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3RD EDITION

Radiographic Manifestations of Tuberculosis

A PRIMER FOR CLINICIANS ON BASIC RADIOGRAPHY OF PULMONARY TB

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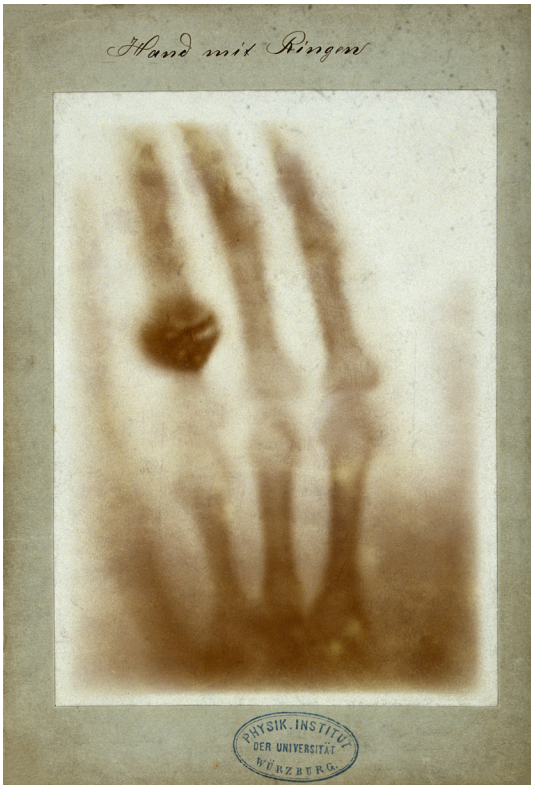
Introduction

Long before the advent of radiography, tuberculosis (TB) was recognized as a disease that predominantly involved the lungs, and a diagnosis of TB was based on a constellation of symptoms and physical examination findings such as rales, rhonchi, and percussion dullness emanating from the lungs. Moreover, the ways in which the lungs were involved and the extent of the involvement could be estimated only by the clinical examination. Obviously, these findings were nonspecific and insensitive; thus, cases were often misdiagnosed, and even correct diagnoses could be stalled until the disease was advanced. Robert Koch's revolutionary discovery of *Mycobacterium tuberculosis* in 1882 provided a test that enabled a specific diagnosis of TB to be confirmed, but it was not widely used for at least several decades after its discovery.

The discovery of x-rays in 1895 by Wilhelm Conrad Röntgen was a second revolutionary development related to TB. Chest radiography greatly reduced both insensitivity and nonspecificity in diagnosing TB and, for the past 130 years, has been a critical tool in the clinical and public health management of the disease. Unfortunately, the coverage of radiographic services remains quite limited in low-resource settings where the prevalence of TB is greatest, although this situation is changing, as will be noted later.



Source: Wikimedia Commons

FIGURE 1.

***Hand mit Ringen* (hand with rings). Print of Wilhelm Röntgen's first "medical" x-ray, of his wife's hand, taken on December 22, 1895.**

Both the discovery of x-rays (documented by Röntgen's famous photo of his wife's hand [Figure 1]) and the very rapid dissemination of the technology were remarkable events. Röntgen's discovery earned him the first Nobel Prize in Physics in 1901, and a flood of scientific papers and books on the topic quickly followed. Many of the publications were technical in nature, while the clinical use of x-ray examinations focused mainly on diagnosing fractures, dislocations, and other bony abnormalities. As other clinical uses were explored, it was soon apparent that radiographic examination of the chest was not only feasible, but would provide more diagnostic information than physical examination, especially as related to TB, an all-too-common disease at the turn of the century.

"The first x-ray machines were large, loud, sparking, smelly, and ostentatious devices, prone to mishap and injury even when fully under the control of the physicians who, in droves, invested money and prestige in them."

Francis H. Williams, MD, a clinician at Boston City Hospital, first reported on use of a fluoroscope to examine the chest in April 1896, a scant 4 months after Röntgen's earthshaking discovery. Due to the long exposure time required to obtain a radiograph, Williams based most of his observations on fluoroscopy, but the findings and principles underlying his observations were equally applicable to both imaging methods.

Dr. Williams went on to articulate several fundamental principles related to thoracic radiology in general and, more specifically, to the use of radiographic examinations for TB (see excerpt on page x). Many of these principles are still relevant today and are embodied in this 3rd edition of *Radiographic Manifestations of Tuberculosis*. In addition, in 1901, Dr. Williams wrote a classic textbook, *The Röentgen Rays in Medicine and Surgery*, one of the first textbooks devoted to radiology. Dr. Williams' most lasting impact was in x-ray examination of the chest, for which he is regarded as a founder of the specialty of thoracic radiology.

During the early 1900s, technical innovations in the science and practice of radiography were evolutionary if not revolutionary. In the words of one medical historian, "The first x-ray machines were large, loud, sparking, smelly, and ostentatious devices, prone to mishap and injury even when fully under the control of the physicians who, in droves, invested money and prestige in them." As implied in the quote, during this time a professional identity for the specialty of "radiology" evolved, despite the drawbacks of the machinery.

X-ray units were rapidly increasing in popularity in the early 1900s, but they were big and cumbersome, a characteristic that limited their use to fixed institutional locations. A fortuitous constellation of events would lead to a major advance in the utility and applicability of radiography. Monico Sanchez Moreno, a brilliant Spanish electrical engineer working in the United States, recognized the need for a more utilitarian x-ray unit. In 1909, Moreno invented a portable machine weighing 22 pounds, as opposed to the nearly 900 pounds that existing units weighed. The unit was marketed as the "Collins Sanchez Portable Device," but it is unclear whether the new device received much attention in either the United States or Europe until World War I.

In the early 1910s, it was clear that a major confrontation was brewing between England and France on one side and Germany on the other. In the run-up to the war, the French government made the seemingly improbable appointment of two-time Nobel Prize winner Marie Curie (Physics,1903 [shared with her husband and Antoine-Henri Becquerel] and Chemistry, 1911) as Director of the Department of Radiology for the French Red Cross. The job required skills in implementation more than inventiveness, and Dr. Curie was more than equal to the task.

With the onset of the war in 1914, Dr. Curie and others quickly recognized that portable units for use in field hospitals could be of great benefit in evaluating war-related injuries and guiding surgical approaches. Consequently, the French government purchased over 50 “Collins Sanchez Portable Devices” and installed them in the ambulances that served the frontlines. Marie Curie grasped the enormous potential for diagnosing wounds on the frontlines and endorsed, extended, and systematized their use. Remarkably, the internationally acclaimed scientist herself drove the portable radiology units (called “petites Curies”) to the frontlines and back, performing x-ray examinations of wounded men along the way (Figure 2).

FIGURE 2. **Marie Curie in a mobile military hospital x-ray unit, circa 1915**

Source: Wikimedia Commons

Dr. Curie’s contributions were not exclusively focused on thoracic radiology, but her implementation of a mobile portable device set the stage for the use of radiography to screen populations for the presence of TB. (The death of Dr. Curie’s mother of TB in 1874 was said to have had a profound effect on the then 7-year-old Marie.)

Also of note, the increased availability of radiography due to Dr. Curie’s implementation skills was not matched by the development of a corps of trained technicians (Dr. Curie herself is said to have taken at least 1,200 radiographs). To remedy this shortage, Dr. Curie developed what was probably the first training program for radiology technicians, a program in which she also taught. Notably, the classes were filled with women, since most men had been drafted into the war.

Even with the success of mobile x-ray units in France and the unfulfilled need for radiographic screening of military recruits for TB in France and the United States, large-scale, population-based screening did not emerge until the early 1940s. The reasons for the slow uptake of radiographic screening for TB included logistic limitations, resistance of physicians to substitute radiography for physical examination, and cost. The affordability of radiographic screening for TB was greatly improved by the development of photofluorography by Brazilian radiologist Manoel de Abreu in 1936. The simple-seeming innovation involved a system that automatically photographed the image on a fluoroscopic screen. Most commonly this produced a 70-mm film image (Figure 3), hence the term “mini mass radiography” (MMR).

FIGURE 3. **70-mm radiographic images from a mass mini photo-fluoroscopy unit**

Source: Freepik

From the 1940s through the 1960s in the United States and other high-income countries, getting an annual chest x-ray in a mobile unit parked in the town square was a common ritual (Figure 4). This practice was discontinued when it became apparent that the cost-per-case identified was exorbitant because the prevalence of TB was rapidly decreasing in high-income countries. How much the annual chest x-rays contributed to the decline in prevalence is unclear. Whether or not routine screening of (presumably) asymptomatic persons is efficient, the finding of a person with previously undiagnosed TB likely had an impact on both personal and public health.

FIGURE 4. **Mobile chest x-ray, circa 1960**

Source: King County, CC BY-NC-ND 2.0

Interestingly, some of the lessons learned from the "chest x-ray in the town square" approach have again become relevant with the development of very compact x-ray units with computer-based interpretation. These innovations have led to a resurgence in interest in radiographic mass population screening in low-income areas of the world where TB is prevalent.

About this book

Radiographic Manifestations of Tuberculosis, 3rd edition, is written primarily for clinicians who are likely to encounter patients with TB, with the clinical use of chest radiography for diagnosis and management of TB in mind. It is not intended to train non-radiologists to provide definitive interpretations of standard thoracic imaging studies. Rather, it serves to indicate when TB should be included in the differential diagnosis of a particular abnormality on a chest radiograph.

In addition, this book provides a common vocabulary to facilitate discussions between clinicians and radiologists. Radiographic imaging is most informative when radiologists and clinicians each bring their unique perspectives and assessments of the image in question to joint discussions. Such discussions result in general agreement on a likely diagnosis and suggest a plan for additional diagnostic tests, especially computed tomographic (CT) imaging and lung or pleural biopsy, if necessary. CT imaging is enormously useful in further elucidating abnormalities seen on the plain chest film and enabling refinement of the differential diagnosis of the finding in question. However, a review of the CT images associated with pulmonary TB is beyond the scope of this book.

The focus of this book is on the use of chest radiography, primarily as a diagnostic tool, generally early in the course of a doctor-patient encounter.

This book is organized so that the reader is presented in Chapter 1 with the radiographic image of the normal thoracic anatomy (as specified by Dr. Williams; see excerpt on page x). The authors have taken great effort to mark and label the structures as clearly as possible, although some features are difficult to discern. An important goal of Chapter 2 is to connect a specific category of abnormality with standard terminology that describes the character of the finding. In Chapter 3 a series of images for the reader to interpret is followed by interpretations and discussions.

The focus of this book is on the use of chest radiography, primarily as a diagnostic tool, generally early in the course of a doctor-patient encounter. An equally important role for radiography is assessing response to treatment. Comparing radiographs over preset intervals or when clinical changes occur provides important information on the effectiveness of therapy. A failure to improve may indicate drug resistance or a wrong diagnosis. Examples of the use of chest radiography to assess response to treatment are included in Chapter 3. Again, as with diagnostic imaging, comparison of images is most informative when clinician and radiologist confer.

As noted, radiography facilities are not widely available in low- and middle-income countries, due to the difficulty of having radiographic equipment and radiologists in low-resource settings. Fortunately, newly developed small portable x-ray units together with computer-assisted interpretation have shown considerable promise for contributing to diagnostic accuracy and for screening populations at risk for TB in low-resource, high-prevalence settings. The role for this technology in diagnostic evaluations in high-resource settings is not yet clear.

The authors have taken pains to use images in which the normal anatomy and abnormalities can be clearly identified, although the print media format of this book does not always lend itself to illustration of subtle findings.

Readers are encouraged to use the book to learn how to better understand the information provided by a chest radiograph and to improve their skills in the diagnosis and management of pulmonary TB.

EXCERPT

The use of radiographic examinations for TB: Fundamental principles

From the 1907 article, *The Use of X-ray Examinations in Pulmonary Tuberculosis*, by Dr. Francis H. Williams

To use the Rontgen rays successfully in practice it is first essential that the physician become familiar with the appearances in the fluoroscope which present themselves in health by examining a number of healthy persons of different weights and ages.

This method (X-ray examination for tuberculosis) may be useful, for example, in:

1. **Making an early diagnosis**
2. **Making precautionary examination where there is possibility that the disease is beginning**
3. **Cases simulating pulmonary tuberculosis**
4. **Determining the extent of the disease**
5. **Determining whether it is diminishing or increasing**
6. **The diagnosis of acute miliary tuberculosis and fibroid tuberculosis**
7. **Recognizing central tuberculosis**
8. **Recognizing sometimes an old tuberculous lesion**
9. **Cases in which emphysema or asthma and pulmonary tuberculosis are associated**
10. **Making an examination for cavities**

Of course, a diagnosis of tuberculosis is not made by the appearances in the fluoroscope alone, they simply indicate an abnormal condition in the lungs.

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Glossary

Terms adapted from *Fleischner Society: Glossary of Terms for Thoracic Imaging (2024)*

Absorption	Pertaining to radiography, absorption is the process of attenuating an x-ray beam. Tissues of different densities transmit numbers of x-ray photons and therefore appear relatively "blacker" (less dense) or "whiter" (denser) on an x-ray film.
Acinar shadow	A round or ovoid, poorly defined pulmonary opacity 4-8 mm in diameter, presumed to represent a pulmonary acinus rendered opaque by consolidation. This term is usually used in the presence of many such opacities.
Air bronchogram	The descriptive term for air-filled airways within partially or completely airless lung parenchyma (whether by virtue of absorption of air or replacement of air or both). The air is visible within the bronchus because the lung surrounding the bronchus is airless. Visualization of an air bronchogram usually implies the presence of an airspace-filling process (consolidation).
Aortopulmonary window	Mediastinal space surrounded anteriorly by the ascending aorta; posteriorly by the descending aorta; superiorly by the aortic arch; inferiorly by the left pulmonary artery; laterally by the left lung; medially by the left aspect of the trachea, left mainstem bronchus, and esophagus, and laterally by the mediastinal pleural covering the left lung. This space normally contains the ligament arteriosum, the left vagus and recurrent laryngeal nerve, lymph nodes, bronchial arteries, and fat and is traversed by the left phrenic nerve.
Atelectasis	Less-than-normal inflation of all or part of a lung with corresponding diminution in volume, often resulting in loss of the normal lucency of the affected portion of lung. Atelectasis manifests on imaging as abnormal fissure, bronchial, and vascular displacement, hyperinflation of adjacent lung, or obscuration of cardiac and mediastinal interfaces.
Attenuation	A collective term for the processes (absorption and scattering) by which the energy of an x-ray beam is diminished in its passage through matter.
Bronchopleural fistula	A direct connection between the pulmonary parenchyma and the pleural space. A bronchopleural fistula is usually manifest on a radiograph as a persistent, often large, pneumothorax, frequently with an air leak when a thoracostomy tube is in place.
Cavitation	The process by which a cavity is formed.

Cavity	A gas-filled space, produced by necrosis of lung tissue and expulsion of the necrotic material via the bronchial tree. An abnormal gas- or fluid-filled structure, isolated, within a zone of pulmonary consolidation, or within a mass or nodule, typically with a thick and often irregular wall. Cavities may or may not contain a fluid level or internal opacity and are characterized with regard to wall thickness and character.
Consolidation	Increased attenuation of lung parenchyma resulting from evacuation of air from the alveoli and replacement by fluid or other material (as in the case of pneumonia). Radiographically, consolidation is seen as a relatively homogeneous opacity in the lung, with effacement of pulmonary blood vessels, little or no volume loss, and sometimes the presence of an air bronchogram.
Cyst	A circumscribed lucent space in the lung, containing gas or liquid whose wall is generally thin and well defined.
Density	Density is a measure of the degree of image darkening (blackness) that reflects the proportion of x-ray photons that are transmitted through the tissue and reach the x-ray detector system. The denser the tissue, the more absorption of the x-ray photons resulting in a whiter image. The less dense the tissue, the blacker the image. In other words, tissues of different density exposed to an x-ray beam produce an image through the process of differential x-ray absorption (see *Differential x-ray absorption*).
Differential x-ray absorption	The process by which different numbers of x-ray photons are attenuated by matter due to differences in the densities of the various components of the matter. When the attenuating matter is human tissue, the process of differential x-ray absorption is responsible for the creation of the radiographic image.
Endobronchial spread	Spread of infected material through the bronchial tree. Radiographically, endobronchial spread often appears as a collection of ill-defined nodules, commonly 4-8 mm in diameter, and often distributed in a segmental or lobar fashion. The nidus of infection, such as a cavity, may be evident. This pattern of disease spread is typical of bacterial causes of infection, including tuberculosis.
Ground glass	An area of increased attenuation that does not completely obscure the underlying bronchial and vascular structures. Compare ground glass with consolidation, in which the underlying anatomic details are completely obscured.
Hematogenous dissemination	Widely but discontinuously distributed throughout an organ or type of tissue. The pattern of hematogenous dissemination is the result of pathology delivered to an organ via the circulation. In the lung the pattern is usually one of well-defined nodules of various sizes distributed throughout the lung, perhaps with a slight basal predominance due to the relatively greater blood flow present in the bases.

Honeycomb pattern	Destruction of lung parenchyma with loss of architecture manifesting as well-defined adjacent cystic structures, typically clustered in the subpleural region, usually accompanied by other findings of fibrosis. The pattern typically presents as one or more layers of thick-walled (2-3 mm) cystic spaces in the peripheral lung, commonly sharing walls, and associated with other findings suggesting fibrotic lung disease, such as traction bronchiectasis and volume loss.
Hydropneumothorax	The presence of both gas and fluid in the pleural cavity.
Interstitium	A continuum of loose connective tissue throughout the lung comprising three subdivisions: the bronchovascular interstitium (surrounding the pulmonary arteries, veins, and bronchi); the parenchymal interstitium (between the alveolar and capillary basement membranes); and the subpleural interstitium (beneath the visceral pleural and within interlobular septa).
Kerley's line (septal line)	Thickening of the interlobular septae in the lung. The interlobular septae are a component of the pulmonary interstitium and represent the margins or walls of the smallest unit of lung structure, known as the secondary pulmonary lobule.
Kerley's A line	A linear opacity 2-6 cm long, obliquely oriented, centrally located, and radiating from the pulmonary hilum, 1 mm or less in thickness. Kerley A lines reflect central interlobular septal thickening.
Kerley's B line	A linear opacity 1-2 cm long and 1-2 mm wide, usually situated in the peripheral and lateral lung base and oriented at right angles to the pleural surface with which it is usually in contact peripherally. Kerley B lines reflect peripheral interlobular septal thickening.
Kerley's C line	Short lines not reaching the pleura (unlike B lines) and not curving obliquely from the hila (unlike A lines). Kerley C lines are also thought to reflect thickened interlobular septae, seen en face, and hence short and not reaching the pleural surface, unlike Kerley B lines.
Lucency	An area of abnormal decreased attenuation, or blackening, on an imaging study reflecting relatively greater x-ray transmission. Examples of lucency in the lung parenchyma include emphysema, cysts, and cavities.
Lymphadenopathy	Abnormal lymph node enlargement. While some may consider this term to also encompass an abnormal increase in number of lymph nodes or abnormal internal lymph node architecture (such as necrosis), the normal allowable number of lymph nodes in a given location is not standardized. The internal architecture of lymph nodes is generally not assessable on chest radiography (except the presence of calcification); thus, the term lymphadenopathy is best reserved for indicating abnormal lymph node enlargement.

Mass	A circumscribed lesion, typically a soft tissue structure (although cavitary, cystic, or calcified constituents may be present to various degrees) greater than 30 mm in diameter. Like nodules (see *Nodule*), masses should be characterized with regard to size, shape, attenuation, and margin characteristics.
Miliary pattern	Diffusely and randomly distributed nodules 1-2 mm in size, the size of millet seeds. The miliary pattern commonly reflects hematogenous spread of a process to the lungs; such processes commonly include infections (particularly mycobacterial and fungal) and metastatic disease.
Nodule	A circumscribed, round or oval pulmonary opacity, less than or equal to 30 mm in average diameter. Like masses (see *Mass*), pulmonary nodules should be characterized with regard to size, shape, attenuation, and margin characteristics.
Opacity	Any focal or diffuse nonspecific area of increased attenuation. Opacity is now preferred over the obsolete term “infiltrate.”
Parenchyma	The functional tissue of an organ; in the case of the lung, the tissue responsible for gas exchange.
Photon	In physics, a corpuscle of energy or particle, a quantum of light or other electromagnetic radiation (e.g., x-rays).
Pleural thickening	An increase in thickness of the pleura, usually resulting from prior inflammation with subsequent fibrosis or tumor. The presence of pleural thickening may be suggested when pleural opacity is stable for long periods of time on serial radiographs (usually over a period of months or years) or when the pleural opacity fails to demonstrate mobility on decubitus radiographs. Note that in the latter circumstance, loculated pleural fluid collections may behave similarly, thus the lack of mobility of a pleural opacity with decubitus radiographs is not pathognomonic for pleural thickening.
Post-primary tuberculosis (reactivation tuberculosis)	The development of tuberculosis one or more years after initial infection, usually appearing as areas of increased opacity in the upper lobes, often with cavitation.
Primary tuberculosis	The initial *Mycobacterium tuberculos*is infection in a previously uninfected individual. Primary tuberculosis commonly manifests on chest radiographs as mid- and lower-lung opacities often associated with hilar and mediastinal lymphadenopathy.
Reticular pattern (reticulation)	A collection of innumerable small linear opacities that together produce the appearance of a net.

