SECTION I

CHEST RADIOLOGY

Chest radiography is the most commonly ordered imaging test in emergency department patients. It can provide considerable diagnostic information for a wide variety of thoracic disorders. Its diagnostic capabilities are based largely on the contrast between the air-filled lungs and pathological processes that cause fluid accumulation within lung tissue.

Although **chest CT** provides greater anatomical detail of the pulmonary parenchyma and is often used in non-emergency patients with pulmonary disease, the use of chest CT in the ED is limited to certain critical conditions that do not produce distinctive findings on conventional radiography. These include pulmonary embolism and aortic dissection. CT is also used in ED patients with major chest trauma to detect an aortic injury, pneumothorax, hemothorax and pulmonary contusions that may not be evident on the supine portable chest radiographs.

WHEN TO ORDER RADIOGRAPHS

In general, a diagnostic test should be ordered when the disease under consideration produces characteristic findings which help confirm or exclude the suspected disorder. A number of approaches can be used in deciding to order a radiograph.

With a simplistic **"geographic" approach,** radiographs are obtained of the region where the patient is having symptoms, e.g., a chest radiograph in a patient with chest pain. Such an approach is ill-advised because it can lead to diagnostic errors, as well as excessive and unnecessary testing.

Using a **symptom-based approach** to radiograph ordering, the decision to obtain radiographs is based on characteristics of the patient's symptoms, for example whether the chest pain is severe or mild, pleuritic or pressure-like (Rothrock 2002).

However, a more rational **diagnosis-based approach** is to first consider the potential disorders that might be present and then to obtain radiography if the suspected disorder has characteristic radiographic findings, such as pneumonia and pneumothorax. This approach is the most likely to yield clinically useful information and to avoid unnecessary testing. Determining which disorders need investigation in an individual patient is ultimately based on the clinical judgment, knowledge and experience of the practitioner.

RADIOGRAPHIC VIEWS

Two perpendicular views should be obtained whenever possible. The preferred frontal view is a postero-anterior view (**PA view**). This view is obtained in the radiology suite with the patient standing and the imaging cassette placed against the patient's anterior chest wall. The x-ray beam is directed horizontally and traverses the patient from posterior to anterior. The patient's hands are positioned on the hips, which moves the scapulae laterally and away from the lungs. The patient is instructed to take a full inspiration. The PA view is preferred because the heart and mediastinum are closest to the x-ray imaging cassette and therefore less distorted by magnification.

When the patient is too ill or debilitated to stand for a PA view, an antero-posterior view (**AP view**) is obtained. The patient is in either a lying or sitting position. The sitting position is preferred whenever possible. The x-ray beam is directed downward towards the patient.

The **lateral view** is obtained with the patient standing or sitting. The arms should be raised. The standard lateral view is a *left* lateral view in which the patient's left side is placed against the imaging cassette. In this way, the heart is closer to the cassette and is seen more clearly.

HOW TO READ A RADIOGRAPH

First, examine the radiograph in its entirety looking for obvious and clinically expected findings. Next, a methodical review is performed to obtain complete information from the radiograph.

There are two complementary approaches—systematic and targeted (Table 1). Using a **systematic approach,** each tissue density (air, soft tissue and bone) is examined in all regions of the image. This provides a relatively simple framework for radiograph review that is easily remembered and thorough.

A **targeted approach** is based on the pathological patterns seen on chest radiographs as well as the radiographic manifestations of various thoracic diseases. Using **pattern-recognition,**

TABLE 1

How to Read a Chest Radiograph

A. Initial Overall Review—Review the image in its entirety
Look for obvious and expected findings

B. Systematic Approach
- Adequacy
  - Penetration—Lower thoracic vertebral bodies are faintly visible behind the heart
  - Rotation—Medial clavicular heads align with the tips of the spinous processes
  - Inspiration—Posterior right 10th or 11th rib is at the *right cardiophrenic sulcus*
- Bones: Ribs, shoulders, vertebral column
- Soft tissues: Heart (cardiothoracic ratio), mediastinum, hila, diaphragm
- Lungs: Use left/right symmetry

Compare lung markings at each intercostal space with that of the opposite lung

or

- Central zone: Heart, mediastinum, trachea, hila, vertebral column
- Middle zone: Lungs
- Periphery: Bones and soft tissues of the chest wall and shoulders

C. Targeted Approach

Pattern recognition—Identify pattern of radiographic abnormality—diffuse airspace filling, focal airspace filling, reticular pattern, etc. (see Table 5). A differential diagnosis is then derived from the radiographic pattern

Diagnosis-based—Requires knowledge of the radiographic appearance of the disease clinically suspected, e.g., pneumonia, congestive heart failure, pneumothorax (see Table 6)

one of several pathological patterns is identified such as airspace filling or a reticular pattern. From the radiographic pattern identified, a differential diagnosis is derived (see Table 5 on p.12) (Reed 2003). Using a **diagnosis-based approach**, disorders suspected based on the clinical examination are specifically sought when reviewing the radiographs (see Table 6 on p.12). This approach depends on knowledge of the radiographic manifestations of thoracic diseases such as pneumonia, pulmonary edema, pneumothorax, and injuries associated with chest trauma.

Both the targeted and systematic approaches are used in radiograph interpretation. A targeted approach is an efficient and effective way to identify both obvious and subtle pathology. A systematic approach provides a complete review of the radiograph, will assure that additional pathology is identified, and provides a step-by-step technique to verify that a radiograph is normal (Loy 2004, Sistrom 2006, Good 1990).

SYSTEMATIC APPROACH TO INTERPRETING A CHEST RADIOGRAPH

A systematic approach provides a step-wise method to review a radiograph. It depends on knowledge of normal radiographic anatomy.

First, the technical **adequacy** of the image is assessed. Then, the **bones, soft tissues** (heart, mediastinum and diaphragm) and, finally, the **lungs** are examined. The bones are examined first so that a skeletal lesion is not overlooked when a more obvious pulmonary abnormality is present. In an alternative scheme, the central region is examined first (heart and mediastinum), then the lungs, and, last, the ribs and chest wall (Table 1).

Adequacy

Three factors are used in assessing the technical adequacy of a chest radiograph: penetration, rotation and level of inspiration (Figure 1).

Penetration In a properly exposed radiograph, the lower thoracic vertebral bodies should be visible through the superimposed heart. When a radiograph is over-penetrated (too dark), lung pathology may not be visible. When under-penetrated (too light), lung markings appear prominent and could be misinterpreted as abnormal.

Rotation When the patient is correctly positioned, an anterior midline skeletal structure (center point between the medial

