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Basic Chest Radiograph Interpretation

Introduction

This chapter presents the basic principles of radiography and the radiographic appearance of the normal thoracic anatomy.

With this knowledge, readers will be better able to distinguish normal from abnormal findings on the chest radiograph, to identify patterns consistent with tuberculosis (TB), as shown in the subsequent chapters of this guide, and to interact knowledgeably with their radiologist colleagues.

This guide is also designed to help clinicians consistently and accurately read and interpret chest radiographs for the presence of disease and to use standard terminology in describing patterns of abnormalities. The proper use of standard terminology ensures that other clinicians can understand the interpretation.

Basic physics of the radiographic image

A discussion of x-ray photon interactions with matter is far beyond the scope of this chapter. However, the general concepts underlying the creation of radiographic images will be explained. These concepts include x-ray absorption, tissue density, and differential x-ray absorption.

X-ray absorption

When x-rays are produced and directed toward the person, they may act in three basic ways.

They may be...	Which means...
unabsorbed	they pass through the person unchanged and strike the x-ray detector
completely absorbed	the energy of the x-ray is totally deposited within the person
scattered	they are deflected within the person but may still strike the x-ray detector

Factors contributing to x-ray absorption

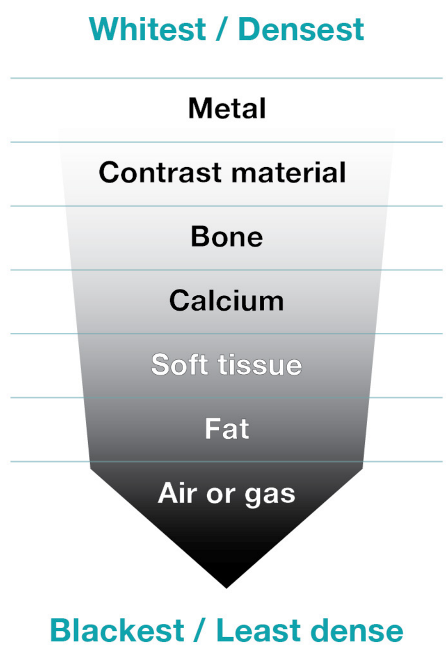
It is important to understand the factors that contribute to x-ray absorption because the final image depends on the relative number of x-rays that are unabsorbed, absorbed, or scattered. In general, the two most important factors that determine how x-rays are absorbed are the **energy** of the x-ray beam and the **density of the tissue** the beam strikes.

Energy

The energy of the beam is usually fairly constant in posteroanterior and lateral chest radiography, thus simplifying further discussion of the factors that influence x-ray absorption for these basic chest imaging views.

Tissue density

Tissue density has a more significant effect on x-ray beam absorption than the energy of the beam. In general, there are seven different densities on chest radiographs. The denser the tissue, the whiter it appears on a radiograph. The less dense the tissue, the blacker it appears. In order, from the densest (whitest) to least dense (blackest), the seven densities visible with chest radiography are:



All normal anatomic structures as well as the diverse range of cardiopulmonary abnormalities are visualized by the interplay among these seven densities. The following sections explain how this is accomplished.

Tissue density and differential x-ray absorption: Why we see what we see

Depending on the tissue density, differing quantities of x-rays will be absorbed when the x-ray beam strikes the person. This concept, called differential x-ray absorption, is the fundamental principle underlying chest radiographic image production and interpretation. In most cases, the higher the density, the greater the absorption of the x-ray photons.

X-RAY PHOTON ABSORPTION	SUBSTANCE	RADIOGRAPHIC APPEARANCE
Highest		**Whitest / Densest**
	Metal	
	Contrast material	
	Bone	
	Calcium	
	Soft tissue	
	Fat	
	Air or gas	
Lowest		**Blackest / Least dense**

For example, heart tissue is denser than lung tissue. Therefore, more photons are absorbed when an x-ray beam strikes a person's heart compared with when an x-ray beam strikes the lung adjacent to the heart. This differential absorption makes the heart appear "whiter" (denser) on the x-ray image than the lung and creates the interface between these two structures, as shown in Figure 1.1A.

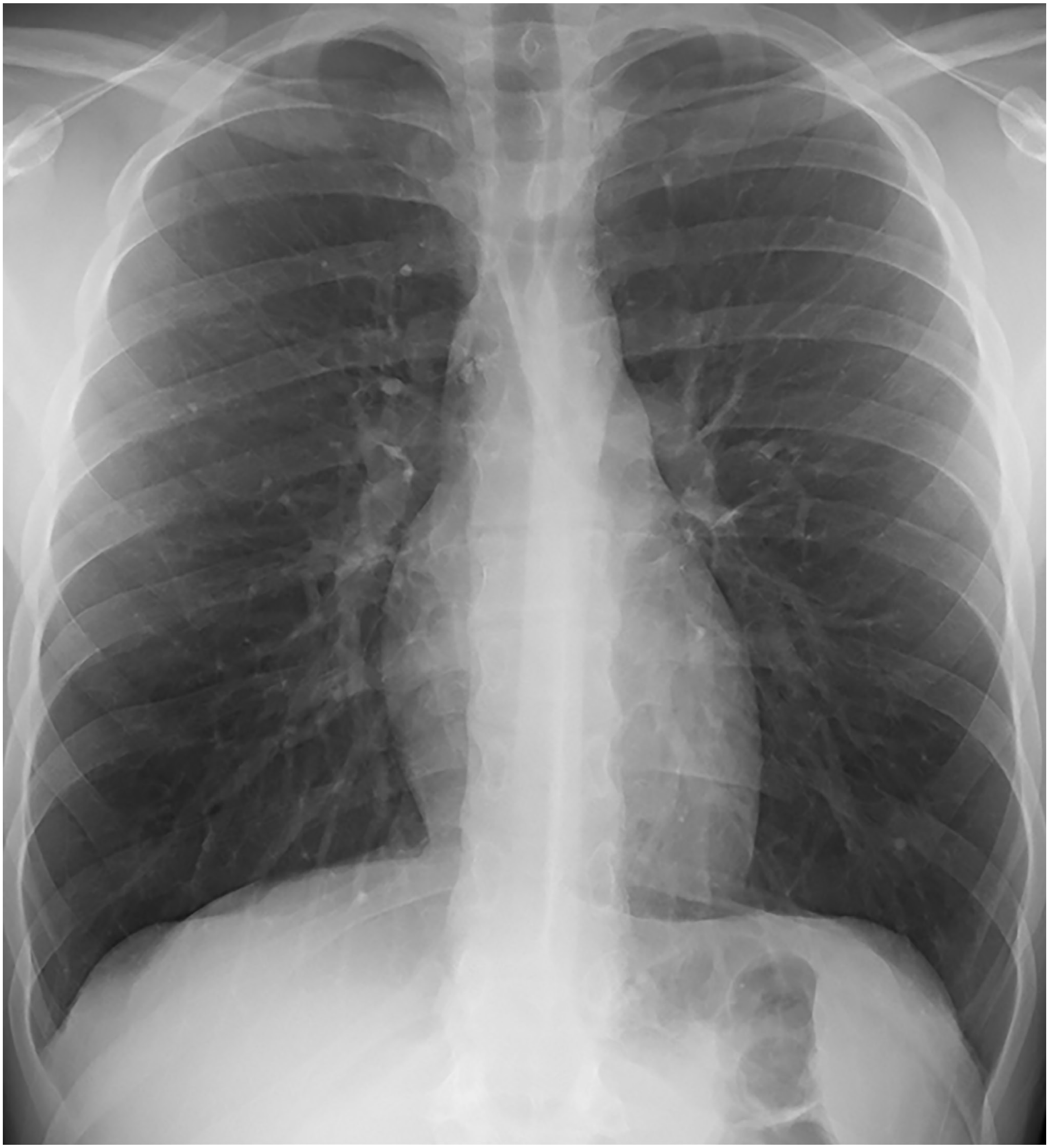
Normal contours created by aerated lung

The presence of aerated lung contacting the diaphragm and cardiomediastinal structures creates several interfaces that are normally expected to be seen and should be routinely examined on every radiograph. These expected interfaces include:

- The aerated lower lobes contact the diaphragm and allow visualization of the diaphragm.
- The medial segment of the right middle lobe contacts and allows visualization of the lateral wall of the right atrium.
- The aerated lingula contacts and allows visualization of the left cardiac contour (created by the left ventricle).
- The right upper lobe contacts and allows visualization of the superior vena cava.
- The left upper lobe contacts and allows visualization of the aortic arch.

When clinicians are familiar with these normal contours, they can correctly recognize the anatomic location of lung parenchymal abnormalities.

FIGURE 1.1A. **Normal frontal chest radiograph**



Use the unmarked image in Figure 1.1A for comparison with Figure 1.1B.

Basic chest radiographic patterns: Normal anatomy

Before exploring chest radiographic patterns of disease and their differential diagnoses, it is important to be familiar with normal chest radiographic anatomy in both the frontal and lateral projections. A basic understanding of radiographic anatomy is needed for accurate image interpretation.

Frontal chest radiograph

On the frontal chest radiograph, several mediastinal structures are usually clearly visible and should be recognized on every examination.

The arrows and other annotations on Figures 1.1B and 1.1D correspond to the descriptions below.

- The **trachea (T)** is usually easily seen on frontal radiographs.
- Occasionally, the **posterior junction line (PJL)** may be seen forming a vertically oriented line overlying the mediastinum, terminating inferiorly at the aortic arch. The posterior junction line represents the point of contact between the two lungs posteriorly.
- The **superior vena cava (SVC)** creates the most superior portion of the right cardiomediastinal contour. The soft tissue stripe created by the interface of the right lateral wall of the trachea and the adjacent right upper lobe is known as the **right paratracheal stripe (RPS)**.
- Occasionally, the **anterior junction line (AJL)** may be seen forming an obliquely oriented line overlying the mediastinum. The anterior junction line represents the point of contact between the two lungs anteriorly.
- Superiorly, the left cardiomediastinal contour is dominated by the presence of the **aortic arch (AA)**. The ascending aorta may form a border along the right cardiomediastinal contour, particularly in older persons.
- Near the inferior portion of the right paratracheal stripe, nestled in the right tracheobronchial angle, the **azygous vein (AV)** is visible.
- Just inferior to the aortic arch, the **main pulmonary artery (MPA)** is visible in the left hilar region. In most persons, the left hilum is slightly more cranially positioned than the right.
- More inferiorly and laterally, the **left interlobar pulmonary artery (LIPA)** dominates the left hilum.
- Because it contacts the lung as it courses inferiorly through the thorax, the left lateral wall of the **descending aorta (DA)** is usually visible.
- The concavity created by the overlap of the aortic arch and the left pulmonary arterial contours is called the **aortopulmonary window (*)**.
- The location of the **tracheal carina** is indicated by ⋀.

- The **left main bronchus (LMB)** is visible just below the main pulmonary artery segment and the left pulmonary artery.
- The region of the **left atrial appendage (LAA)** projects slightly inferior to the left main bronchus along the left cardiomediastinal contour.
- Just caudal to the azygous vein is the right hilum; the **right interlobar pulmonary artery (RIPA)** may be seen exiting this region, coursing laterally and inferiorly.
- The **right atrium (RA)** forms the right cardiac border. Occasionally a small contour coursing obliquely within the right cardiophrenic angle may be seen, reflecting the inferior vena cava.
- The **azygoesophageal recess (AER)** is the interface of the subcarinal mediastinum with the right lower lobe and appears as a vertical line/stripe leftward convex interface extending from the azygos arch to the right hemidiaphragm.
- The **left ventricle (LV)** completes the remainder of the left cardiomediastinal contour.
- The **right hemidiaphragm (RHD)** and **left hemidiaphragm (LHD)** contours are clearly visible.
- Under normal conditions, an adequate inspiratory effort for chest radiography will reveal the 10th posterior rib **(10)** near the diaphragmatic contour.
- The lateral **costophrenic angle (CPA)** is visible in the lower left portion of the thorax in this image.
- Upper abdominal structures are often partly visible on chest radiography, including the stomach, the **left colon (LC)**, and the **spleen (Spl)**.

FIGURE 1.1B. **Normal frontal chest radiograph**

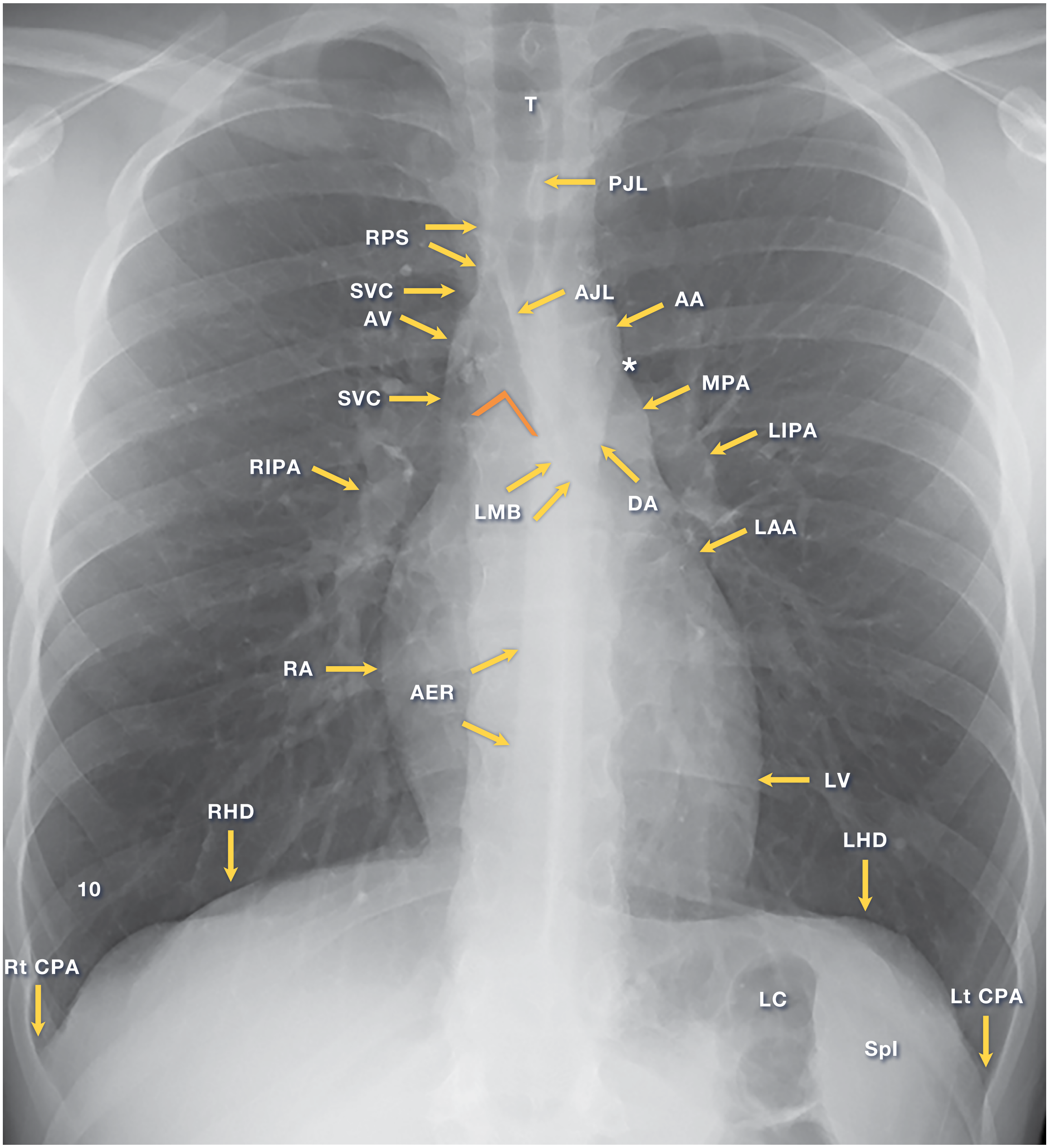
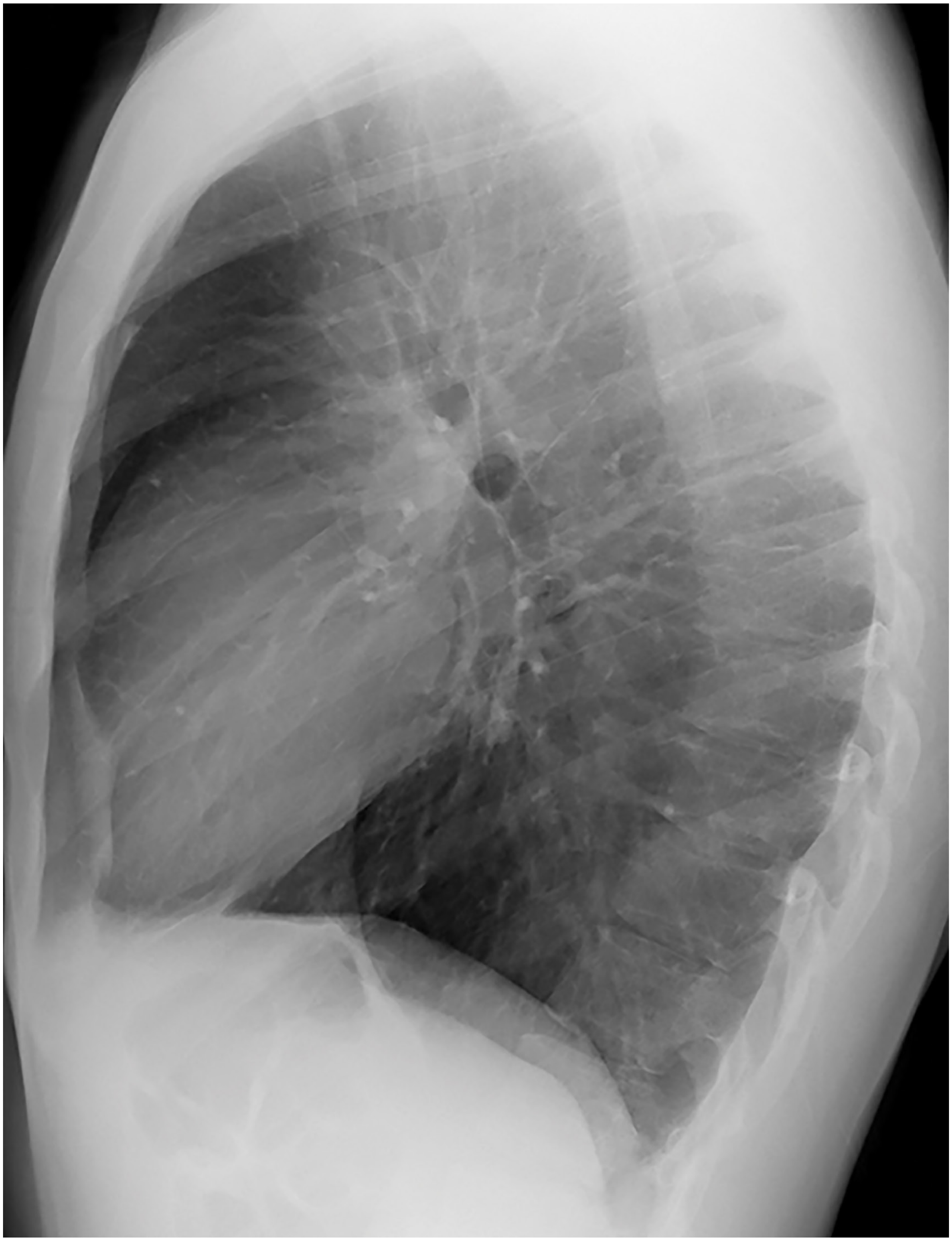