Reticulonodular pattern	A collection of innumerable small linear and small nodular opacities that together produce a composite appearance resembling a net with small, superimposed nodules. The linear and nodular elements are usually similar in magnitude.
Retrosternal clear space	The lung parenchyma visible on the lateral radiograph posterior to the sternum. Usually only a few pulmonary blood vessels are visible in this region.
Right paratracheal stripe	A vertically-oriented linear opacity 2-3 mm wide that extends from the thoracic inlet to the right tracheobronchial angle on the frontal radiograph. It is situated between the air shadow of the trachea and the right lung and is formed by the right wall of the trachea and contiguous mediastinal tissue and adjacent pleura.
Scatter	Pertaining to radiography, scatter refers to radiation that enters a patient and is deflected from its initial course but may still contact and expose the x-ray film. Scatter radiation contributes to the patient radiation dose and degrades the radiographic image.
Septal line	A generic term for fine linear opacities of varied distribution produced by the interstitium between pulmonary lobules when the interstitium is thickened by fluid, dust deposition, cellular material, etc. See also *Kerley's line*.
Silhouette sign	The effacement of a normally visualized contour that was created by the juxtaposition of structures with different radiographic densities (e.g., soft tissue contacting air). When two adjacent structures that differ in density are altered in such a way that both structures become the same density, as occurs when normally aerated lung becomes consolidated, the normally visual contour at the interface of these structures will no longer be visualized.
Stripe	An extended, longitudinal, composite opacity 2-5 mm wide, used as a descriptor of shadows created by mediastinal structures.
Unabsorbed	Pertaining to radiography, unabsorbed refers to that portion of the x-ray beam that traverses the patient and does not interact with the patient's tissues. These x-ray photons pass through the patient unaffected and expose the x-ray film, thereby contributing to the creation of the radiographic image.

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1

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

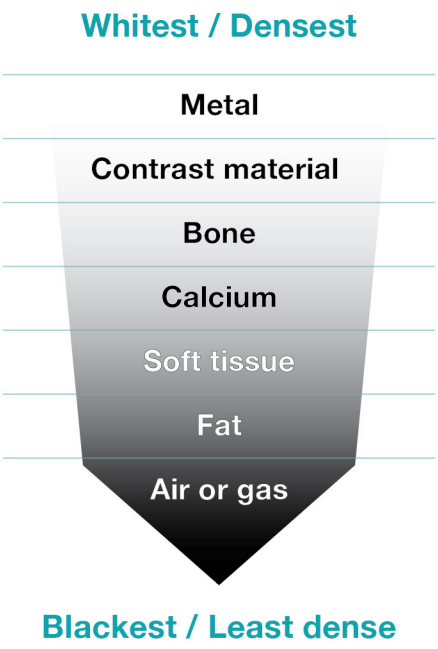
It is important to understand the factors that contribute to x-ray absorption because the final image depends on the relative number of x-rays that are unabsorbed, absorbed, or scattered. In general, the two most important factors that determine how x-rays are absorbed are the **energy** of the x-ray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

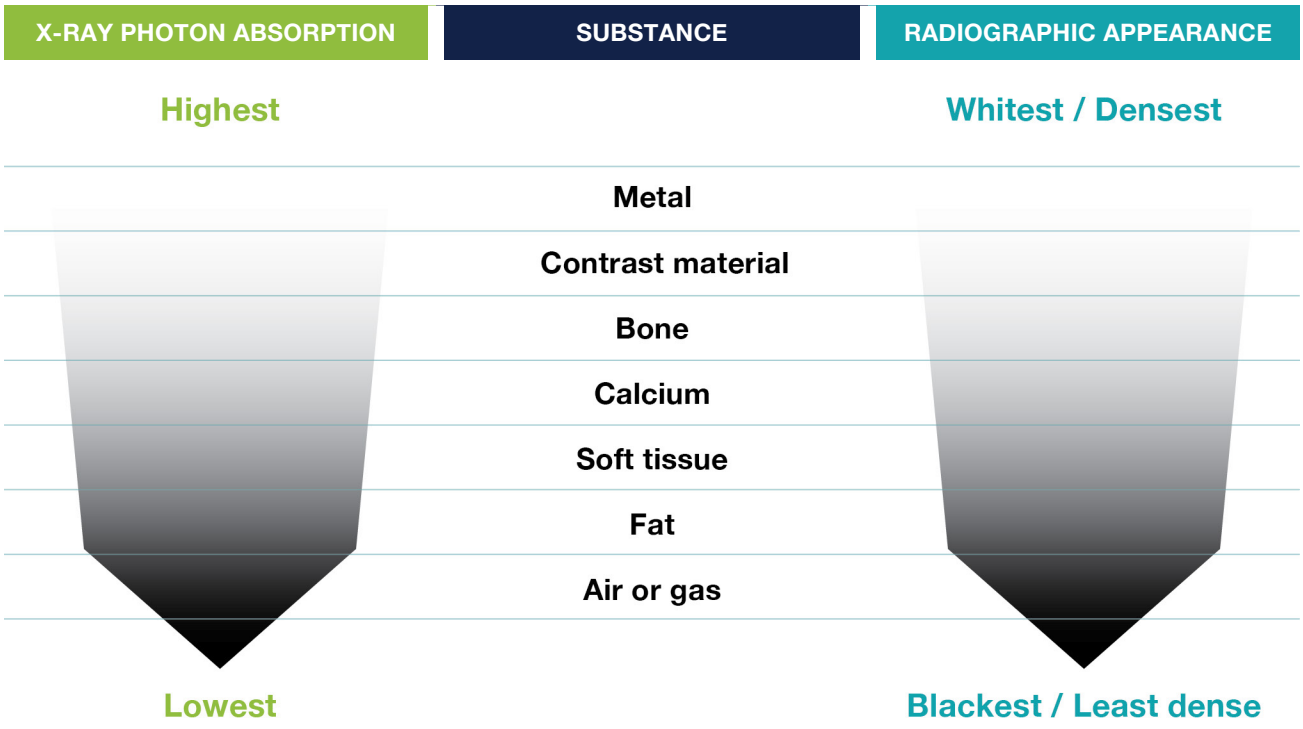
Tissue density has a more significant effect on x-ray beam absorption than the energy of the beam. In general, there are seven different densities on chest radiographs. The denser the tissue, the whiter it appears on a radiograph. The less dense the tissue, the blacker it appears. In order, from the 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.



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.

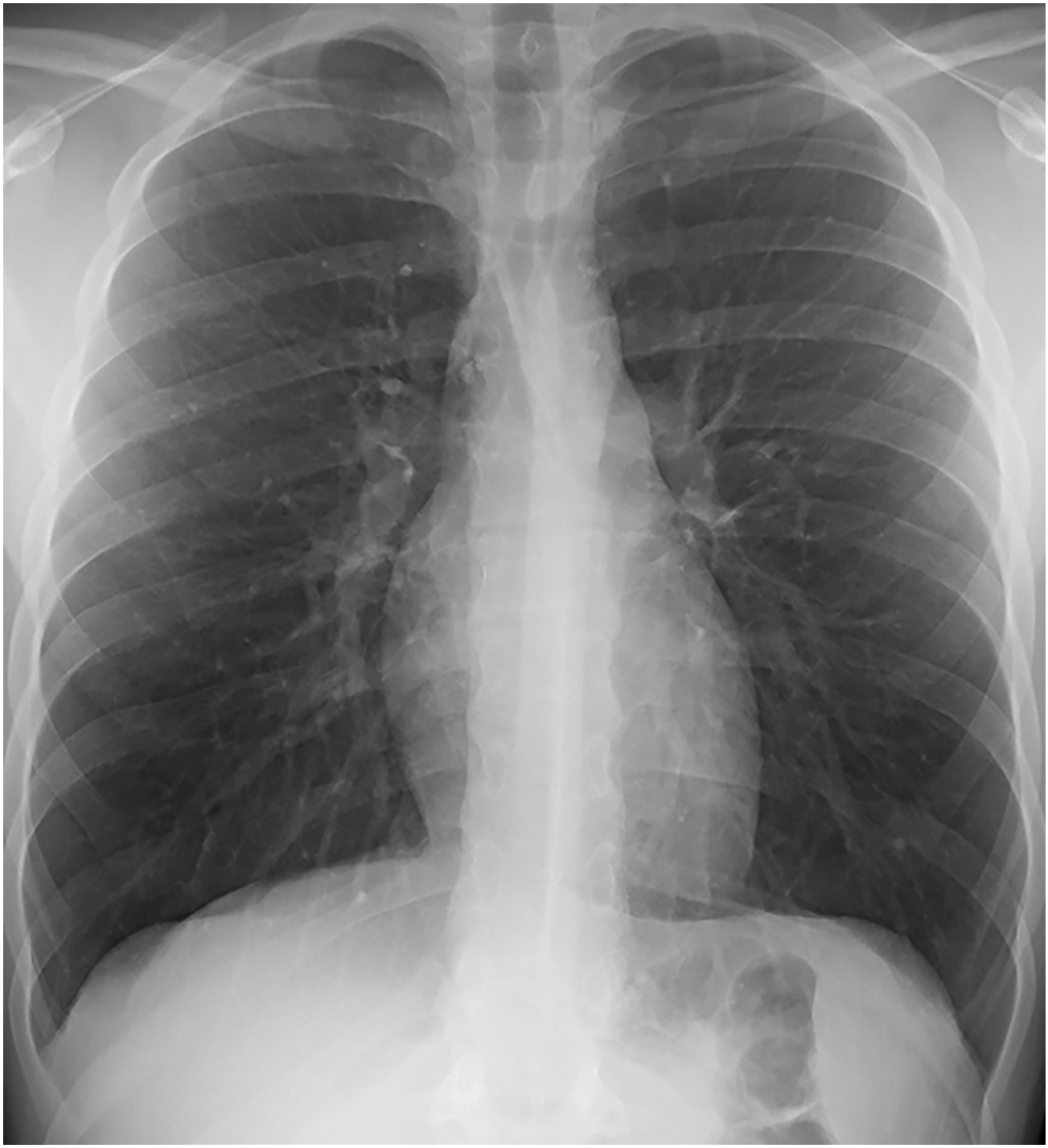
Normal contours created by aerated lung

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**

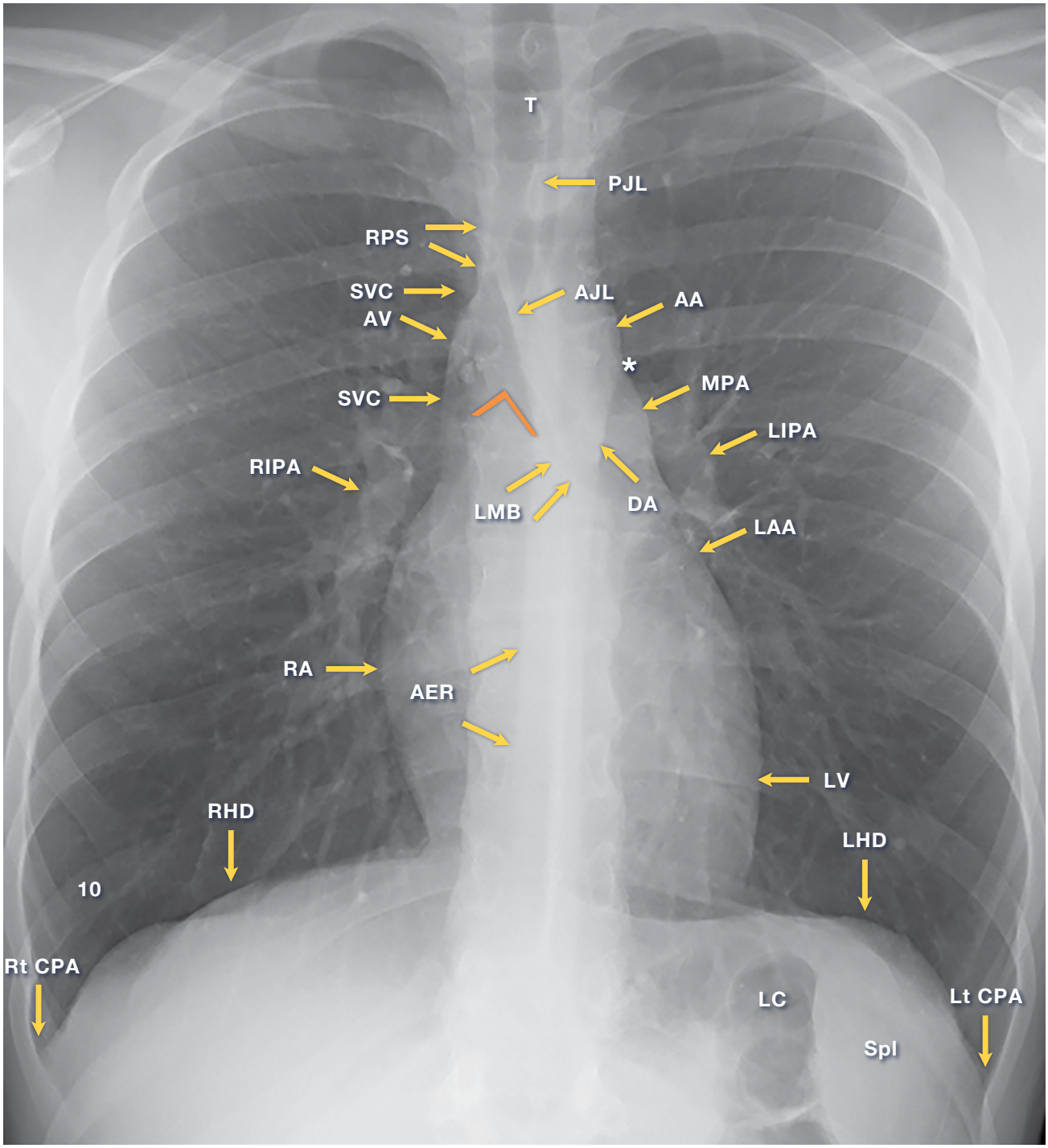
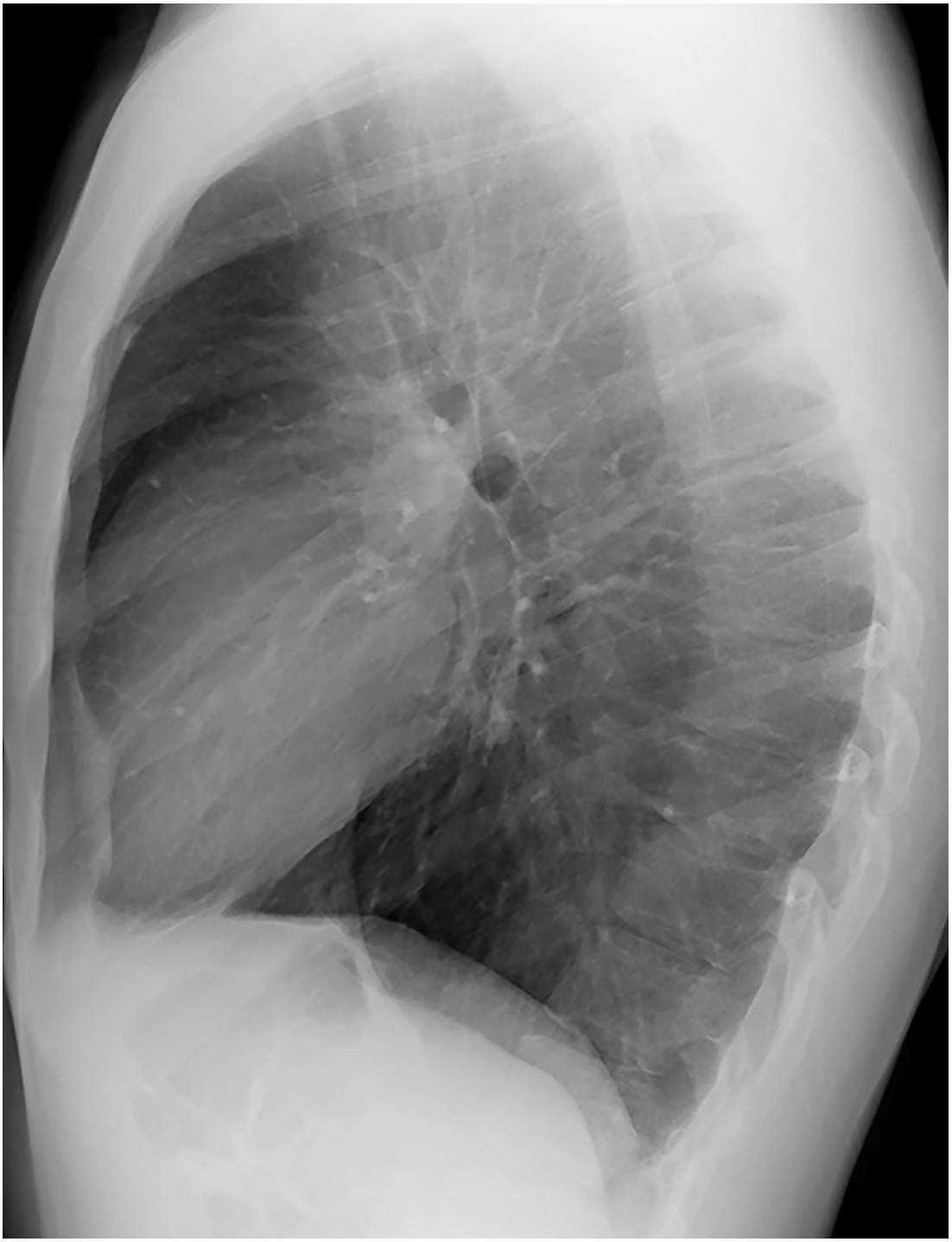


