Introduction

The chest x-ray (CXR) remains one of the most commonly requested imaging studies, yet is one of the most complex and least understood, particularly the intensive care unit (ICU) bedside examination. In addition to deciphering numerous lines, tubes, lung and pleural findings of the AP (anterior-posterior) radiograph, critical care providers look to radiologists’ reports to summarize any pertinent changes in underlying pathological processes. This article will provide an overview of the bedside chest radiograph in the ICU setting, as well as a guide to effective reporting for the radiologist.

While computed tomography (CT) has added tremendous value in chest imaging in ICU patients, the CXR remains the mainstay in ICU imaging. Compared to CT scans, the CXR can be obtained more readily and is associated with less radiation; thus, CXRs can be performed serially for temporal comparison. Ultrasound is becoming more commonplace and can often be complementary to CXR, CT, and physiologic parameters.1

This article presents an overview of common CXR findings in the ICU setting with example reporting, in the hope of increasing awareness of accepted report terminology. It will also touch on traditional views, new techniques/approaches to bedside chest imaging, and technological advances that may improve diagnostic accuracy on CXR and negate the need for CT in some conditions.2

Topic points include positions of lines and tubes, abnormal collections of fluid and air, and common causes of pulmonary opacities. Radiologists should keep in mind that ICU physicians want to know findings that may alter management, those which are potentially life-threatening, as well as pertinent temporal changes.

Approach to the Bedside Chest X-Ray

The recommended approach to CXR interpretation is to first identify abnormal findings, including their location and distribution, and then further define patterns to help classify and categorize. This represents the body of the report. Based upon this information and correlation with any pertinent history, radiologists generate a differential diagnosis, or conclusion; that is, the impression section of the report.

For example, the report body and impression of a CXR describing a consolidation in a patient with cough, fever, and elevated white blood cell count may look like this:

**Findings:** A focal patchy opacity is noted in the right upper lung field with air-bronchograms.

**Impression:** Consolidation on right, consistent with pneumonia

It is important to have a systematic approach to CXR interpretation, especially when reviewing complex studies, such as the case shown in **Fig. 1**. One method uses a mnemonic-based search pattern consisting of the ABCDEs twice. The acronym includes the following: Airway (including an endotracheal [ET] tube, when applicable), Aorta (contours, edges, central lines), Breathing (lungs and pleura), Bones (quick review since this often does not significantly change in the ICU), Circulation (pulmonary vessels), Cardiac (silhouette), Diaphragm (free air, costophrenic angles), Deformity (post-operative, positioning considerations), Soft tissues (chest wall), Shoulders (periphery of projection). Other search patterns include starting in the midline and working one’s way outward or vice versa. The key point is to have a systematic search pattern which includes all aspects of the CXR and ensuring that the pattern is followed on each and every examination. This will help avoid becoming overwhelmed, especially when there are a multitude of findings.
Figure 1. Example of a Potentially Perplexing Case Simplified Through a Systematic Approach and Routine Reporting. Starting with the ET tube, the tip is easily seen at the inferior medial clavicles within 5cm from the carina. Although the NG tube tip is not seen, the sideport is within the stomach; therefore, there is no need to say the tip is not seen. Next, describe the chest tubes and the Swan-Ganz catheter with its tip in right PA. Then move on to the tube effects, such as the subcutaneous emphysema, surgical clips, and extracardiac lucency. In evaluating the hemithoracies, the diaphragmatic silhouette is obscured, especially on the left due to a pleural effusion. Pulmonary opacities within the left hemithorax result from a pleural effusion with underlying parenchymal consolidation versus atelectasis. The cardiac silhouette and aortic contour are enlarged and show lucency on the left representing a pneumomediastinum. Finally, evaluate the extrathoracic regions of the film, including the upper abdomen, soft tissues, and bony structures.

Figure 2. Incorrect Positioning of an Endotracheal Tube. A CT scout image (A) shows an ET tube located within the left mainstem bronchus. Portable chest radiograph following repositioning of the ET tube (B) demonstrates correct positioning within the trachea with residual right lower lobe atelectasis from prior malpositioning; the region of atelectasis resolved on subsequent films (not shown).

