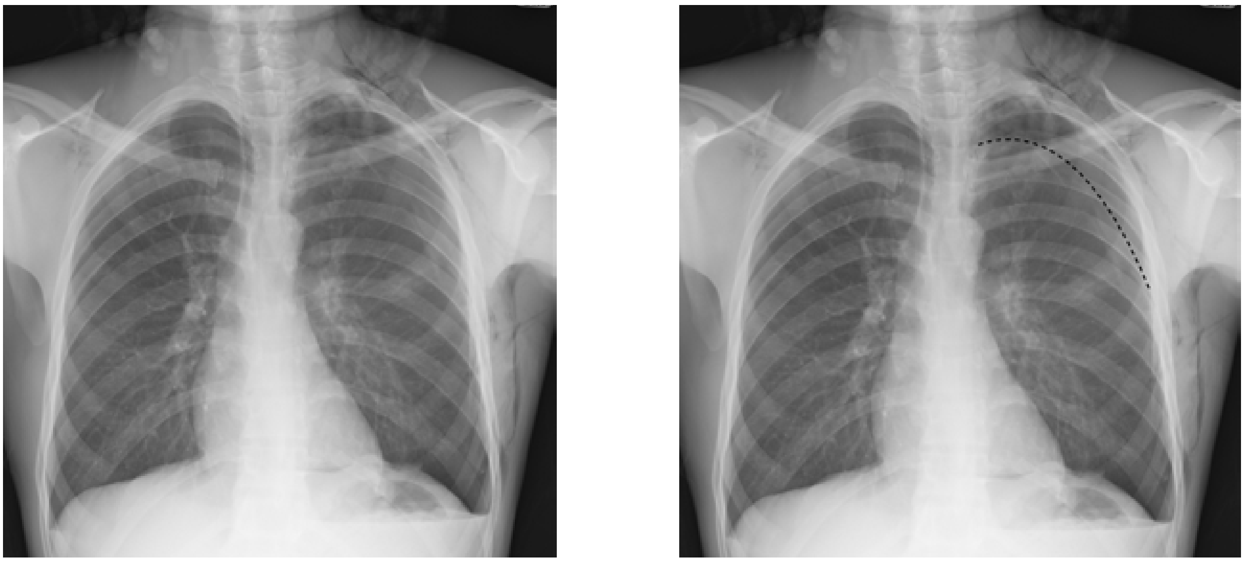

Figure 11. Chest radiograph demonstrating a left pneumothorax (dotted line) with soft tissue emphysema of the chest wall. Also note the artefact overlying the soft tissues of the neck secondary to hair extensions.

appearance is therefore directly related to patient positioning. In an erect patient a crescenteric lucency is usually seen at the lung apex, depending on the size of the pneumothorax, with an adjacent thin pleural line and the absence of lung markings extending to the periphery. In a supine patient, the free air rises anteromedially. The free air may extend into the costophrenic recesses resulting in a 'deep sulcus sign' or may be trapped in the subpulmonic area.

A tension pneumothorax results when there is persistent accumulation of air within the pleural cavity without outflow of free air secondary to a ball-valve effect. This continues until the intra-thoracic pressure exceeds atmospheric pressure and leads to cardiac and respiratory compromise. Classically, mediastinal shift away from the side of the pathology is seen on chest radiograph. In critically ill patients, decreased lung compliance secondary to ARDS (acute respiratory distress syndrome) and PEEP (positive end expiratory pressure) ventilation may prevent mediastinal shift. Other radiographic features include depression of the ipsilateral hemidiaphragm as well as shift of the cardiac border.

- Pneumomediastinum (Figure 13)

Free air within the mediastinum (pneumomediastinum) may result from an airway or oesophageal injury or may extend from soft tissue emphysema in the neck or retroperitoneum.

Radiologically, air can be seen outlining the great vessels including the superior vena cava (SVC) and azygos vein.