Figure 1.1B Key

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

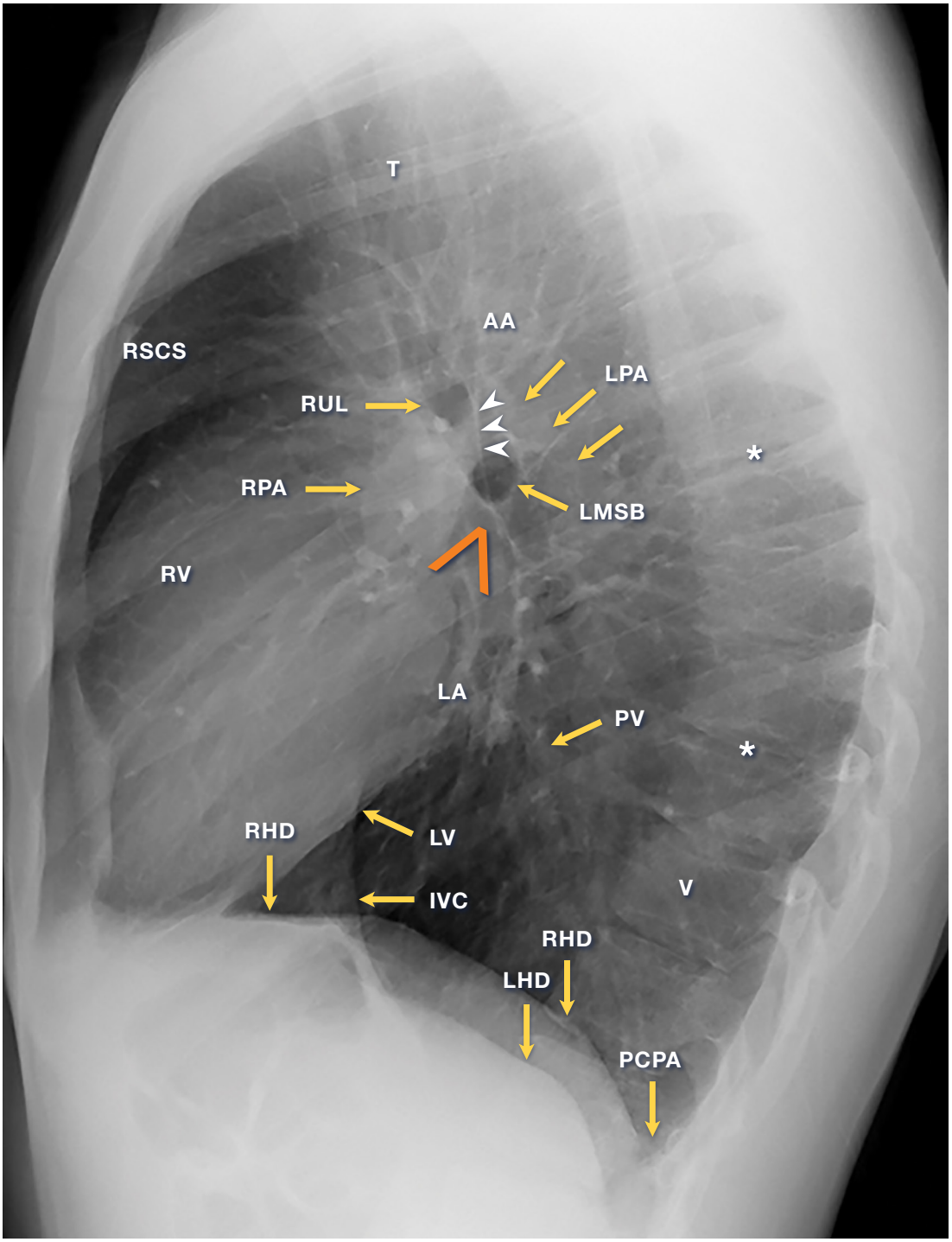


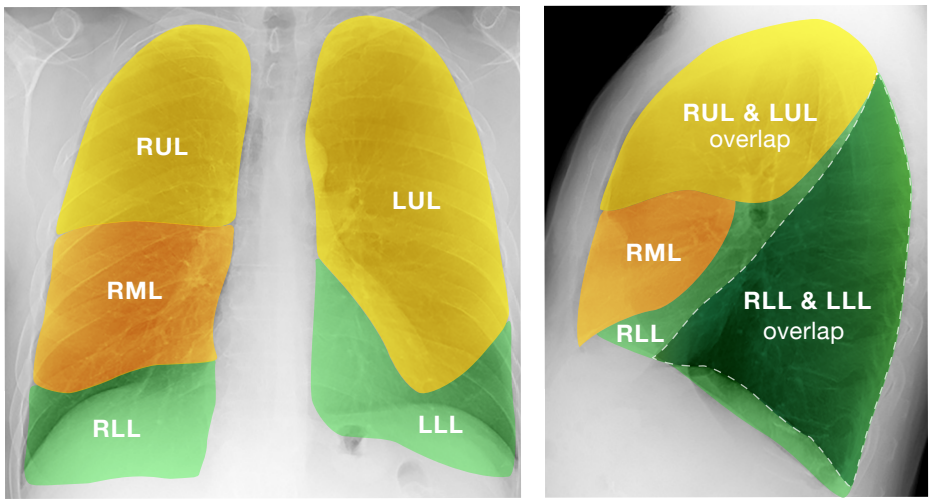
Figure 1.1D Key

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

Radiographic lobar anatomy

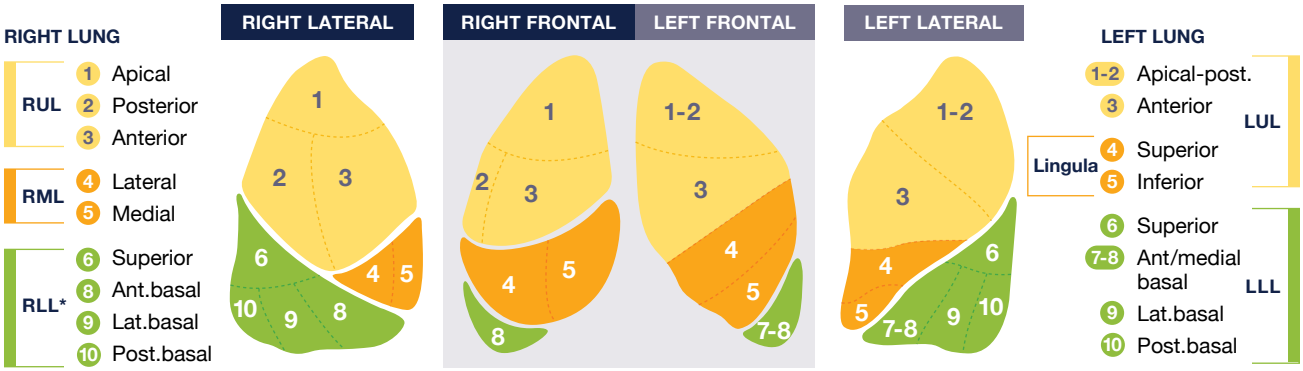
Formal radiology readings may refer to findings in relation to pulmonary lobar anatomy. Note that the right and left lobar anatomy are not symmetrical, and that abnormalities in the superior segments of the lower lobes, best seen on a lateral view, may present quite high (cephalad) in the two-dimensional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

FIGURE 1.1E. **Radiographic lobar anatomy**



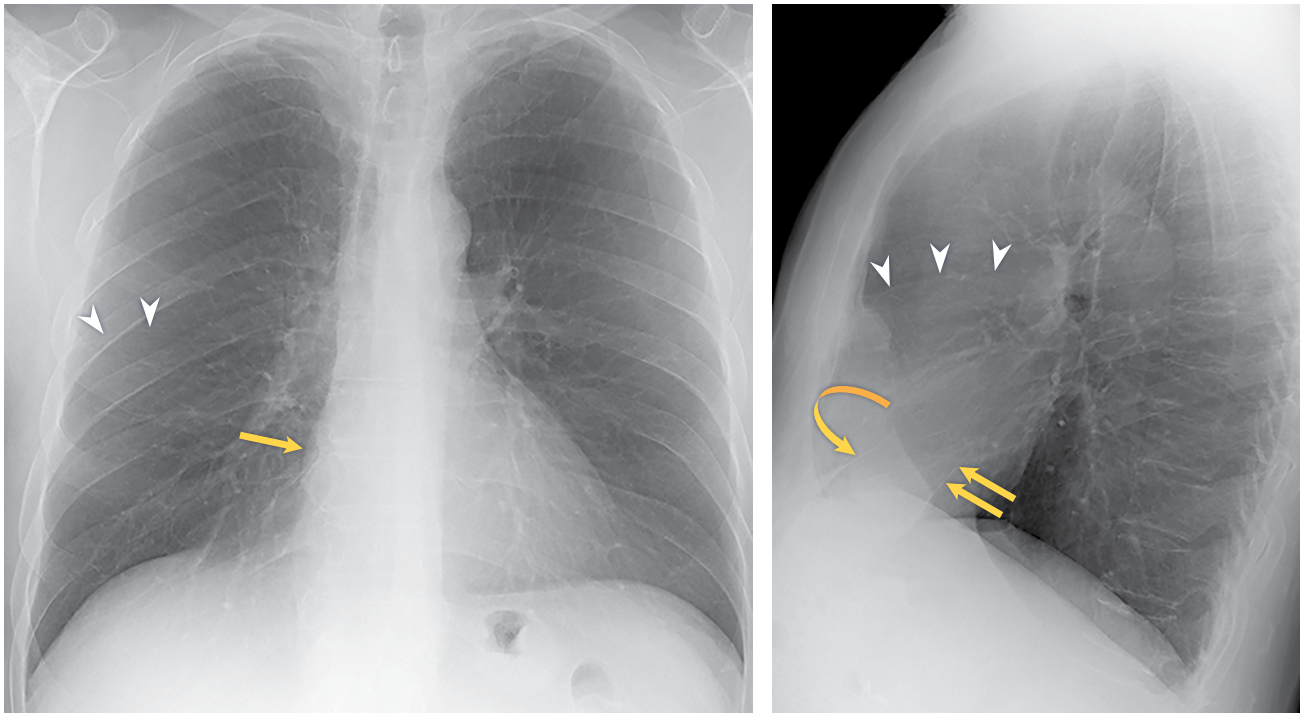
- The right upper lobe (RUL, yellow) is separated from the right middle lobe (RML, orange) by the right minor fissure.
- Note that the right major fissure separates the right lower lobe (RLL, green) from both the right upper and middle lobes, as demonstrated on the lateral chest radiograph.
- The most 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**



* 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**

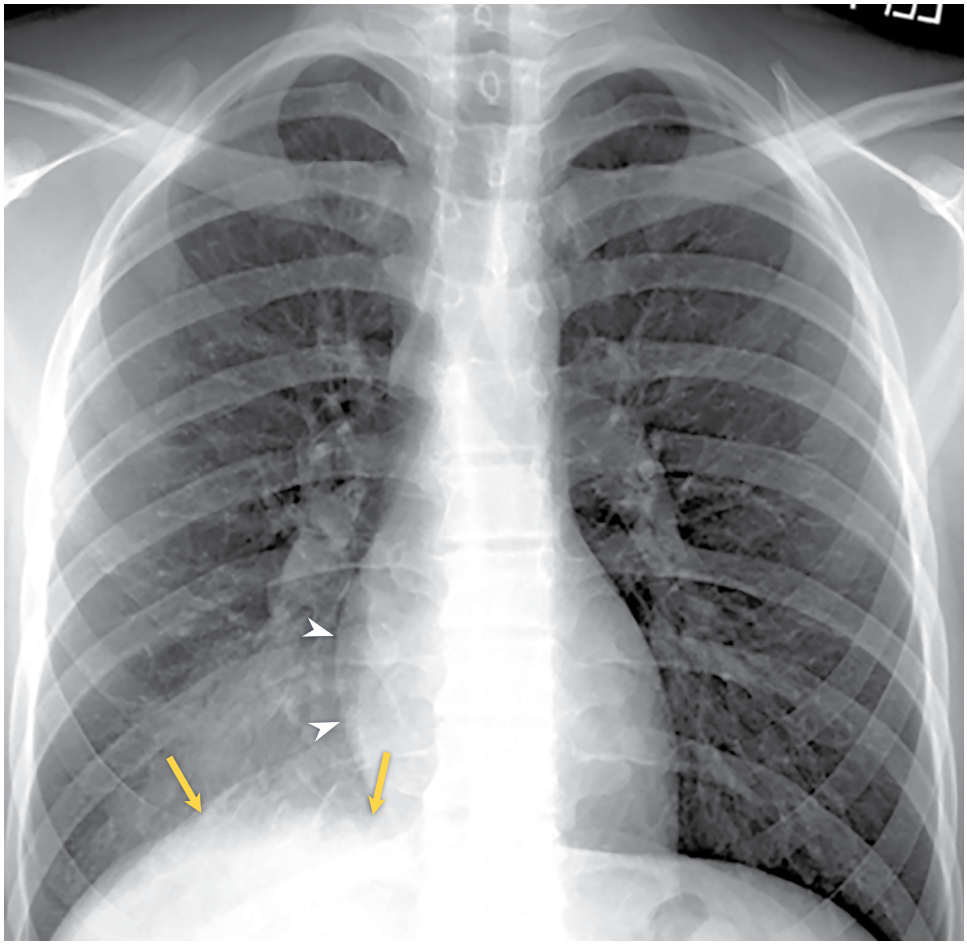
With the notable exception of artifacts in an image, any opacity seen on a chest radiograph will be located in one (or more) of the four potential locations listed above. Accurately localizing the abnormality is fundamental to developing a reasonable differential diagnosis.

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**

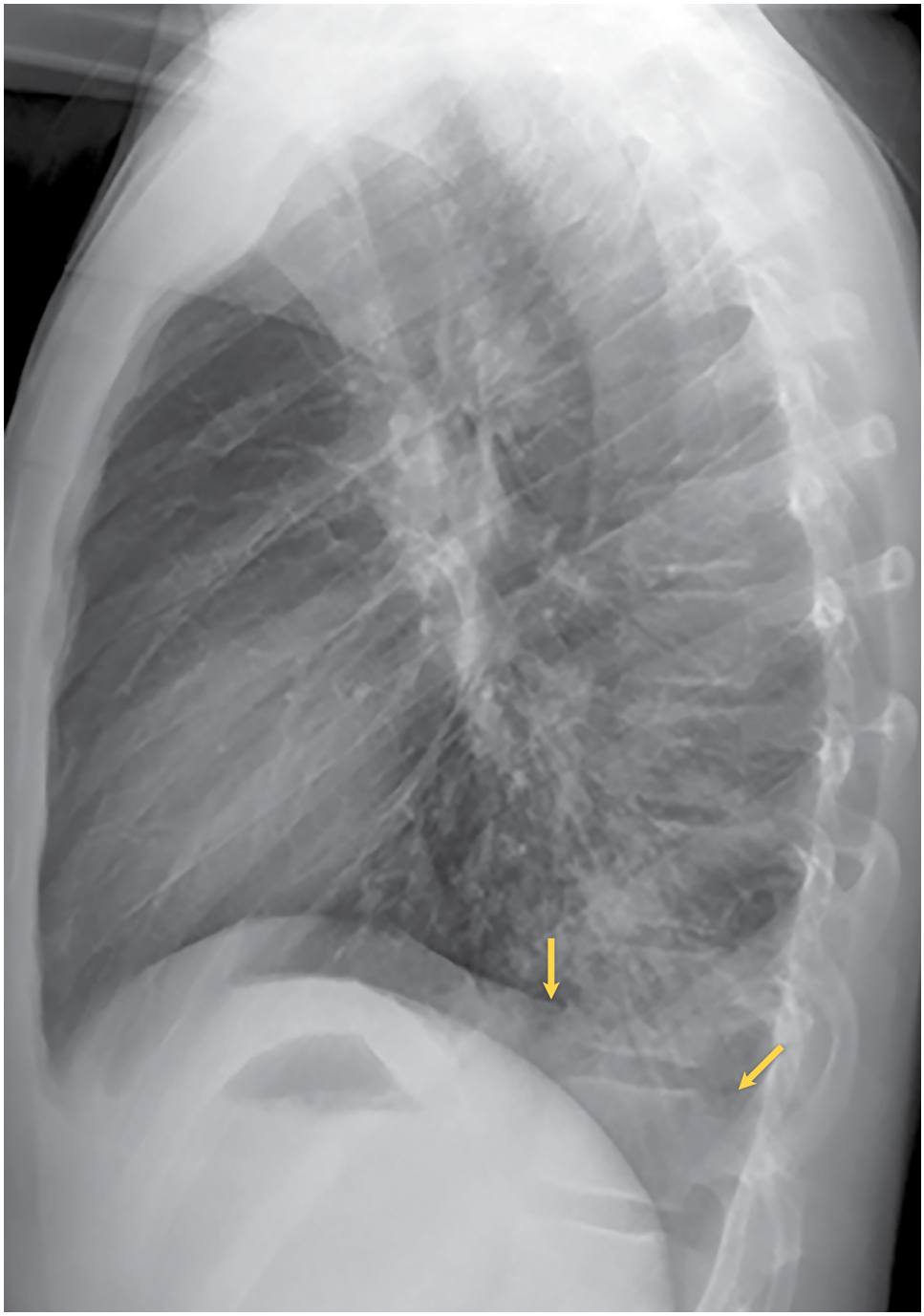


When aerated lung contacts a structure of different density (such as the heart, mediastinum, or diaphragm), an interface is created and, under normal conditions, a boundary is visible. In Figure 1.2A, the arrowheads point to the normal right heart border. This interface is created because the normally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

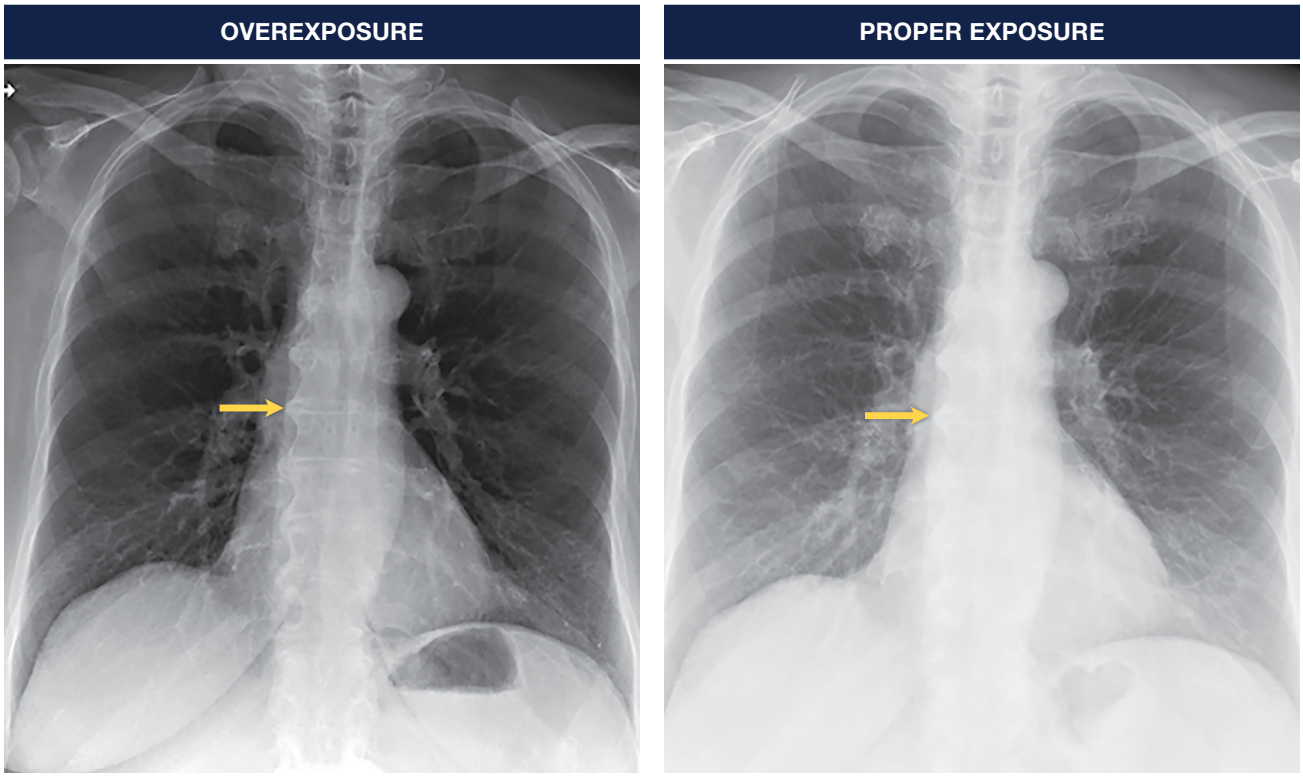
The medial ends of the clavicles will usually overlie the junction of the medial ends of the first anterior ribs with the manubrium and will be equidistant from the tracheal air column. The spinous processes will be visualized though the tracheal air column. When the clavicles are projected cranial to 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.

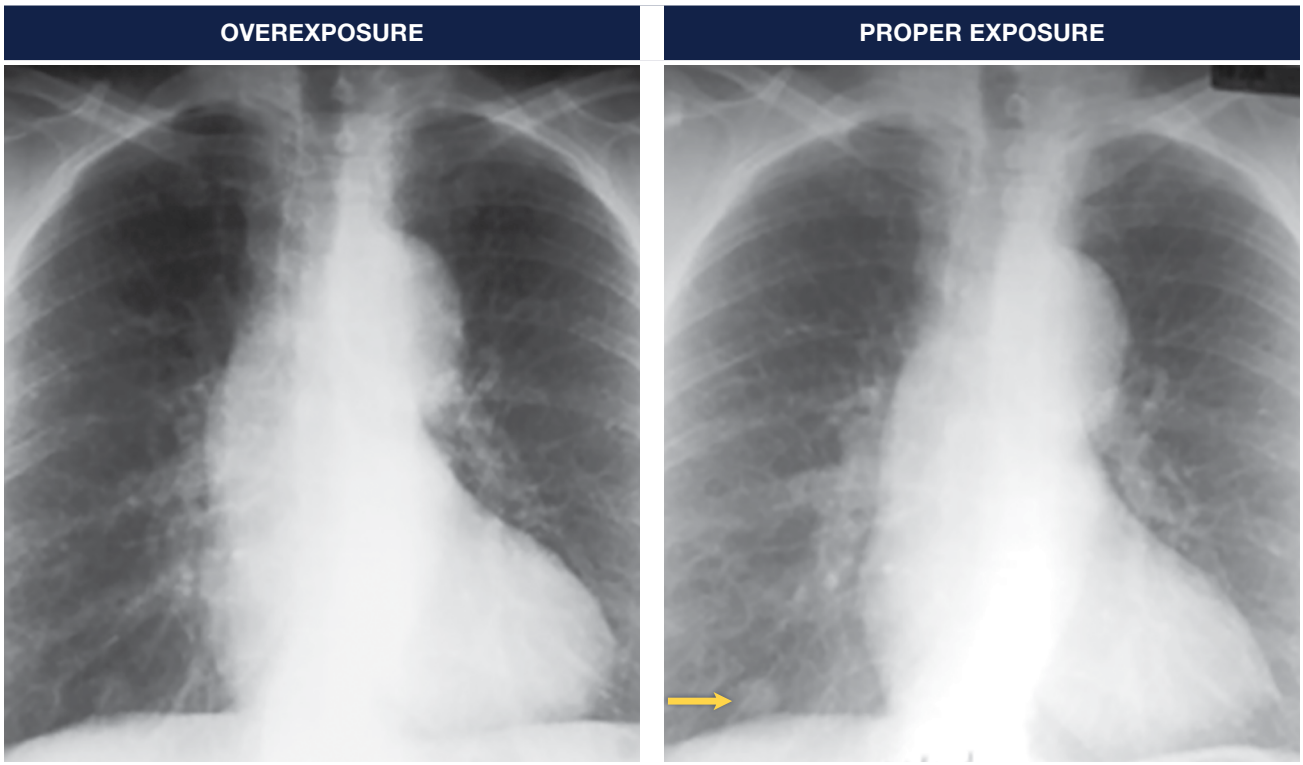
Low lung volumes often result in basilar vascular crowding and atelectasis and may create the appearance of interstitial lung disease or pneumonia in the lung bases. Additionally, low lung volumes often create the appearance of cardiac enlargement. Caution must be exercised when interpreting radiographs 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**