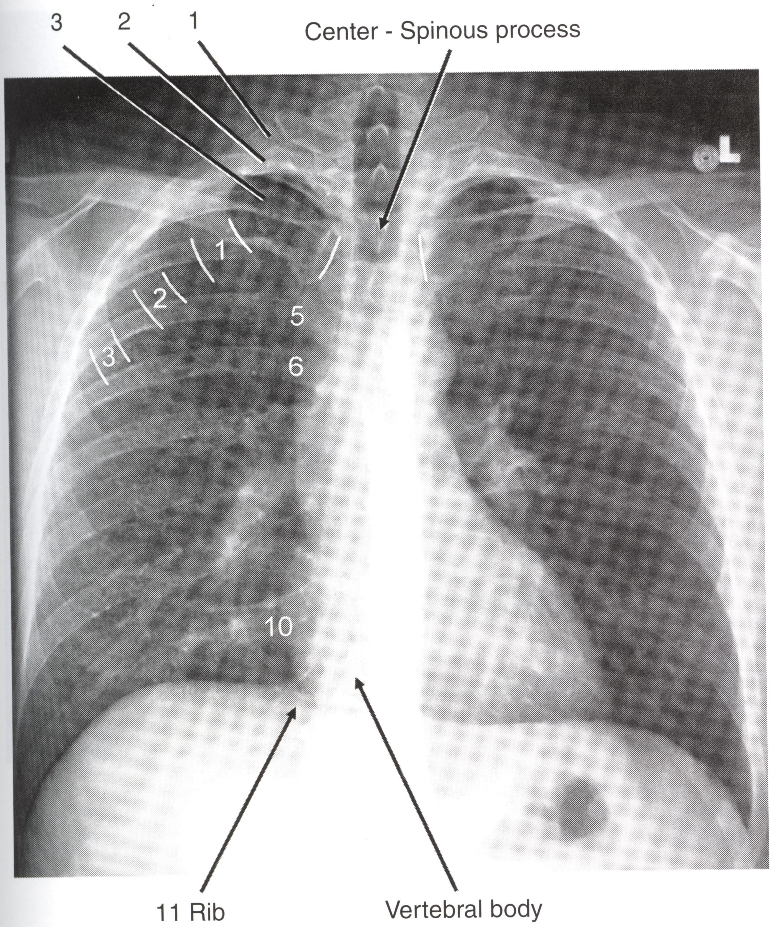

FIGURE 1 Normal PA view in a young adult—Adequacy.
The three factors used to assess adequacy are:
Penetration—The lower vertebral bodies are visible.
Rotation—The spinous processes are centered between the clavicular heads (*white lines*).
Inspiration—The 10th or 11th rib is located at the right cardiophrenic sulcus.
The ribs are counted beginning at the anterior aspects of the first two or three ribs because their posterior aspects overlap and cannot be distinguished. Then, the posterior aspects of ribs 3 to 11 can be counted.

clavicular heads) aligns with a posterior midline structure (tips of the spinous processes). When the patient is rotated, the mediastinum appears displaced or widened.

In the absence of rotation or mediastinal shift, the trachea should be in the midline. However, alignment of the trachea over the spinous processes should not be used to assess positioning because the trachea is a mobile structure. For example, if the patient is rotated to the right and the mediastinum is shifted to the left, the trachea overlies the spinous processes and mediastinal shift could be missed.

Inspiration The posterior aspect of the right tenth or eleventh rib should be at the *right cardiophrenic sulcus* (where the diaphragm intersects the right heart border). To assess inspiration, the posterior aspects of the ribs are counted from the thoracic apex to the diaphragm. Because the posterior aspects of the first, second and occasionally third ribs overlap, the anterior aspects of the first two or three ribs should be located and then the rib contours traced to their posterior aspects. Once the posterior aspects of the first two or three ribs have been identified, the other ribs can be counted (Figure 1).

When the level of inspiration is correct, the lung markings (pulmonary vasculature), heart and mediastinum are clearly depicted. With an incomplete inspiration, the lung markings appear crowded, particularly at the lung bases, and the heart and mediastinum appear widened.

NORMAL RADIOGRAPHIC ANATOMY

Lungs

The right lung has three **lobes**, and the left has two (Figure 2). The **interlobar fissures** separate the lobes—the right lung has the right major (oblique) and minor (horizontal) fissures, and the left lung has the left major (oblique) fissure. Portions of the fissures may be visible on the chest radiograph, appearing as fine white lines on the PA and lateral views (Figure 3).

Each lung is divided into **segments**—nine on the left and ten on the right (Figure 2). These segmental divisions correspond to the branches of the bronchial tree and not divisions within the pulmonary parenchyma. Consequently, although pulmonary parenchymal disorders tend to be localized to one segment, disease processes often spread to adjacent segments. The interlobar fissures, however, are usually not crossed (Hayashi 2001).

Heart

Assessment of **cardiac enlargement** is made using the **cardiothoracic ratio.** The heart at its widest extent should be no greater than half the width of the thorax measured between the inner rib margins at the widest region of the thorax (Figures 3, 4 and 5).

The **heart borders** are formed by particular **cardiac chambers.** On the frontal view, the right heart border represents the *right atrium*, while the left heart border is made up by the *left ventricle* (Figure 3A). A concavity at the superior portion of the left heart border indicates the location of the *left atrial appendage*. When the left atrium is enlarged, a convex bulge appears in this region (Figure 5A). The *right ventricle* is an anterior structure and is therefore only seen on the lateral view,

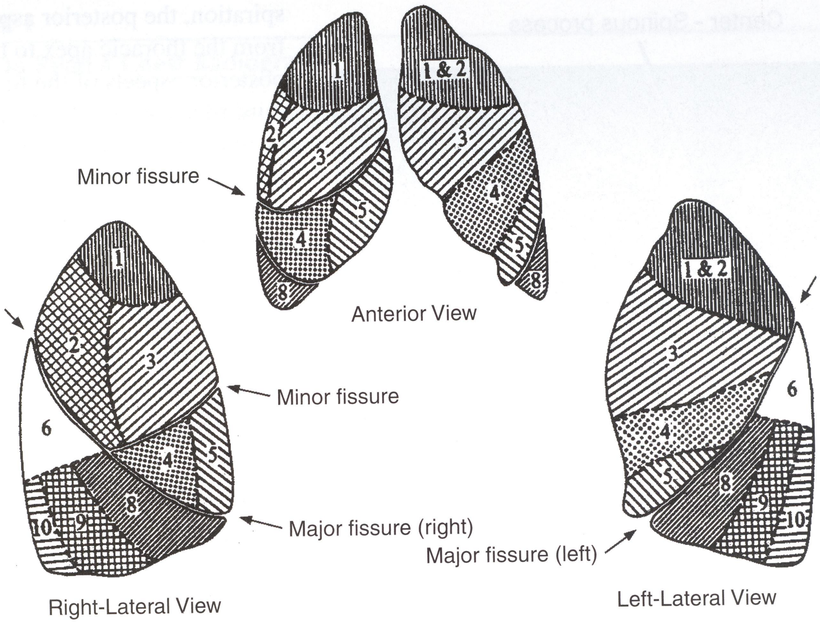

FIGURE 2 Lobes, interlobar fissures, and segments of the lungs.

Right upper lobe	1. Apical 2. Anterior 3. Posterior
Right middle lobe	4. Lateral 5. Medial
Right lower lobe	6. Superior 7. Medial basal 8. Anterobasal 9. Lateral basal 10. Posterobasal
Left upper lobe	1 & 2. Apical posterior 3. Anterior 4. Superior lingular 5. Inferior lingular
Left lower lobe	6. Superior 7. Medial basal 8. Anterobasal 9. Lateral basal 10. Posterobasal

[From: Pansky B: *Review of Gross Anotomy*, 6th ed. McGraw Hill, 1996, with permission.]

making up the anterior heart border. The *left atrium* is a posterior structure and is not normally visible on the frontal view (Figure 5B).

When the thorax is abnormally widened as in chronic obstructive pulmonary disease (COPD), the cardiothoracic ratio is not a reliable indicator of cardiac enlargement (Figure 6).

Aorta

The **aortic knob** represents the posterior portion of the aortic arch. In young individuals, the ascending aorta is not normally visible. The left margin of the **descending aorta** is seen inferior to the aortic knob and parallels to the vertebral bodies (Figure 3). Between the inferior margin of the aortic knob and the left pulmonary artery is a small concave fat-containing region known as the **aorticopulmonary window.** This is obliterated or convex when there is mediastinal fluid or adenopathy.

On the **lateral view,** only the aortic arch is normally seen. The descending aorta lies within mediastinal soft tissues and is not visible (Figure 3B).

In **elderly persons,** particularly those with hypertension, the aortic wall is weakened and the aorta becomes dilated (ectatic) and elongated ("uncoiled"). This is known as a **tortuous aorta** (Figure 4). On the PA view, aortic knob is enlarged. The ascending aorta may be visible as a curved shadow superior to the right heart border and the elongated descending aorta is displaced to the left. On the lateral view, the elongated arc of the descending aorta is seen adjacent to the thoracic vertebrae. The descending aorta is visible because it is adjacent to air-filled lung (visibility of the descending aorta is *not* due to calcification).