Figure 13. Chest radiograph of an adult patient demonstrating pneumomediastinum.

- Pneumopericardium

Pneumopericardium describes the presence of air trapped between the pericardium and the heart. This may result from injury, cardiac surgery or extend from a pneumothorax. If the collection of air becomes large enough it may lead to cardiac compromise.

A lucent line is seen outlining the cardiac silhouette on chest radiograph. The 'continuous diaphragm sign' occurs when air accumulates inferior to the heart and crosses the midline above the diaphragms.

- Soft tissue emphysema (Figure 14)

Soft tissue emphysema, sometimes referred to as surgical emphysema, occurs when free air tracts between the fascial planes of the soft tissues. It often accompanies pneumothoraces and may be related to trauma, injury, surgery or placement of indwelling catheters and devices.

- Abnormal accumulation of fluid
  - Pleural effusion (Figure 2)

Abnormal accumulation of fluid within the pleural space is termed a pleural effusion. Empyema (pus) or a haemothorax (blood) will have a similar radiographic appearance.

As with a pneumothorax, the radiological appearance varies greatly with patient positioning. Fluid will accumulate in the dependent areas, therefore in an erect patient, fluid collects at the lung bases and manifests with blunting of the costophrenic recesses. In the supine position, fluid accumulates posteriorly and may appear as increased density (veiling) of the one hemithorax compared to the contralateral side. Depending on the amount of fluid, the costophrenic

Figure 14. Chest radiograph of an adult patient demonstrating marked soft tissue emphysema outlining the pectoralis muscles and extending into the neck.

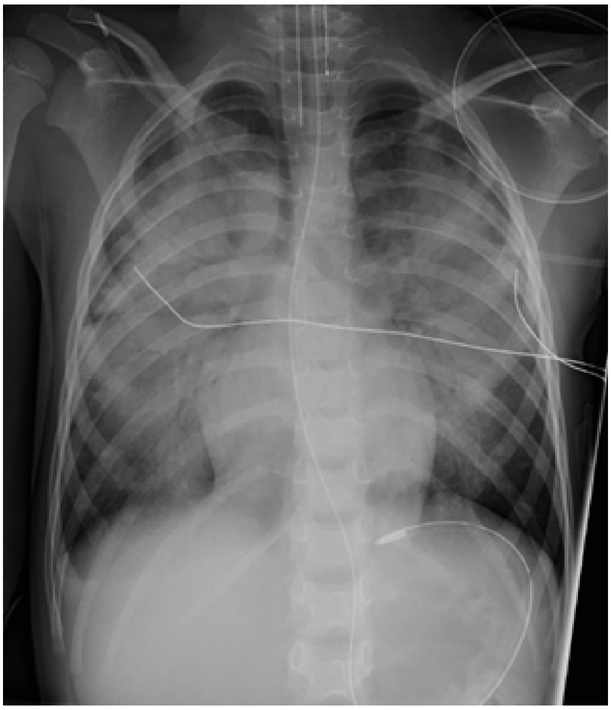

Figure 15. Chest radiograph of an adult patient demonstrating pulmonary oedema in a typical batwing distribution.
(Case courtesy of Dr Bruno Di Muzio, Radiopaedia.org. From the case rID: 51604)

recesses may become blunted as well as capping of the lung apices. Small effusions may still be missed and if it is clinically suspected, a lateral decubitus film may assist with diagnosis. A lateral decubitus film may also assist with differentiation between a loculated and free effusion.

- ◦ Pericardial effusion

A pericardial effusion refers to an abnormal accumulation of fluid within the pericardial space. The size of the effusion and rate of accumulation determines the presence and severity of cardiac compromise. Small effusions are difficult to differentiate from cardiomegaly on chest radiograph whereas larger effusions result in a globular cardiac silhouette. Confirmation is usually done with echocardiography.