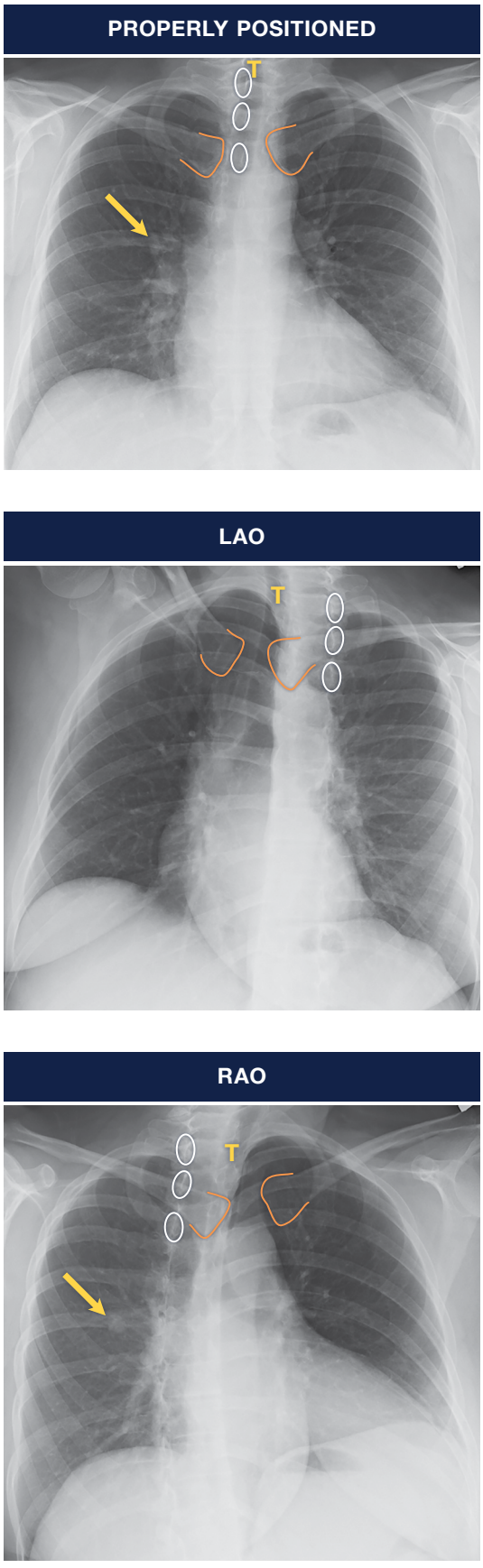
The frontal chest radiograph on the left is overexposed, resulting in excessive image "blackening." Note how the lungs appear very dark, and the intervertebral disc spaces (arrow) are easily visualized. The image on the right is properly exposed. Note how lung vessels are more readily seen compared to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

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



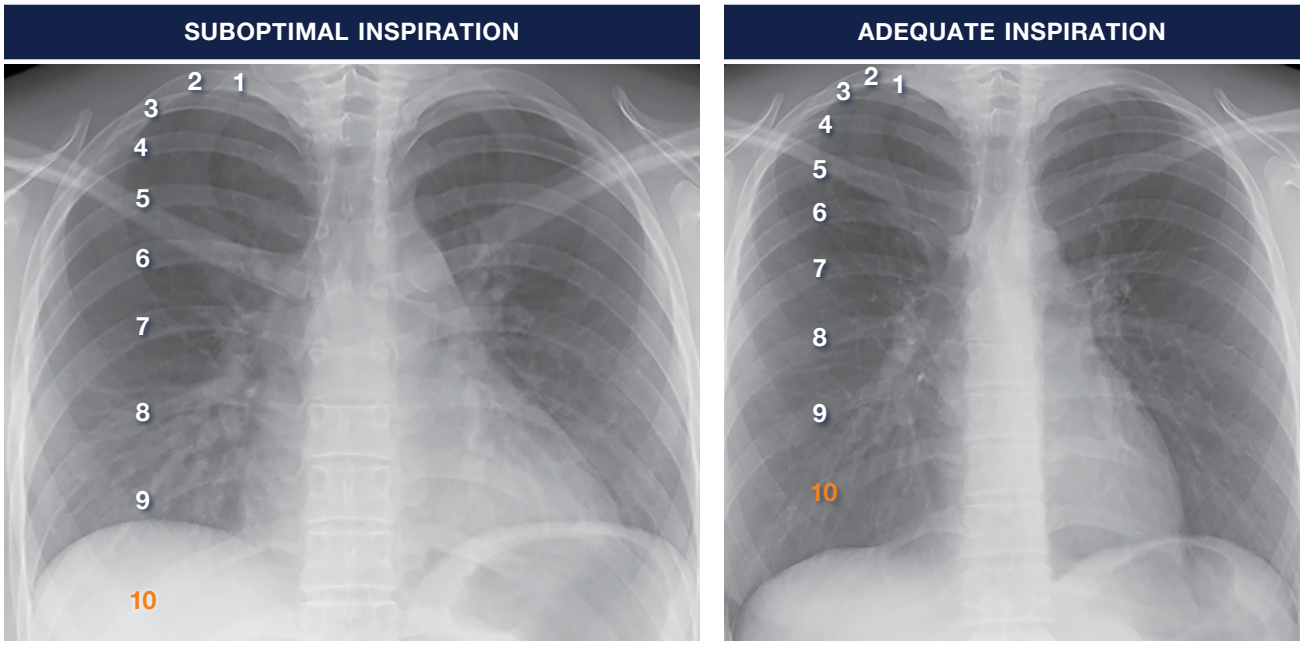
The image on the left demonstrates how a right lower lung nodule may be easily overlooked due to technical overexposure (note how blackened the right lungs appear with loss of detail for pulmonary vasculature and visualization of the posterior ribs). With improved exposure technique, the nodule (arrow)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

FIGURE 1.4. **Chest radiographic positioning**



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**

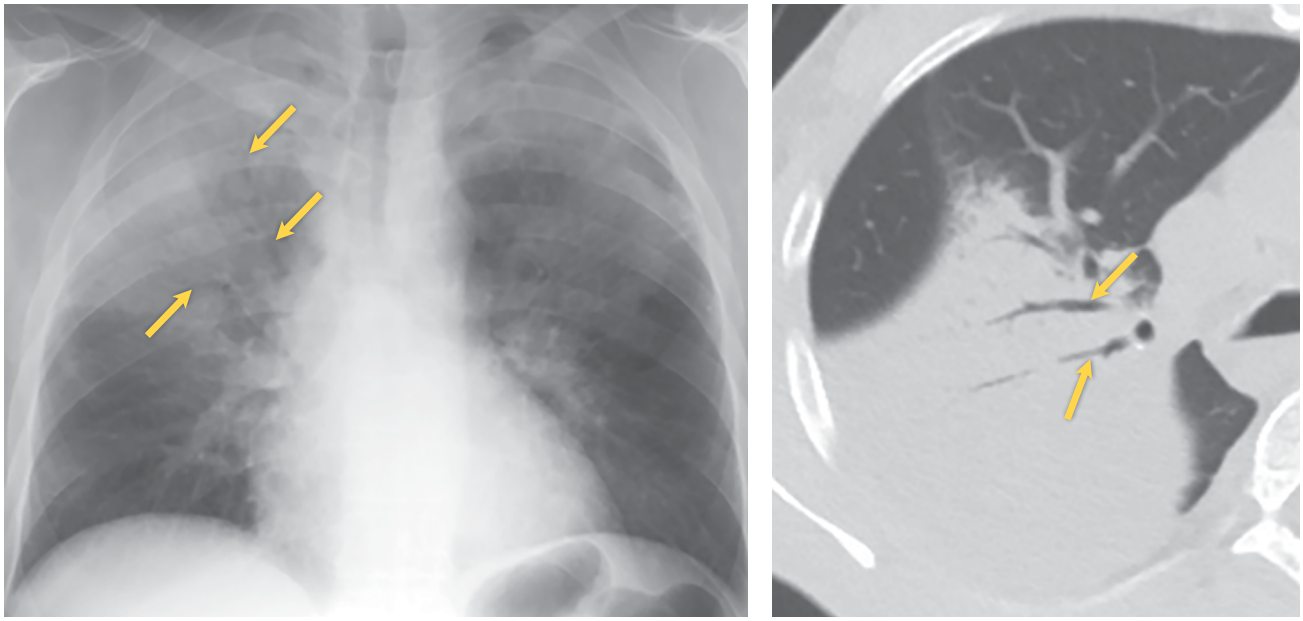
When interpreting radiographs, it is important to understand that more than one of the basic patterns may be present simultaneously. Such radiographs can be quite challenging to interpret. In general, a final interpretation should attempt to synthesize multiple patterns into a single diagnosis whenever 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**

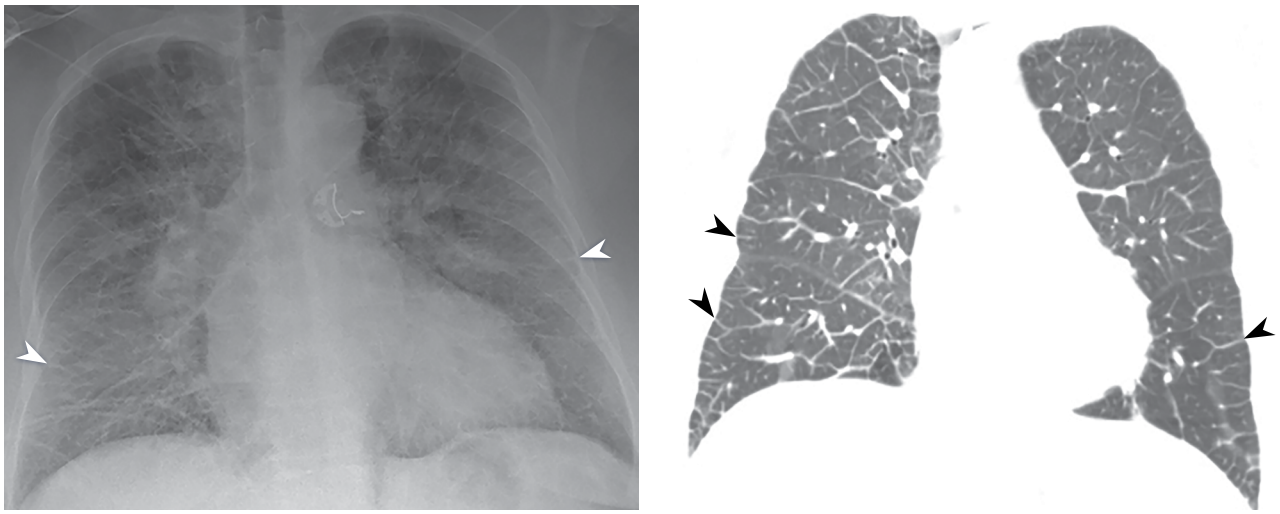


Figure 1.7 demonstrates numerous abnormalities, but one feature in particular is characteristic of interstitial opacity: interlobular septal thickening or Kerley's B lines (arrowheads).

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**

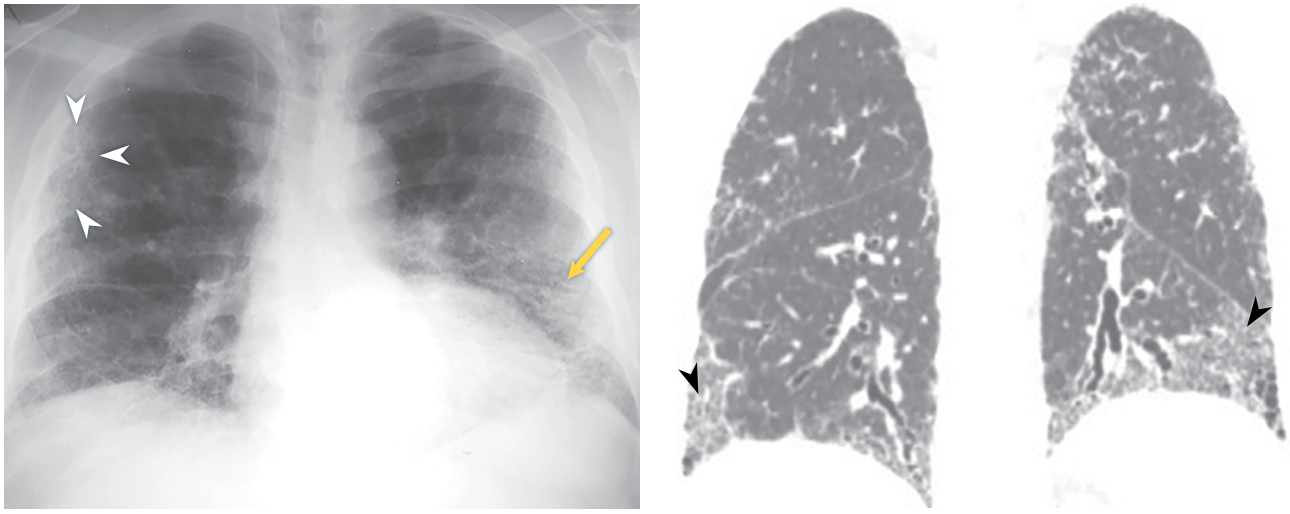


Figure 1.8 demonstrates features consistent with an interstitial lung process. Note the basal and peripheral distribution and low lung volumes. Specific features visible are:

- 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**

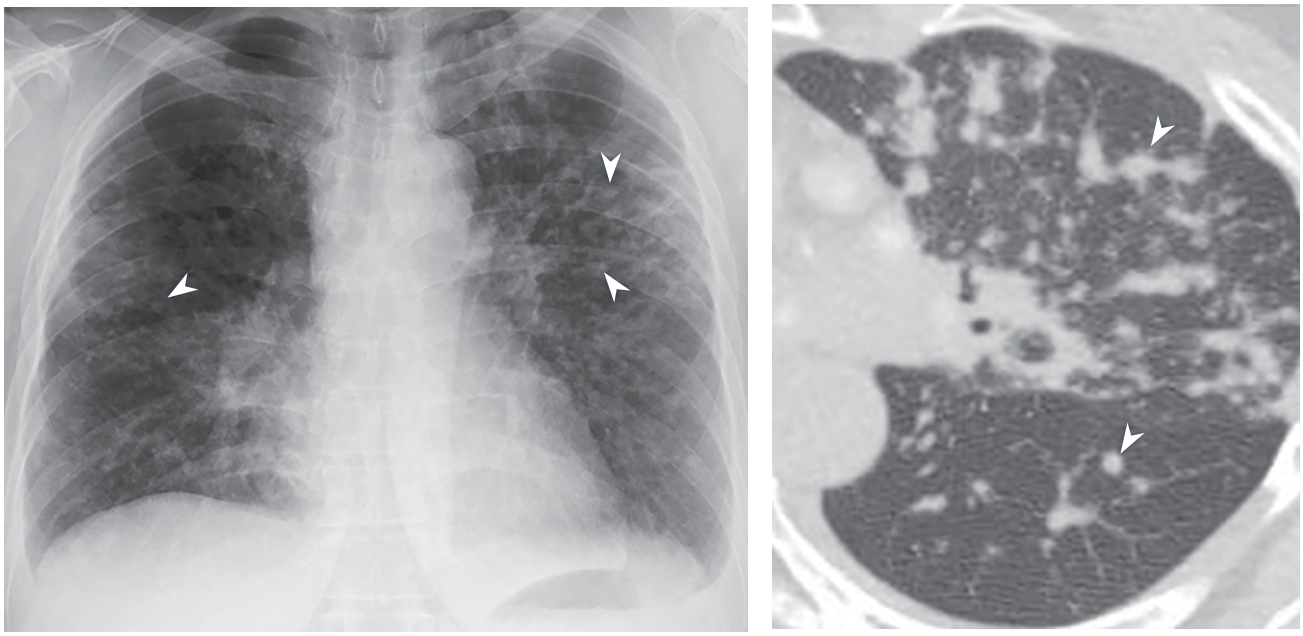


Figure 1.9 demonstrates features characteristic of interstitial opacity: nodules — small, discrete, with an upper-lung predominance (arrowheads).

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**

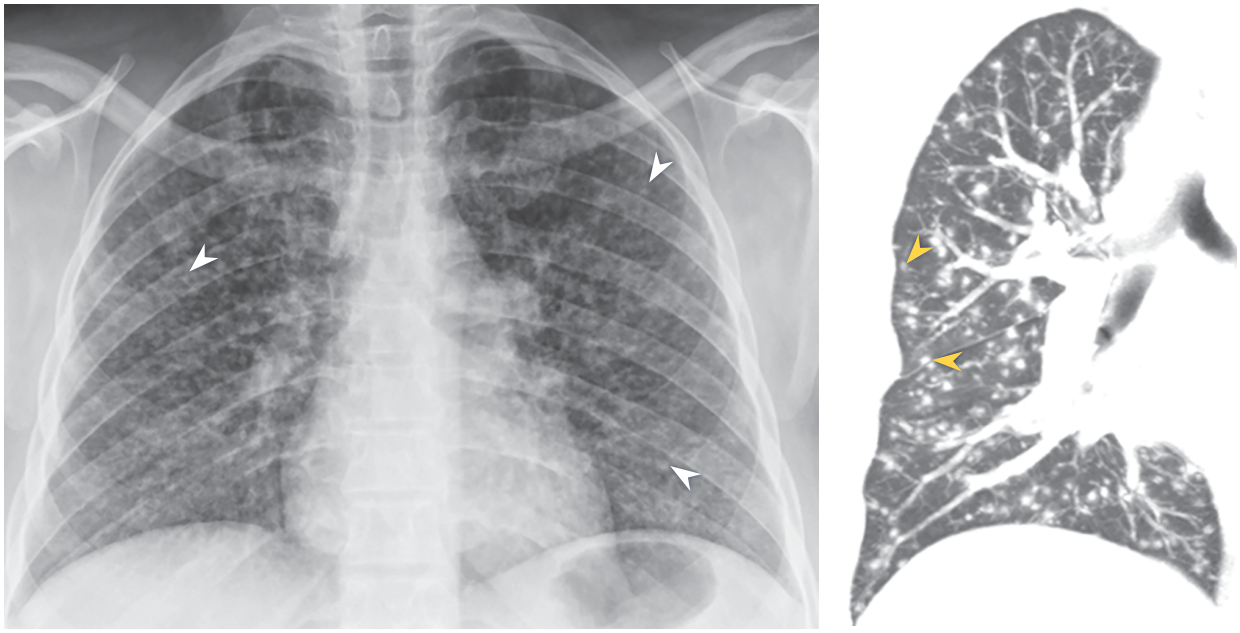


Figure 1.10 demonstrates characteristics suggestive of an interstitial process: small, well-defined nodules (arrowheads) scattered diffusely throughout the lung parenchyma, representing a miliary pattern.