Figure 1.1B Key

^	tracheal carina	**DA**	descending aorta	**PJL**	posterior junction line
10	10th posterior rib	**LAA**	left atrial appendage	**RA**	right atrium
*	aortopulmonary window	**LMB**	left main bronchus	**RHD**	right hemidiaphragm
AA	aortic arch	**LC**	left colon	**RIPA**	right interlobar pulmonary artery
AER	azygoesophageal recess	**LHD**	left hemidiaphragm	**RPS**	right paratracheal stripe
AJL	anterior junction line	**LIPA**	left interlobar pulmonary artery	**Spl**	spleen
AV	azygous vein	**LV**	left ventricle	**SVC**	superior vena cava
CPA	costophrenic angle	**MPA**	main pulmonary artery	**T**	trachea

FIGURE 1.1C. **Normal lateral chest radiograph**



Use the unmarked image in Figure 1.1C for comparison with Figure 1.1D.

Lateral chest radiograph

- The **trachea (T)** is easily visualized on the lateral radiograph.
- The aorta may be seen extending superiorly from the heart as the ascending aorta, then coursing posteriorly as the **aortic arch (AA)**, and finally coursing inferiorly as the descending thoracic aorta.
- Anteriorly, the sternum can be seen as well as the portion of lung just deep to the sternum, called the **retrosternal clear space (RSCS)**.
- The orifice of the **right upper-lobe bronchus (RUL)** appears as a circular lucency projecting over the continuation of the tracheal air column.
- The **left pulmonary artery (LPA)** appears as a soft tissue density structure coursing superolaterally and posteriorly to the left upper-lobe bronchus.
- Just inferior and posterior to the orifice of the right upper-lobe bronchus, a soft tissue stripe is often visible. This stripe represents the **posterior wall of the bronchus intermedius** (arrowheads).
- Just inferior to the right upper-lobe bronchus orifice, a second circular lucency may be seen. This is the junction of the **left mainstem and left upper-lobe bronchus (LMSB)**.
- The **right pulmonary artery (RPA)** is visible as a rounded soft tissue density. It is anterior and slightly inferior to the orifice of the right upper-lobe bronchus.
- An area known as the **infrahilar window (^)** may be seen just inferior to the right pulmonary artery. Normally, this area is relatively clear; it should contain only vessels and bronchi. Unexpected contours in this region raise suspicion for lymphadenopathy in the right hilum or subcarinal space (see Figures 1.17A and 1.17B).
- The **right ventricle (RV)** comprises the anterior and superior portion of the cardiac contour on lateral radiographs. Right ventricular contours are not normally visible on frontal radiographs.
- Just inferior to the right pulmonary artery, the **left atrium (LA)** is visible along the posterosuperior portion of the cardiac contour. **Pulmonary veins (PV)** may be seen as tubular or nodular soft tissue densities projecting over this region.
- The **vertebral bodies (V)** and **intervertebral disc spaces (*)** are visible posteriorly.
- More inferiorly the **left ventricle (LV)**, forming the posteroinferior cardiac contour, is visible.
- The **inferior vena cava (IVC)** may occasionally be seen as a curvilinear shadow with a concave posterior border along the inferior aspect of the heart intersecting the right hemidiaphragm.
- The **right and left hemidiaphragm (RHD and LHD)** contours are visible inferiorly.
- The **posterior costophrenic angles (PCPA)** are visible inferiorly.

FIGURE 1.1D. **Normal lateral chest radiograph**

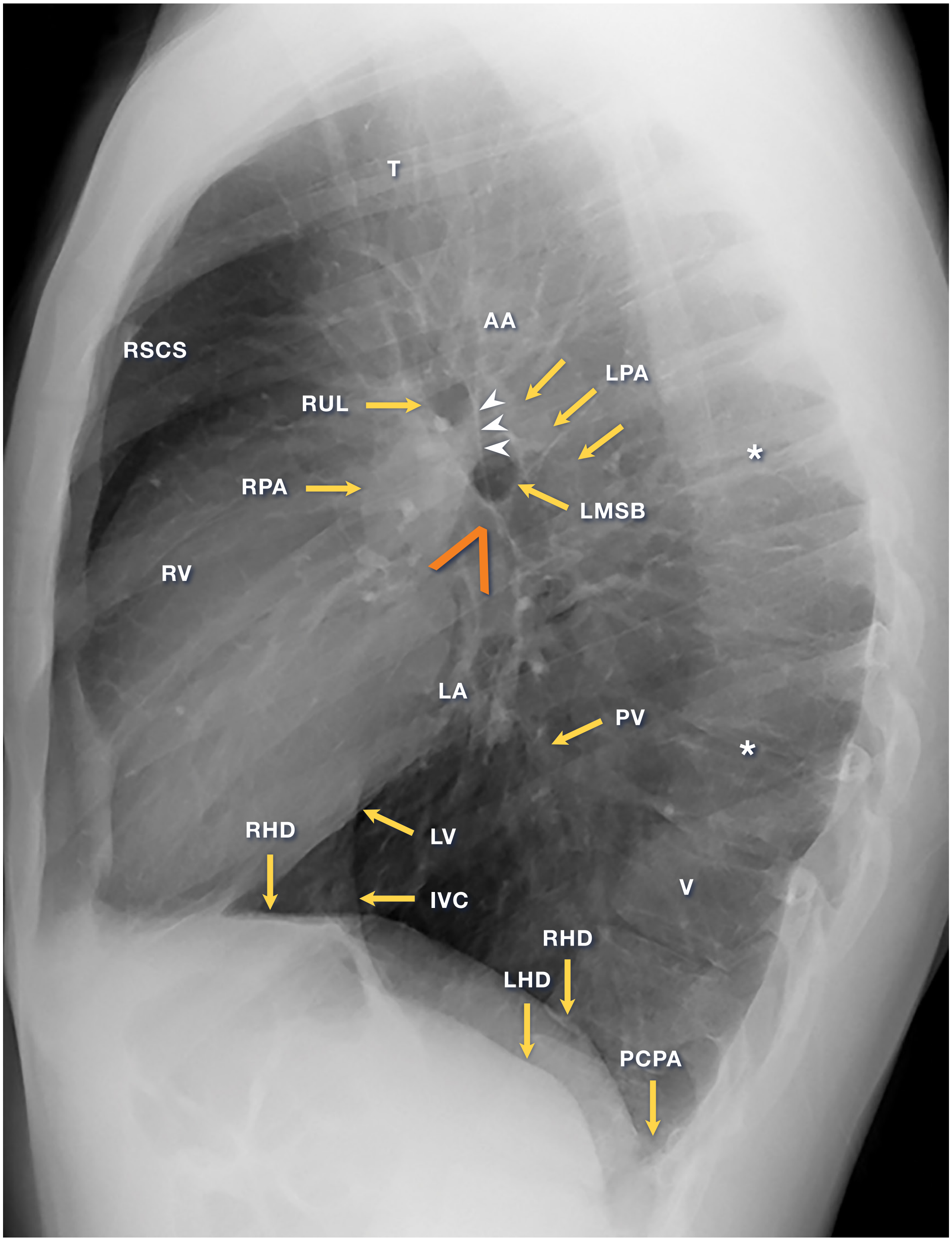


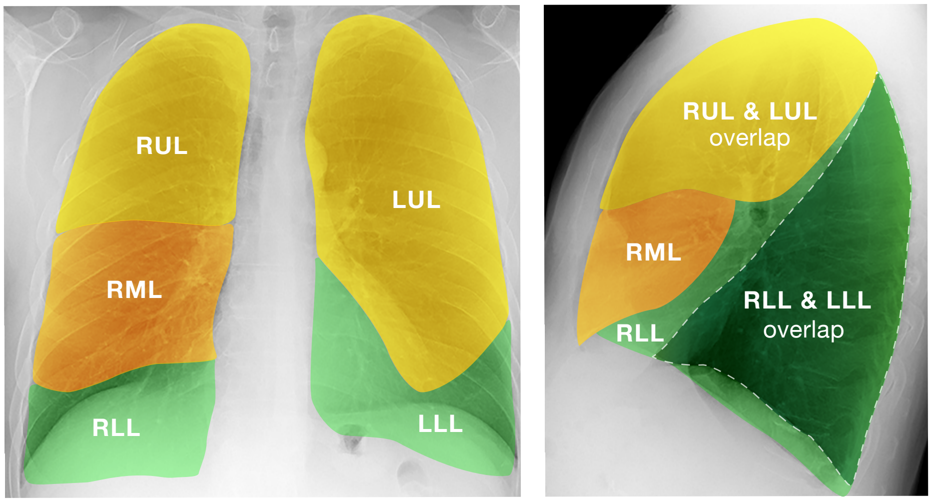
Figure 1.1D Key

*	intervertebral disc spaces	**LHD**	left hemidiaphragm	**RHD**	right hemidiaphragm
^	infrahilar window	**LMSB**	left mainstem and left upper-lobe bronchus	**RPA**	right pulmonary artery (RPA)
➤	posterior wall of the bronchus intermedius	**LPA**	left pulmonary artery	**RSCS**	retrosternal clear space
AA	aortic arch	**LV**	left ventricle	**RUL**	right upper-lobe bronchus (RUL)
IVC	inferior vena cava	**PCPA**	posterior costophrenic angles	**RV**	right ventricle (RV)
LA	left atrium	**PV**	pulmonary veins	**T**	trachea
				V	vertebral bodies

Radiographic lobar anatomy

Formal radiology readings may refer to findings in relation to pulmonary lobar anatomy. Note that the right and left lobar anatomy are not symmetrical, and that abnormalities in the superior segments of the lower lobes, best seen on a lateral view, may present quite high (cephalad) in the two-dimensional frontal view.

FIGURE 1.1E. **Radiographic lobar anatomy**

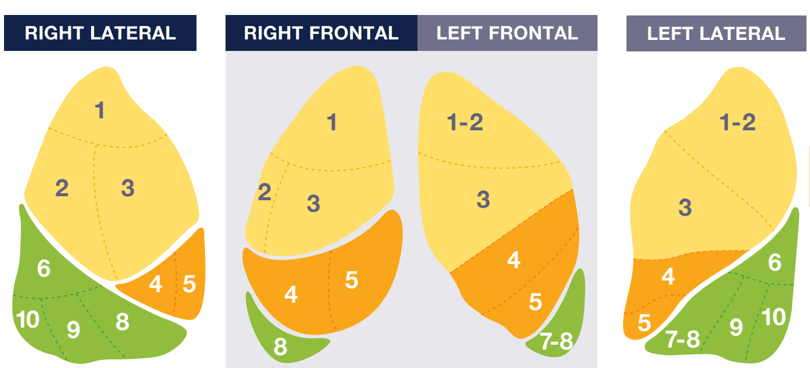


- The right upper lobe (RUL, yellow) is separated from the right middle lobe (RML, orange) by the right minor fissure.
- Note that the right major fissure separates the right lower lobe (RLL, green) from both the right upper and middle lobes, as demonstrated on the lateral chest radiograph.
- The most inferior portion of the left upper lobe (LUL, yellow) is the lingula; note how the aerated LUL contacts the left heart border, creating an interface that is normally visible on frontal chest radiographs. The left lower lobe (LLL) is highlighted in green.
- On the lateral radiograph, the area of dashed lines (dark green) shows the superimposition of the RLL and LLL. Similarly, the RUL and LUL superimpose to a large degree on the lateral chest radiograph.
- Lobar anatomy is further divided into segments as seen in Figure 1.1F.

FIGURE 1.1F. **Frontal and lateral views of lobar segments**

RIGHT LUNG

- RUL: 1 Apical; 2 Posterior; 3 Anterior
- RML: 4 Lateral; 5 Medial
- RLL*: 6 Superior; 8 Ant.basal; 9 Lat.basal; 10 Post.basal

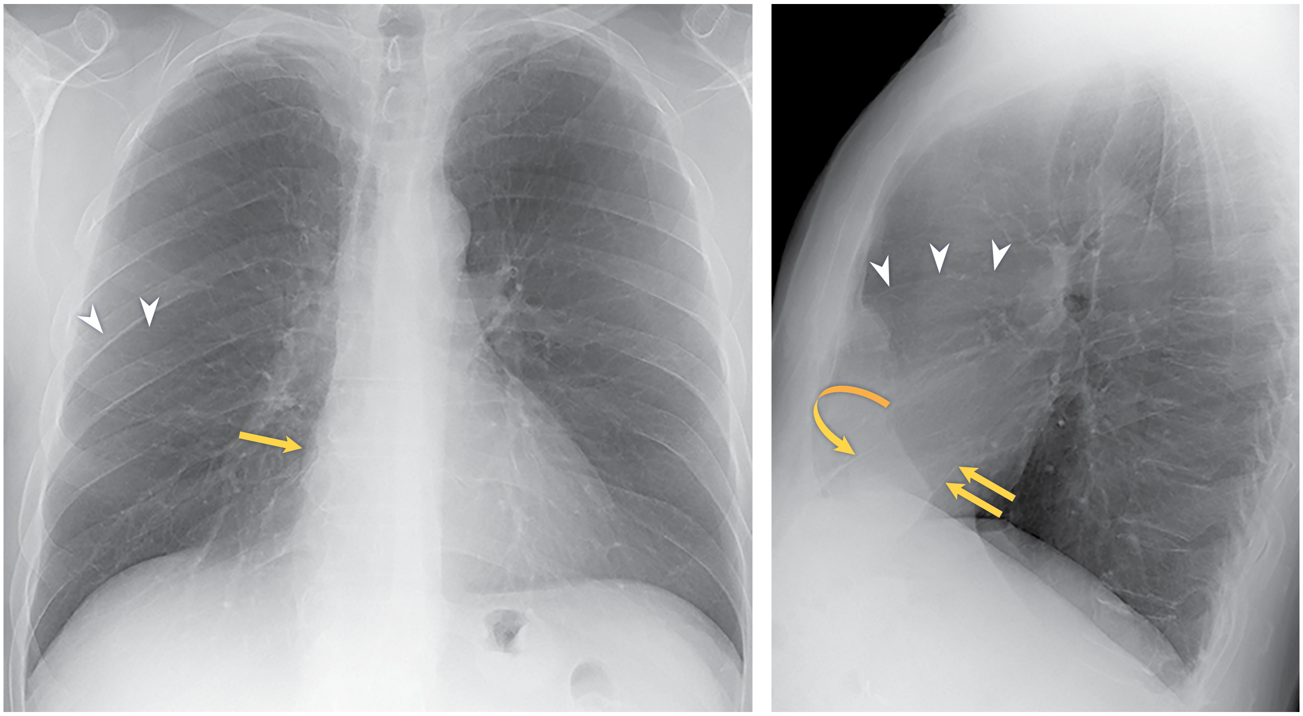


LEFT LUNG

- LUL: 1-2 Apical-post.; 3 Anterior; Lingula: 4 Superior; 5 Inferior
- LLL: 6 Superior; 7-8 Ant/medial basal; 9 Lat.basal; 10 Post.basal

* 7. Medial basal segment of RLL hidden on frontal and lateral views.