Support Devices: Lines and tubes

The ICU generates many requests for support device placement on CXR, especially serial examinations in patients with multiple lines and tubes. The American College of Radiology (ACR) appropriateness criteria provides guidelines for imaging in the setting of line and tube placement. The literature supports obtaining a CXR immediately following placement of endotracheal, enteric (especially feeding tubes), and chest tubes; however, it does not support daily CXRs in the absence of a change in clinical condition or suspected line or tube migration.

A comprehensive review of lines and tubes is beyond the scope of this article. However, it is important to know which types of lines and tubes have been placed, along with their optimal locations and potential complications of malpositioning. Figs. 2, 3,
and 4 demonstrate examples of correct and incorrect positioning of endotracheal tubes and central venous catheters. Chest tube positioning is discussed in the section covering pathology of the pleural space.

Positioning, Technique Ideas and Technical Advances

The portable CXR is often inconsistent and sometimes limited due to variable patient positioning (rotation, tilt, angle of inclination, etc.). For example, it can be difficult to evaluate pleural effusions on serial examinations when technologists have different degrees of inclination and thresholds for placing the “Upright,” “Erect,” or “Semierect” markers on the cassette. Rotation is often accentuated in bedside imaging compared to standard PA projections performed in the Radiology Department, making changes on serial exams more difficult to assess. Overlying material, such as the external component of tubes and lines, also limit visualization and evaluation of underlying structures.

New technologies to improve CXR interpretation are available or in design and include dual energy, temporal subtraction, tomosynthesis, and decision support. Also available is line and tube visualization software, which improves conspicuity of various support devices (Fig. 5). Some centers are using portable CT in the ICU, which has been found to be advantageous due to minimizing the need for patient transport (especially with many support devices) and obtaining more rapid assessments with superior spatial resolution.

Pleural Fluid, Air, and Loculations

Pleural effusions are common in ICU patients. It is important to distinguish effusions from other pathologic processes, as well as to assess for changes over time on serial examinations. Since fluid is dependent when not loculated or otherwise bound, optimal positioning in as upright a position as possible is paramount. Inconsistent positioning over time often gives false impressions of changes in severity and has variable effects on masking of underlying conditions, such as pneumonia or atelectasis. Technologists will often indicate patient positioning with use of arrows or
markers stating “Upright;” however, there is poor agreement or consistency as to when to use such indications. For example, defining a threshold angle of 60 degrees before an examination is to be considered “Upright.” The angle of inclination also affects evaluation for pneumothoraces or free intra-abdominal air.

The use of decubitus projections can be extremely valuable in assessing the mobility and possibly the drainability of pleural fluid, often negating the need for CT (Fig. 6). One should keep in mind, however, that with the many support devices and critical nature of the patient’s underlying medical condition, decubitus positioning in the ICU is often difficult and in some cases not possible. The decubitus view to order is the side of the effusion or what technologists often refer to as “side down, side seen.” This means that a right-sided effusion should be evaluated with a right side down decubitus projection. This is opposite of the abdominal decubitus projection when looking for free-air (“side up, side seen”) where a left lateral decubitus projection detects free air at the liver margin. Although this appears intuitive, it is important to be clear with the terminology when recommending, ordering, performing, or interpreting decubitus examinations.

Empyemas represent localized infectious collections within the pleural space and are not uncommon in the ICU setting. Differentiation from simple pleural effusions is a common and important question of ICU

Figure 5. Application of the Line and Tube Visualization Software. In this patient who underwent right forequarter amputation from a scapular sarcoma, standard (A) and post-processed (B) CXR images were obtained. The post-processed image (B) more readily identifies the malpositioned left PICC line within the right brachiocephalic vein. There are also postoperative features to the lungs bilaterally with resultant volume loss to left lower lung field. Note a prototype inclination marker in the upper left portion of the image with demonstrates an inclination angle of 60 degrees.

Figure 6. How the Decubitus Projection Can Determine Mobility of Pleural Effusions. Frontal (A) and lateral (B) chest radiographs demonstrate a moderate-sized right pleural effusion with suspected peripheral loculations. The right-side down decubitus view (C) verifies free mobility of the pleural fluid without evidence of loculations, thus negating the need for a CT examination.
Chest X-Ray, Folio

Figure 7. Empyemas.
Frontal chest radiograph (A) reveals peripheral opacities along the lateral margins of the thoracic cavities, some of which have irregular borders. The size and extent of the collections were resulting in cardiac tamponade. Coronal reformatted CT image (B) better depicts the loculated collections which were subsequently drained but recurred.