Mediastinum

Aside from the heart and aorta, several other **mediastinal structures** are visible on the PA view (Figures 3 and 7).

The **trachea** is a midline air-filled structure that branches at the carina to form the left and right mainstem bronchi. The **left subclavian artery** extends superiorly from the aortic arch. The **descending aorta** extends inferiorly from the aortic knob. The **superior vena cava** forms a faint shadow along the right superior mediastinum.

Mediastinal Pleural Reflection Lines

Several air/fluid interfaces between the lung and mediastinal soft tissue structures are often seen. Distortion or displacement of these contours occurs with accumulation of fluid, lymphadenopathy or masses in the mediastinum (Figure 7).

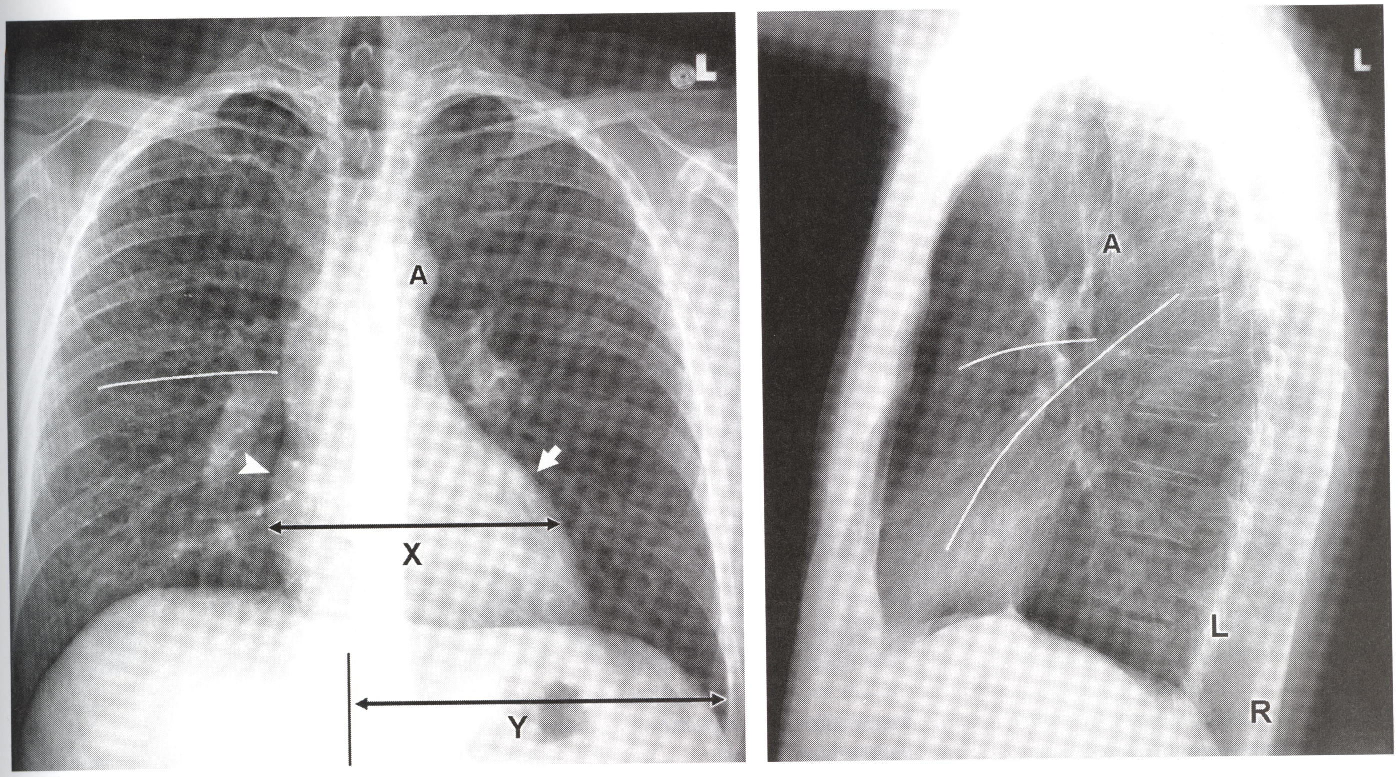

FIGURE 3 Normal PA and lateral radiographs in a young adult.

Heart: The cardiac width (X) is normally less than half the width of the thorax (Y) **(cardiothoracic ratio).** The left heart border is formed by the left ventricle (*arrow*) and the right heart border by the right atrium (*arrowhead*).

Interlobar fissures: On PA view, a white line indicates approximate location of the minor (horizontal) fissure. On the lateral view, the major (oblique) and minor (horizontal) fissures are seen.

Aorta: On the PA view, the aortic knob is small (A). On lateral view, only the aortic arch is visible (A); the descending aorta is not seen because it is within the mediastinal soft tissues.

Ribs: On the lateral view, the **right ribs** (R) are further from the radiograph cassette and therefore magnified and more posterior than the **left ribs** (L).

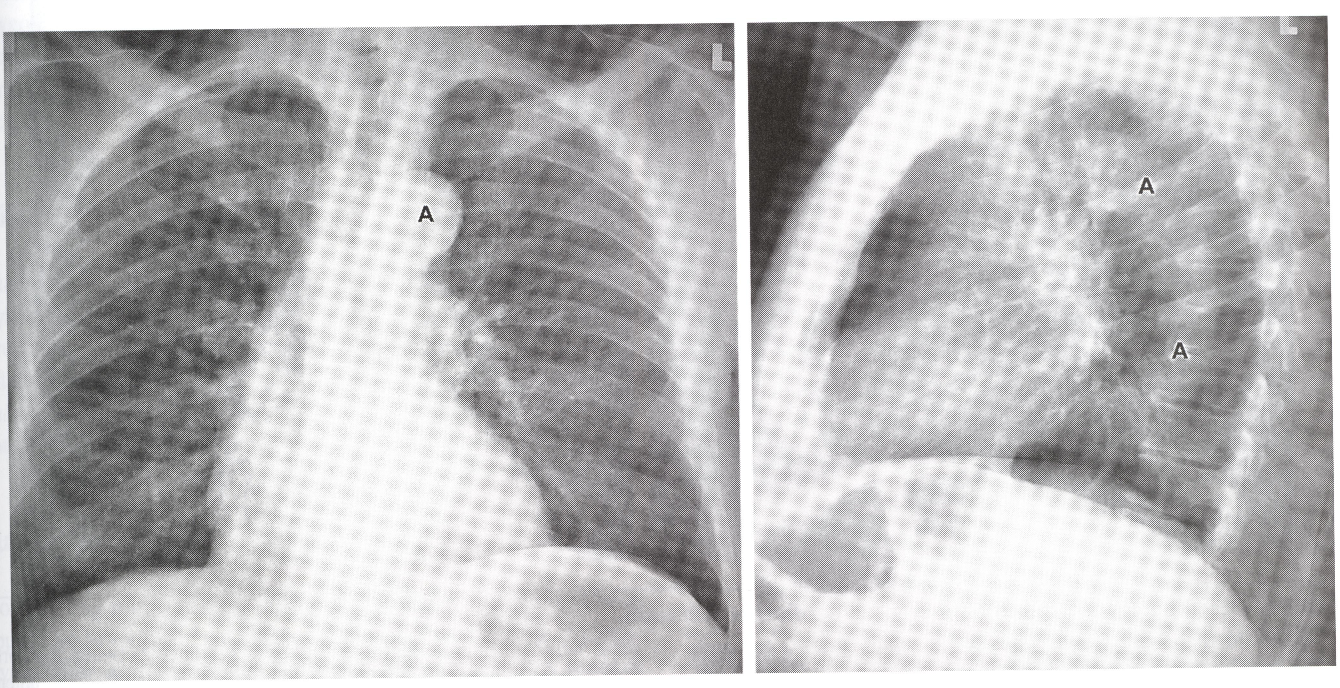

FIGURE 4 Normal PA and lateral radiographs in an elderly adult—Tortuous aorta.
On the PA view, the aortic knob is enlarged (A).
On lateral view, the elongated descending aorta is visible adjacent to thoracic vertebrae (A-A).