FIGURE 1.1G. **Visualizing the minor and major fissures**



- The **minor (horizontal) fissure** is seen on the front projection (arrowheads) roughly at the level of the 6th posterior rib. The minor fissure separates the right upper and right middle lobes.
- The right heart border (single arrow) denotes the right atrium, which creates an interface with the right middle lobe.
- The **major (oblique) fissures** can occasionally be partly visualized on frontal chest radiographs but are normally not as conspicuous as the right minor fissure.
- On the lateral projection, the minor fissure (arrowheads) is seen as a thin line extending from the anterior right hilum to the anterior chest wall.
- The major fissures are particularly well seen in this lateral example. The left major fissure (double arrows) is seen contacting the anterior left hemidiaphragm, and the right major fissure (curved arrow) is seen contacting the anterior right hemidiaphragm.

Localizing an abnormality

Once a clinician understands the physical principles underlying the chest radiographic image and basic thoracic anatomy, an important next step is to become familiar with the proper terms used to characterize and localize abnormalities found on the chest radiograph. Each pattern of disease discussed includes a specific radiographic example and its proper interpretation.

Using proper terms is essential for accurate characterization of chest abnormalities and to clearly communicate findings to other physicians and medical staff. Accurately and precisely characterizing an abnormality on a radiograph is the basis for generating differential diagnoses.

At the most basic level, when an area of increased density (i.e., an area that appears “whiter”) is apparent on a radiograph, the term “opacity” is used.

Once an abnormal opacity is noted, it is important to further characterize the opacity by localizing its position as:

- **Parenchymal** (within the lung)
- **Extraparenchymal** (either within the pleural space or the chest wall)
- **Mediastinal**
- **Outside the person**

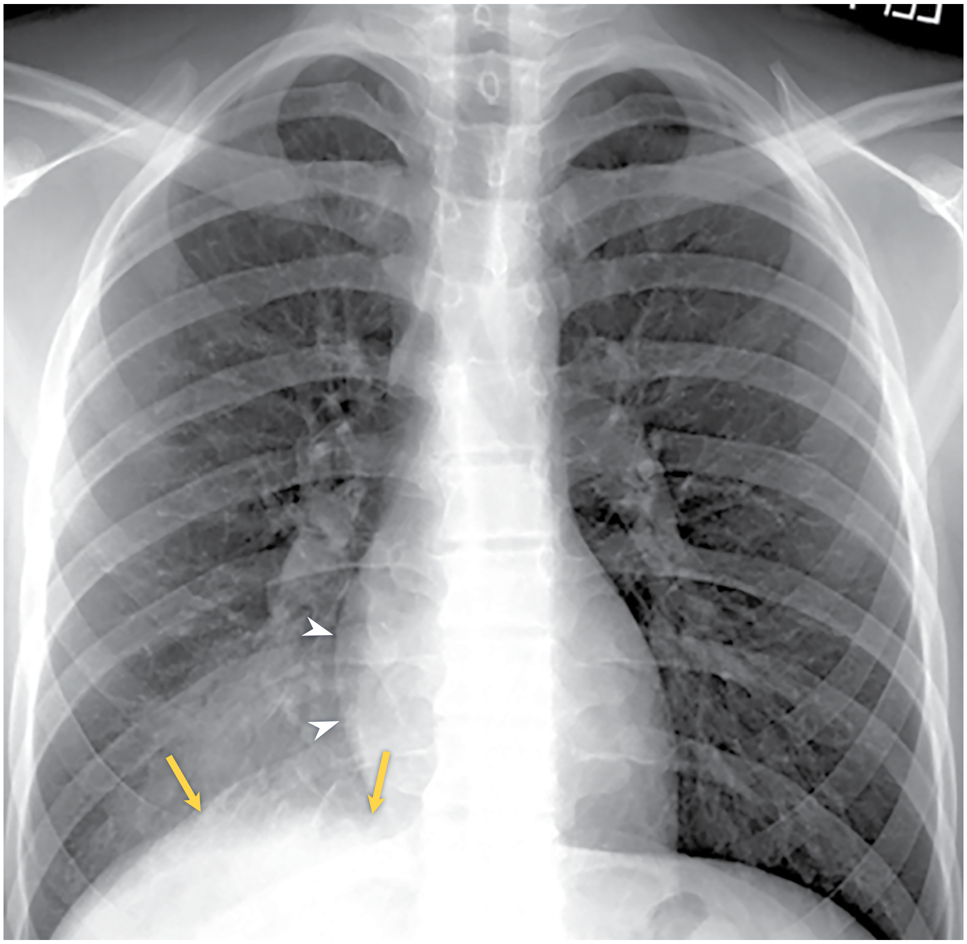
With the notable exception of artifacts in an image, any opacity seen on a chest radiograph will be located in one (or more) of the four potential locations listed above. Accurately localizing the abnormality is fundamental to developing a reasonable differential diagnosis.

Interfaces

If two structures of the same density are adjacent to each another, they will not be seen as separate structures because there is no density difference to create an interface. The heart is a good example. Although the heart consists of very different tissues (blood, muscle, pericardium, etc.), the heart's tissues are of similar density. The heart appears as one discrete structure on chest radiographs because the x-ray beam "sees" only one density, and thus one structure, as demonstrated in Figure 1.2A.

The limited density range that can be discriminated by the x-ray beam is a limitation of chest radiography. However, understanding the concept of differential x-ray absorption can still allow a viewer to accurately localize and characterize pathology on chest radiographs. How this is accomplished is illustrated by a basic chest radiographic finding known as the **silhouette sign**.

FIGURE 1.2A. **Silhouette sign**

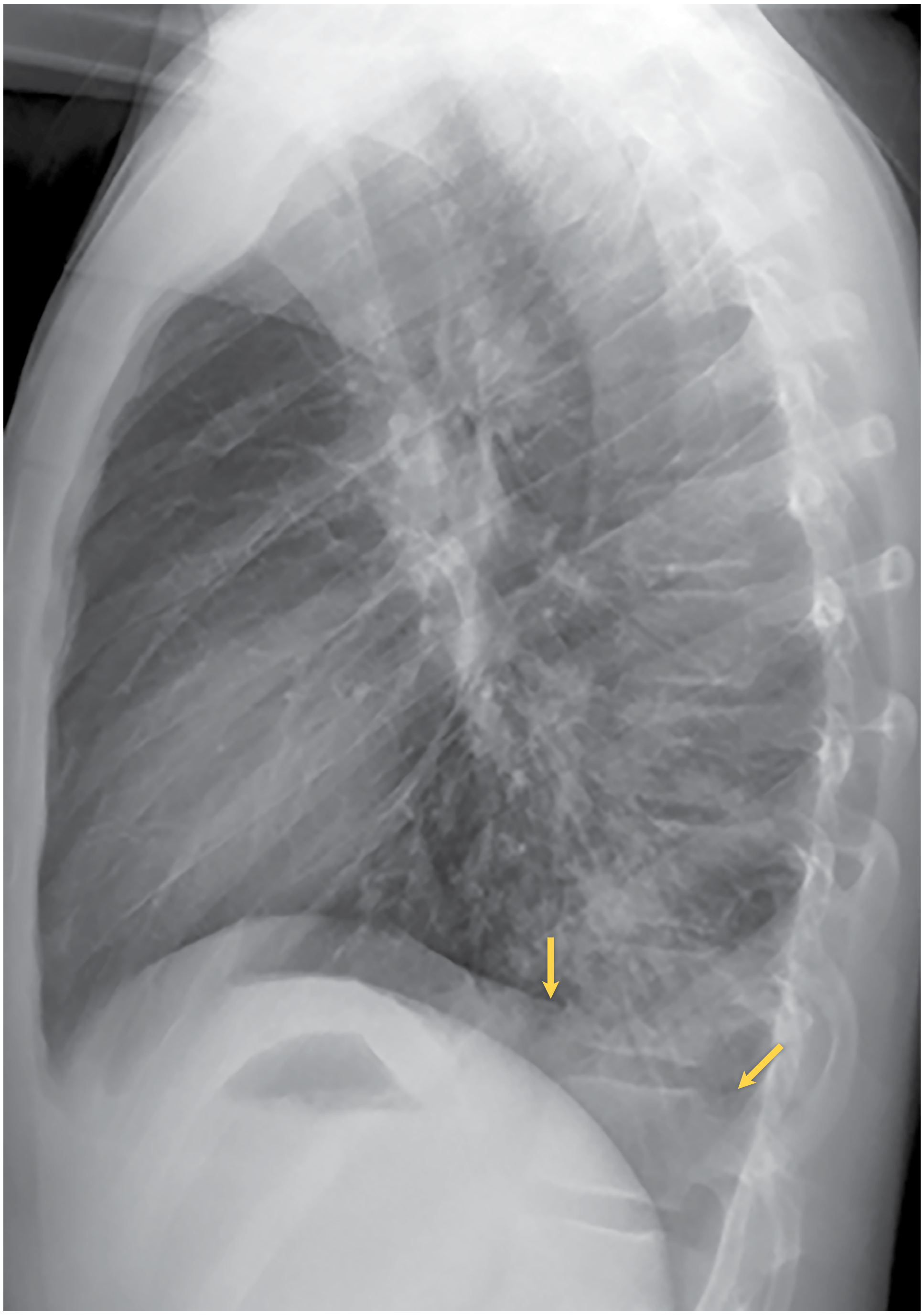


When aerated lung contacts a structure of different density (such as the heart, mediastinum, or diaphragm), an interface is created and, under normal conditions, a boundary is visible. In Figure 1.2A, the arrowheads point to the normal right heart border. This interface is created because the normally aerated lung (in this case the right middle lobe) contacts the right atrium.

When the air within the lung is replaced by another substance, such as when fluid fills the air spaces (consolidated lung), the interface created by the aerated lung is lost, indicating an abnormal condition.

Consolidated lung parenchyma, whether due to pus, blood, tumor cells, or edema fluid, has density equal to water, as does the soft tissue of the heart, mediastinum, and diaphragm. When the consolidated lung is adjacent to soft tissues such as the heart or mediastinum, the normal interface created by aerated lung is lost. The loss of the normal air-water density interface (when the lung becomes consolidated) is called the **silhouette sign**. The arrows in Figure 1.2A indicate the loss of the medial right hemidiaphragm contour due to the presence of the adjacent consolidated lung, while the lateral right and entire left hemidiaphragm contours are easily identified because the lateral right lower lobe and left lower lobe remain aerated. Note how the right heart border remains visible, indicating that the right middle lobe remains aerated.

FIGURE 1.2B. **Silhouette sign – consolidation**



In the lateral view in Figure 1.2B, note that the right hemidiaphragm contour is obscured. The loss of the normally visualized hemidiaphragm contour is the result of consolidation within the right lower lobe caused by bronchopneumonia, indicated by the arrows.

Familiarity with the concept of differential x-ray absorption helps clinicians not only to understand the normal radiographic image but also to recognize pathologic alterations.

Assessing the technical quality of radiographic studies

Before a radiograph is interpreted, the reader should always assess the quality of the study, including the following technical parameters:

- Exposure
- Proper positioning
- Inspiratory effort

Exposure

A properly exposed frontal radiograph allows faint visualization of the thoracic spine and intervertebral disc spaces as well as clear visualization of branching vessels through the heart. If the radiograph is underexposed, it becomes difficult to "see through" the mediastinal contours and heart, and thus the lung parenchyma in these areas cannot be adequately visualized. On the other hand, if the radiograph is over-exposed, the image will appear "too black." This situation may render small lung nodules or other faint pulmonary parenchymal opacities very difficult to visualize.

Proper positioning

A properly positioned radiograph shows the medial ends of the clavicles equidistantly positioned from the spinous processes of the vertebral bodies, which are seen though the trachea; essentially no patient rotation is present in this situation. Patient rotation does not necessarily render a radiograph uninterpretable, but it can create a confusing appearance.

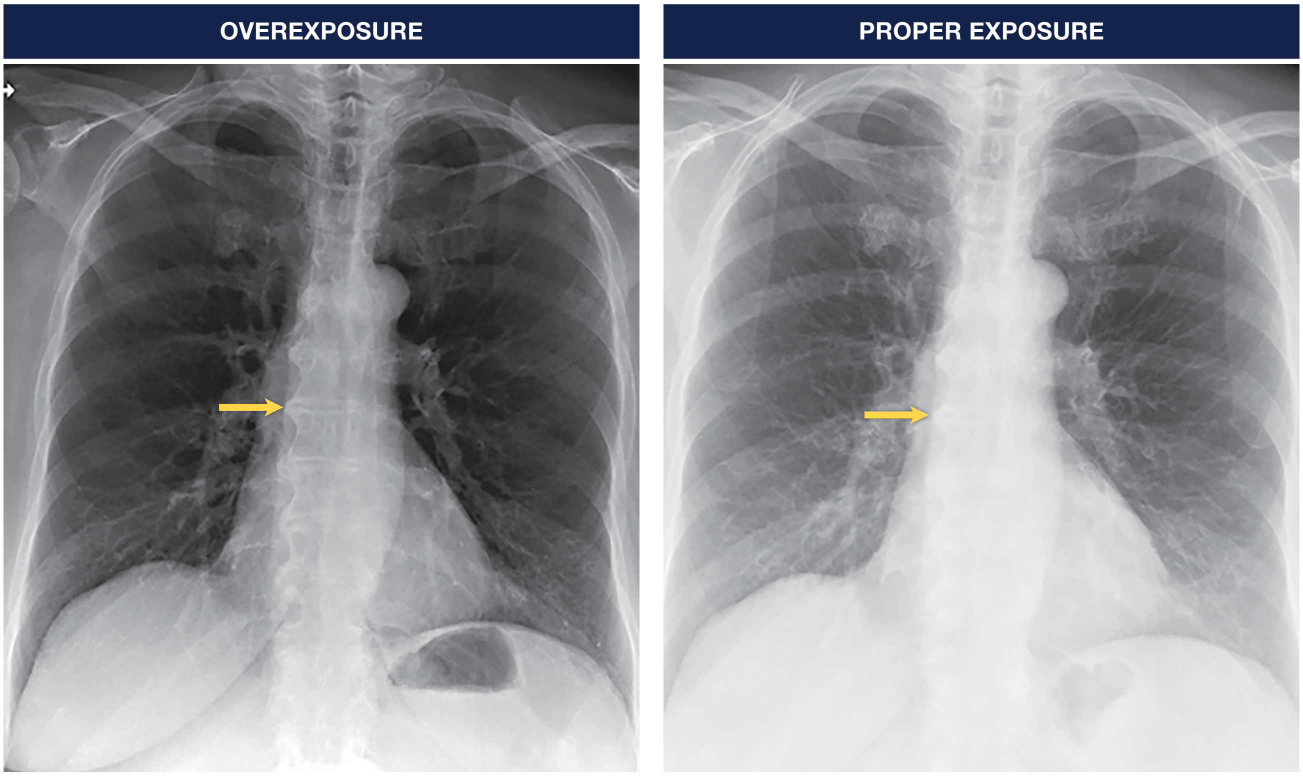
The medial ends of the clavicles will usually overlie the junction of the medial ends of the first anterior ribs with the manubrium and will be equidistant from the tracheal air column. The spinous processes will be visualized though the tracheal air column. When the clavicles are projected cranial to the first ribs, the projection is said to be lordotic. Lordotic projections can be useful for visualizing the pulmonary apices, but such projections are not desirable for routine frontal radiographs.

Inspiratory effort

Full inspiration in persons with normal lungs usually results in the diaphragm projecting over the level of the tenth posterior ribs. When the diaphragm is projected below the eleventh posterior ribs, the lung volumes are usually considered abnormally large. This situation may reflect air trapping or obstructive pulmonary disease. When the diaphragm projects near or cranial to (above) the eighth posterior ribs, the lung volumes are abnormally low. This situation may reflect poor inspiratory effort or restrictive lung disease.