Figure 8. Lung Abscess.
Frontal (A) and lateral (B) chest radiographs show a lung cavity with air-fluid level in the superior segment of the right lower lobe (right upper lung field) that has the same size and configuration on both the PA and lateral views, confirming a spherical shape. Biopsy revealed an aspergilloma in this patient with Job’s syndrome.

staff. However, the distinction cannot be made on CXR alone. Common findings include loculated, non-mobile collections of pleural fluid (Fig. 7). A relatively specific finding for empyemas includes air-fluid levels that are disparate in size/length when comparing the frontal and lateral projections. This supports a non-spherical shape and is helpful in distinguishing empyemas from simple effusions or pulmonary abscesses.

Most parenchymal abscesses or cavities are spherical in shape, resulting in air-fluid levels of similar size/length on all projections (Fig. 8). Although there are findings suggestive of empyemas on CXR, recommending a CT and potentially image-guided drainage is often in order.

Visualization of air-fluid levels in the pleural space is a useful finding in the setting of subtle pneumothoraces (Fig. 9). A dependent fluid level in the lower lung field often indicates the presence of a hydropneumothorax. Treatment of pneumothoraces often depends upon the size and pneumothorax and clinical status of the patient. Often times, placement of a chest tube is necessary.

Chest tubes can be malpositioned in a manner where bedside radiography alone is not adequate for evaluation. In this setting, CT is often necessary to evaluate for a malpositioned tube, typically when an abnormal course is identified on CXR or the tube is not draining properly. Common findings associated with malpositioning include visualization of the tube within a pulmonary fissure (Fig. 10) or in a superficial location with the sideports outside of the chest cavity. Placement within the pulmonary parenchyma or the
Pulmonary/Lung Opacities

Pulmonary opacities are commonly seen in the ICU setting. Distinguishing between air space disease and atelectasis, especially on hypoinflated portable CXR, is a common dilemma for radiologists. When air space opacities are identified, differential conditions include pneumonia, pulmonary edema, acute respiratory distress syndrome (ARDS), and pulmonary hemorrhage. Atelectasis often mimics air space disease on CXR,

chest wall is less common.

Figure 9. Air-fluid Level in the Pleural Space Indicative of a Hydropneumothorax.
Frontal chest radiograph (A) demonstrates an air-fluid level within the inferior right hemithorax (thick arrows). Magnified view of the right upper thoracic cavity (B) reveals a subtle pneumothorax (thin arrows).

Figure 10. Malpositioned Chest Tube.
Frontal chest radiograph (A) shows bilateral chest tubes with persistent pneumothoraces. The chest tube on the right was not draining properly. Para coronal/axial (B) and sagittal reformatted (C) CT images demonstrate an interfissural course of the right-sided chest tube.

Figure 11. Pneumonia.
Frontal chest radiograph (A) demonstrates a focal rounded consolidation, likely within the lateral right middle lobe due to the lack of obscuration of the diaphragmatic border. Coronal reformatted (B) and axial (C) CT images confirm the middle lobe location and best depict the central air bronchograms in this patient with fever and X-linked agammaglobulinemia (XLA), which is the underlying cause of the lower lobe bronchiectasis noted on the CT examination.
since it often presents as a focal opacity with or without air bronchograms. A key distinguishing feature is volume loss within the affected lobe, which may be subtle but is a useful discriminator.

The imaging pattern of infectious pneumonia is dependent upon the causative agent. Bacterial infections present with lobar air space disease, which may be localized or multi-focal (Fig. 11). Parapneumonic effusions or empyemas may be seen. Atypical infections, such as viral or Mycoplasma, tend to be interstitial but may occasionally be lobar as well. Nosocomial infections are more diffuse and aggressive with a higher prevalence in patients who are immunosuppressed. Cavititation is common and the morbidity and mortality is significantly higher than community-acquired pneumonia.

Left-sided congestive heart failure demonstrates a predictable sequence of findings on CXR (Fig. 12). Initially, there is enlargement of the cardiac silhouette with cephalization of pulmonary blood flow. As the degree of heart failure progresses, interstitial edema is noted with prominent interstitial markings along the periphery of the lung fields (Kerley B lines). Finally, edema extends into the pulmonary parenchyma and pleural space, resulting in air space opacities and pleural effusions.