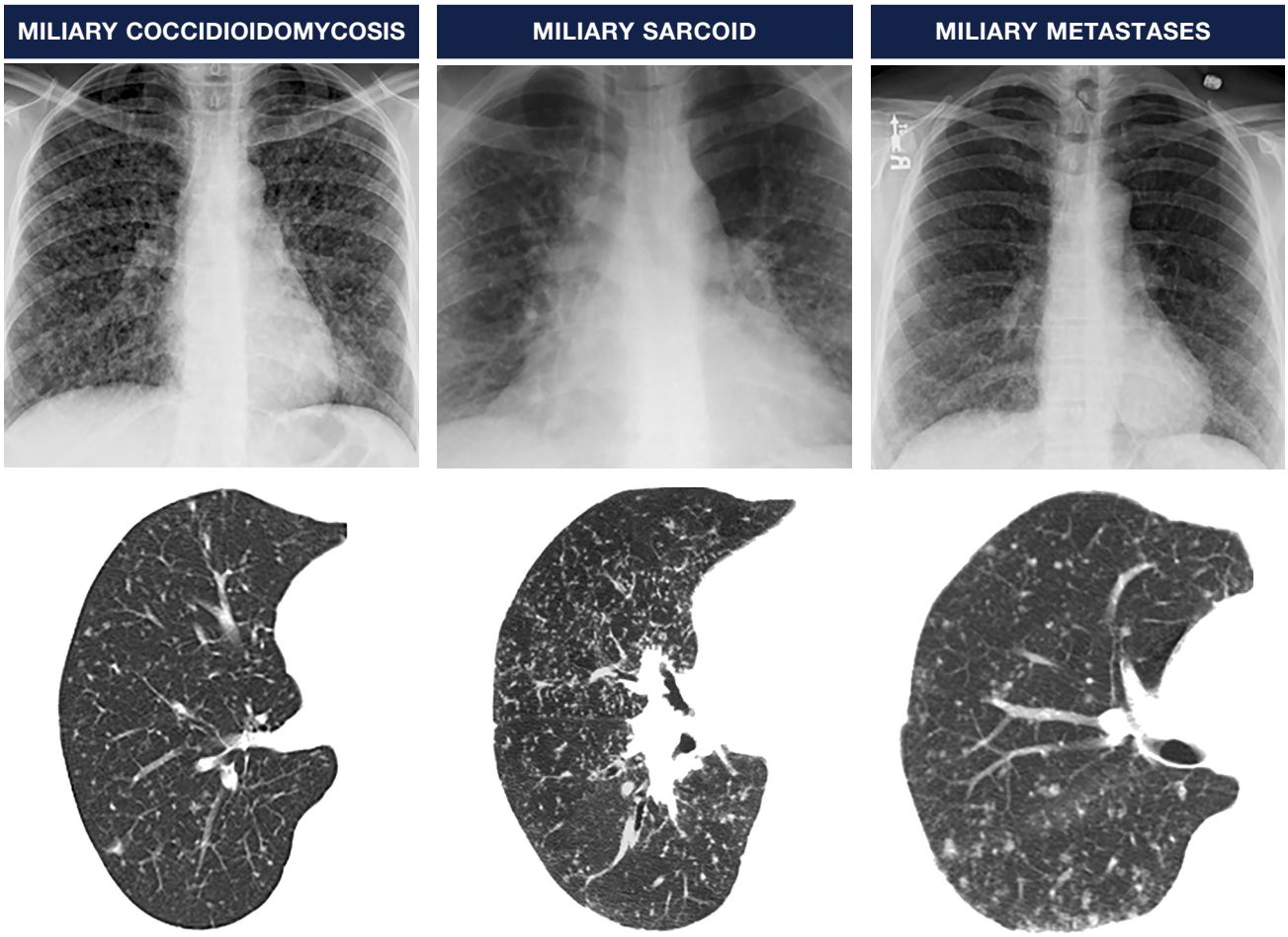
KEY POINTS

- 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**

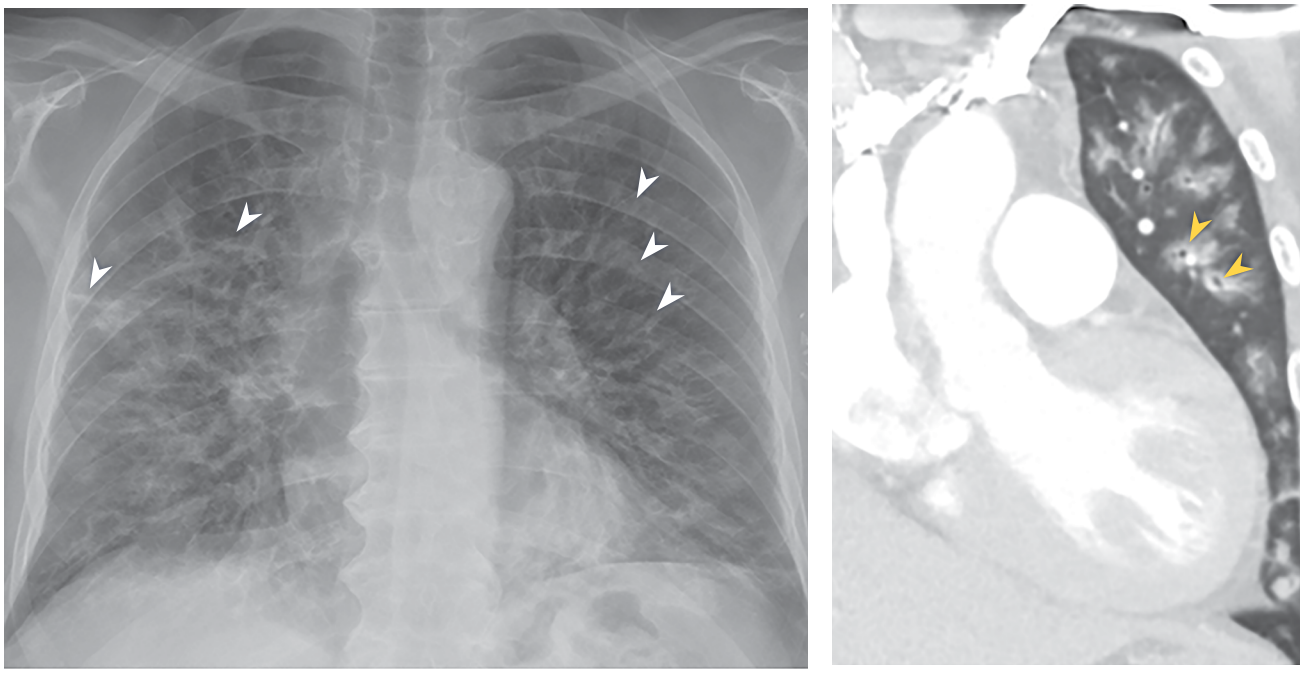


Figure 1.12 demonstrates features of interstitial opacity: thickening of the bronchovascular bundles as they course peripherally from the hila (arrowheads).

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

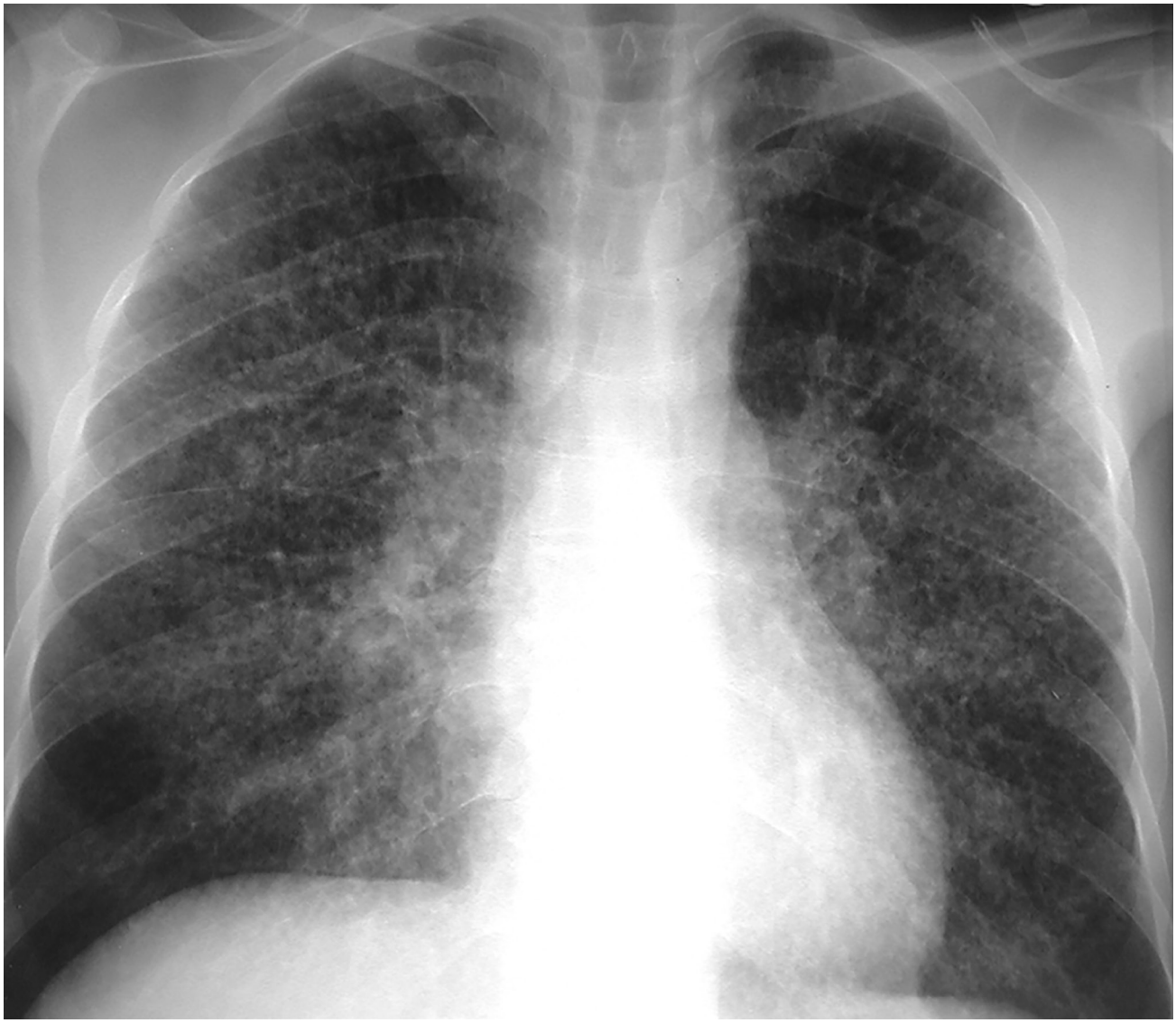


Figure 1.14

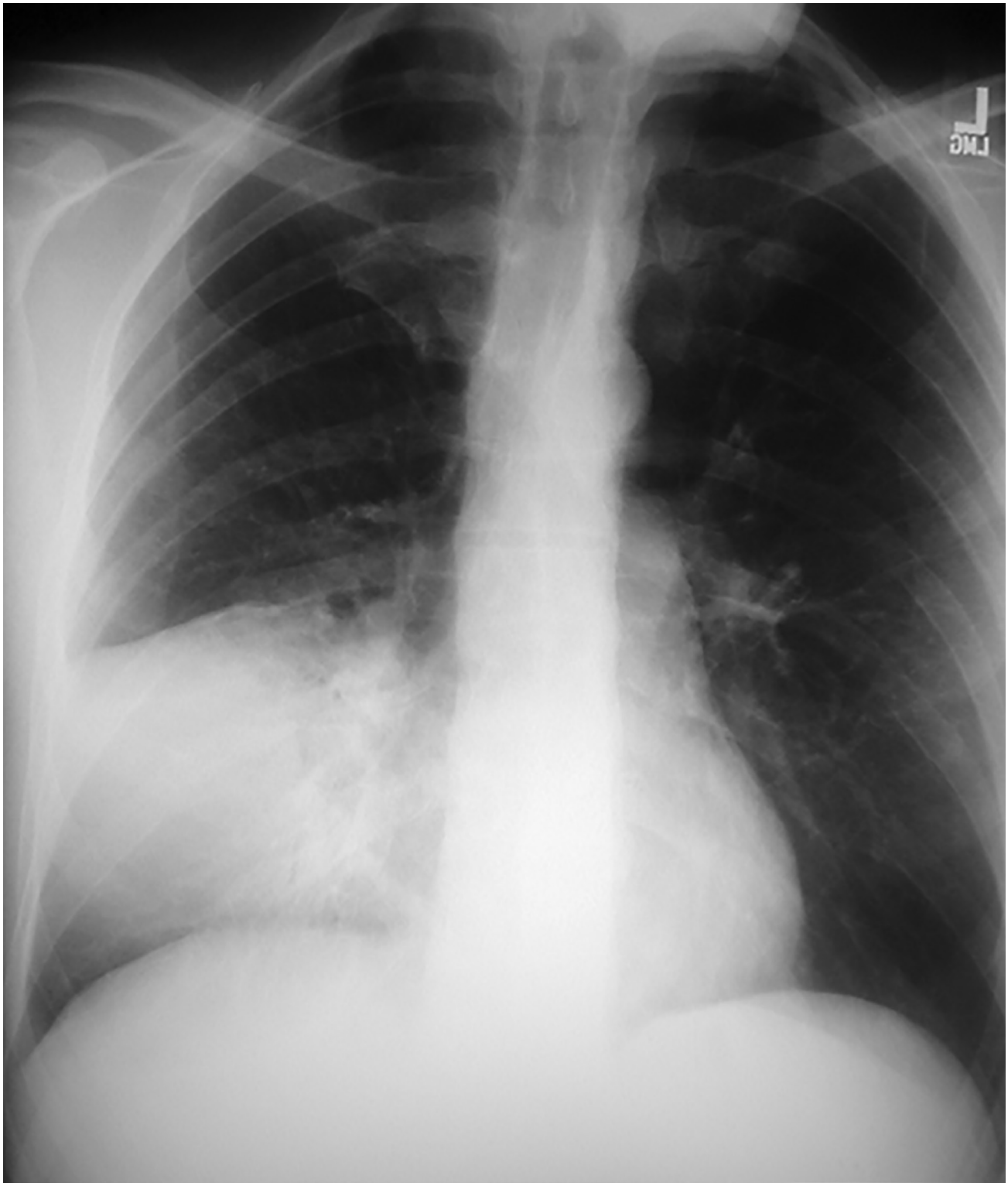
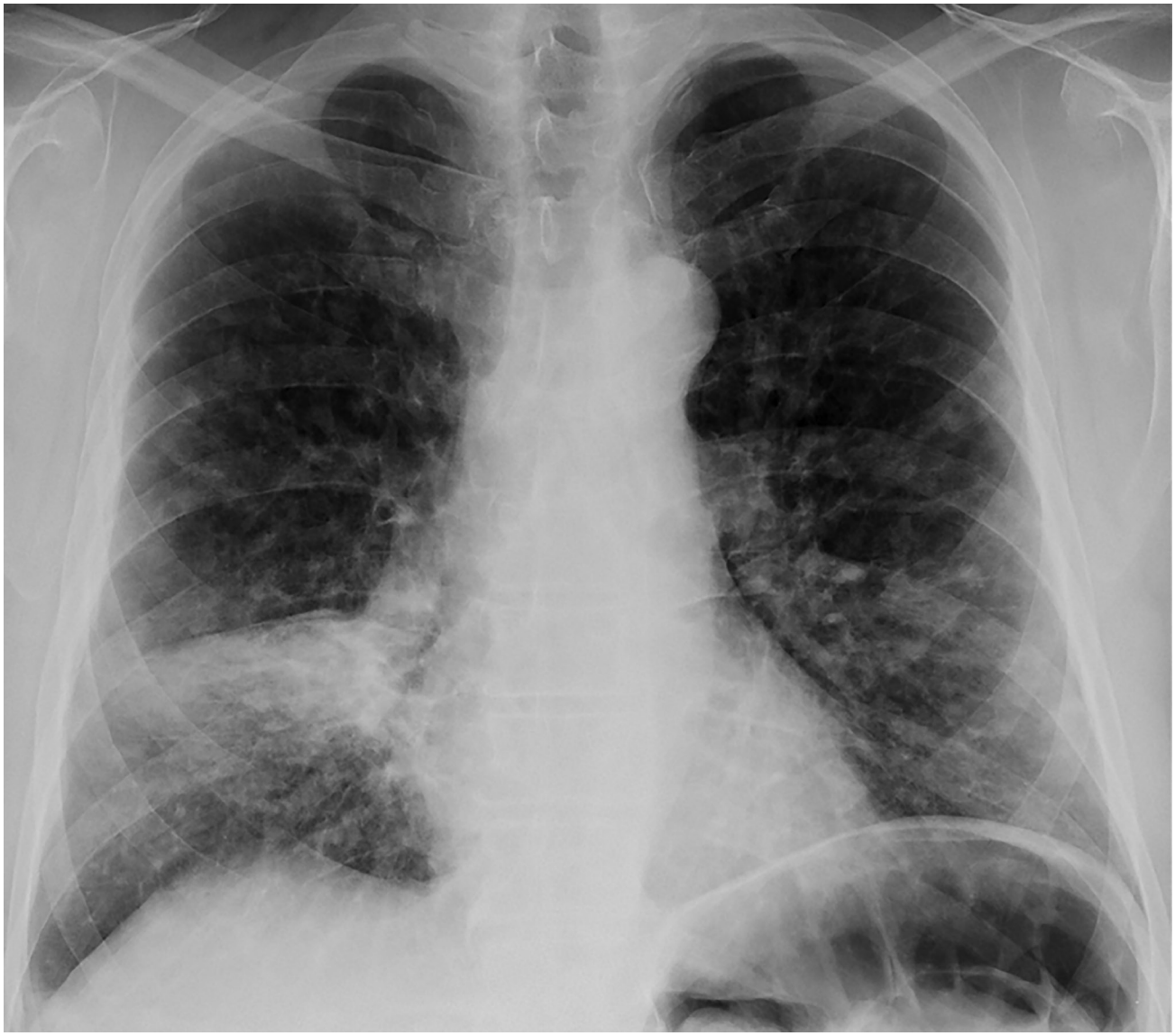


Figure 1.15



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**

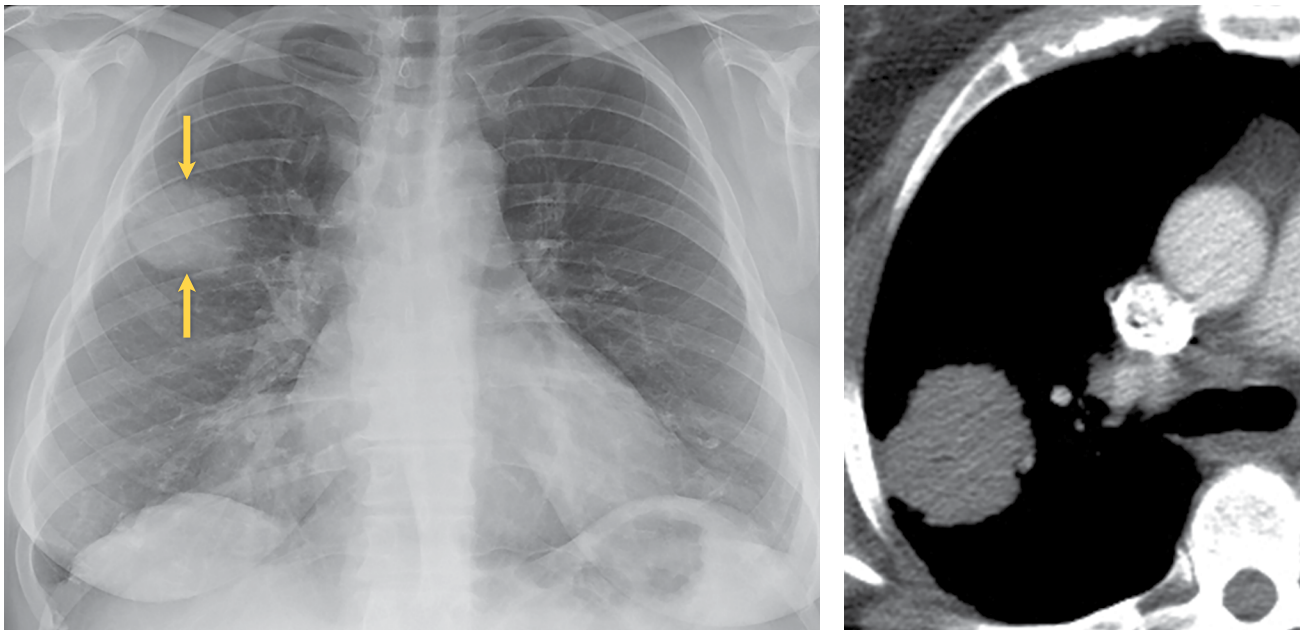


Figure 1.16 demonstrates a right upper-lobe pulmonary mass: solitary circumscribed area of increased opacity measuring greater than 30 mm in diameter (arrows).

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**

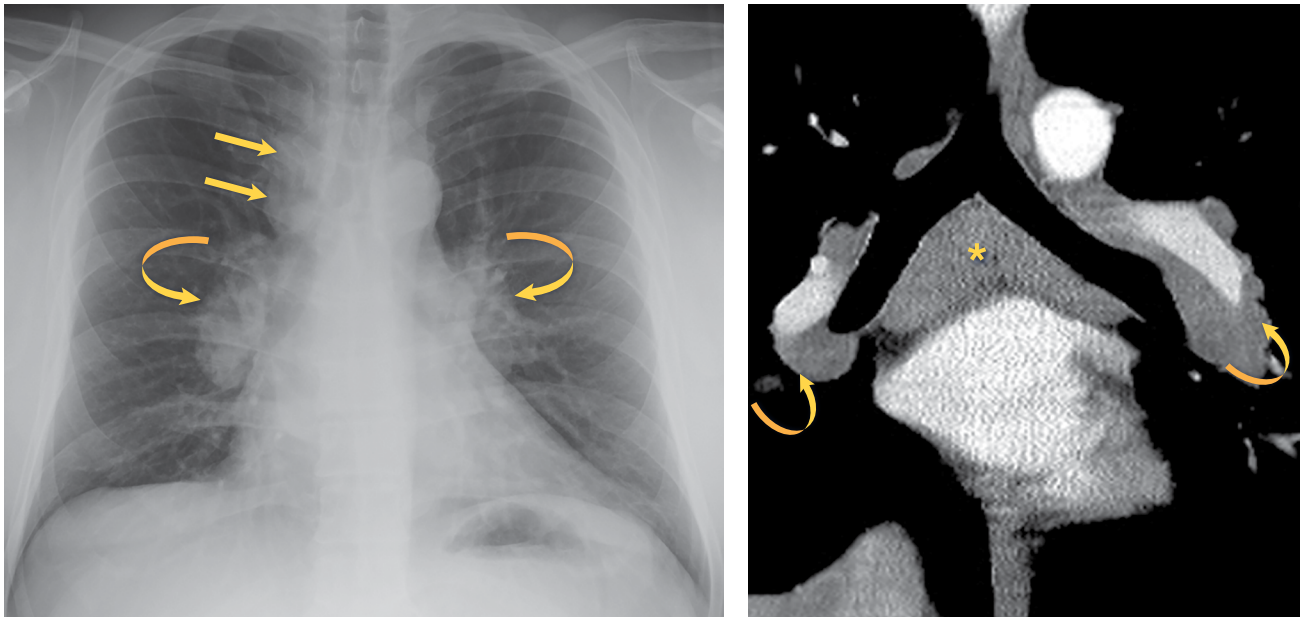


Figure 1.17A demonstrates the following (compare to Figures 1.1A and 1.1B):