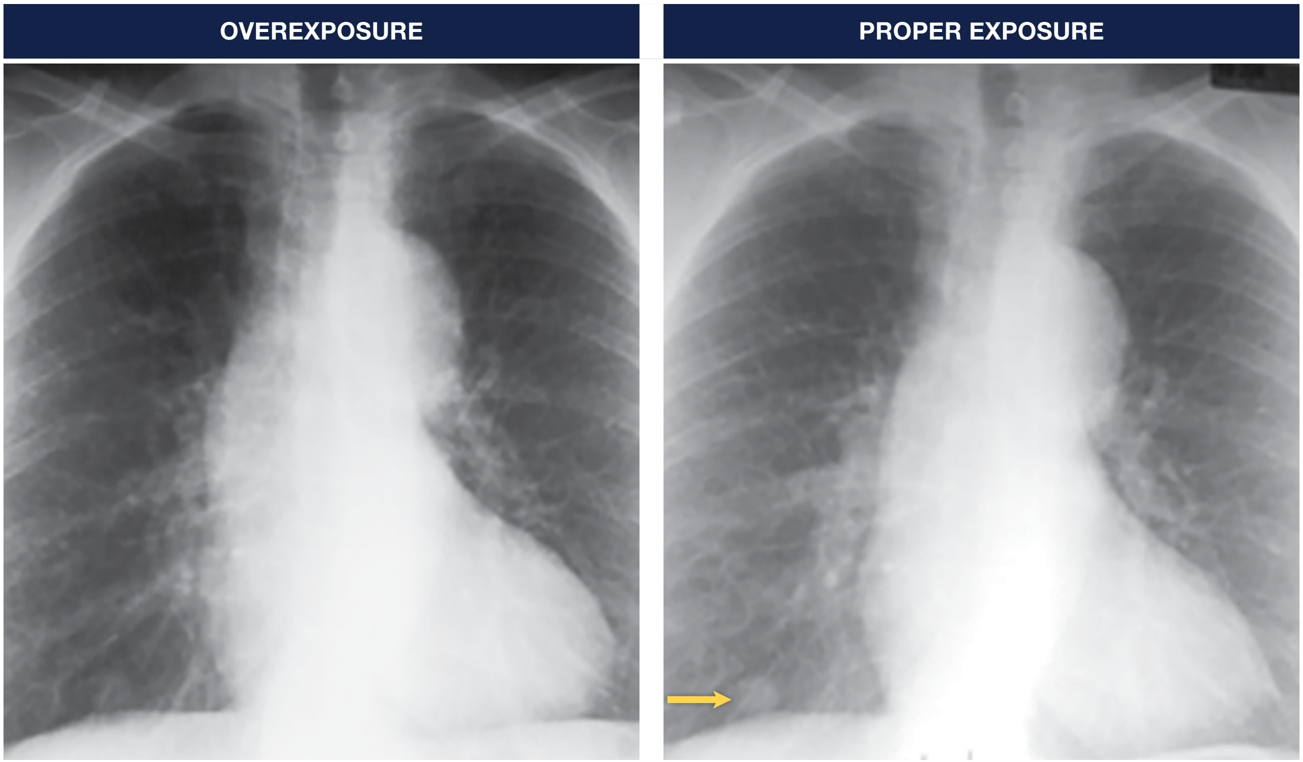
Low lung volumes often result in basilar vascular crowding and atelectasis and may create the appearance of interstitial lung disease or pneumonia in the lung bases. Additionally, low lung volumes often create the appearance of cardiac enlargement. Caution must be exercised when interpreting radiographs with low lung volumes because significant disease can easily be overlooked, or the radiograph may be overinterpreted in this setting.

FIGURE 1.3A. **Chest radiographic exposure**



The frontal chest radiograph on the left is overexposed, resulting in excessive image "blackening." Note how the lungs appear very dark, and the intervertebral disc spaces (arrow) are easily visualized. The image on the right is properly exposed. Note how lung vessels are more readily seen compared to the overexposed image, and the intervertebral disc spaces (arrow) are just visible.

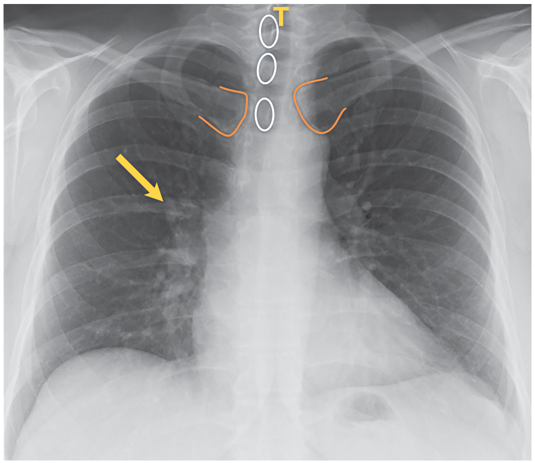
FIGURE 1.3B. **Second example of chest radiographic exposure**



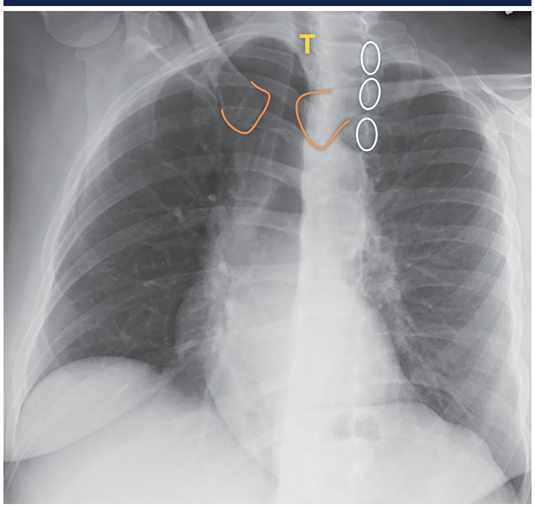
The image on the left demonstrates how a right lower lung nodule may be easily overlooked due to technical overexposure (note how blackened the right lungs appear with loss of detail for pulmonary vasculature and visualization of the posterior ribs). With improved exposure technique, the nodule (arrow) is easily visualized in the image on the right.

FIGURE 1.4. **Chest radiographic positioning**

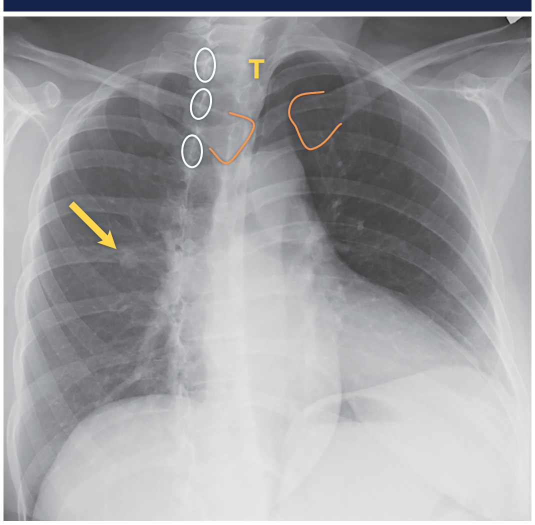
PROPERLY POSITIONED



LAO

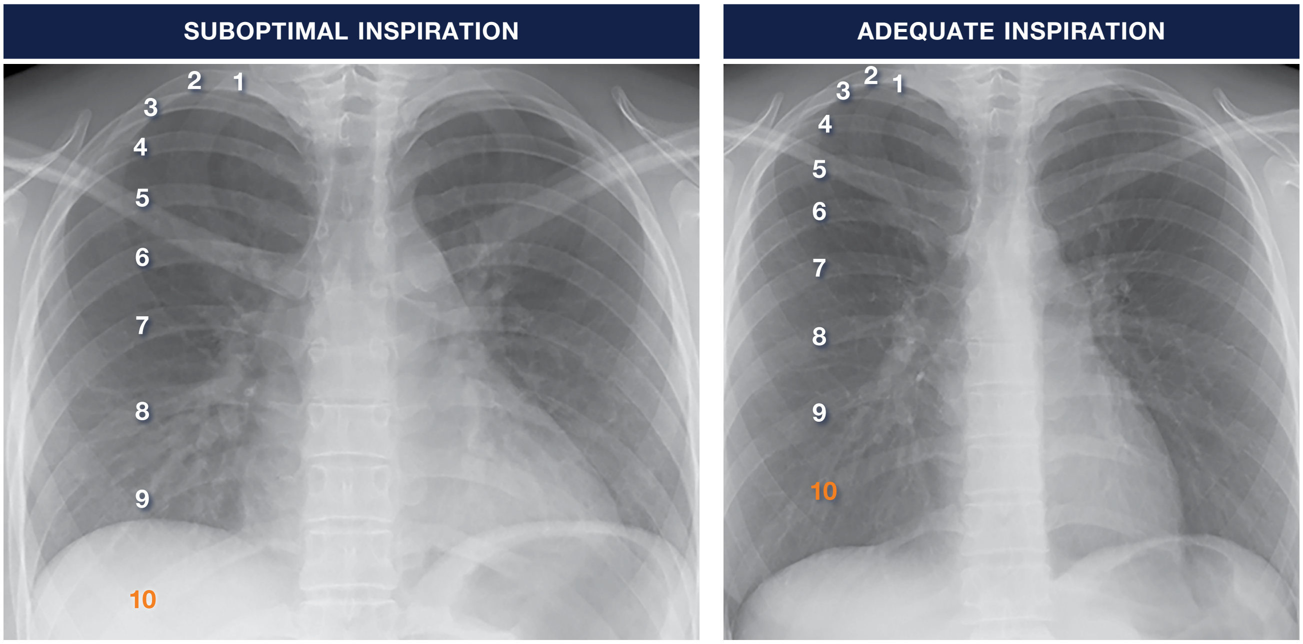


RAO



The frontal chest radiograph on the top is properly positioned. Note how the thoracic spinous processes (ovals) project through the tracheal air column (T), and the medial heads of the clavicles (outlines) are roughly equidistant from the spinous processes (ovals). A nodule (arrow) is present adjacent to the right hilum. The frontal chest radiograph in the center shows left anterior oblique (LAO) rotation – the left side of the patient's chest is somewhat anteriorly rotated (and hence the patient's right side has rotated posteriorly). Note how the medial head of the left clavicle (outline) has moved toward and just across midline, and the medial head of the right clavicle (outline) is positioned toward the right. The thoracic spine posterior elements (ovals) are now seen toward the left of midline and do not project through the tracheal air column (T). The frontal chest radiograph on the bottom shows right anterior oblique (RAO) rotation – the patient's right clavicle (outline) has moved toward midline and the left clavicular head (outline) is positioned well from midline toward the left. The thoracic spine posterior elements (ovals) project well toward the right, and not through the tracheal air column (T). Notice how the nodule (arrow) is more easily detectable now that it is projected away from the right hilum.

FIGURE 1.5. **Chest radiographic inspiratory effort**



The frontal chest radiograph on the left was obtained with suboptimal inspiratory effort. Posterior ribs are numbered. Note how the cardiomediastinal contour appears enlarged, basilar linear opacities are present, and the posterior 10th rib projects below the hemidiaphragm. The image on the right was obtained with adequate inspiratory effort only moments after the image on the left. Note how the cardiomediastinal contours appear normal, the basal bronchovascular thickening has resolved, and the posterior 10th rib is visualized just cranial to the hemidiaphragm.

Chest radiograph interpretation: Basic patterns of disease

This section will describe the basic patterns of disease visualized on the chest radiograph, including the proper terminology used to describe radiographic abnormalities. Correct use of descriptive terminology conveys information that localizes the abnormal processes and helps the viewer to generate accurate differential diagnoses. The basic patterns of disease visible on chest radiography and the acceptable terms to describe these disease patterns are:

- **Consolidation** (or airspace filling)
- **Interstitial** (including linear and reticular opacities, small well-defined nodules, miliary patterns, and peribronchovascular thickening)
- **Nodule**
- **Mass**
- **Lymphadenopathy**
- **Cyst/cavity**
- **Pleural abnormalities**

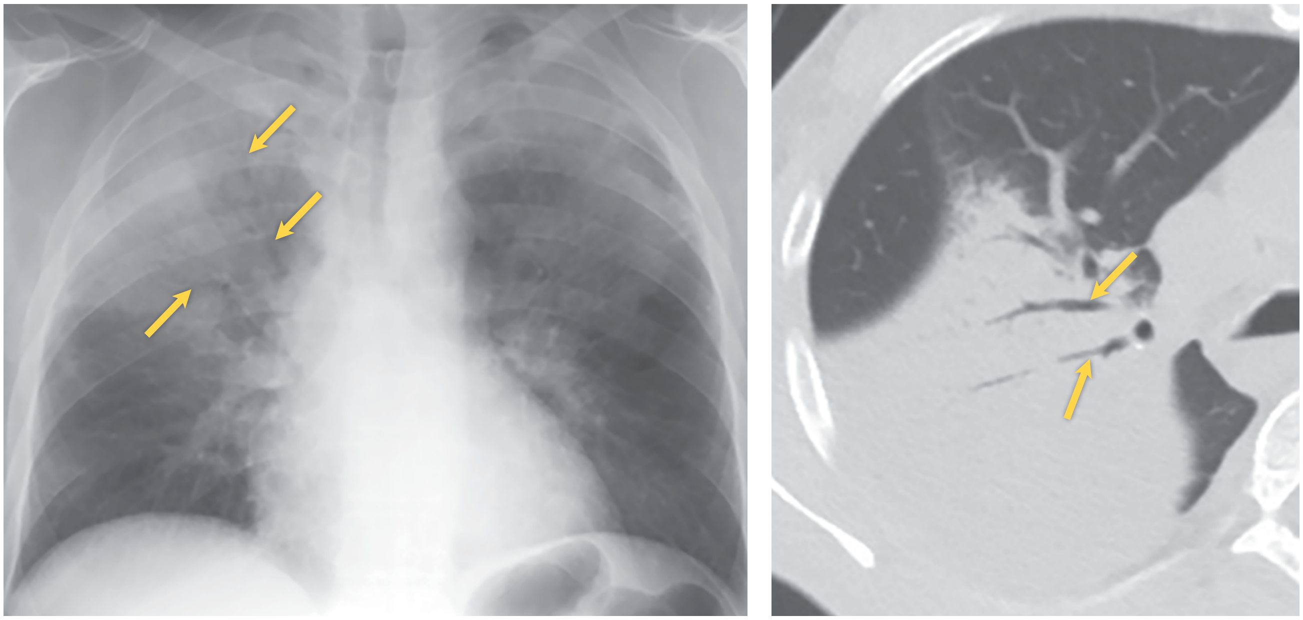
When interpreting radiographs, it is important to understand that more than one of the basic patterns may be present simultaneously. Such radiographs can be quite challenging to interpret. In general, a final interpretation should attempt to synthesize multiple patterns into a single diagnosis whenever possible. For example, the combination of a pulmonary nodule, an ipsilateral pleural effusion, and lymphadenopathy is suggestive of bronchogenic carcinoma with nodal (and perhaps pleural) metastases.

Occasionally it is simply not possible to combine several disease patterns into a single, unifying diagnosis. Under such circumstances, it is often best to generate a differential diagnosis based on the dominant disease pattern present.

Consolidation (airspace opacity)

Consolidation appears as a confluent, ill-defined opacity, obscuring the normal interfaces created by pulmonary blood vessels, and often extends to pleural surfaces (Figure 1.6; also see Figure 1.2A and 1.2B, arrows indicating the obscured right hemidiaphragm). Consolidation occurs when air within the pulmonary parenchyma is replaced by another substance, such as blood, pus, water (i.e., edema), or tumor cells.

FIGURE 1.6. **Basic features of consolidation (airspace opacity)**
Also see Figures 1.2A and 1.2B



Air bronchograms

An air bronchogram may be seen when consolidation is present. An air bronchogram is a manifestation of the basic principle of differential x-ray absorption. Normally, air within bronchi is not visible because normal bronchi are surrounded by aerated lung. When the alveoli become airless, or consolidated, bronchi become visible because the air within them is now contrasted with surrounding fluid density within the lung parenchyma. The air bronchogram is a fundamental sign of consolidation, or airspace filling, and confidently localizes an opacity on the chest radiograph as within the lung parenchyma.

Acinar shadow

Another indication of airspace filling or consolidation, acinar shadows appear as ill-defined 4-8 mm opacities, presumed to represent opacification of pulmonary acini. Multiple acinar shadows create the confluent, ill-defined opacity characteristic of consolidation previously described.

KEY POINTS

- Consolidation represents an airless lung; it occurs when air in the lung parenchyma is replaced by some other substance such as pus, blood, edema, or tumor cells.
- The air bronchogram is created when the consolidated lung surrounds air-filled bronchi, causing these bronchi to be visible.

DIAGNOSIS

- Right upper lobe pneumonia. Air bronchograms (arrows) are visible in the right upper lobe and clearly shown on CT.

Interstitial opacity

Linear opacities, septal lines, reticular opacities, peribronchovascular thickening, nodules, and the miliary pattern are radiographic manifestations of interstitial lung disease. These patterns suggest a disease process localized to the pulmonary interstitium, as opposed to the air spaces, and lead to specific differential diagnoses.

Linear opacity: Septal lines

- Occasionally, thin, 1-3 mm thick, straight lines, 1.5-2 cm in length, and perpendicular to the pleural surface, may be visible on radiographs. These opacities are called septal lines, or Kerley's B lines, and they represent thickening of the interlobular septae.
- When these lines are 1-2 mm thick, 2-6 cm in length and extend from the hilum toward the periphery, they may be called Kerley's A lines. These structures also represent thickened interlobular septae.

FIGURE 1.7. **Linear opacity**

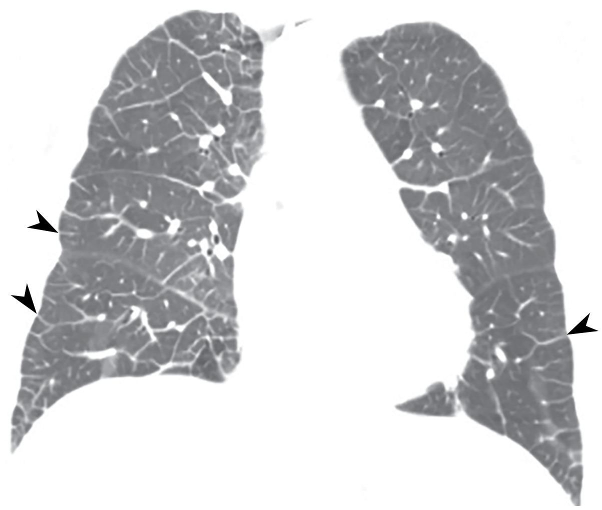


Figure 1.7 demonstrates numerous abnormalities, but one feature in particular is characteristic of interstitial opacity: interlobular septal thickening or Kerley's B lines (arrowheads).