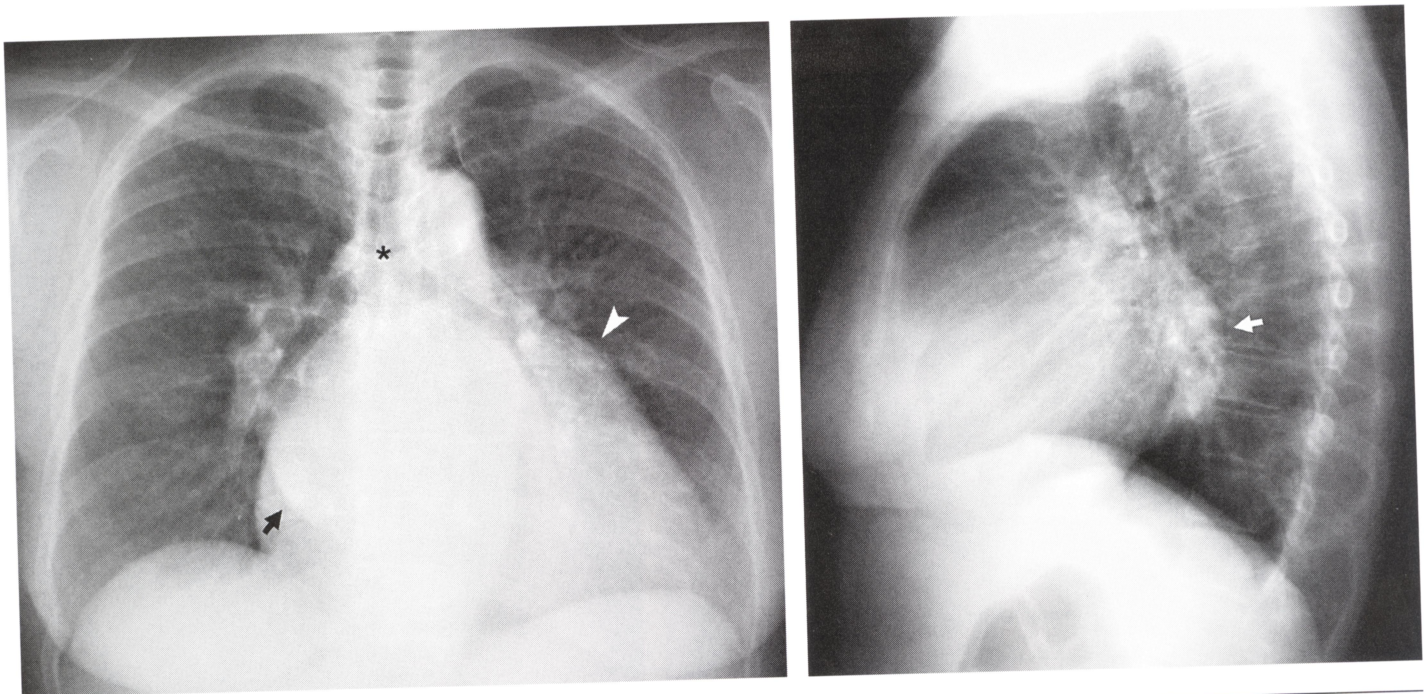

FIGURE 5 Cardiomegaly in a patient with rheumatic heart disease—Mitral and aortic stenosis.

Left atrial enlargement causes widening of the angle between the left and right mainstem bronchi at the carina (*asterisk*), convexity at the superior portion of the left heart border due to the enlarged left atrial appendage (*arrowhead*), and a double-density behind the heart at the margin of the left atrium (*arrow*).

On the **lateral view,** the superior portion of the posterior heart border bulges posteriorly due to left atrial enlargement (*arrow*).

Left ventricular enlargement causes an increased cardiothoracic ratio of 60%.

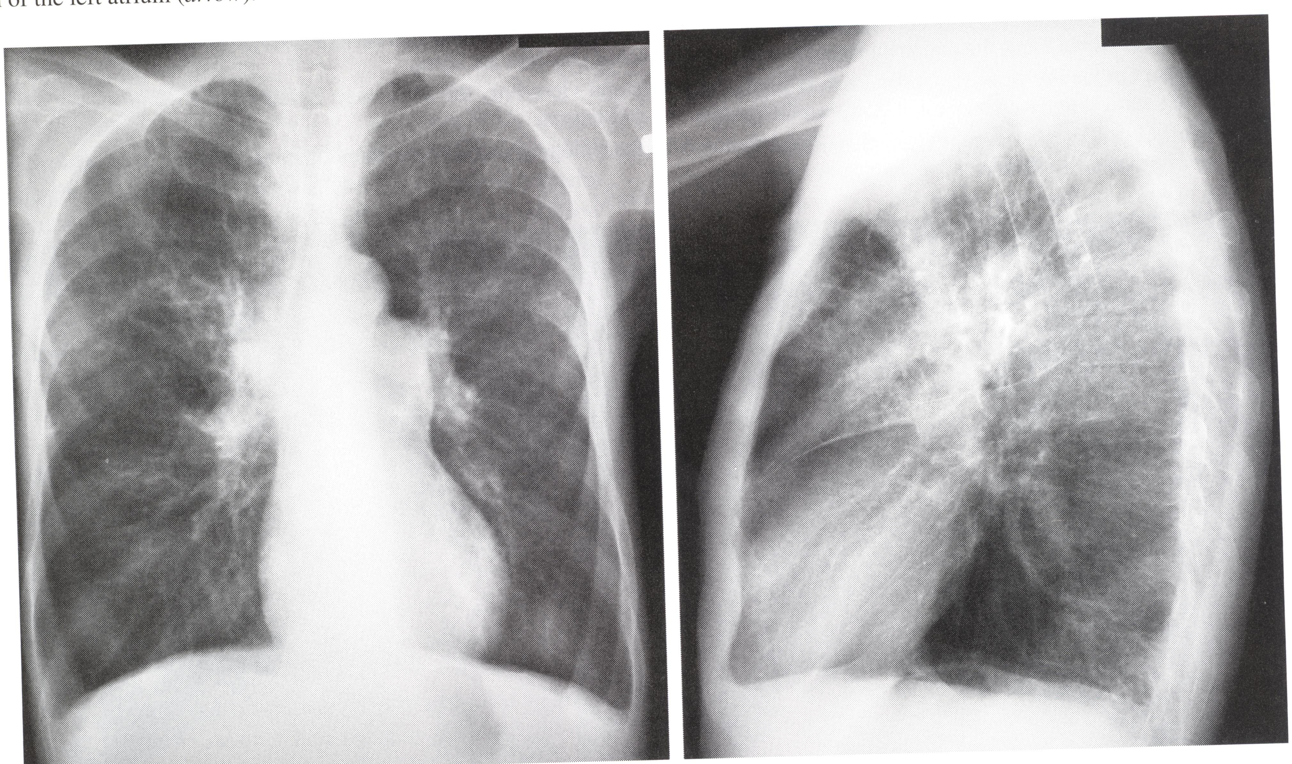

FIGURE 6 Cardiomegaly without an increased cardiothoracic ratio.