- 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**

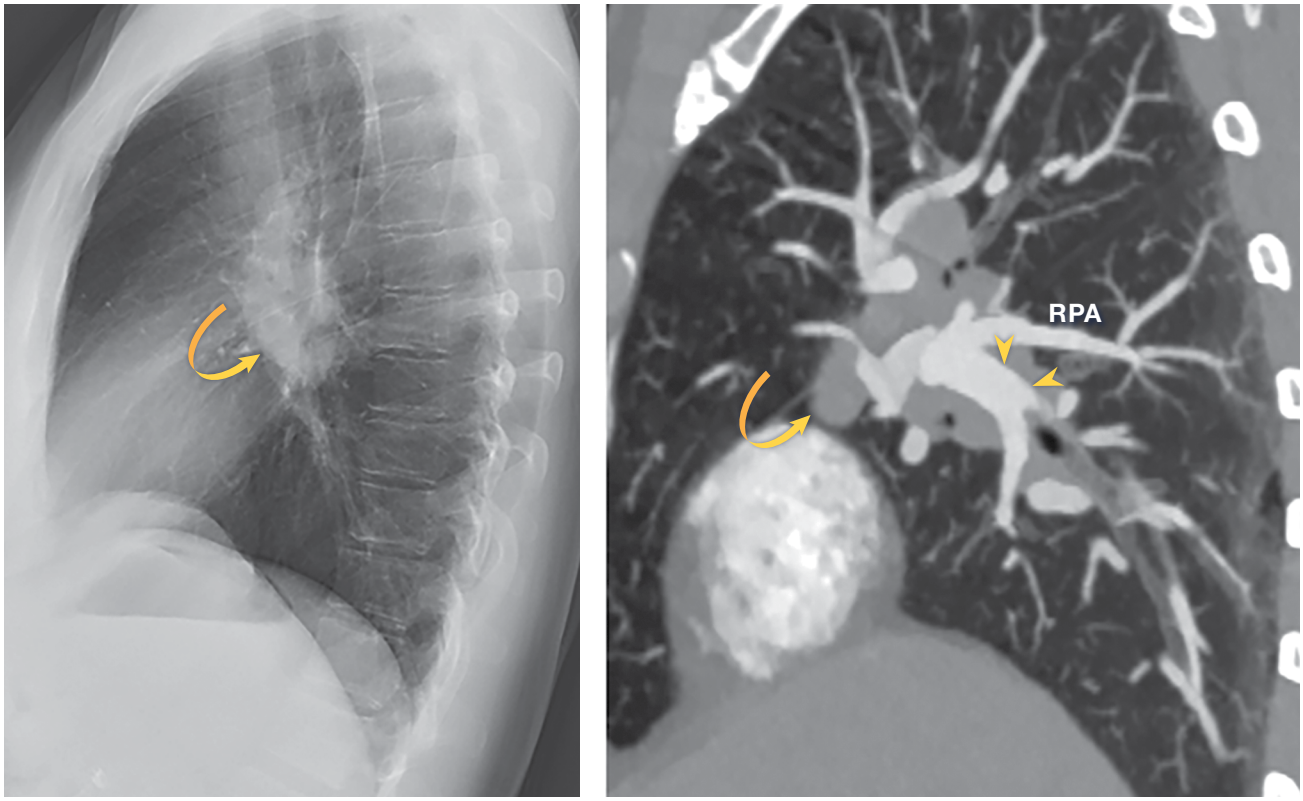


Figure 1.17B demonstrates abnormal soft tissue opacity inferior to the right pulmonary artery (arrowheads), filling the normally clear area known as the infrahilar window (curved arrow). CT shows the right peribronchial lymphadenopathy (curved arrow) adjacent to the interlobar branch of the right pulmonary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

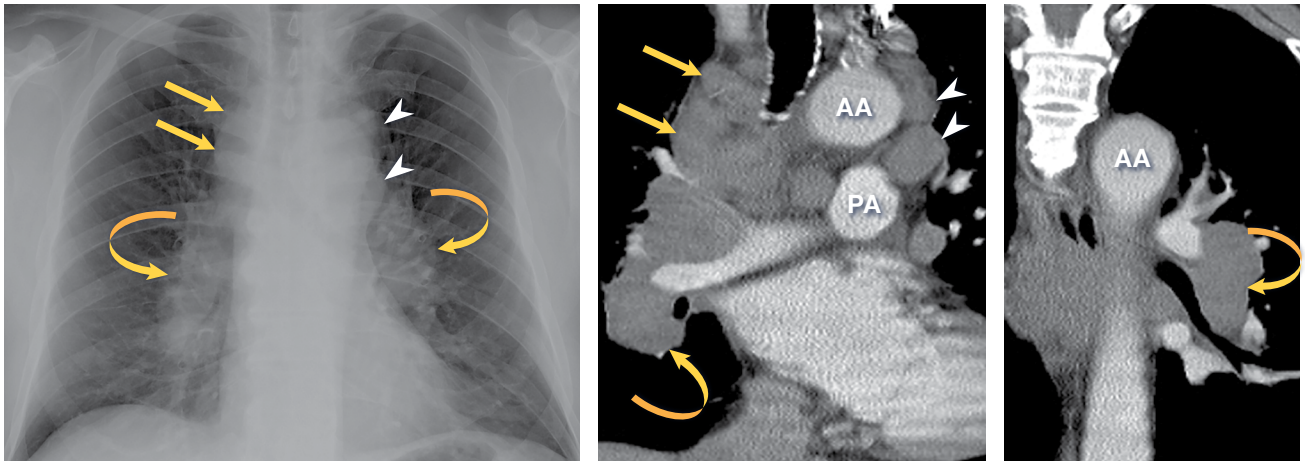


Figure 1.18 demonstrates an unexpected contour along the interlobar pulmonary arteries (curved arrows). The right paratracheal stripe is widened (arrows), and an abnormal contour is seen along the left aspect of the mediastinum near the aortic arch (arrowheads). The hila appear lobulated and indistinct (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**

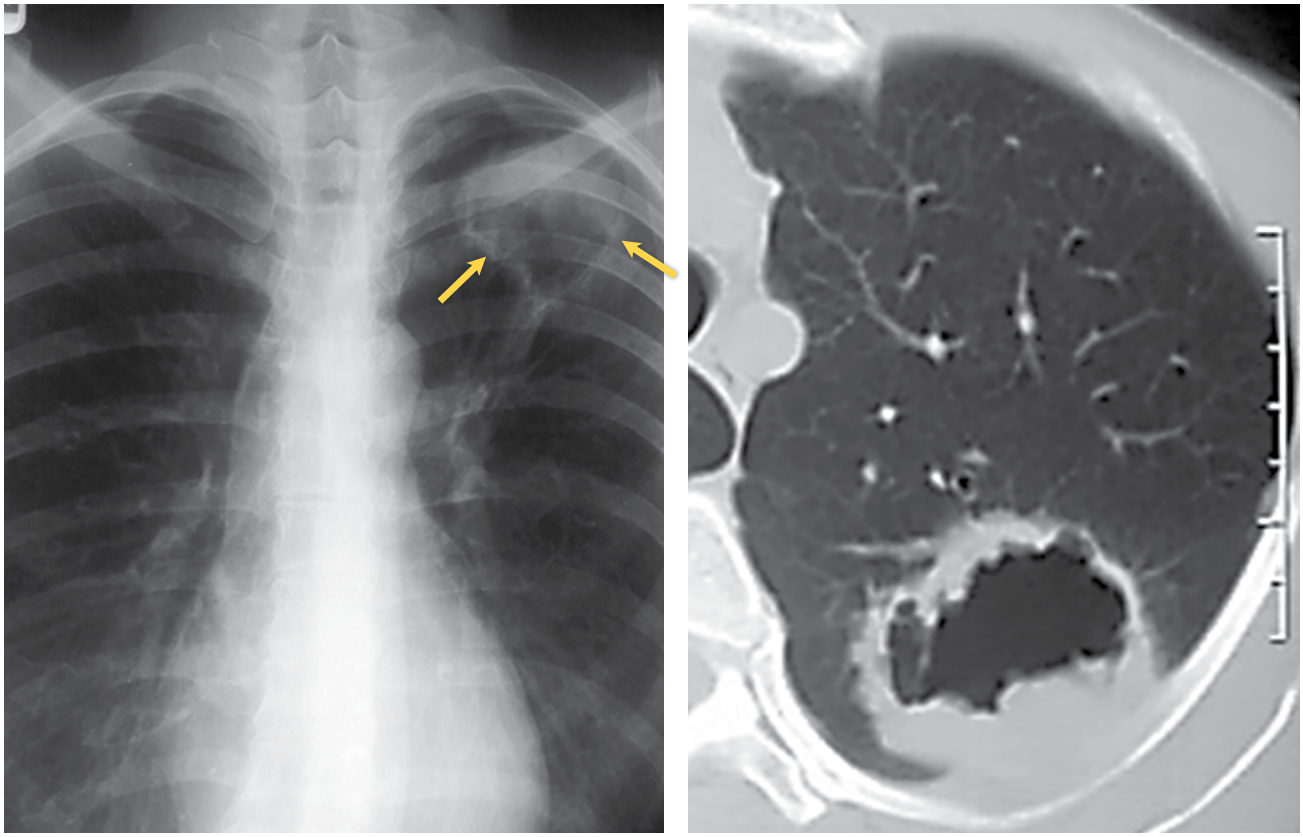


Figure 1.19 demonstrates localized lucent area in the left lung apex (arrows). A pulmonary cavity is a circumscribed lucent area within the lung containing air and/or fluid, surrounded by a wall of variable thickness resulting from necrosis of pulmonary parenchyma.

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

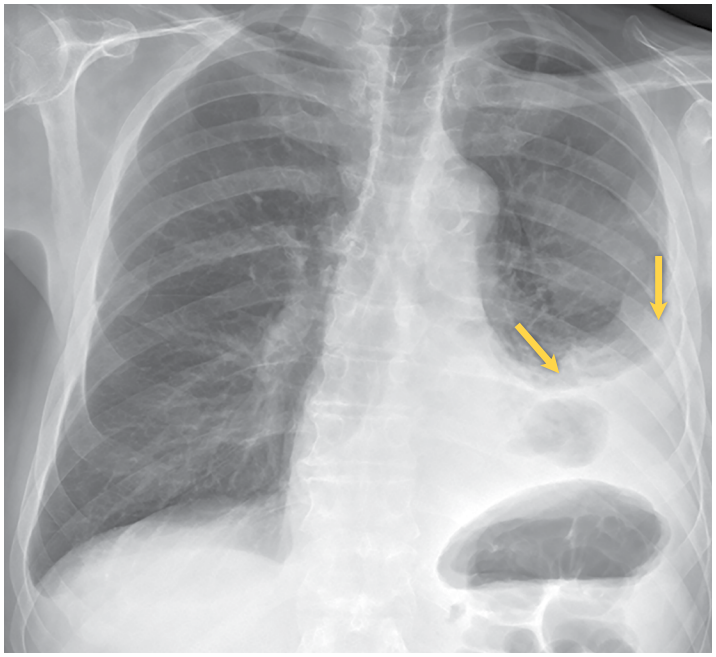
Pleural processes may calcify, particularly in prior tuberculous empyemas, prior hemothoraces, and asbestos-related pleural disease.

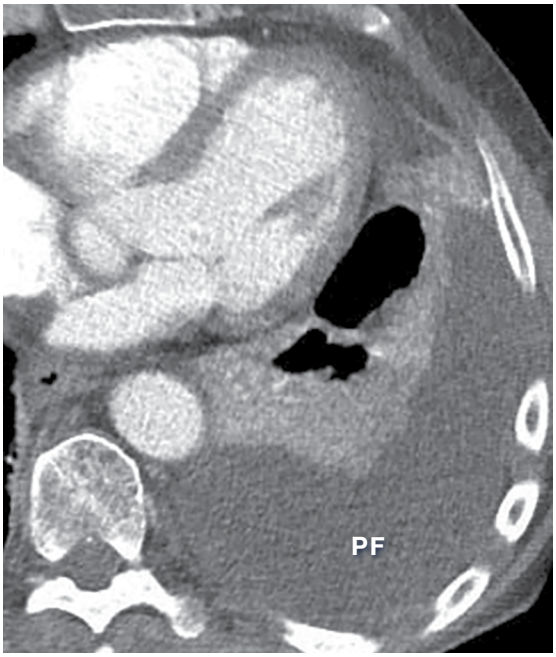
Pleural abnormalities

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

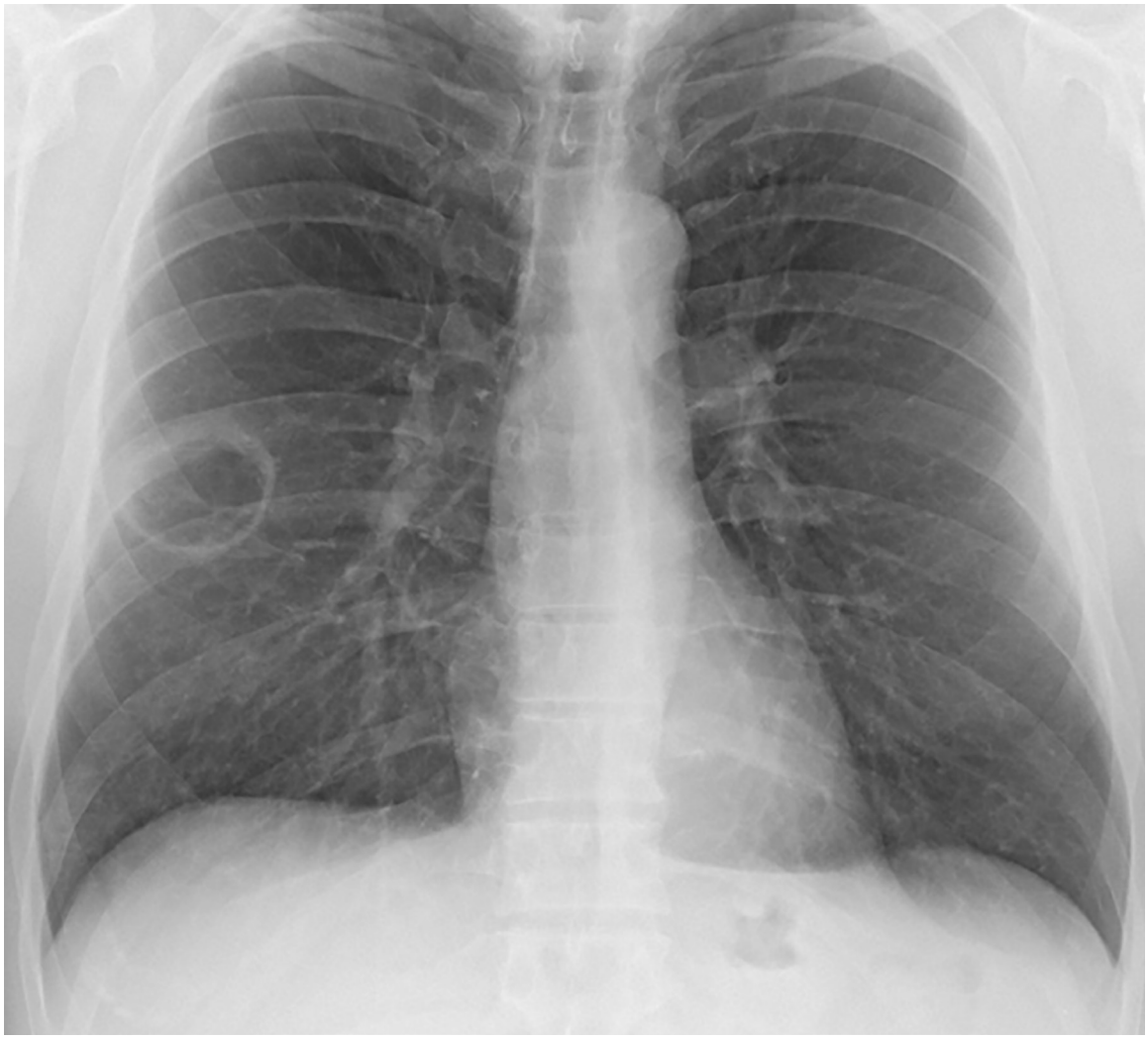
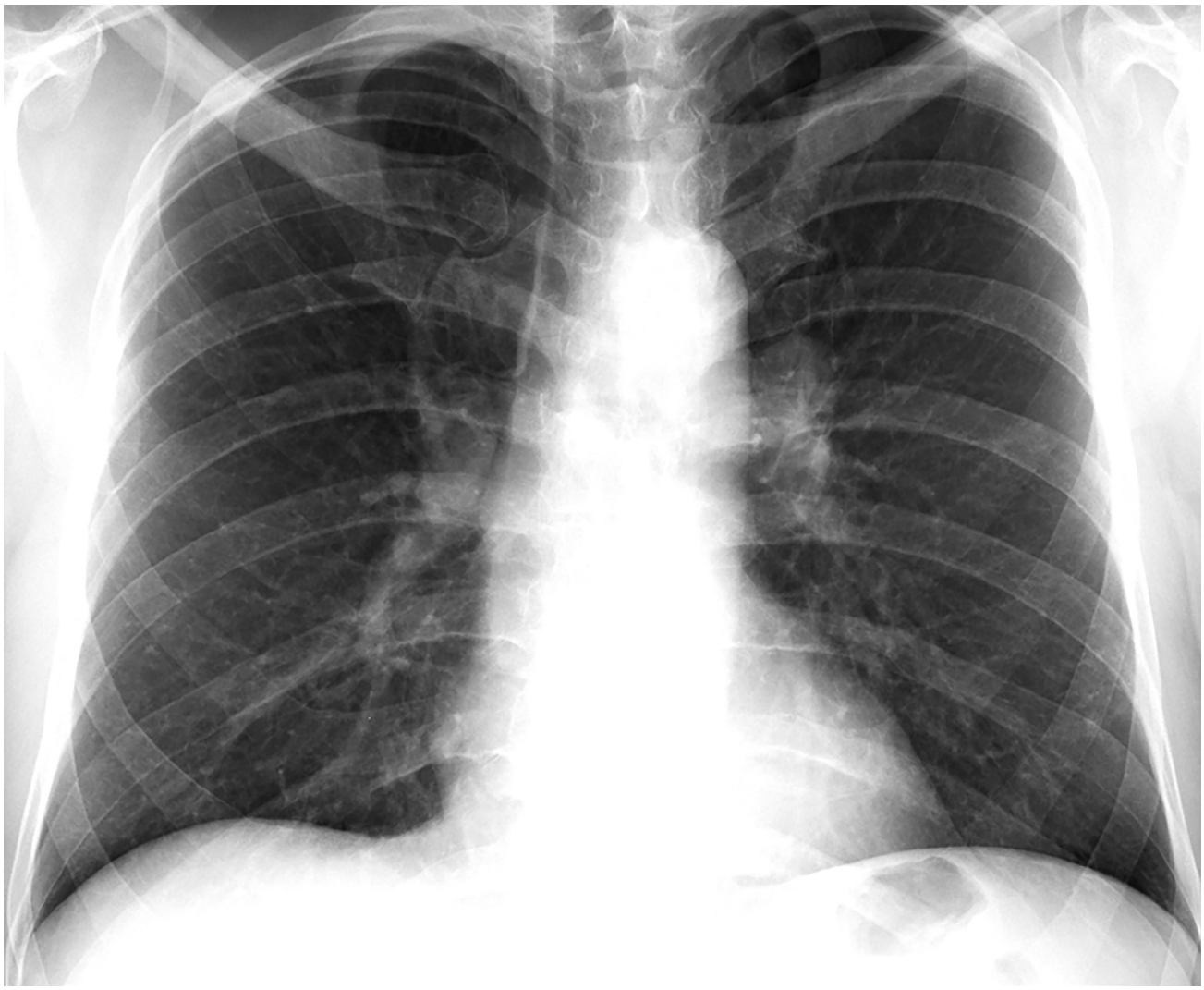