KEY POINTS

- Kerley's B lines are thin, linear opacities perpendicular to the pleural surface. In this radiograph, they are best visualized in the lateral portion of the thorax.
- Kerley's B lines represent thickening of the interlobular septae.
- When interlobular septal thickening is a prominent feature on chest radiography, the differential diagnoses include increased pressure edema (heart failure, volume overload, etc.), neoplasia (carcinomatosis, mechanical lymphatic obstruction due to lymphadenopathy, lymphoma, and Kaposi sarcoma) and, less commonly, diffuse fibrotic lung diseases (sarcoidosis).

DIAGNOSIS

- Congestive heart failure

Reticulation

Reticulation refers to the multiple tiny lines that intersect each other at several angles, creating a netlike pattern on the chest radiograph.

FIGURE 1.8. **Reticulation**

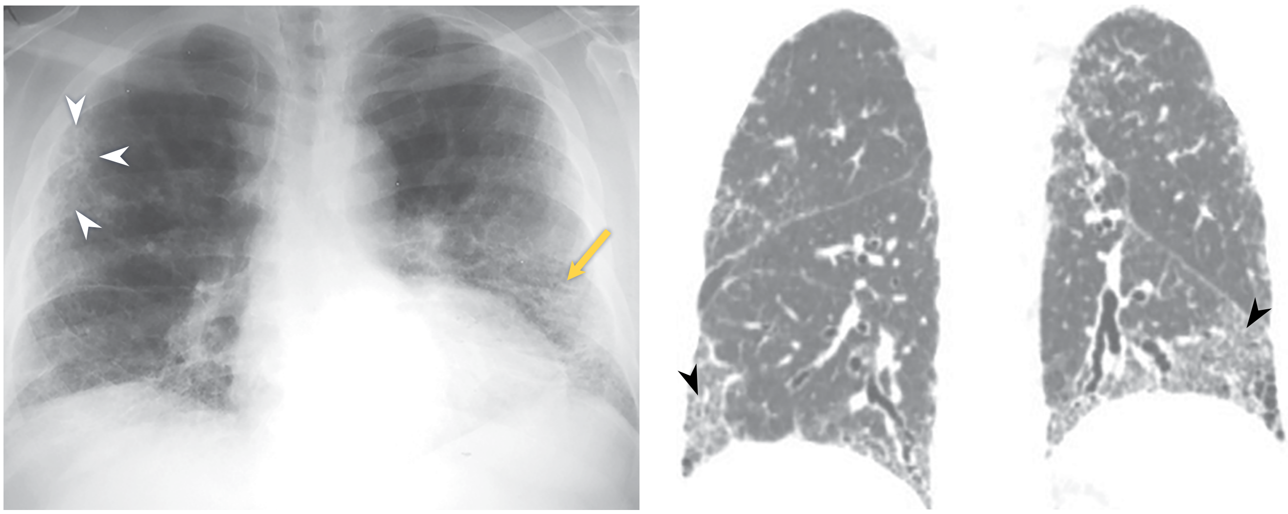


Figure 1.8 demonstrates features consistent with an interstitial lung process. Note the basal and peripheral distribution and low lung volumes. Specific features visible are:

- Linear opacity (arrow)
- Reticular opacity (arrowheads); note fine paintbrush-like lines on coronal CT
- Diminished lung volumes
- Basal and peripheral distribution

KEY POINT

- The reticular opacity is the result of many intersecting lines (or linear opacities), creating a netlike pattern. In Figure 1.8, this pattern is most readily appreciated peripherally, in the regions outlined by arrowheads.

DIAGNOSIS

- Idiopathic pulmonary fibrosis

Nodules

This term may be applied to opacities that are roughly circular, 2-30 mm in diameter, usually with fairly discrete margins. Nodules may be a manifestation of interstitial lung diseases, although they are not exclusively seen with diseases affecting the pulmonary interstitium. The term “mass” may be used when the nodule exceeds 30 mm in size.

FIGURE 1.9. **Nodules**

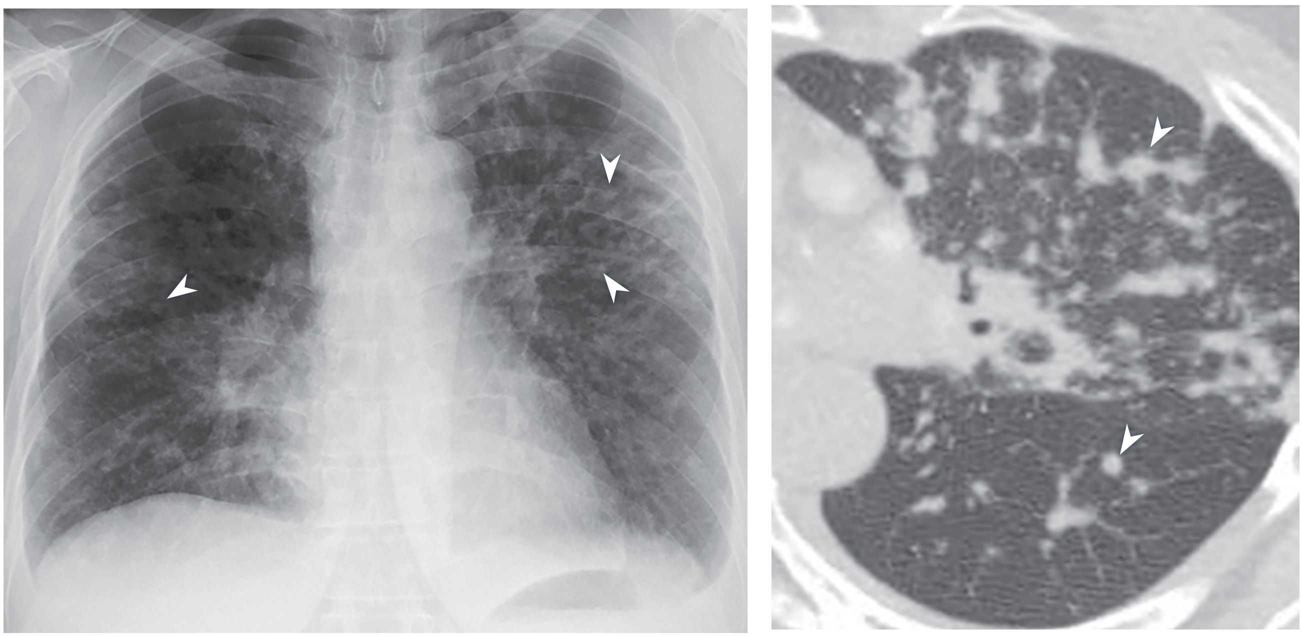


Figure 1.9 demonstrates features characteristic of interstitial opacity: nodules — small, discrete, with an upper-lung predominance (arrowheads).

KEY POINT

- The mid- and upper-lung predominance of small nodules is suggestive of sarcoidosis, a common interstitial process.

DIAGNOSIS

- Sarcoidosis

Miliary pattern

This term refers to numerous small nodules, approximately 1-2 mm in diameter, that are well-defined and diffuse in distribution.

FIGURE 1.10. **Miliary pattern**

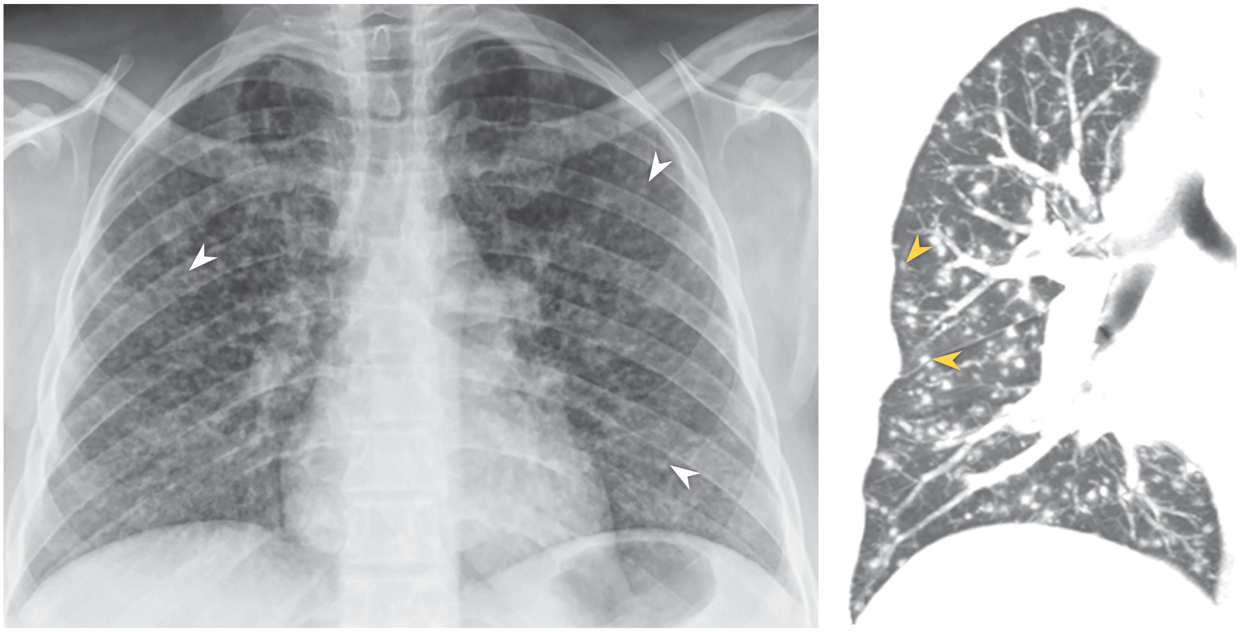


Figure 1.10 demonstrates characteristics suggestive of an interstitial process: small, well-defined nodules (arrowheads) scattered diffusely throughout the lung parenchyma, representing a miliary pattern.

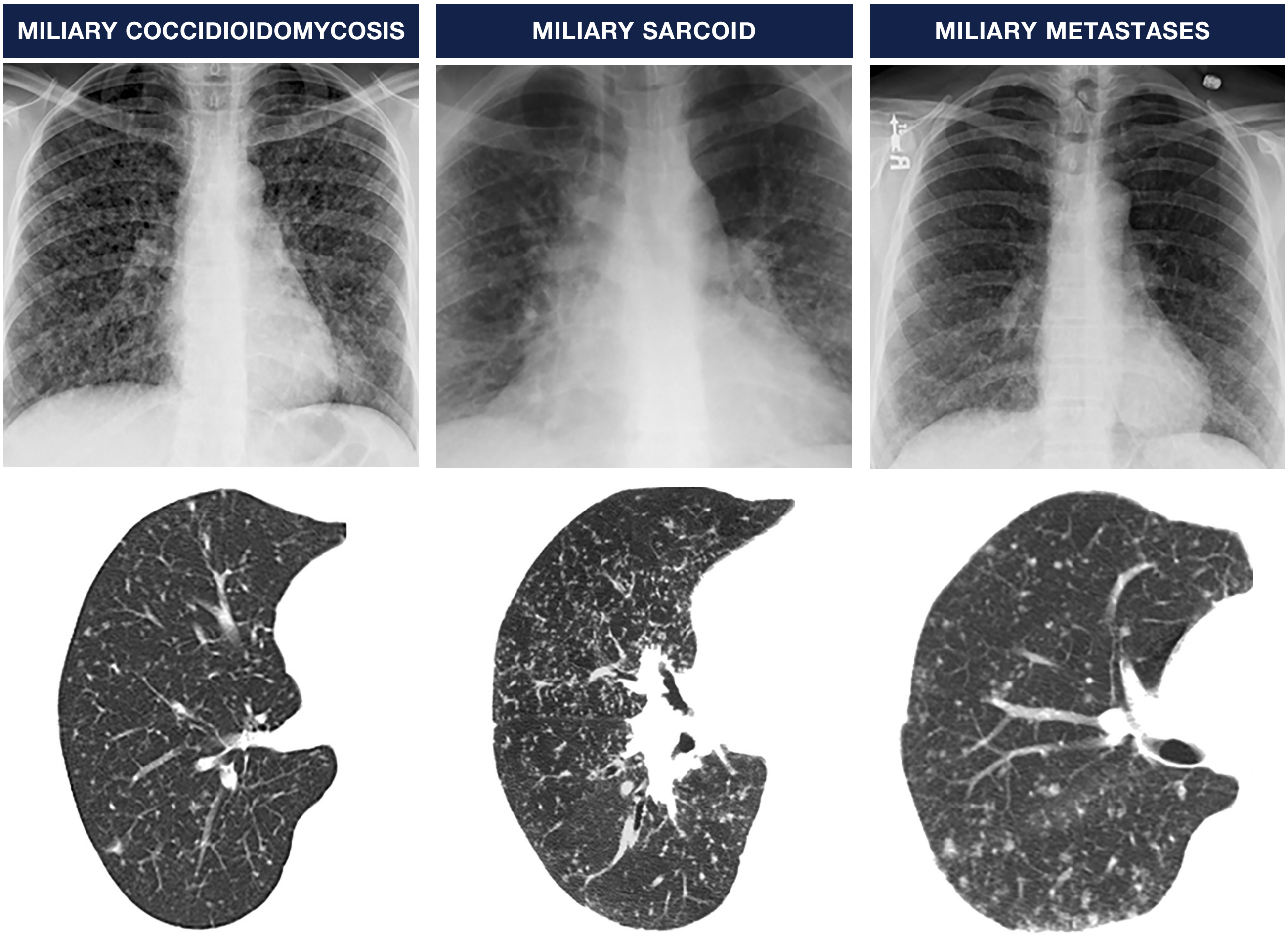
KEY POINTS

- The presence of small, well-defined nodules, approximately 1-2 mm in diameter and scattered diffusely throughout the lung parenchyma, is characteristic of a miliary pattern.
- While TB is a common cause of miliary nodules, other etiologies such as fungal disease, metastatic disease, pneumoconiosis, and sarcoidosis, may result in this pattern.

DIAGNOSIS

- Miliary TB

FIGURE 1.11. **Miliary patterns other than TB**



Peribronchovascular thickening

This is a qualitative term that refers to an increase in thickness of the bronchovascular bundles as they course peripherally from the hila. Any process that affects the following structures and the connective tissue surrounding these structures may result in peribronchovascular thickening:

- Bronchial walls
- Bronchial mucosa
- Pulmonary arteries and veins
- Lymphatics

The term "peribronchovascular thickening" is a subjective descriptor that requires a fair amount of experience to apply accurately.

FIGURE 1.12. **Peribronchovascular thickening**

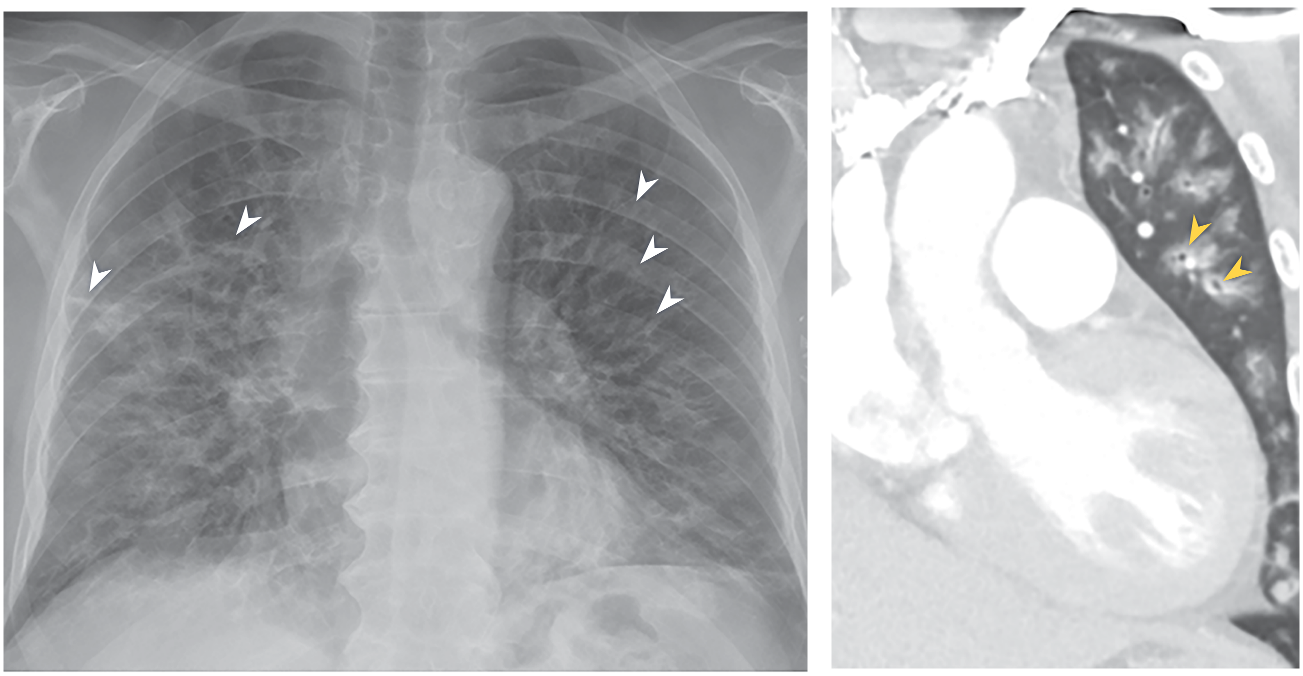


Figure 1.12 demonstrates features of interstitial opacity: thickening of the bronchovascular bundles as they course peripherally from the hila (arrowheads).