A 70-year-old man with COPD and cardiomegaly due to **cor pulmonale**. The lungs are hyperexpanded, the thoracic width is increased, and the cardiothoracic ratio is therefore not a reliable indicator of cardiac enlargement.

There are several radiographic signs of **severe COPD.** The diaphragm is flattened on both the PA and lateral views. On the PA view, the thoracic height is increased (note the great distance between the aortic knob and the lung apices). On the lateral view, the thoracic anteroposterior diameter is increased.

Pulmonary artery hypertension secondary to COPD causes hilar enlargement due to pulmonary artery distention.

FIGURE 7 Mediastinal anatomy.
Left subclavian artery—A curved shadow that disappears at the superior border of the clavicle.
Right paratracheal stripe—Normally < 5 mm wide; terminates inferiorly at the *arch of the azygos vein.*
Aorticopulmonary window—Space under aortic arch and above superior border of left pulmonary artery.
Left paraspinal line—Up to 15 mm wide; normally disappears above the aortic knob.
Azygo-esophageal recess—Medial surface of the right lung extends into the mediastinum inferior to the arch of the azygos vein and lies against the esophagus (it is not the right side of the descending aorta).
Superior vena cava— Extend superiorly from the right mainstem bronchus.

The **right paratracheal stripe** is a thin layer of connective tissue that lies along the right tracheal wall adjacent to the right lung. It is normally no more than 5 mm thick. The right paratracheal stripe terminates inferiorly at the **arch of the azygos vein** that crosses over the right mainstem bronchus. Widening > 1 cm is a sign of pulmonary venous hypertension (e.g., congestive heart failure).

Inferior to the arch of the azygos vein and carina, the medial surface of the right lung lies against the esophagus forming the **azygo-esophageal recess**. The **left and right paraspinal lines** parallel the margins of the thoracic vertebral bodies. The left paraspinal line normally disappears at the level of the aortic arch.

Hilum

The hila are composed of the *main pulmonary arteries* and the *superior pulmonary veins*, which appear as branching vascular structures (Figures 3 and 7). The lower lobe pulmonary arteries extend for 2 to 4 cm before branching (Figure 8). The *inferior pulmonary veins* enter the left atrium inferior to the hila and do not contribute to hilar density.

Lung Markings

Normal lung markings are pulmonary arteries and veins. These appear as branching vascular structures that become successively finer and disappear within 1 cm of the lung margin (Figure 8). Due to the overlap of blood vessels, normal lung markings can have a reticular or cyst-like appearance. Abnormal lung markings are caused by thickening of the interstitial connective tissues, which are not normally visible.

The **lung markings and hila** are two problematic areas of chest radiology. There is a wide range of normal appearances and abnormalities can be subtle. Identification of abnormalities of the hila or lung markings must therefore be based on an understanding of their normal radiographic anatomy and the changes expected with various pathological processes (discussed in subsequent chapters).

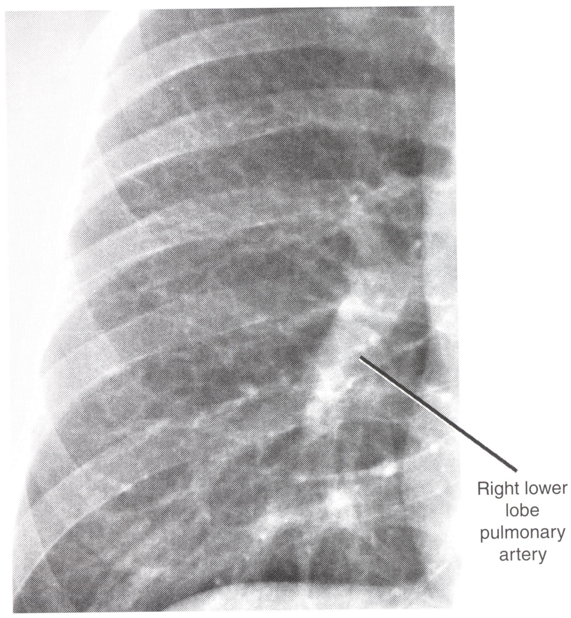

FIGURE 8 Normal hila and lung markings.
Normal lung markings are pulmonary arteries and veins that have a branching vascular appearance. Due to overlap, they can have a reticular or cyst-like appearance. Blood vessels seen on-end appear as small white dots. The lower lobe pulmonary arteries extend 2 to 4 cm from the hilum before branching.

THE LATERAL CHEST RADIOGRAPH

How to Read the Lateral View

A *systematic approach* begins with assessment of the technical **adequacy** of the radiograph. Although there are no clearly defined criteria, penetration, rotation and level of inspiration all affect image quality and interpretation. Next, the **bones** (vertebral bodies, ribs and sternum), **soft tissues** (diaphragm, heart and mediastinum), and **lungs** are examined.

The lateral view is useful to visualize pathology that may not be evident on the PA view (Table 2).

Intrapulmonary opacities (pneumonia or tumors) can sometimes be more easily seen on the lateral view. They also can be localized to a particular segment of the lung.

Normally, the lower vertebral bodies appear more radiolucent (dark) than the superior vertebral bodies because there is more overlying lung and less overlying soft tissue. When the lower vertebral bodies appear more "white," there is a lower lobe infiltrate (postero-basal segment). The retrocardiac and retrosternal regions are also better seen on the lateral than the frontal view (Figure 9).

Mild (interstitial) **pulmonary edema** can be detected on the lateral view buy noting **thickened interlobar fissures.** In addition, **small pleural effusions** may only be seen on the lateral view in the posterior costophrenic sulcus.

Hilar abnormalities, particularly hilar adenopathy, can often be more easily identified on the lateral view. **Cardiomegaly** due to enlargement of the right ventricle and left atrium can be detected on the lateral view.

TABLE 2

Useful Findings on the Lateral View

1. Intrapulmonary opacities—pneumonia, tumors
2. Thickened interlobar fissures—interstitial pulmonary edema
3. Small pleural effusion in posterior costophrenic sulcus
4. Hilar abnormalities—adenopathy, masses, increased vascularity
5. Cardiomegaly, heart chamber enlargement, and aortic abnormalities

Radiographic anatomy

The lateral view provides a view of thoracic structures perpendicular to the PA view (Figure 9) (McComb 2002). The left and right **lungs** are superimposed. Portions of the left and right major (oblique) fissures and the minor (horizontal) fissure are often visible (Figure 3B).

The left and right domes of the **diaphragm** are visible and can be differentiated using four criteria. The most reliable method is to identify the right ribs, which are more posteriorly located on the standard left lateral view (Figures 3B, 4B and 5B). The right dome of the diaphragm extends posteriorly to the right ribs at the *posterior costophrenic sulcus*. In addition the left dome of the diaphragm is usually more inferiorly located than the right side, it may be associated with the gastric air bubble, and it tends to disappear anteriorly because it is adjacent to the heart. The right dome of the diaphragm extends to the anterior chest wall.

The **heart** is seen in a different view than on the frontal view (Figure 9). The *right ventricle* forms the anterior heart border. The posterior heart border is formed superiorly by the *left atrium* and, inferiorly, the *left ventricle*. With right ventricular enlargement, the inferior portion of the retrosternal clear space is filled by the heart. With left ventricular enlargement, the heart extends posteriorly into the retrocardiac space to the vertebral bodies. With left atrial enlargement, the superior portion of the posterior cardiac border bulges posteriorly (Figure 5B).