Acute respiratory distress syndrome (ARDS) often occurs in the setting of shock or inhalation toxicity and results in fluid accumulation within the lung parenchyma. The air space disease may appear similar to that of pulmonary edema; however, it is not typically associated with cardiomegaly or pleural effusions. The air space disease also tends to occur along the lung periphery. Chronically, ARDS may result in pulmonary fibrosis.

Pulmonary hemorrhage may be focal, especially in the setting of trauma, or diffuse secondary to an underlying systemic or autoimmune disease process. Chest x-rays demonstrate multifocal air space opacities, which may be ground glass, consolidated, well-defined, or diffuse (Fig. 13). Cavitation is not uncommon.

**Reporting/Terminology**

Findings in the body of the report should support the conclusions in the impression. A finding that includes consolidation, for example, should have an impression which includes a portion of the well-known

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**Figure 12. Congestive Heart Failure/Pulmonary Edema.**

Sequential frontal chest radiographs in a patient with progressive heart failure (A, B, and C) show an initial normal examination (A) with subsequent development of cardiomegaly, cephalization of pulmonary vasculature, and increased peripheral interstitial markings – referred to as Kerley B lines (B). Air space disease and pleural effusions are common and best depicted on images B and C. The relative increased lung volumes on image C are the result of interval intubation; enteric tubes and a right IJ CVC were also placed in this patient (C) and are appropriately positioned. A coronal reformatted image (D) nicely shows the peripheral Kerley lines, as well air space disease within the right lower lobe.
differential diagnosis of water, pus, blood, protein, and cells based upon the clinical history. If there is a new finding of a focal opacity and the critical care team is looking for infection, then pneumonia is most likely. If the opacity is diffuse, then fluid or blood (DAH) may be added to the list of differentials.

There are unique considerations in CXR terminology with regards to 2-dimensional representation of 3-dimensional structures. For example, there is considerable overlap and variability of lung lobes; hence the use of the term lung “fields,” which is commonly used and appropriate. Also, if a central line tip appears low in the superior vena cava (SVC), positioning and projection could mean that the tip is actually in right atrium; therefore, the broader phrase “overlying the cavoatrial junction” may be useful.

ICU staff, like radiologists, are busy and want concise information at their fingertips. The radiologist should avoid extraneous information and be consistent and predictable. If the tip of the enteric tube is not seen but the sideport is visible, state the location of the sideport; there is no need to state that the tip is not seen in such cases.

Although residents and fellows are often taught not to use the term “infiltrate,” it may provide flexibility for both the radiologist and the ordering provider. For example, if one commits to “consolidation” or “fluid,” this may minimize options for the clinician. Keeping the differential (impression) broader allows providers to apply the clinical information to their management. However, there is a fine line between keeping differentials broad and being noncommittal or “hedging.”

Having an organized search pattern is essential in evaluating the entire film. It also helps prevent “satisfaction of search” where obvious abnormalities...
are noted initially and more subtle findings are overlooked.\textsuperscript{20} Fig. 14 shows an unsuspected case of pneumatocele intestinalis picked-up on a CXR for line and tube placement.

**Interaction With Intensive Care Team; The Report is Just the Beginning; ICU Rounds, Process**

Although the radiology report represents the final product of a particular diagnostic imaging study, it may also represent the beginning of a diagnostic and procedural dialogue with ordering providers. A continuous feedback and understanding of clinicians’ needs provides insight that is otherwise not gained if radiologists remain in isolation. Breaking the misguided and stereotypical perceptions of radiologists keeping to themselves in a dark room will improve communication chains with ordering providers and help guide the work-up and care for the most critically-ill patients.

**Summary**

The chest x-ray remains one of the most common, important, and complex examinations in the ICU setting. Given the multitude of pathologies and support devices often encountered, it is critical that radiologists develop and follow a logical search pattern to help define the underlying abnormalities, evaluate all aspects of the film, and avoid “satisfaction of search.” Correlating findings with the patient’s clinical status will aid in providing a useful list of differentials. Most importantly, continuous communication with ordering providers will allow radiologists to help guide the work-up and management of the most critically-ill patients.

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**References**


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