KEY POINT

- Peribronchovascular thickening is another type of interstitial opacity that occurs when the bronchovascular structures emanating from the hila appear thickened. This may be due to disease infiltration along bronchial walls, inflammatory processes involving the mucosa of the bronchi and peribronchial tissue, thickening of the connective tissue framework of the lung (the pulmonary interstitium), or pathologic alterations of pulmonary vessels themselves.

DIAGNOSIS

- Medication-induced organizing pneumonia

Practice chest radiographs, part 1

Use the following three chest radiographs (Figures 1.13 – 1.15) to practice describing the findings. Check descriptions on page 1.37.

Using a systematic approach, practice the following steps:

- Describe the image technical quality (exposure, proper positioning, inspiratory effort).
- Describe the abnormalities seen (location, size) using the descriptive terms from the preceding sections (consolidation/airspace opacity; interstitial opacity – linear/reticular opacities, nodules, miliary pattern, and bronchovascular thickening).

Figure 1.13

Figure 1.14

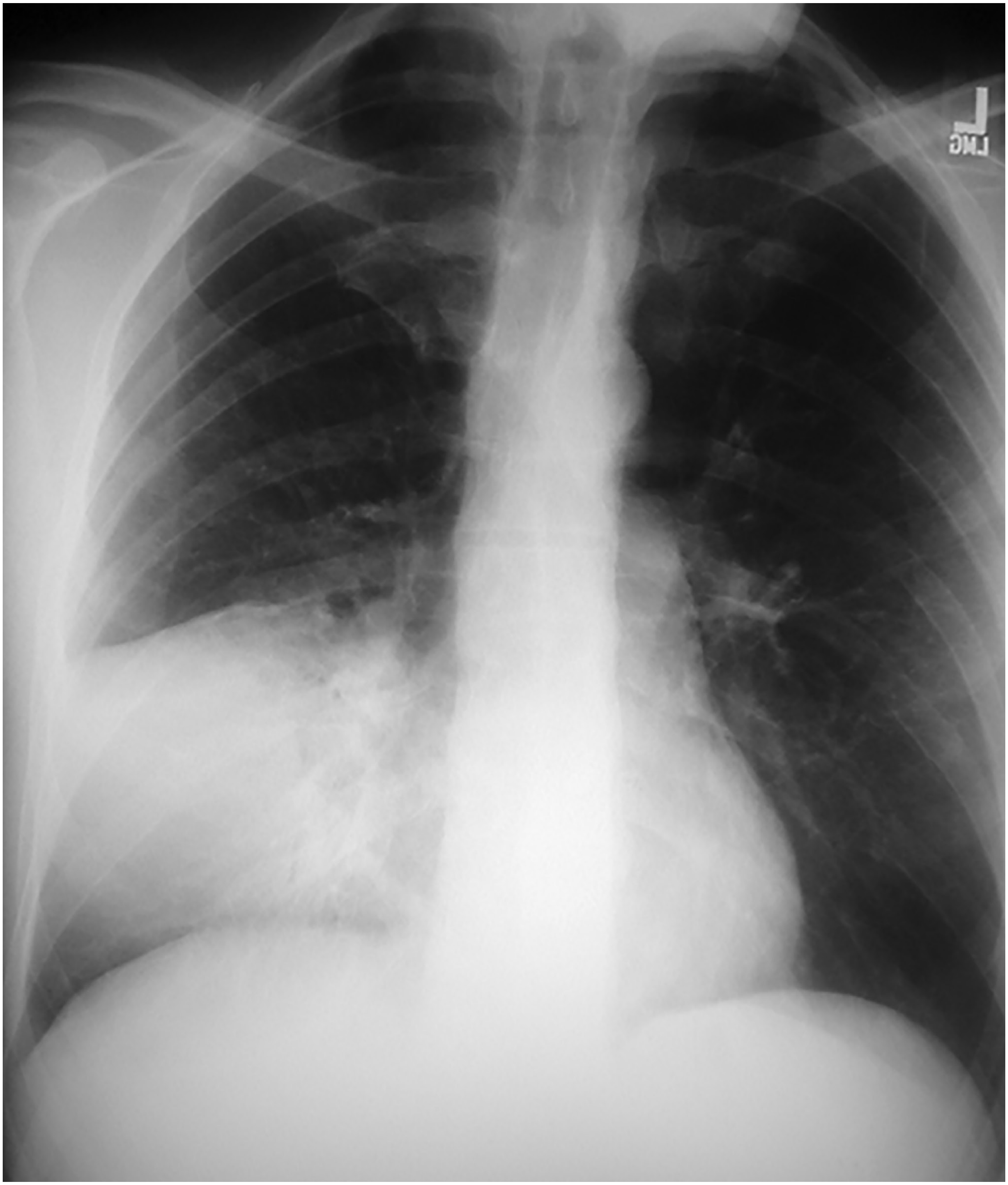


Figure 1.15

Descriptions: Practice chest radiographs, part 1

Figure 1.13 description

Technical quality: Inspiratory effort is appropriate, the "penetration" is also appropriate (the thoracic intervertebral disc spaces are just visible), and the chest radiograph is properly positioned.

Imaging findings: The chest radiograph shows multiple small well-defined nodules consistent with a miliary pattern. No consolidation is evident, and no pleural abnormality is seen. The hila appear prominent bilaterally, the right paratracheal region appears thickened, and lymphadenopathy is not excluded.

Diagnosis: Miliary TB

Figure 1.14 description

Technical quality: Inspiratory effort is appropriate, the "penetration" is also appropriate (the thoracic intervertebral disc spaces are just visible), and the chest radiograph is properly positioned.

Imaging findings: The chest radiograph shows homogeneous opacity with faintly seen air bronchograms in the right lower lung, consistent with consolidation. The right hemidiaphragm contour is preserved, whereas the right heart border is obscured, consistent with localization within the right middle lobe. No lymphadenopathy or pleural abnormality is seen, and no nodules are present.

Diagnosis: Right middle-lobe community-acquired pneumonia due to *Streptococcus pneumoniae*

Figure 1.15 description

Technical quality: Inspiratory effort is appropriate, and the "penetration" is also appropriate (the thoracic intervertebral disc spaces are just visible). The chest radiograph is slightly rotated in a right anterior oblique direction.

Imaging findings: The chest radiograph shows homogeneous opacity projected over the right hilum, limited cranially by the right minor fissure, consistent with consolidation in the right middle lobe. No pleural abnormality is seen and no evidence of lymphadenopathy is present, but multiple small somewhat poorly defined nodules are present bilaterally. The nodules are small, less than one centimeter, but too large to be considered miliary.

Diagnosis: Right middle-lobe consolidation and bilateral nodules due to coccidioidomycosis. The nodules reflect pulmonary dissemination of the infection from the primary focus in the right middle lobe.

Chest radiograph interpretation: Other radiographic patterns of disease

In addition to the patterns of consolidation (airspace filling) and interstitial opacities previously described, there are many other radiographic patterns of disease with which to be familiar for proper disease characterization. These additional patterns will be discussed in the following broad categories:

- Nodules and masses
- Lymphadenopathy
- Cysts and cavities
- Pleural disease
- Cardiomediastinal contour abnormalities
- Soft tissue and osseous abnormalities

Nodules

A nodule is a discrete opacity on a chest radiograph measuring 2-30 mm in diameter. The description of a nodule should be qualified with respect to these factors:

- Number
- Size
- Margin characteristics (descriptors include smooth, lobulated, and spiculated)
- Location
- Presence or absence of calcification

Nodule margin characteristics and presence or absence of calcification can implicate the likelihood of a benign etiology for a given lung nodule. Nodules with smooth margins and nodules with calcification have a higher likelihood of being benign; nodules with spiculated margins are common with bronchogenic carcinoma.

While nodular opacities, as previously described, are representative of interstitial abnormalities, there is often significant overlap between the radiographic appearances of interstitial and airspace opacities. Nodules can also often represent a primary airspace disease process, particularly when the nodules are inflammatory in etiology.

Note: Both airspace disease and interstitial abnormalities may coexist.

Correct characterization often depends on the integration of the person's clinical history as well as on the overall pattern on the chest radiograph. For example, if linear opacities accompany a nodule, then an interstitial process may be most likely; when nodules are seen in conjunction with consolidation, an airspace etiology may be more likely.

Masses

Masses are similar to nodules in many respects. The term “mass” is used when the discrete opacity on the radiograph is greater than 30 mm in diameter. Masses may occur with airspace disease, interstitial disease, or both. As with nodules, masses should be characterized regarding number, size, margin characteristics, location, and presence or absence of calcification.

FIGURE 1.16. **Mass**

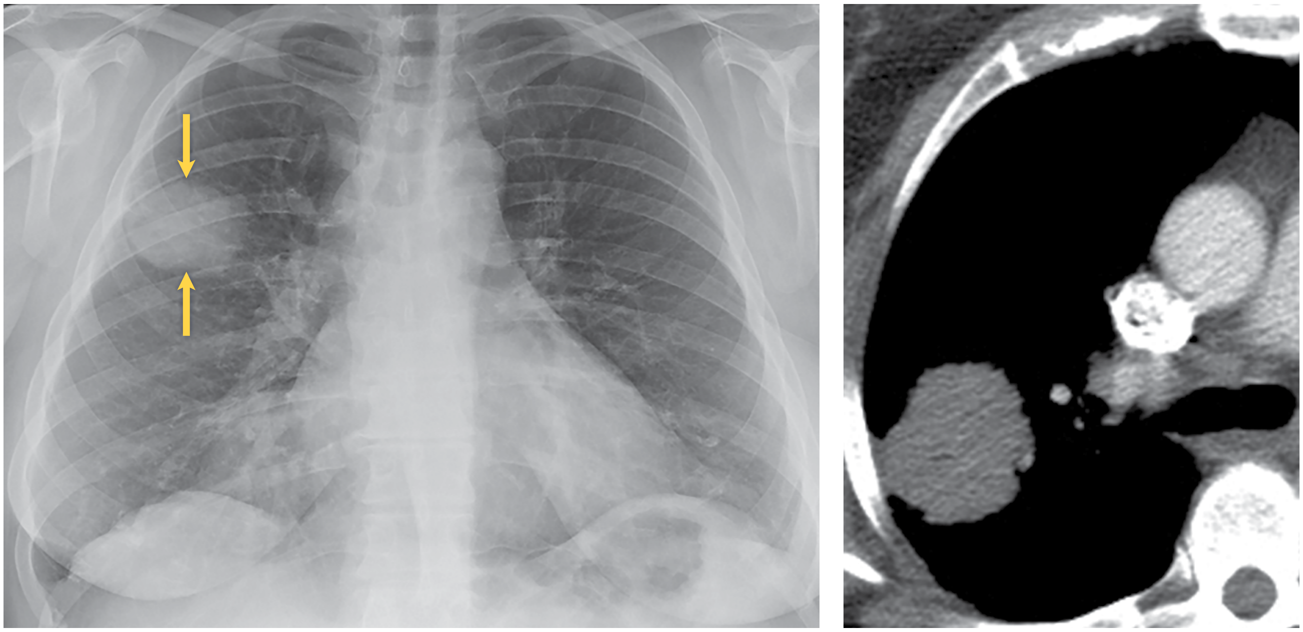


Figure 1.16 demonstrates a right upper-lobe pulmonary mass: solitary circumscribed area of increased opacity measuring greater than 30 mm in diameter (arrows).

KEY POINTS

- Nodules and masses are discrete areas of increased lung opacity whose borders do not conform to anatomic divisions (such as a fissure).
- Masses are similar to nodules except that they are larger, measuring greater than 30 mm in diameter.
- Nodules and masses should be described by noting their size, the sharpness of their margins, their number, their location, and the presence or absence of calcification.

DIAGNOSIS

- Bronchogenic carcinoma

Lymphadenopathy

Enlarged lymph nodes appear on the chest radiograph as soft tissue opacities in characteristic locations. These locations include:

- Right paratracheal area
- Hila
- Aorticopulmonary window
- Subcarinal region
- Superior mediastinum
- Paravertebral region
- Retrosternal area on the lateral radiograph (internal mammary lymphadenopathy)

One or more regions may be involved, and, in certain conditions, nodes may calcify. Differential diagnosis depends on the presence of other features on the radiograph and the clinical context.

FIGURE 1.17A. **Lymphadenopathy on frontal chest radiograph**

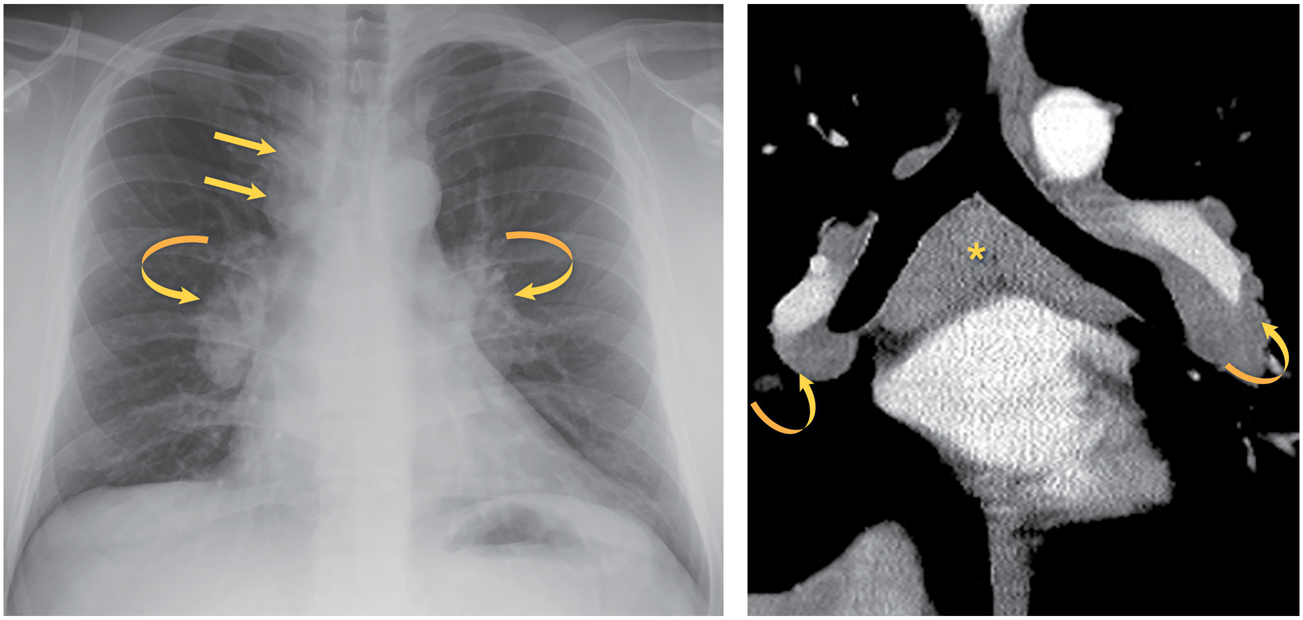


Figure 1.17A demonstrates the following (compare to Figures 1.1A and 1.1B):

- Right paratracheal stripe thickening (straight arrows)
- Bilateral lobular hilar enlargement (curved arrows)
- Subcarinal lymphadenopathy shown on CT (*) is not readily appreciated on the frontal chest radiograph

KEY POINTS

- An abnormal opacity in the right paratracheal region can be seen with intrathoracic goiter, tortuous vasculature, and lymphadenopathy, among other less common causes.
- Hilar enlargement may be due to lymphadenopathy, although vascular enlargement with pulmonary arterial hypertension may result in a similar appearance.
- Hilar enlargement due to pulmonary arterial hypertension is often smooth.
- Hilar enlargement due to lymphadenopathy is frequently lobular.