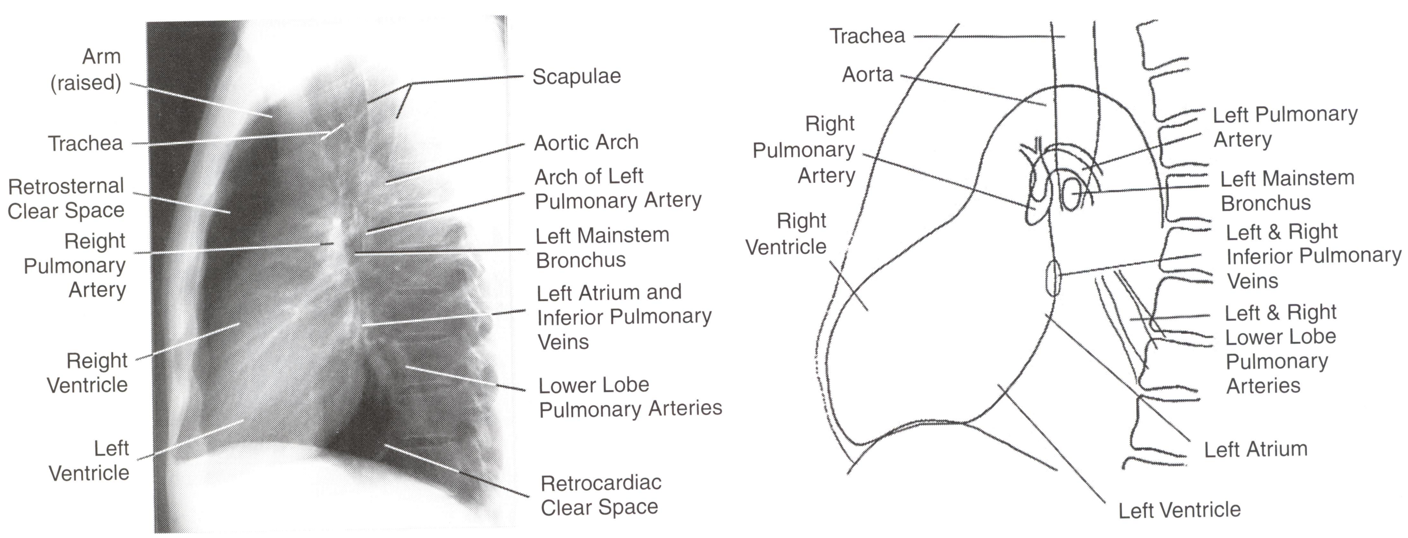

FIGURE 9 **The lateral chest radiograph.**

The **trachea** and **aortic arch** are visible on the lateral view (Figure 9). In young adults, the **descending aorta** is not seen because it is located within the mediastinal soft tissues (Figure 3B). In an elderly patient with a **tortuous aorta,** the descending aorta is elongated and is visible on the lateral radiograph because it lies next to the vertebrae and adjacent left lung (Figure 4B).

Anterior to the distal trachea and carina, the **right pulmonary artery** forms a radiopaque region (Figure 9). The **left pulmonary artery** arches over the **left mainstem bronchus. The left mainstem bronchus** therefore appears as a radiolucent oval.

Hilar adenopathy can often be readily identified on the lateral view. They are seen as areas of abnormally increased opacity adjacent to the air-filled distal trachea. Normally, the regions posterior and inferior to the distal trachea are radiolucent; when they are radiopaque, there is retrotracheal and subcarinal adenopathy.

The left and right **lower lobe pulmonary arteries** extend inferiorly and posteriorly from the hilum. These can be difficult to distinguish from a lower lobe infiltrate (Figure 9). Inferior to the hilum, along the posterior cardiac border, is a radiopaque area where the **inferior pulmonary veins** are seen on end (Figure 9). These normal vascular structures should not be misinterpreted as pathological lesions.

TABLE 3

Distortions on an AP Portable Chest Radiograph

Rotated positioning of the patient—apparent shift of trachea and mediastinum
Poor inspiration—crowded lung markings at the bases
Suboptimal exposure—over or under-penetrated
Cardiac enlargement
Widened and indistinct mediastinum
Pneumothorax and pleural effusion difficult to see on a supine view
Superimposed extrathoracic objects—spine immobilization boards, tubes, monitoring wires, and clips

THE AP PORTABLE CHEST RADIOGRAPH

AP portable chest radiographs are obtained when a patient is unable to stand and cannot be transported to the radiology suite. (Figure 10). Interpretation of an AP chest radiograph uses the same principles as a PA view, although differences in radiographic technique must be taken into account.

Several factors can either obscure or mimic pathological findings on an AP view (Table 3). The AP portable view is frequently technically suboptimal: rotated positioning, poor inspiration, and over-or under-penetrated. These factors can make the heart appear enlarged and the mediastinum appear widened and indistinct. With supine positioning, pleural fluid or a pneumothorax are located, respectively, posterior or anterior to the lung and therefore difficult or impossible to detect. Finally, superimposed extraneous objects can obscure radiographic findings.

Whenever possible, the AP view should be obtained in the *sitting position* because there will be less distortion, the patient is better able to take a full inspiration, and pleural fluid or a (pneumothorax) are more readily identified.

Another shortcoming of portable radiography is that only one view of the thorax is obtained—there is no lateral view to confirm or localize abnormalities seen on the AP view. Subtle radiographic signs of pathology such as the "silhouette sign" are therefore especially important to recognize.

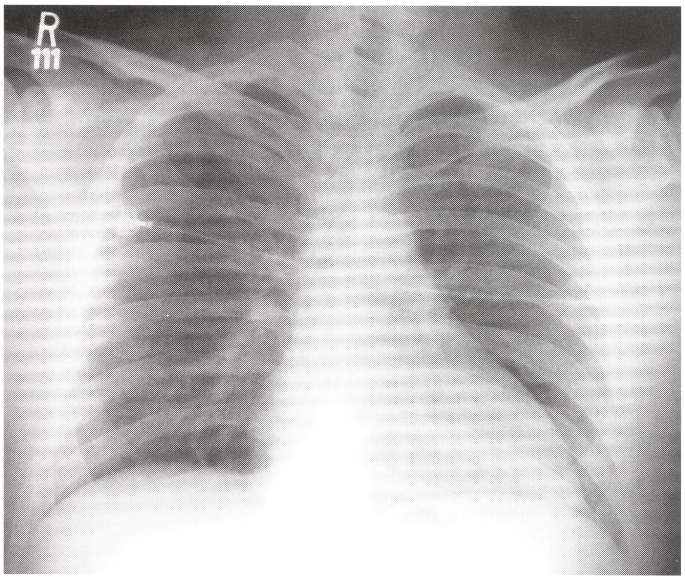

FIGURE 10 A properly performed supine AP portable chest radiograph.

The penetration and level of inspiration are good; the patient is slightly rotated to the left. The cardiac appearance is typical for portable radiogrphy, slightly enlarged and horizontal. The mediastinal structures are not well defined, but do not appear widened. A cardiac monitor lead traverses the chest.

RADIOGRAPHIC PATTERNS OF PULMONARY DISEASE—INCREASED PULMONARY OPACITY

Many pulmonary pathological processes increase or, less commonly, decrease the radiographic opacity of the lungs. Pulmonary disorders that cause fluid accumulation within lung are readily detected on chest radiography. However, diseases such as asthma or pulmonary embolism cause little or no change in pulmonary opacity and radiography generally provides little evidence of their presence.

In evaluating a region of increased opacity, the first step is to determine whether the opacity is within the lung, the pleural space, chest wall, or outside the body. Correlation with the lateral view can help localize an opacity.

There are **three patterns of increased pulmonary opacity**—either the airspaces or interstitial tissues have increased fluid content, or there is diminished aeration of a portion of the lung (known as collapse or atelectasis) (Table 4 and illustrated in subsequent chapters). Airspace-filling can be either localized or diffuse; increased interstitial tissue density has either a reticular or nodular appearance; and with atelectasis, there are signs of lung volume loss.