Figure 1.22



Figures 1.23A and 1.23B

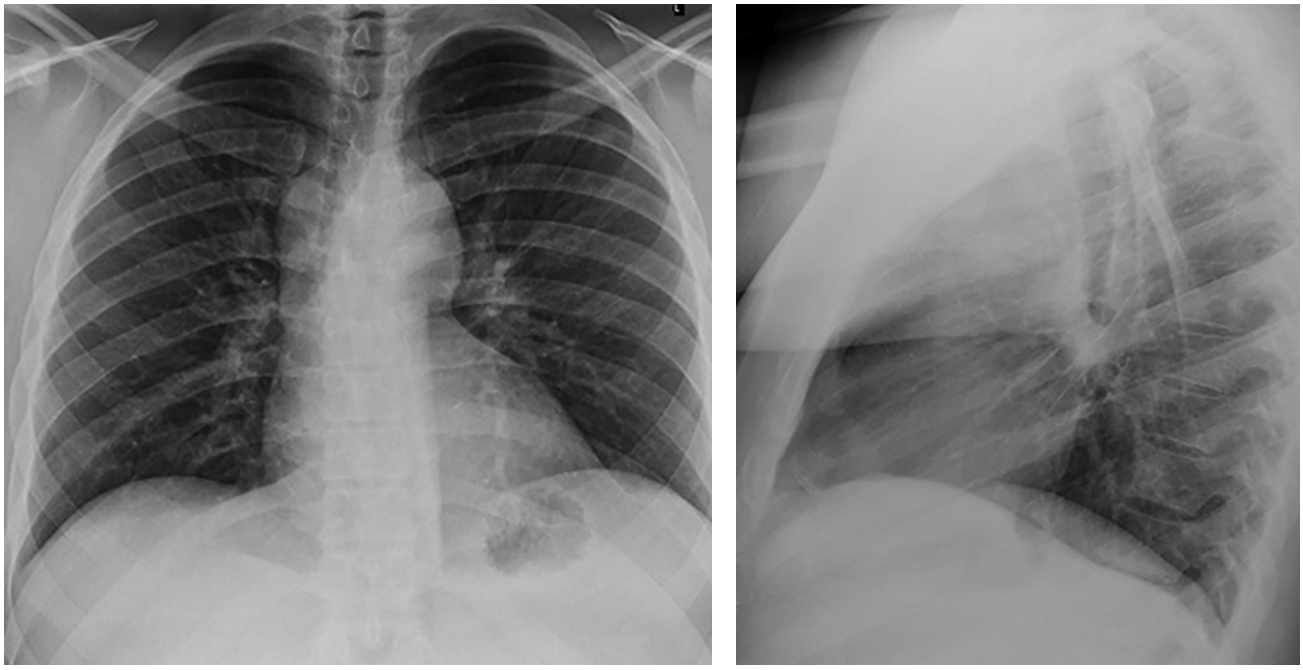
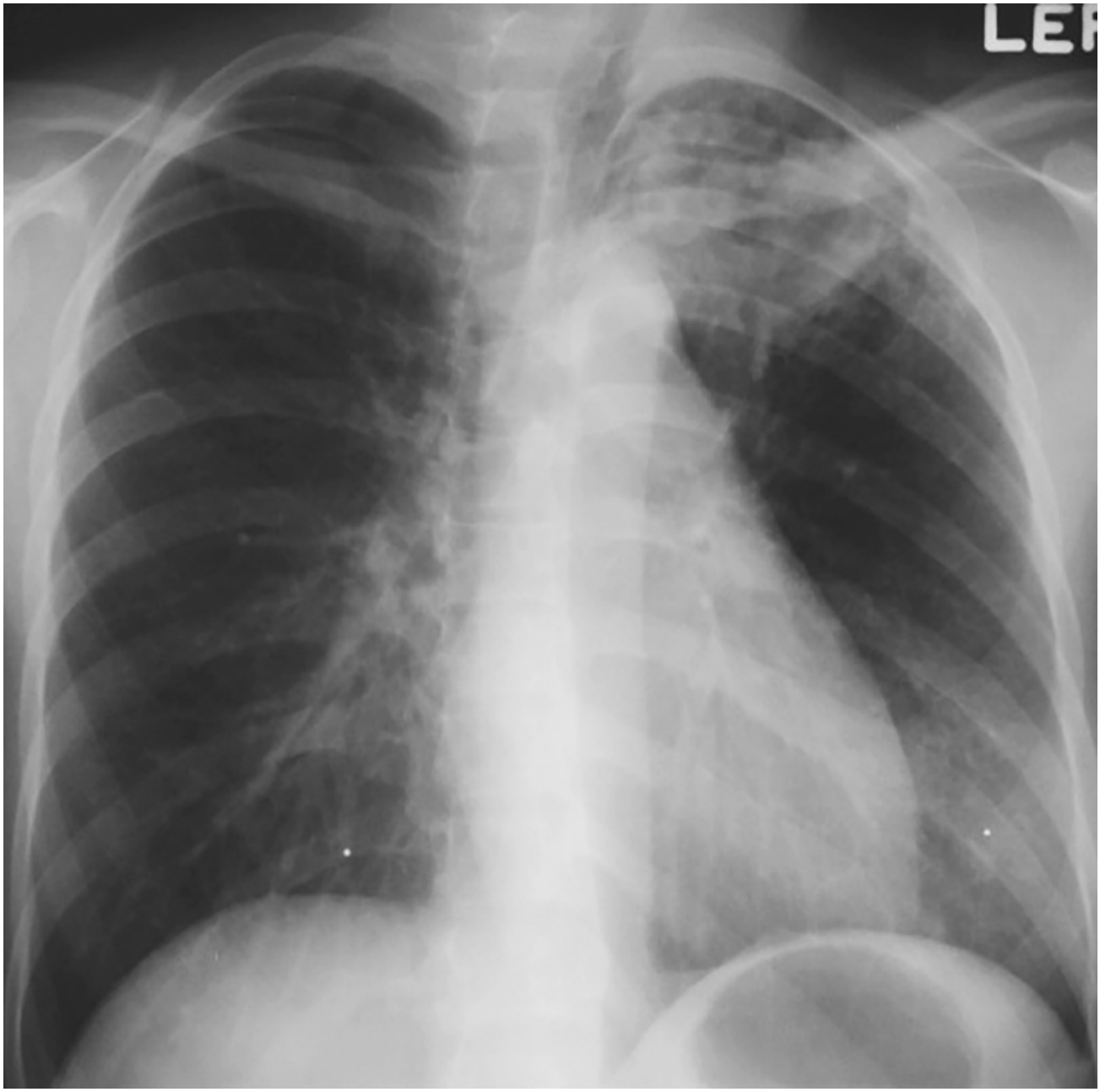


Figure 1.24



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**

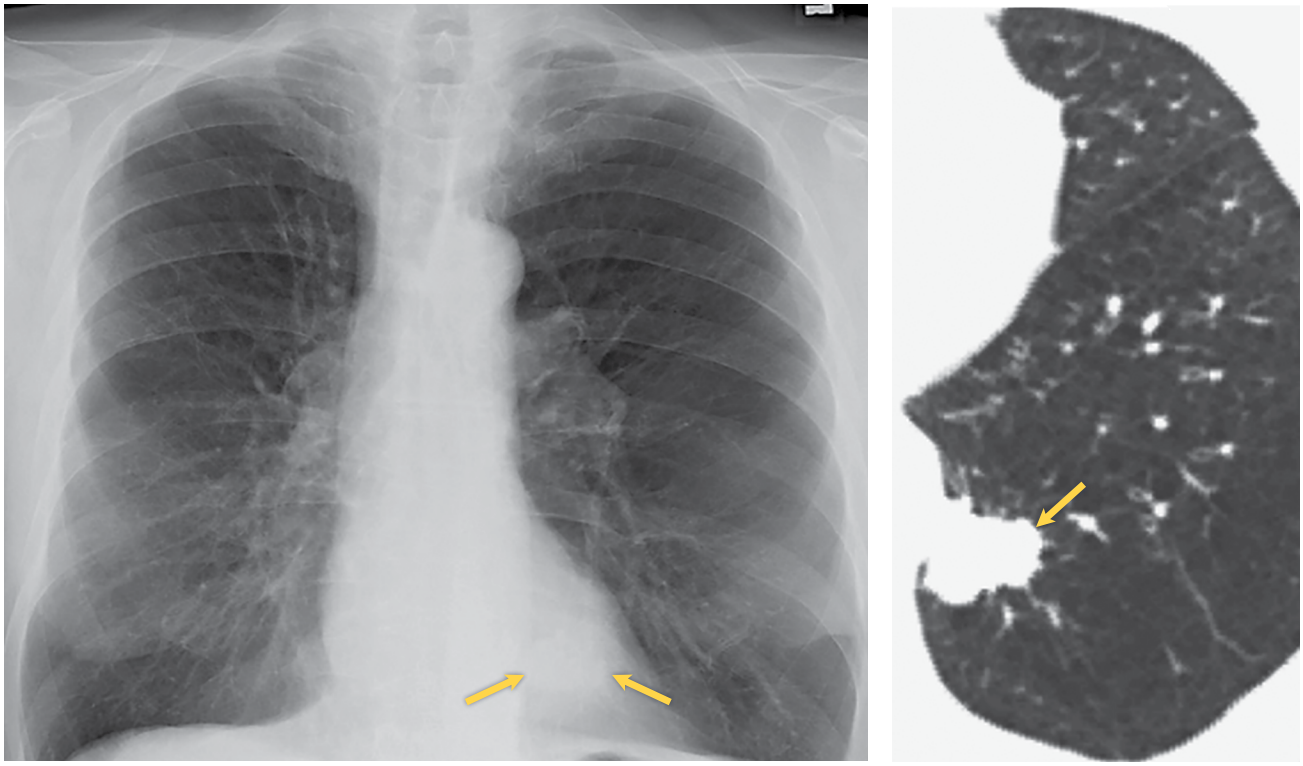
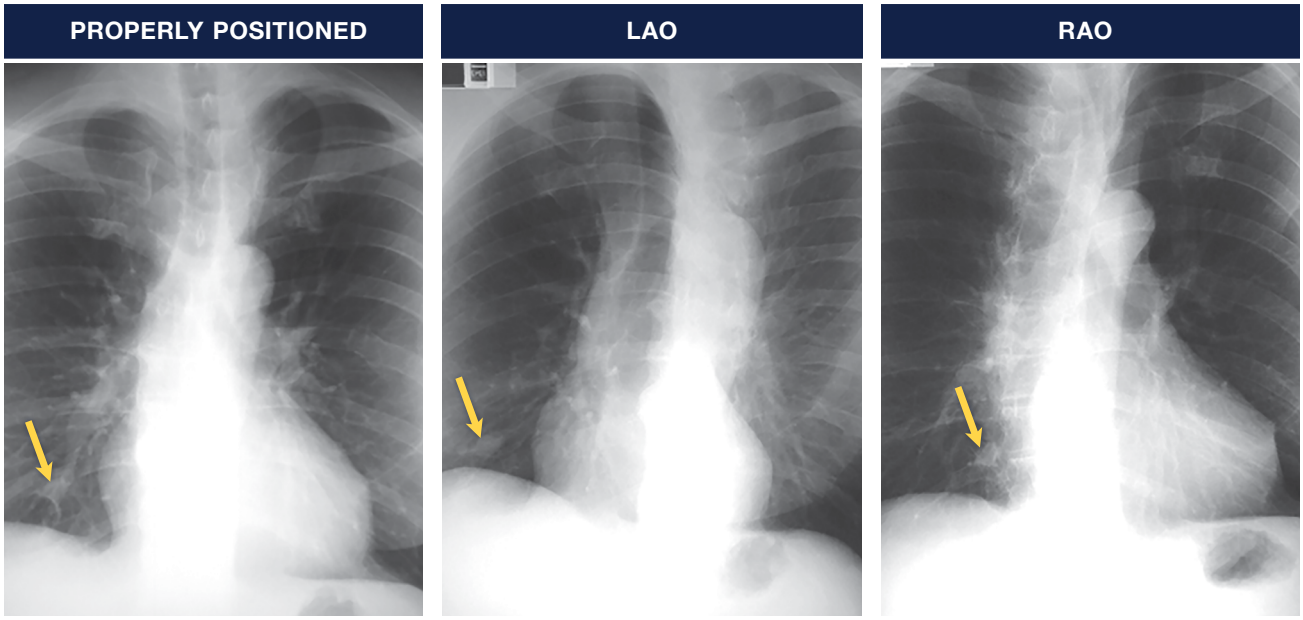


Figure 1.25 demonstrates an unusual contour seen "through" the left heart, representing lung carcinoma (arrows).

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

- Bankier AA, MacMahon H, Colby T, et al. Fleischner Society: glossary of terms for thoracic imaging. *Radiology*. 2024;310(2):e232558. doi:10.1148/radiol.232558. https://pubs.rsna.org/doi/full/10.1148/radiol.232558
- Jiao A, Nadim B, Hammer M, et al. 3D visual guide to lines and stripes in chest radiography. *RadioGraphics*. 2023;43(9):230017. doi:10.1148/rg.230017. https://pubs.rsna.org/doi/full/10.1148/rg.230017

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2

Pulmonary Tuberculosis

Introduction

Chapter 1 presented the basic principles of chest radiography, how to distinguish the images of the normal thoracic anatomy from abnormal findings, the common radiographic patterns of thoracic disease, and standard terminology used to describe abnormal findings.

Chapter 2 reviews the radiographic manifestations of pulmonary tuberculosis (TB) and how to apply the terminology covered in Chapter 1 to describe the radiographic findings. By the end of this chapter, readers will be familiar with the various radiographic manifestations of TB.

Because TB has a two-phase pathogenetic sequence by which the disease develops, and because each phase in the sequence is associated with different radiographic features, this chapter begins with an overview of the pathogenesis of TB.

Overview of the pathogenesis of TB

When tubercle bacilli (*Mycobacterium tuberculosis*) are inhaled into the lungs they are deposited in the airways and alveoli in more ventilated areas of the lung – typically in the middle- to lower-lung zones. In previously uninfected persons the bacilli cause an inflammatory reaction which may or may not be seen radiographically. If there is a radiographically visible abnormality, it is referred to as a primary or Ghon focus. This initial infection generally does not produce symptoms.

During this early stage of infection, organisms can spread via lymphatics to the draining lymph nodes in the chest and result in enlargement of hilar and mediastinal lymph nodes. Bacilli can also enter the bloodstream where they spread hematogenously throughout the body. Disease presenting at this stage is referred to as primary TB and is associated with particular radiographic findings.

After several weeks, the host develops a cell-mediated immune response as indicated by a positive tuberculin skin test or interferon gamma release assay. It is estimated that approximately 4.0% of people infected with TB will develop TB disease by the end of 1 year following infection. A cumulative total of approximately 8.0% will have developed TB by the end of the 25th year after infection. Healed lesions may contain viable bacilli that can progress to active TB, although the risk decreases as time after infection increases. Such progression is termed reactivation or post-primary TB. Reactivation disease is also associated with characteristic radiographic findings with typical abnormalities occurring in the upper lobes. This entire pathogenetic sequence is a continuum and many of the radiographic manifestations of primary and reactivation TB overlap. Moreover, in immunodeficiency states such as HIV/AIDS, or treatment with immunosuppressing drugs, atypical radiographic abnormalities are common.

This chapter reviews the radiographic manifestations of TB in line with this pathogenetic sequence. It is important to note that the distinction between primary and reactivation TB has little clinical relevance. Active TB should be treated regardless of whether it is thought to be primary or reactivation. As this chapter will describe, abnormalities thought to be “characteristic” are not specific for TB disease. However, such findings should initiate a clinical and microbiological evaluation that includes tests for TB.

Primary TB

After inhalation of the tubercle bacillus, an early inflammatory response develops at the site of infection that is referred to as the primary focus or Ghon focus. The Ghon focus may be visualized on the chest radiograph as an airspace opacity and is commonly associated with a radiographically evident enlargement of the ipsilateral hilar or paratracheal lymph nodes. The combination of the Ghon focus and ipsilateral lymphadenopathy is called the primary complex or Ranke complex.

In order to review the radiographic manifestations of primary TB, the findings are divided into the following categories:

- Distribution of parenchymal disease
- Patterns of disease
- Tracheobronchial disease
- Hilar and mediastinal lymphadenopathy
- Pleural disease

Distribution of parenchymal disease

Although primary TB can affect any segment of the lung parenchyma, the lower lobes are characteristically involved more often in primary TB than in reactivation disease. However, this predilection varies with age. In children, the upper and lower lobes are involved with equal frequency, whereas in adults, lower-lobe involvement is slightly more common.

Figures 2.1, 2.2, and 2.3 show examples of the parenchymal distribution of primary TB in children and adults.

Primary TB in children and adults

FIGURE 2.1. **Primary TB in a child: Example 1**

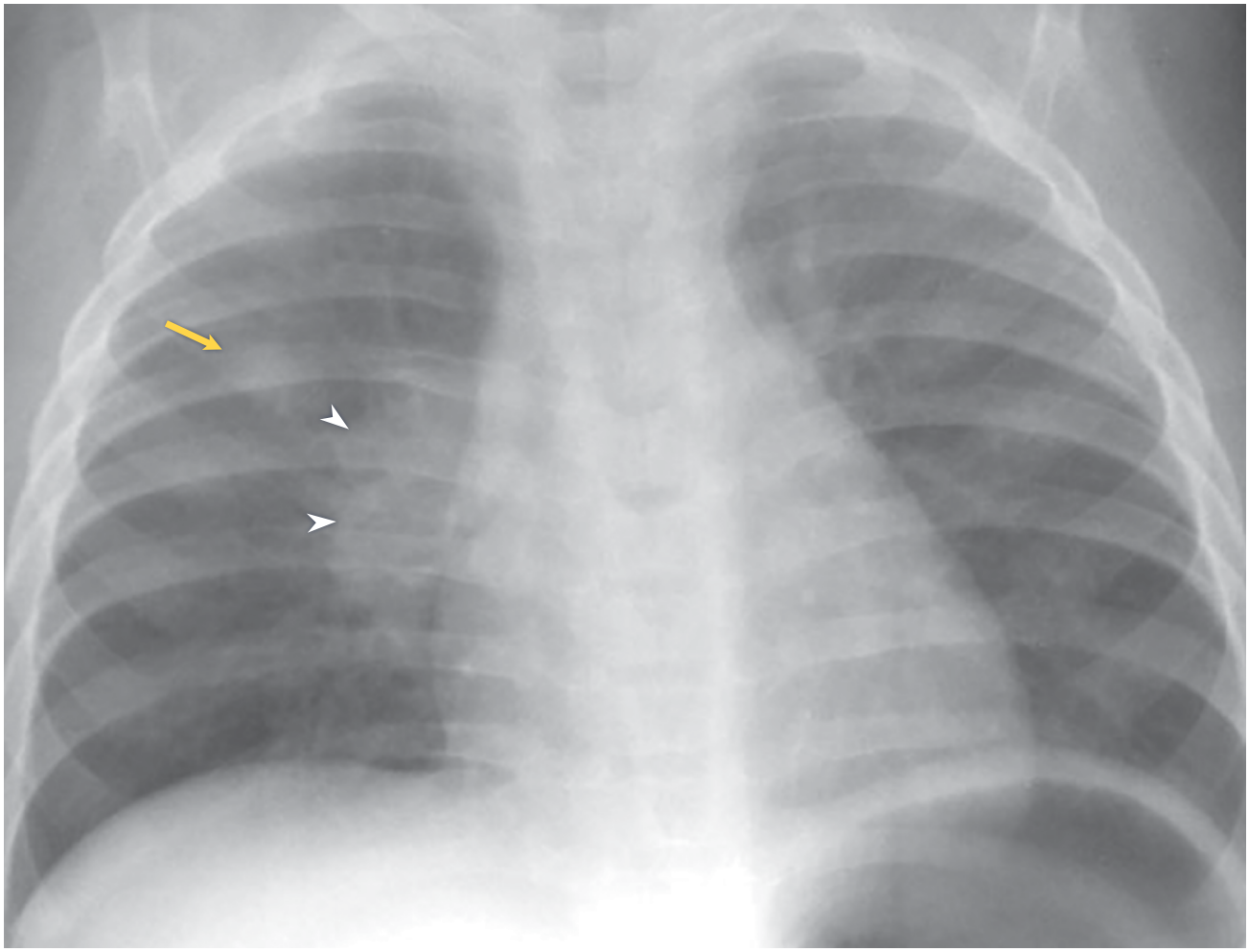


Figure 2.1 demonstrates a right upper-lobe nodule (arrow) and right hilar lymphadenopathy (arrowheads). This is an example of the primary complex (Ghon focus and ipsilateral hilar lymphadenopathy constituting a Ranke complex) that is typical of primary TB in a child.

FIGURE 2.2. **Primary TB in a child: Example 2**

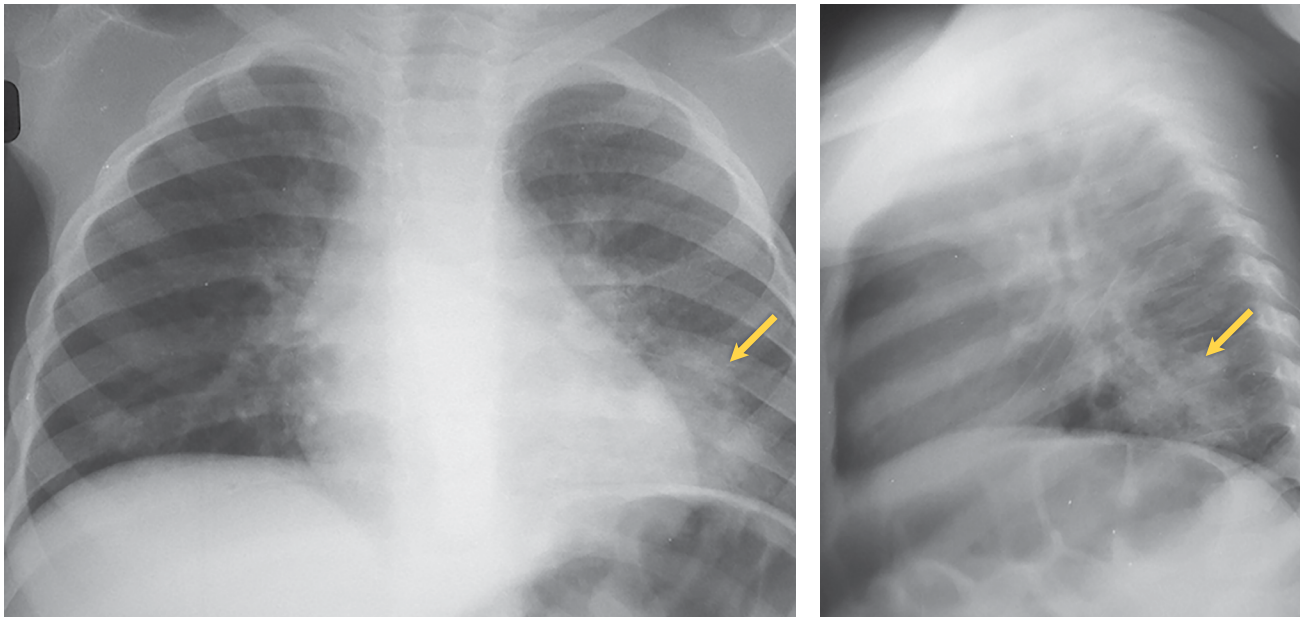


Figure 2.2 demonstrates left lower consolidation (arrow) in a 4-year-old child with TB.