DIAGNOSIS

- Sarcoidosis

FIGURE 1.17B. **Lymphadenopathy on lateral chest radiograph**

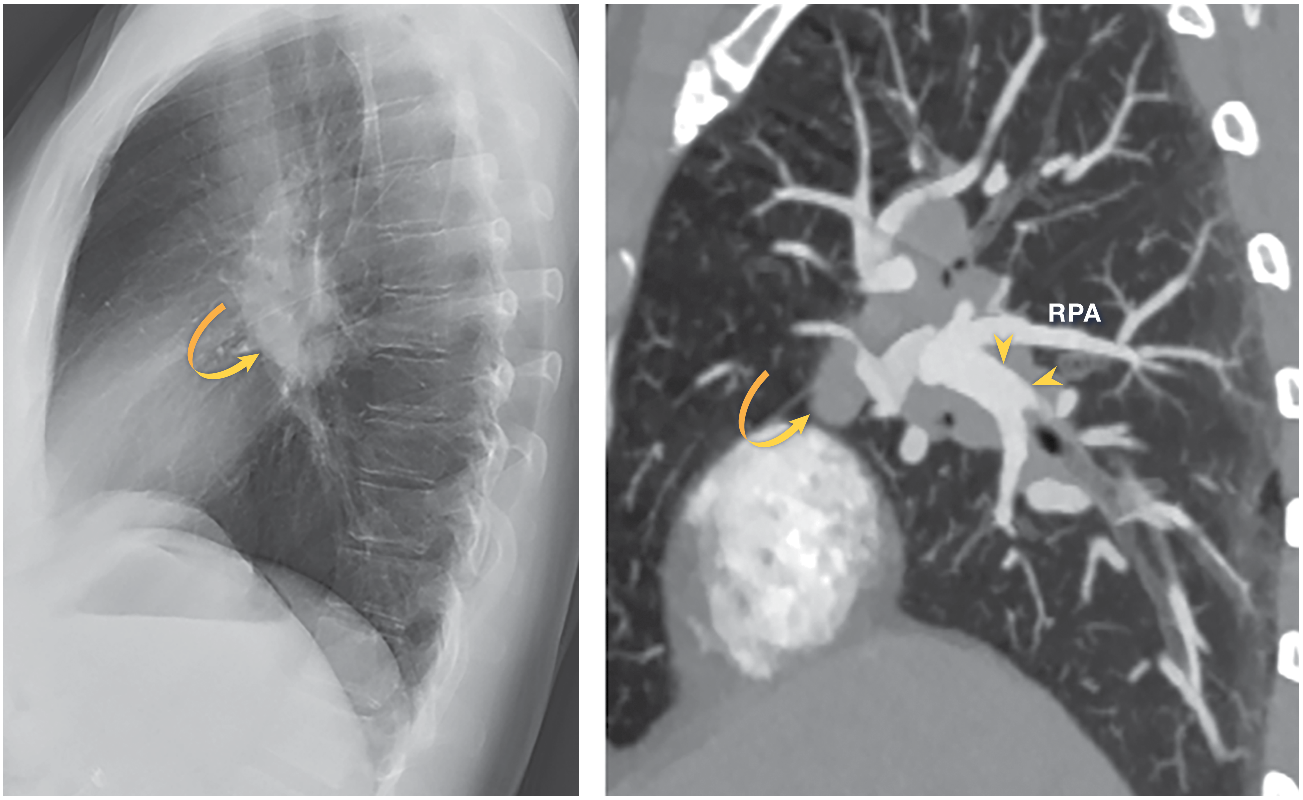


Figure 1.17B demonstrates abnormal soft tissue opacity inferior to the right pulmonary artery (arrowheads), filling the normally clear area known as the infrahilar window (curved arrow). CT shows the right peribronchial lymphadenopathy (curved arrow) adjacent to the interlobar branch of the right pulmonary artery (arrowheads).

KEY POINTS

- Lymphadenopathy in the right hilum or subcarinal space is often best visualized on the lateral radiograph when it fills the normally clear infrahilar window with an unexpected contour. This fact underscores the need for a thorough understanding of basic anatomy on this view.
- Thickening of the posterior wall of the bronchus intermedius may be due to lymphadenopathy, tumor, or edema.

DIAGNOSIS

- Sarcoidosis

FIGURE 1.18. **Mediastinal lymphadenopathy**

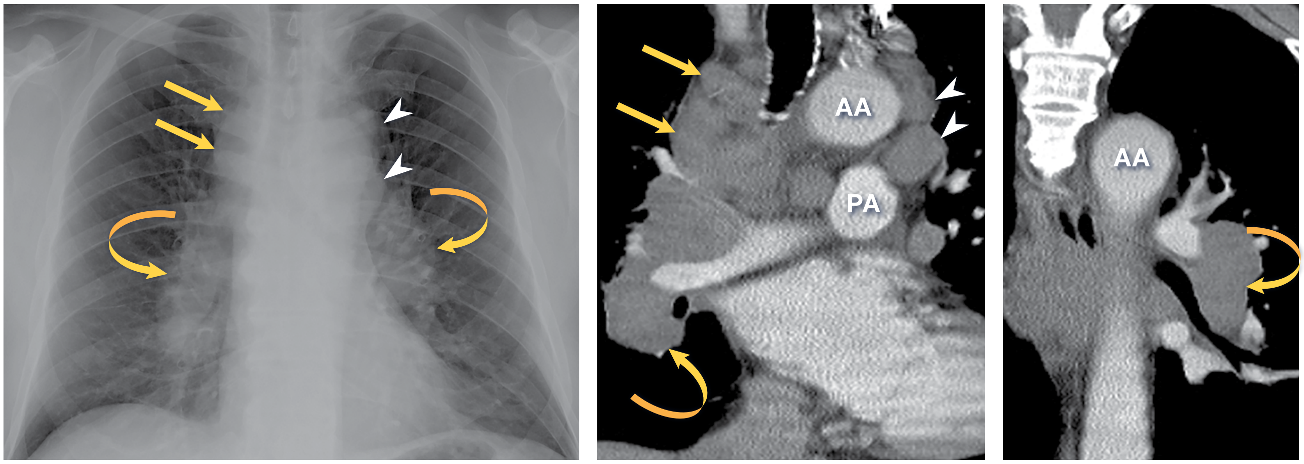


Figure 1.18 demonstrates an unexpected contour along the interlobar pulmonary arteries (curved arrows). The right paratracheal stripe is widened (arrows), and an abnormal contour is seen along the left aspect of the mediastinum near the aortic arch (arrowheads). The hila appear lobulated and indistinct (curved arrows). This lymphadenopathy is shown to advantage on coronal CT (AA = aortic arch, PA = pulmonary artery).

KEY POINTS

- The appearance of the abnormal contour along the right aspect of the upper mediastinum (arrows) is characteristic of lesions in the right paratracheal space, often lymphadenopathy.
- The abnormal left mediastinal contour (arrowheads) is created because an abnormal soft tissue opacity within the mediastinum is forming a border with the adjacent lung, creating a new, unexpected contour. This is how mediastinal lymphadenopathy becomes visible on the chest radiograph.
- Bilateral hilar lymphadenopathy (curved arrows) manifest as lobulation.

DIAGNOSIS

- Mediastinal lymphadenopathy and peribronchial lymphadenopathy due to sarcoidosis

Pulmonary cysts and cavities

Pulmonary cysts and cavities manifest as focal lucent areas on chest radiographs and may be thought of simplistically as “holes in the lung.”

Pulmonary cysts

Pulmonary cysts are circumscribed and well-defined air-containing structures in the lung parenchyma. They may be congenital or acquired. Cysts usually have thin walls, which may be composed of cellular elements, and they may develop as the result of airway obstruction with distal airspace dilatation, airway wall necrosis, or lung parenchymal protease-induced destruction.

Pulmonary cavities

Pulmonary cavities are abnormal gas- or fluid-filled structures in the lung parenchyma, often possessing a thick and irregular wall, resulting from the expulsion or drainage of a necrotic part of the lesion into the tracheobronchial tree.

Characterize pulmonary cysts and cavities by noting these factors:

- Size
- Distribution
- Number
- Character of the inner lining
- Thickness of the wall (at the thickest portion, not including air-fluid levels)
- Description of the contents of the lesion (if present)

Other causes of focal lucent areas on the chest radiograph include bronchiectasis and emphysema.

FIGURE 1.19. **Cavity due to squamous cell carcinoma**

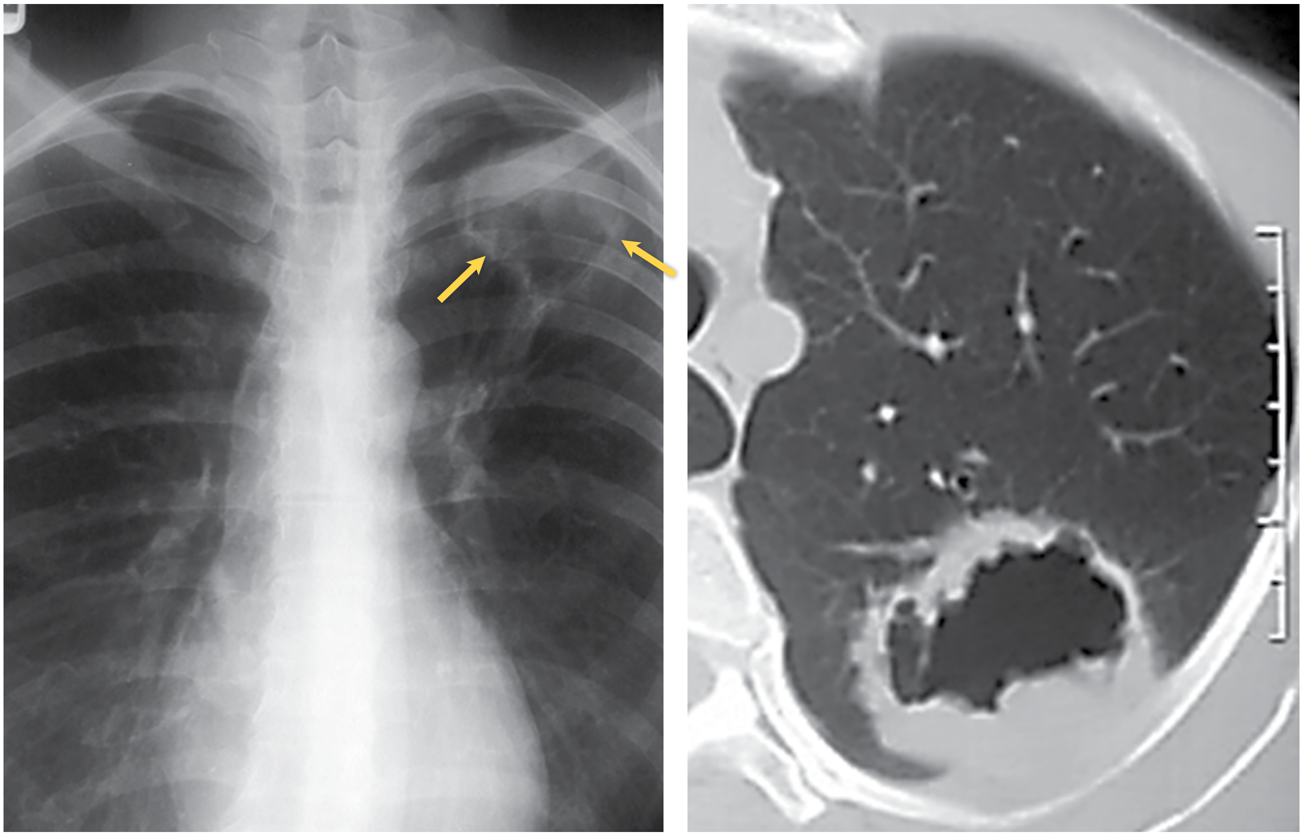


Figure 1.19 demonstrates localized lucent area in the left lung apex (arrows). A pulmonary cavity is a circumscribed lucent area within the lung containing air and/or fluid, surrounded by a wall of variable thickness resulting from necrosis of pulmonary parenchyma.

KEY POINTS

- Focal lucent areas within the lung may result from cavities, cysts, emphysema, and bronchiectasis.
- Pulmonary cysts differ from cavities in that cavities are created by necrosis of lung parenchyma, whereas true cysts are formed by other means.
- Pulmonary cavities may result from infection, non-infectious inflammation, neoplasm, and infarction.
- Pulmonary cysts commonly result from infections, trauma, or toxic ingestion, as well as other rare etiologies.

DIAGNOSIS

- Squamous cell lung carcinoma

Pleural disease

Pleural disease has many manifestations — the most common and familiar form is pleural effusion.

Pleural effusion

Effusions may be first detected on lateral radiographs as blunting of the posterior costophrenic angles. Effusions have many appearances on chest radiographs, ranging from such blunting of the costophrenic angle to complete opacification of an entire hemithorax, with mass effect causing displacement of the cardiomediastinal silhouette.

Pleural thickening

Occasionally pleural diseases may manifest nonspecifically as thickening. Thickening is revealed by the nondependent (nonlayering) nature of the opacity on decubitus radiographs. Nodular pleural thickening may suggest malignancy. The likelihood of malignancy is incrementally increased by the presence of any of the following patterns:

- Nodularity
- Thickness greater than 1 cm
- Involvement of the entire circumference of the hemithorax
- Involvement of the mediastinal and/or fissural pleural surfaces
- Associated volume loss

Calcification

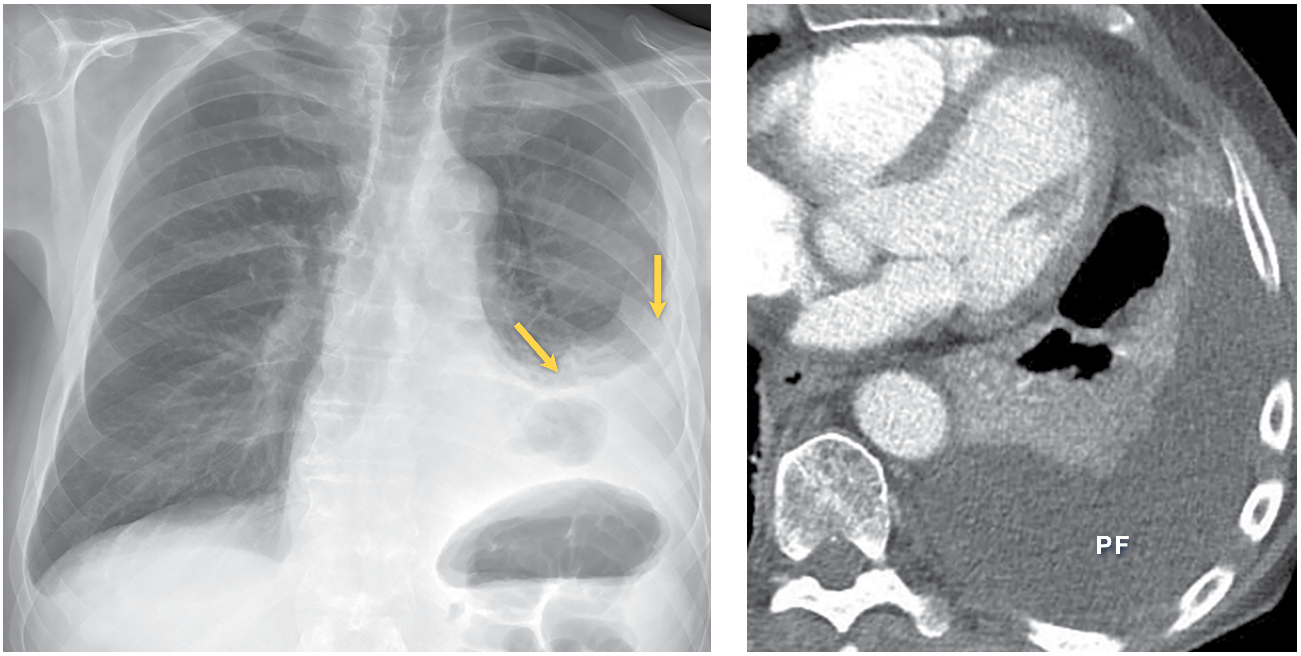
Pleural processes may calcify, particularly in prior tuberculous empyemas, prior hemothoraces, and asbestos-related pleural disease.

Pleural abnormalities

The chest radiograph in Figure 1.20 demonstrates extensive opacity in the lateral aspect of the left hemithorax, creating a very smooth, discrete interface with the adjacent lung (arrows). This radiograph indicates:

- Large left pleural effusion
- Left lung consolidation

FIGURE 1.20. **Pleural effusion**



KEY POINTS

- Because pleural abnormalities are, by definition, outside the lung parenchyma (extraparenchymal), an air bronchogram cannot be seen.
- Pleural abnormalities are usually homogeneous opacities.
- In the upright patient, a pleural effusion will form a curvilinear interface with aerated lung that resembles a meniscus (arrows). This occurs because the pleural fluid settles dependently within the pleural space.
- In the supine patient, a pleural effusion may layer posteriorly in a dependent fashion, creating a hazy opacity over the entire involved hemithorax.
- When pleural effusions are loculated, they may appear nondependent. Focal pleural thickening or neoplasms involving the pleura may occasionally have a similar appearance.

DIAGNOSIS

- Large left pleural effusion (arrows delineate meniscus) secondary to pneumonia. Pleural effusion (PF) is seen within the dependent portion of the left thorax on CT.

Cardiomediastinal contour abnormalities and soft tissue and osseous abnormalities

Cardiomediastinal contour abnormalities are apparent on chest radiography because they cause unexpected interfaces with an adjacent lung. However, a discussion of cardiomediastinal abnormalities and soft tissue and bone abnormalities on chest radiography is beyond the scope of this guide. Two excellent references regarding chest radiograph interpretation are listed at the end of this chapter.

Practice chest radiographs, part 2

Practice describing the abnormalities seen in the following four chest radiographs, Figures 1.21 – 1.24.