Infiltrates

An *ill-defined* area of increased pulmonary opacity is often termed an "infiltrate." (*Well-defined* opacities, i.e. those with sharp borders, are referred to as *masses* or *nodules*.) However, "infiltrate" is not a proper radiologic term. It is a histopathological term that refers to infiltration of the lung parenchyma (airspaces or interstitium) with abnormal cellular material (inflammatory or neoplastic cells). Not all ill-defined opacities are infiltrates. For example, airspace pulmonary edema can look radiographically like an infiltrate, but is due to fluid accumulation rather than cellular infiltration of lung tissue. It is therefore preferable to describe the radiographic finding as an "ill-defined opacity" and avoid the term "infiltrate," which has pathological connotations that may or may not be applicable (Patterson 2005, Friedman 1983, Tuddenham 1984).

When there is relatively homogenous opacification of the airspaces of the lung, the radiographic finding can be termed *consolidation.* Unlike the term "infiltrate," consolidation does not have unwarranted pathological implications.

Infiltration of the **interstitial tissues** of the lung with inflammatory or neoplastic cells could be termed an "interstitial infiltrate." However, this usage should be avoided because interstitial pulmonary edema can have a similar radiographic appearance even though it is not truly an infiltrate. It is therefore preferable to describe the lesion's radiographic appearance.

Interstitial lung disorders can have a reticular, nodular or reticulonodular appearance. However, many interstitial lung diseases also involve the airspaces of the lung, resulting in ill-defined opacities of airspace filling. There is thus often a disparity between the histopathology of an interstitial lung disease and its radiographic appearance, e. g.,—patchy multifocal airspace filling rather than an interstitial pattern. High-resolution CT (HRCT) can better characterize a pulmonary pathological process, although it is generally not warranted in the ED (Kazerooni 2001, Gotway 2005).

TABLE 4
Patterns of Increased Pulmonary Opacity

AIRSPACE FILLING
Localized = segmental
Diffuse or multifocal
INTERSTITIAL PATTERNS
Reticular—fine or coarse linear shadows
Reticulonodular
Nodular—small (2 to 3 mm), medium, large, or masses (>3 cm)
ATELECTASIS
Diminished aeration of lung.
Associated with signs of volume loss

RADIOGRAPHIC FINDINGS AND CLINICAL DIAGNOSIS

Radiography is used in two complementary ways to assist in making a diagnosis. First, by identifying a particular radiographic pattern, a list of potential diagnosis can be generated (Table 5 and Case A) (Reed 2003). Second, based on a patient's clinical presentation, certain disorders will be suspected, and examination of the radiographs is targeted to identifying radiographic signs of the suspected diseases (Table 6). Certain disorders can have subtle radiographic manifestations and the examiner must search carefully for these findings (Case B).

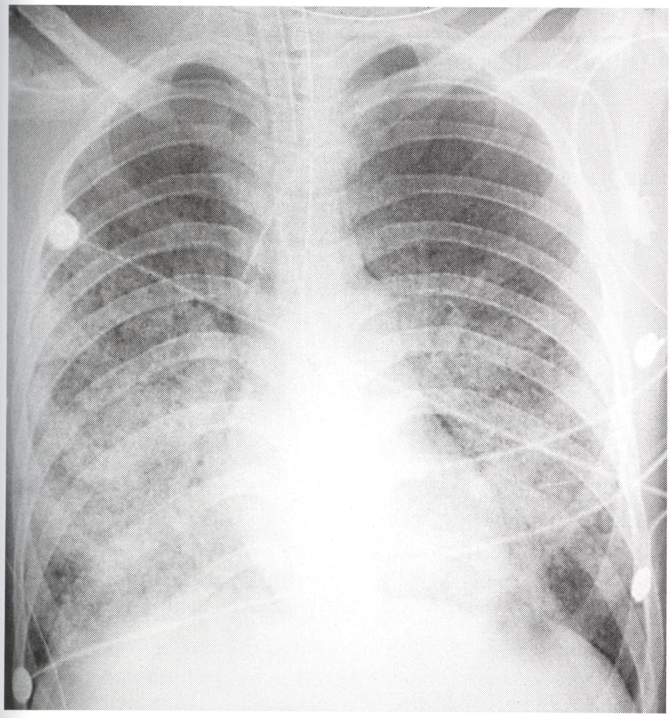

FIGURE 11 Case A

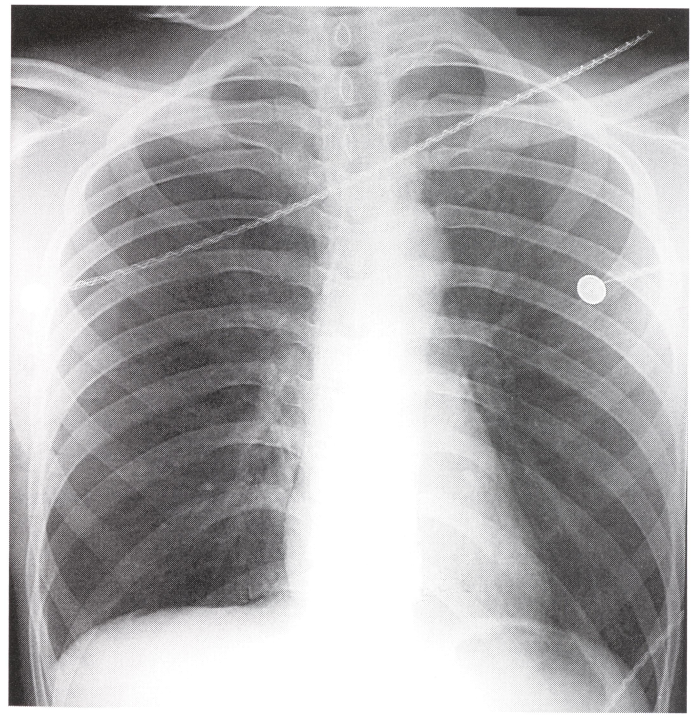

FIGURE 12 Case B

CASE A.
PATTERN RECOGNITION IN RADIOGRAPH INTERPRETATION

A 21-year-old man presented with cough and hemoptysis that had developed over two days. He was previously healthy. He expectorated a teaspoon quantity of blood mixed with clear phlegm. Initially, his respiratory rate was 28, pulse 110, and auscultation of his lungs revealed scattered râles. He was placed in respiratory isolation because of concern about tuberculosis.

While being observed in the ED over the next three hours, he developed increasing respiratory difficulty, hypoxia, and tachypnea that required endotracheal intubation. His temperature rose to 103.6°F.

His chest radiograph is shown (Figure 11).

- What disorders should be suspected based on the clinical presentation and radiographic findings?

CASE B.
TARGETED APPROACH TO RADIOGRAPH INTERPRETATION

A 25-year-old man presented with an abrupt onset of unilateral pleuritic chest pain. He had no prior medical problems. His physical examination was normal, including equal breath sounds bilaterally.

His chest radiograph appears normal (Figure 12).

In this patient, a systematic approach to radiograph interpretation would be time-consuming and could potentially miss the pertinent finding. A targeted review of the radiograph looking for subtle signs of the clinically suspected disorder will lead quickly to the correct diagnosis.

- What is this patient's diagnosis?