- Parenchymal abnormalities
  - ◦ Pulmonary oedema (Figure 15)

Accumulation of fluid within the pulmonary interstitium is known as pulmonary oedema. It is commonly encountered in critically ill patients and often the cause for clinical deterioration. The causes are divided into cardiogenic and non-cardiogenic aetiologies and are vast, including cardiac failure, fluid overload, near-drowning, pulmonary embolism etc. Chest radiographs remain the most useful method of evaluating and quantifying pulmonary oedema.

Figure 16. Chest radiograph of an adult patient demonstrating a triangular density behind the heart in keeping with collapse (atelectasis) of the left lower lobe.

Radiographic features may include pulmonary venous engorgement with resultant upper lobe blood diversion and an increased cardio-thoracic ratio. Pulmonary interstitial oedema is indicated with septal lines (Kerley lines***), interlobar septal thickening and peribronchial thickening (cuffing). If the pulmonary oedema progresses, pulmonary alveolar oedema occurs resulting in air space opacification, usually in a 'batwing' distribution.

- ◦ ARDS

Acute respiratory distress syndrome (ARDS) results from severe pulmonary injury secondary to pulmonary and extra-pulmonary causes including sepsis, trauma, aspiration, etc.

The pulmonary damage leads to fluid accumulation in the alveoli and therefore the radiological appearance is similar to that of pulmonary oedema. The clinical findings, including duration of onset and severity of respiratory compromise, differentiate ARDS from pulmonary oedema.

The chest radiograph findings develop rapidly over 24 hours after the initial insult and may persist for days or weeks. There is usually bilateral air space opacification, however, cardiomegaly and upper lobe blood diversion is not usually present as in cardiogenic pulmonary oedema.

- ◦ Atelectasis (Figure 16)

Atelectasis can occur passively secondary to an effusion or pneumothorax, or it may be resorptive resulting from alveolar hypoventilation e.g. in the case of a mucous plug. The amount of affected lung varies

*** Kerley lines are septal lines resulting from prominence of the interlobular septa. Kerley A lines are 2–6 cm in length and extend towards the hila. Kerley B lines are short lines, 1–2 cm in length at the periphery of the lungs. Kerley C lines do not extend to the pleura and Kerley D lines are seen on lateral radiograph.

Figure 17. Chest radiograph of an adult patient demonstrating left lower lobe and lingula consolidation.

from small subsegmental areas to lobar or total lung collapse.

Linear streaks from plate atelectasis are often seen on chest radiograph. Lobar collapses have pathognomonic radiological appearances depending on the involved lobe. A common finding with lobar collapse is elevation of the ipsilateral hemidiaphragm and displacement of the ipsilateral hilum secondary to volume loss.

◦ Consolidation (Figure 17)

Consolidation occurs as a result of filling of the alveoli with fluid, pus or blood. The radiographic appearance of air space opacification, usually in conjunction with air bronchograms, may affect a small area of lung (subsegmental) or may extend to involve one lobe (lobar consolidation) or multiple lobes (multilobar consolidation). Clinical findings of infection usually accompany the radiological findings.

◦ Aspiration

Aspiration of gastric contents is often encountered in patients with an impaired level of consciousness and may lead to aspiration pneumonitis. The radiological findings are similar to those of consolidation, with a predilection of the dependent lower zones of the lungs.

Conclusion

In summary, chest radiographs are commonly and frequently encountered in a critical care setting. Nursing staff can add great value by understanding the basic concepts of technique as well as interpretation, thereby optimising patient care.

References

1. Amorosa JK, Bramwit MP, Mohammed TL, et al. ACR appropriateness criteria routine chest radiographs in intensive care unit patients. Journal of the American College of Radiology : JACR. 2013 Mar;10(3):170-4.
2. Jain SN. A pictorial essay: Radiology of lines and tubes in the intensive care unit. The Indian Journal of Radiology and Imaging. 2011 Jul;21(3):182-90.