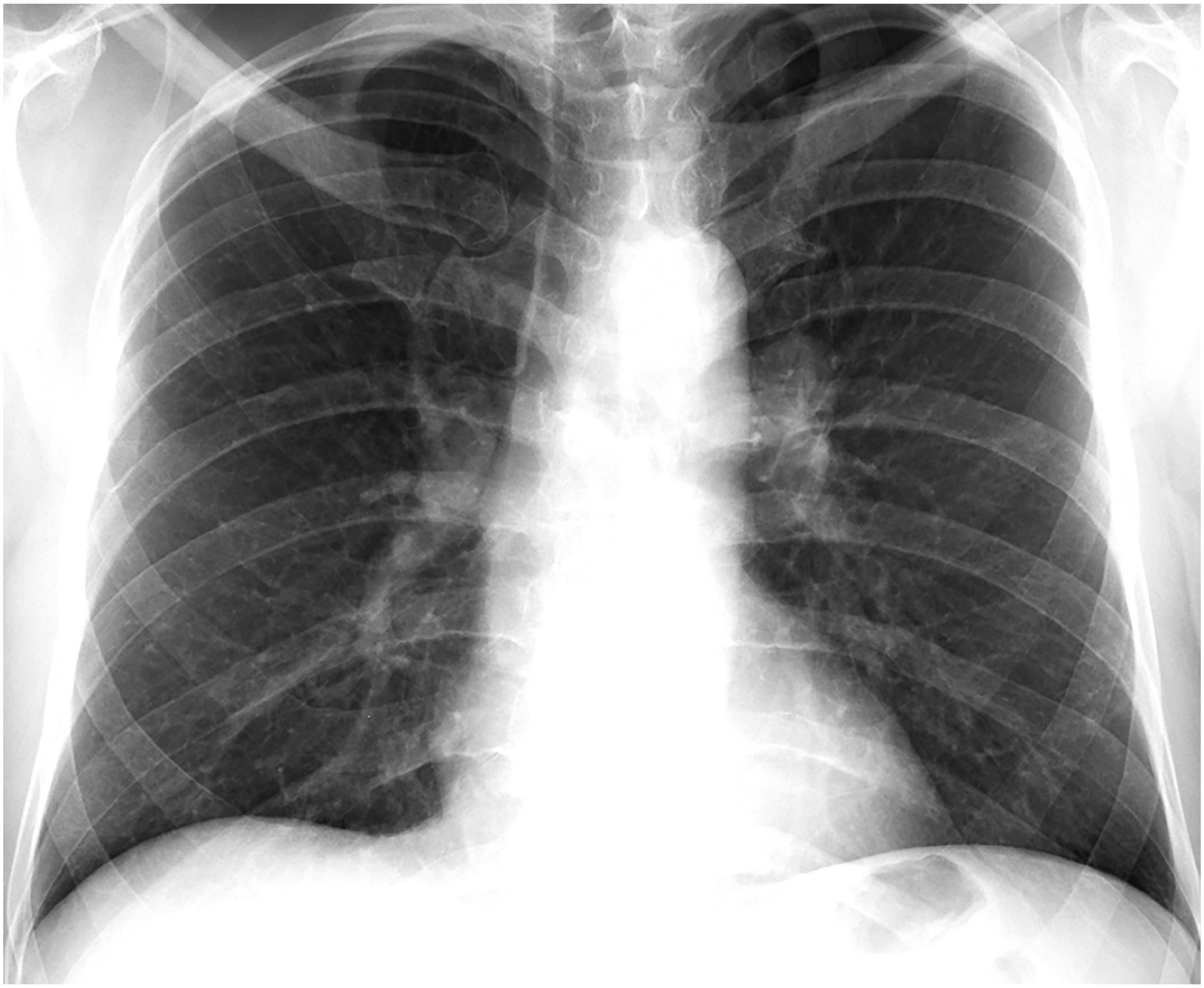
Using lessons from this section, apply the appropriate details to describe the following findings:

- Assessment of the technical adequacy of the chest radiograph
- Nodules or masses: number, size, margin characteristics, location, and the presence or absence of calcification
- Lymphadenopathy: locations involved
- Cysts and cavities: size, distribution, number, character of the inner lining, thickness of the wall (at the thickest portion, not including air-fluid levels), and description of the contents of the lesion (if present)
- Pleural disease (fluid, thickening, calcification): size, location, and amount of involvement

Check descriptions on pages 1.53 and 1.54.

Figure 1.21

Figure 1.22



Figures 1.23A and 1.23B

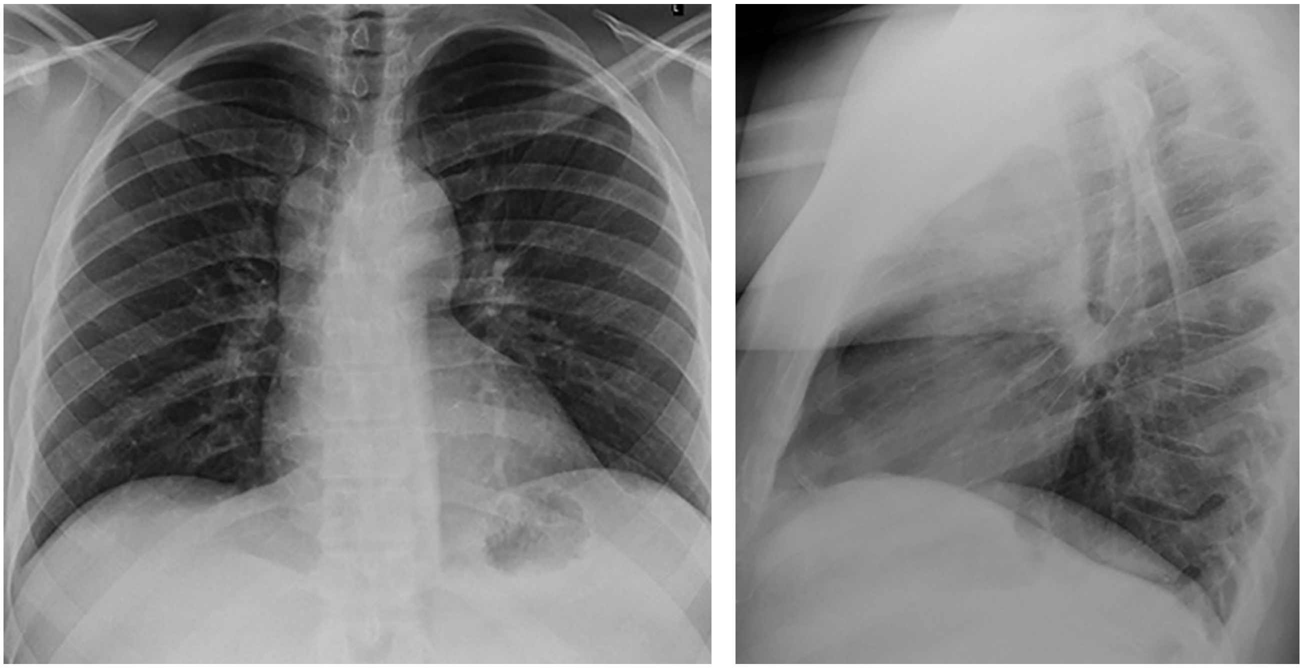


Figure 1.24

Descriptions: Practice chest radiographs, part 2

Figure 1.21 description

Technical quality: Inspiratory effort is appropriate, and the “penetration” is also appropriate (the thoracic intervertebral disc spaces are just visible). The chest radiograph is very slightly rotated in a right anterior oblique direction.

Imaging findings: The chest radiograph shows a right lower peripheral lung lesion with internal lucency consistent with a cyst or cavity. The outer and inner walls of the cyst are smooth, and no surrounding lung opacity is evident. The superior wall of the lesion is mildly thickened compared with the remainder of the cyst. No pleural abnormality, lymphadenopathy, or lung nodules are present.

Diagnosis: Chronic coccidioidomycosis

Figure 1.22 description

Technical quality: Inspiratory effort is appropriate, and the “penetration” is also appropriate (the thoracic intervertebral disc spaces are just visible). The chest radiograph is rotated in a left anterior oblique direction.

Imaging findings: The chest radiograph shows a normal heart size, clear lungs, and no pleural abnormality. An abnormal contour is visible along the pulmonary artery in the left hilum, representing lymphadenopathy.

Diagnosis: TB

Figures 1.23A and 1.23B description

Technical quality: Inspiratory effort is appropriate, and the “penetration” is also appropriate (the thoracic intervertebral disc spaces are just visible). The chest radiograph is appropriately positioned.

Imaging findings: The frontal chest radiograph shows a normal heart size, no evidence of consolidation, and no pleural abnormality. Some minimal nodular opacity in the left upper lobe is faintly visible. The right paratracheal stripe appears abnormally thickened, the left hilum is enlarged, and the aortopulmonary window region appears convex, all consistent with lymphadenopathy. The lateral chest radiograph shows an abnormal soft tissue contour in the inferior hilar window region, also suggesting lymphadenopathy.

Diagnosis: Coccidioidomycosis

Figure 1.24 description

Technical quality: Inspiratory effort is appropriate, and the "penetration" is also appropriate (the thoracic intervertebral disc spaces are just visible). The chest radiograph is rotated in a rather steep right anterior oblique position.

Imaging findings: The frontal chest radiograph shows an irregular lucent lesion in the left apex consistent with a complex-appearing cavity. Some mild nodularity is visible along the left inferior and lateral margin of the lesion. No consolidation or pleural abnormality is present, and no lymphadenopathy is seen. The punctate dense foci projected over the lung bases bilaterally represent radiographic nipple markers.

Diagnosis: Reactivation TB

A final word about evaluating the entire radiograph

A final point cannot be overemphasized: The entire radiograph must be evaluated. Certain areas of the radiograph that are either difficult to examine or often overlooked include:

- The left and right retrocardiac areas (behind the heart)
- The apices
- The hilar regions
- Below the diaphragm

FIGURE 1.25. **Left lower lobe lung carcinoma**

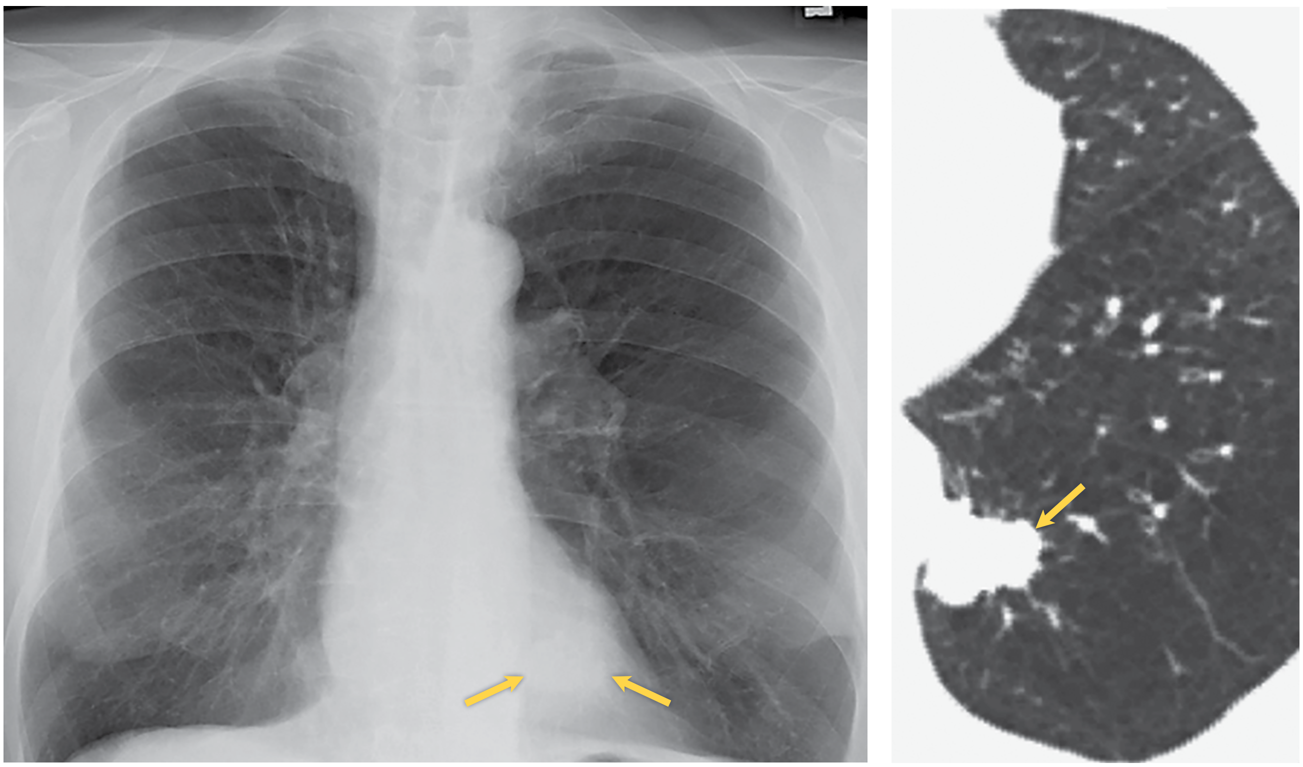
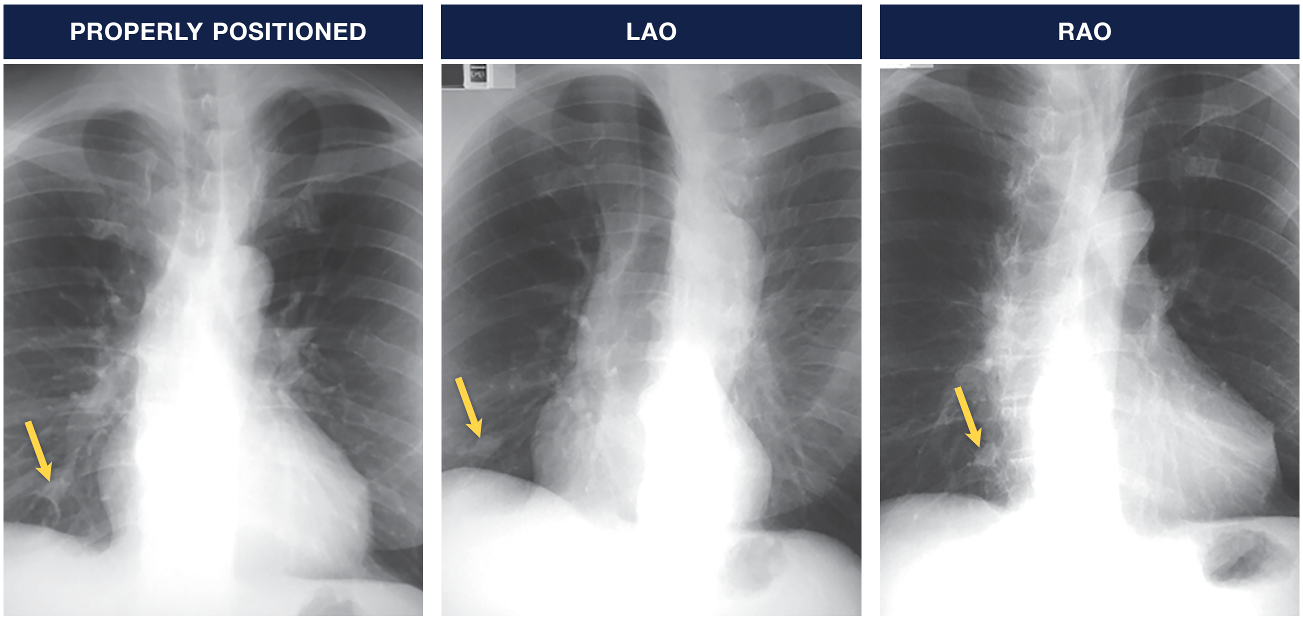


Figure 1.25 demonstrates an unusual contour seen “through” the left heart, representing lung carcinoma (arrows).

Knowledge of normal radiographic anatomy is needed to actively “look through” the heart and diaphragm to evaluate the underlying pulmonary parenchyma. In the apices and hilar regions, one must mentally subtract the overlying bones and vascular structures to “see through” them to evaluate the underlying pulmonary parenchyma.

When required, apical lordotic views may provide better visualization of the lung apices. Frontal shallow oblique radiographs with 5-10° obliquity are occasionally useful to distinguish superimposed shadows that may create the appearance of a pulmonary nodule from a true pulmonary nodule.

FIGURE 1.26. **Bilateral frontal shallow oblique radiographs**



The frontal chest radiograph (properly positioned) shows a subtle medial right base nodular opacity (arrow). The left anterior oblique (LAO) image more clearly demonstrates the nodule (arrow). The movement of the clavicles is the clue to the direction of obliquity (see Figure 1.4): in the LAO image the left clavicular head moves across midline, whereas the right clavicular head moves in a right lateral direction; the opposite behavior is seen in the right anterior oblique image (RAO, arrow = nodule). Oblique images also allow some degree of nodule localization. The key to localizing a lung opacity with oblique imaging is to note the heart's position. In this case, the motion of the nodule "follows" the heart. Because the heart is anteriorly located in the thorax, if the nodule "follows" the heart's motion (in this case, both move toward the right in the LAO image), it too must be anteriorly located. CT confirmed a nodule in the right middle lobe.

Distribution of disease

After an abnormality is identified, the distribution of the findings should be noted.

- Diseases affecting the pulmonary parenchyma are broadly characterized as having an **upper-, middle-, or lower-lung distribution**. For example, upper-lung, predominately small nodules and linear opacities, particularly with bilateral hilar lymphadenopathy, suggest the diagnosis of sarcoidosis.
- Characterization of a process as either **central or peripheral** may also evoke a specific differential diagnosis. Patchy migratory and peripheral consolidations, for example, are common manifestations of either eosinophilic pneumonia or organizing pneumonia.
- Finally, a disease process may be characterized as **focal, multifocal, or diffuse**. Proper characterization of disease distribution often allows a limited differential diagnosis to be generated.

Take-home points

- A basic understanding of the physics of radiography is required to understand how radiographic images are created and to properly characterize abnormal findings.
- A working understanding of normal radiographic anatomy of the thorax is necessary to distinguish normal structures from abnormal findings and to accurately localize disease processes.
- Carefully scrutinize the entire radiograph, paying special attention to areas that are often overlooked, to ensure that abnormalities are not missed.
- Standard terminology should be used to convey the characteristics and location/distribution of abnormal findings verbally or in writing.

References

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