TABLE 5

Patterns of Increased Pulmonary Opacity—Differential Diagnosis

A. Focal Airspace Disease
- Pneumonia
- Pulmonary embolism: infarction or intrapulmonary hemorrhage
- Neoplasm: alveolar cell carcinoma, lymphoma (usually diffuse)
- Atelectasis: opacity accompanied by signs of volume loss

B. Diffuse or Multifocal Airspace Disease
- Pulmonary edema: CHF and non-cardiogenic pulmonary edema
- Pneumonia: bacterial, viral, Mycoplasma, Pneumocystis
- Hemorrhage: trauma (contusion), immunologic (Goodpasture's), bleeding diathesis, pulm. embolism
- Neoplasm: alveolar cell carcinoma, lymphoma
- Desquamative interstitial pneumonitis (DIP), alveolar proteinosis

Bat-wing pattern—Central opacification with peripheral clearing—characteristic of pulmonary edema

C. Fine Reticular Pattern

Acute:
- Interstitial pulmonary edema
- Interstitial pneumonitis: viral, Mycoplasma
- (Airspace filling often accompanies interstitial pneumonia and pulmonary edema)

Chronic:
- Lymphangitic metastasis, sarcoidosis, eosinophilic granuloma, collagen vascular diseases, inhalation injuries, idiopathic pulmonary fibrosis ("fibrosing alveolitis"), resolving pneumonia

D. Coarse Reticular Pattern—Honeycomb lung—end-stage pulmonary fibrosis
- Also seen when pneumonia or pulmonary edema occurs in patients with underlying emphysema

E. Reticulonodular Pattern
- A common radiographic pattern that encompasses the same disorders as reticular patterns

F. Miliary Pattern—2 to 3 mm well-defined nodules ("micronodular pattern")
- Tuberculosis, Fungal, Nocardia, Varicella
- Silicosis, Coal Worker's lung, Sarcoidosis, Eosinophilic granuloma
- Neoplastic (adenocarcinoma, thyroid)

G. Nodular Pattern—Margins of the lesions are generally well-defined. Mass: >3 cm
- Neoplasm: metastatic, lymphoma; benign tumors
- Fungal or parasitic infection, septic emboli
- Rheumatoid nodules, Wegener's granulomatosis

TABLE 6

Radiograph Interpretation Based on Clinical Presentation

Symptom	Disorders that Have Characteristic Radiographic Findings
Cough and/or fever	Pneumonia, tuberculosis, cancer
Chest pain	Pneumothorax, aortic dissection, pulmonary embolism, rib fracture, cancer
Dyspnea	Congestive heart failure/pulmonary edema, pulmonary embolism, COPD, pericardial effusion, cancer
Trauma	Aortic injury, pneumothorax, hemothorax, pulmonary contusion, rib fractures

CASE A (CONTINUED).
PATTERN RECOGNITION IN RADIOGRAPH INTERPRETATION: DIFFUSE AIRSPACE FILLING

The radiograph shows diffuse opacification of the airspaces of both lungs (Figure 11). It has a uniform (as opposed to central) distribution. Centrally distributed airspace filling is characteristic of congestive heart failure.

Fluid that fills the airspaces of the lungs may be either an inflammatory exudate (pneumonia), pulmonary edema (cardiogenic or non-cardiogenic), blood or neoplastic cells. Although neoplastic infiltration of the lung usually has an interstitial pattern (nodules or masses), bronchoalveolar cell carcinoma and occasionally lymphoma can fill the airspaces. Miscellaneous causes of airspace filling include desquamative interstitial pneumonitis (DIP) and alveolar proteinosis (Table 5 part B).

In a young man with high fever and diffuse airspace filling, pneumocystis pneumonia related to AIDS is a major concern. However, this patient denied any risk factors for HIV infection.

Among the many causes of **hemoptysis,** pneumonia and bronchitis are most common; tuberculosis and cancer are most feared (although his radiographic findings were not consistent with these disorders); and pulmonary edema usually causes pink, frothy sputum. Other causes of hemoptysis include pulmonary embolism and pulmonary hemorrhagic disorders.

This patient was admitted to the medical intensive care unit and treated with ceftriaxone, azithromycin, trimethoprim/sulfamethoxazole, amikacin, isoniazid, rifampin, pyrazinamide, ethambutol, amphotericin B, and high-dose corticosteroids. He did not improve. To evaluate microscopic hematuria, a renal consultant ordered the correct diagnostic test—an antiglomerulobasement membrane antibody. The antibody levels were markedly elevated, which is diagnostic of Goodpasture's syndrome. Emergency plasmapheresis was attempted but the patient did not survive.

Although Goodpasture's syndrome is often considered a disease that primarily causes renal failure, in some cases pulmonary manifestations predominate. Rapid progression of pulmonary hemorrhage is typical.

This case illustrates the use of pattern recognition (diffuse airspace filling) in determining a list of diagnostic possibilities.

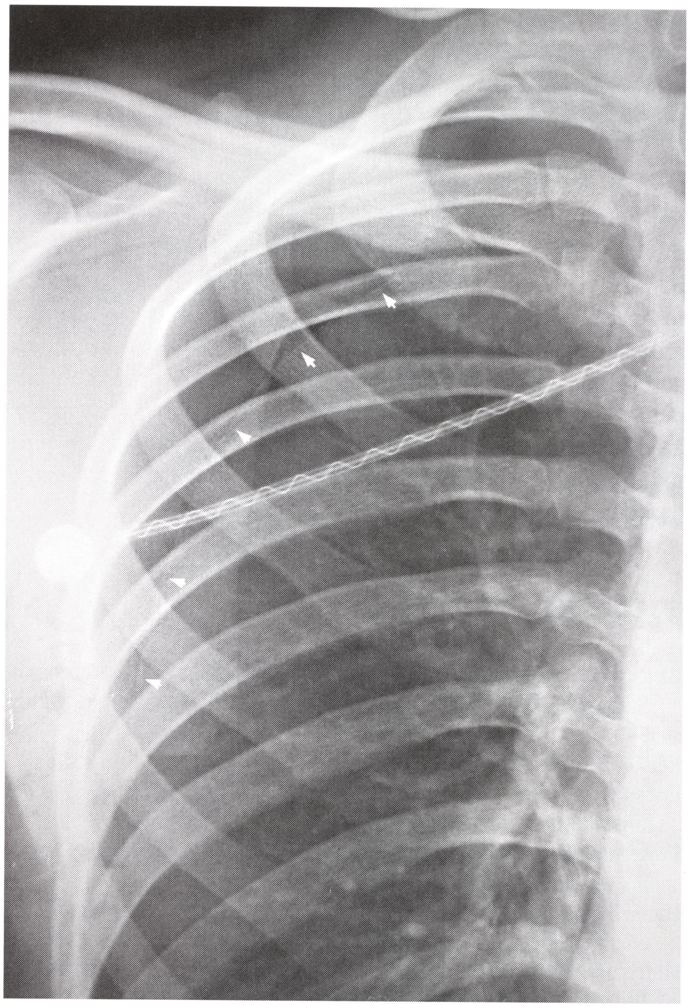

FIGURE 13 Case B (detail)

CASE B (CONTINUED).
TARGETED APPROACH TO RADIOGRAPH INTERPRETATION

In this patient, spontaneous pneumothorax was one of the principal diagnoses suspected. However, there are no obvious radiographic signs of pneumothorax. Examination of the radiograph should therefore be directed to looking for subtle signs of a pneumothorax—a fine line representing the surface of the collapsed lung that parallels the margin of the thorax.

In this patient, a pneumothorax can be seen along the right pleural margin, the side of the patient's chest pain (Figure 13, *arrowheads*).

A targeted approach to radiograph interpretation can provide quick and accurate results. After noting the expected abnormality, the entire radiograph should be reviewed systematically to avoid missing other potentially significant findings.

HARD AND SOFT RADIOGRAPHIC SIGNS

Some radiographic findings have greater diagnostic reliability than others. *Hard signs* clearly show the presence of disease, whereas *soft signs* are less clearly distinguished from normal structures, particularly structures that have a range of normal radiographic appearances such as lung markings and the hila. For example, normal lung markings that are prominent or crowded can have a similar radiographic appearance to pneumonia, an ill-defined pulmonary nodule or mild pulmonary edema.

For an individual patient, the clinician must ultimately decide whether treatment, further testing or follow up is appropriate. Nonetheless, a clear understanding of the radiographic manifestations of various diseases allows subtle but definite pathological findings to be reliably identified.

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