- The upper and lower lobes are affected equally in children.
- Radiographically, the primary complex consists of a parenchymal opacity and enlargement of ipsilateral thoracic lymph nodes.
- Involvement of the anterior segment of the upper lobes can occur in primary disease but is uncommon in reactivation disease in adults.

FIGURE 2.3. **Primary TB in an adult**

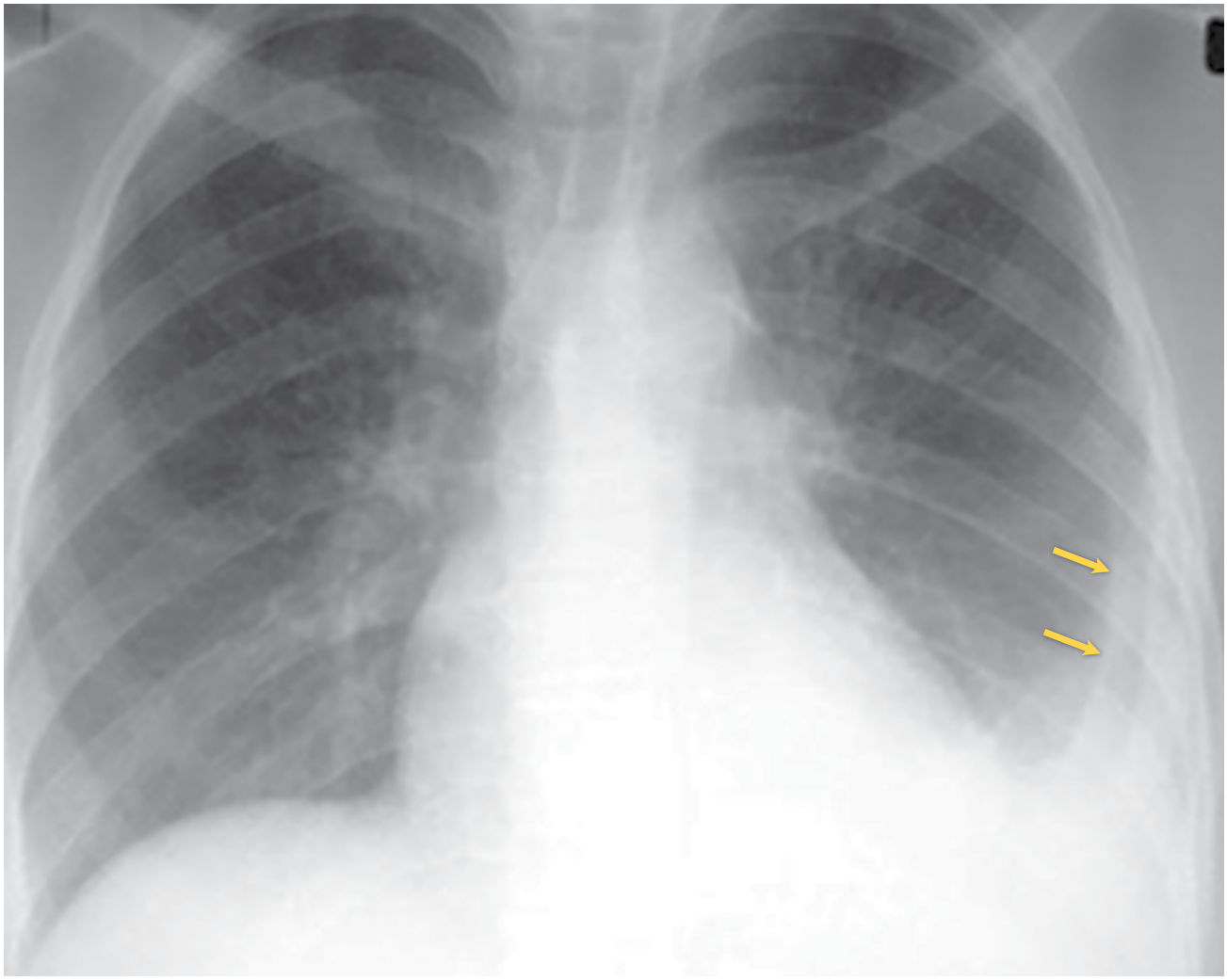


Figure 2.3 demonstrates left lower-lobe airspace opacity and a homogeneous opacity extending along the left lateral chest wall (arrows). These findings are consistent with consolidation and a pleural effusion, which are characteristic of primary TB in an adult. Note that the left hemidiaphragm is not visible (silhouette sign).

- The lower lobes are affected more often than the upper lobes in adults with primary disease.
- Anterior segment involvement can occur, which is unusual in reactivation disease.
- Cavitation, though unusual, can occur in adults with progressive primary TB.

Patterns of disease

In primary TB, parenchymal opacities may be airspace or interstitial in nature. Airspace consolidation is the most common radiographic pattern in primary disease. The most common interstitial pattern of primary disease is that of miliary (or disseminated) TB. Other primary manifestations of TB include tracheobronchial disease, hilar and mediastinal lymphadenopathy, and pleural disease.

Airspace consolidation

FIGURE 2.4. **Primary TB in a child with airspace consolidation**

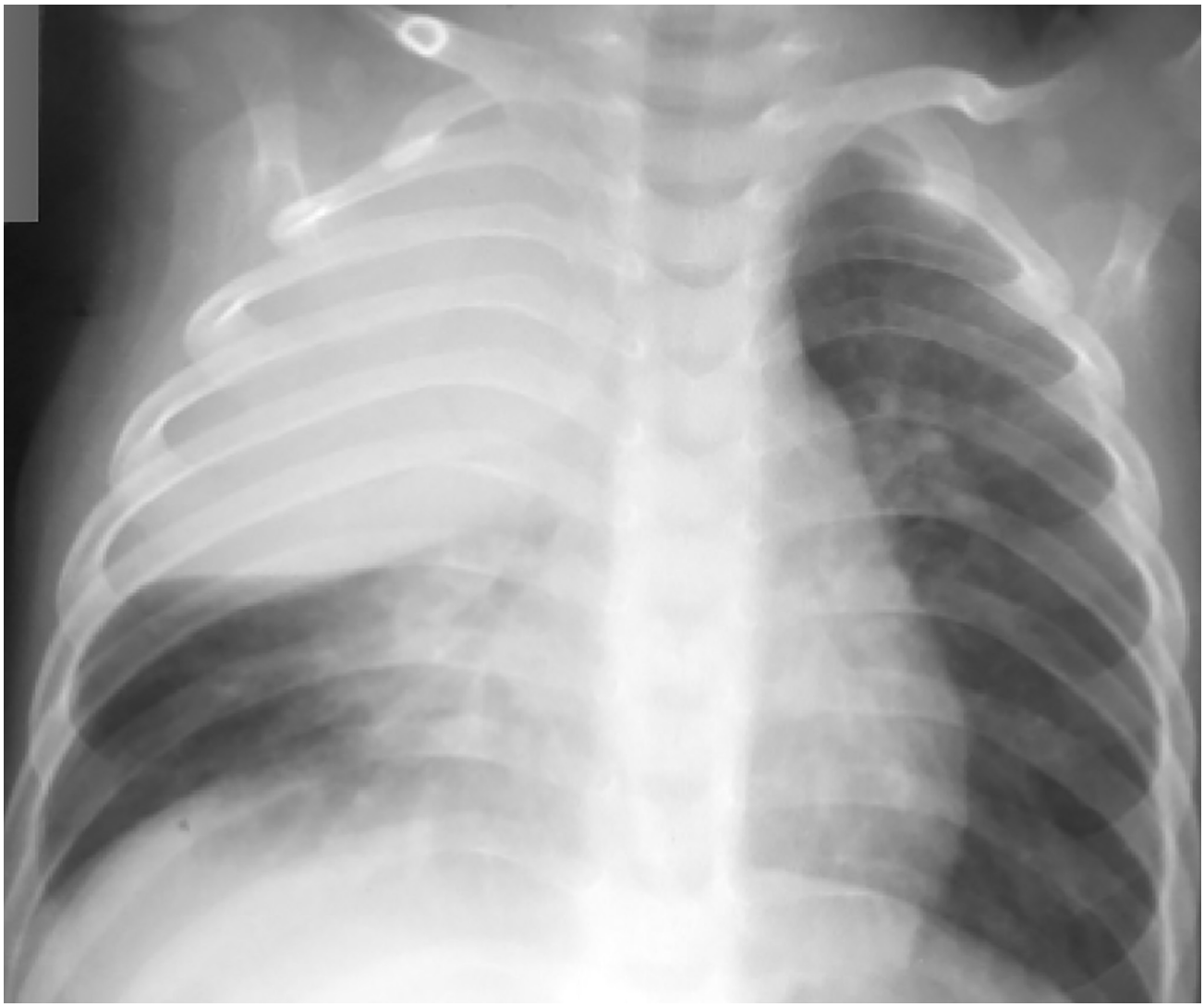


Figure 2.4 demonstrates a right upper-lobe consolidation in a young child. Note the absence of aerated lung in the right upper lobe.

FIGURE 2.5. **TB in a young adult with airspace consolidation**

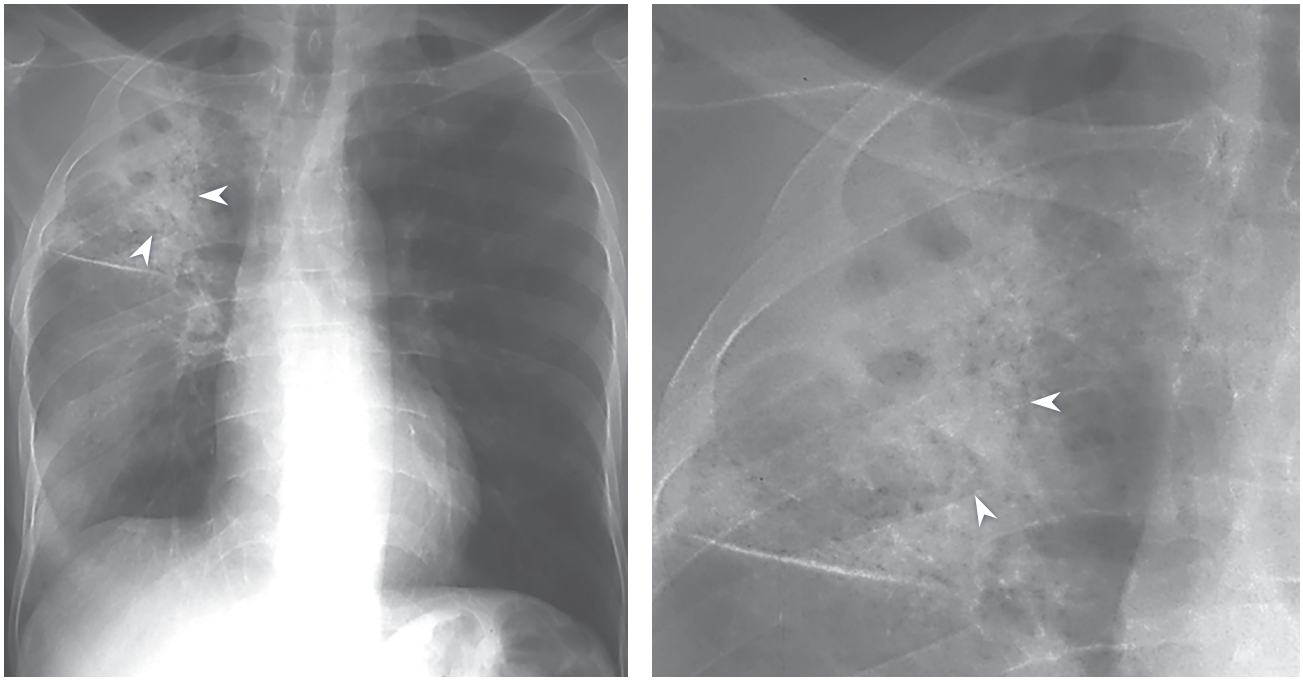


Figure 2.5 demonstrates right upper-lobe airspace consolidation with cavitation and air bronchograms (arrowheads), seen more clearly on the detail image of the right upper lobe. The patient was a college student with TB.

- Airspace consolidation is the typical appearance of primary disease in an adult.
- The consolidation is usually homogeneous in density.
- Air bronchograms may be visualized in the area of consolidation.
- Cavitation is unusual.

Airspace consolidation with cavitation

FIGURE 2.6. **Primary TB with cavitation**

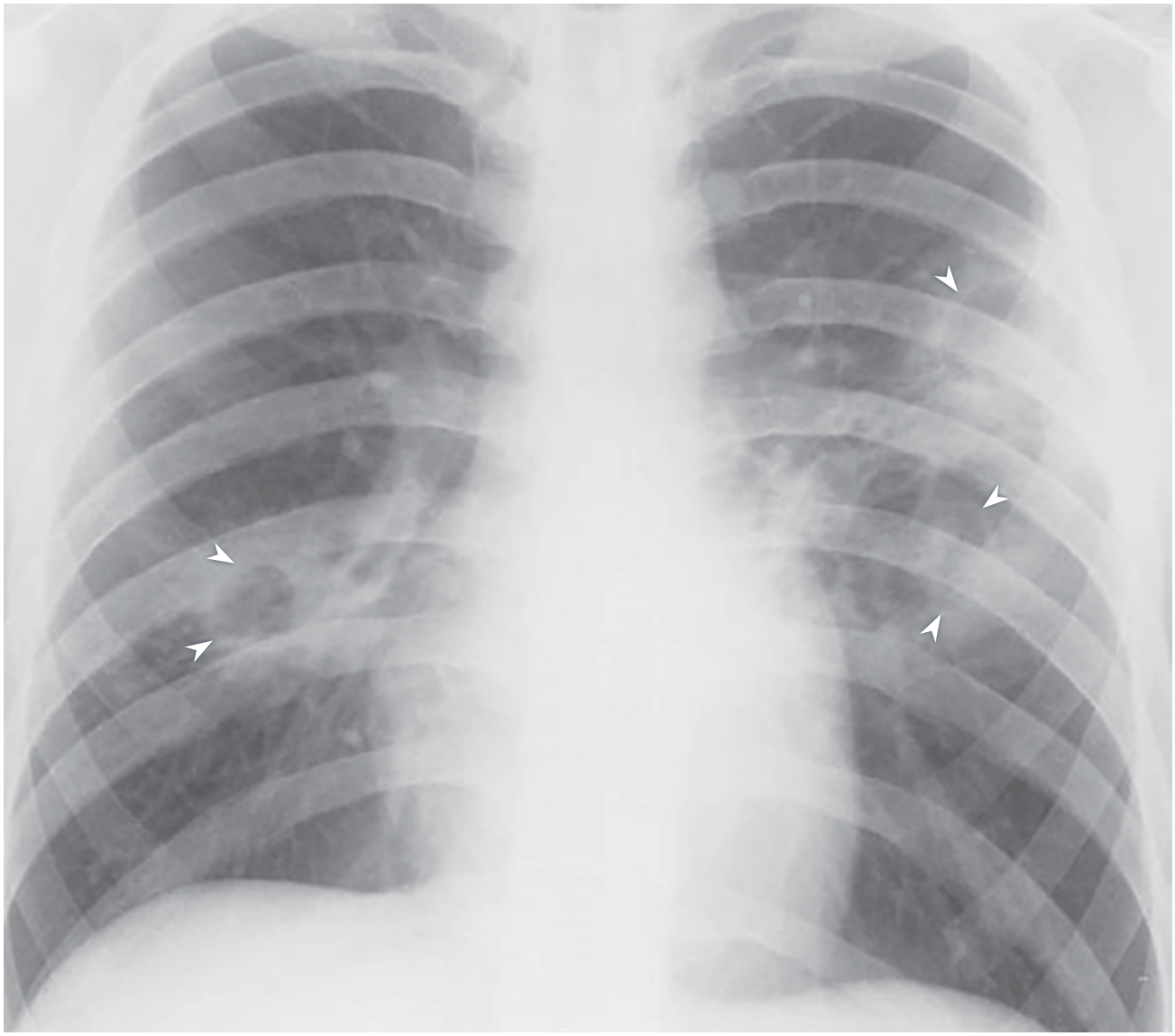


Figure 2.6 demonstrates bilateral opacities with foci of cavitation (arrowheads). The patient was a 35-year-old man who developed TB soon after exposure to another infected individual.

- Cavitation is relatively uncommon in primary disease, particularly in young children.
- Cavitation can occur with progressive primary disease.

Interstitial pattern (miliary)

FIGURE 2.7. **Miliary pattern**

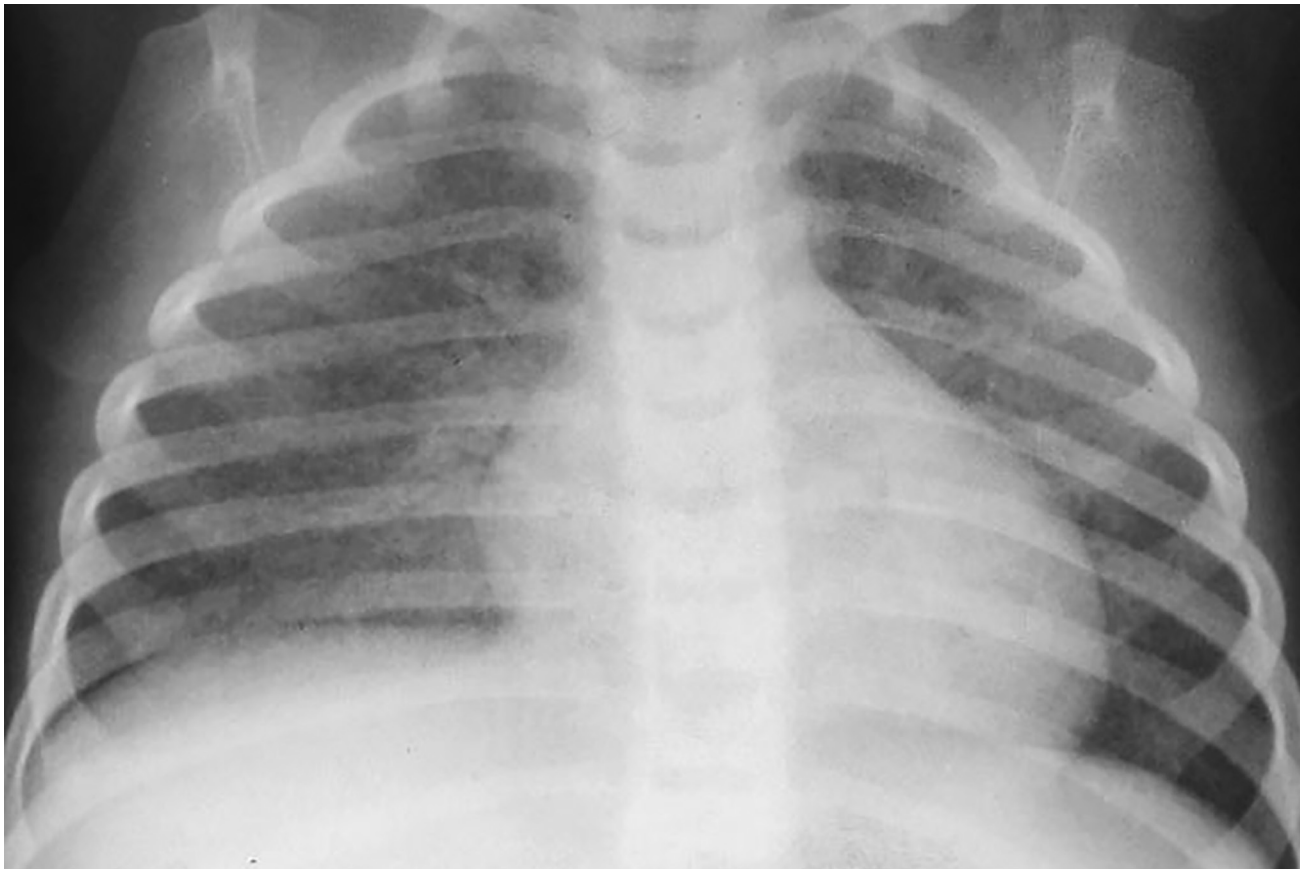


Figure 2.7 demonstrates bilateral diffuse small nodules (2-3 mm in diameter) consistent with a miliary pattern. The patient was a 5-year-old girl with disseminated TB.

- Miliary disease can occur as a consequence of primary or reactivation disease.
- A miliary pattern results from hematogenous dissemination of tubercle bacilli that leads to many nodules of similar size, initially present in the interstitium and ultimately involving the air spaces.
- Most of the nodules in miliary TB are 2 mm in diameter (the size of a millet seed).
- Because miliary nodules result from hematogenous dissemination, more nodules are usually present in the lower-lung zones because of greater blood flow to the bases compared with the apices of the lungs.

Tracheobronchial disease

Lung volume loss (atelectasis) can be caused by fibrotic scarring, endobronchial obstruction, or extrinsic compression of airways by enlarged lymph nodes. Extrinsic compression of airways is particularly common in children because they have compressible airways. In primary TB, endobronchial lesions and extrinsic compression by enlarged lymph nodes are the most common reasons for volume loss.

FIGURE 2.8. **Airspace consolidation with atelectasis**

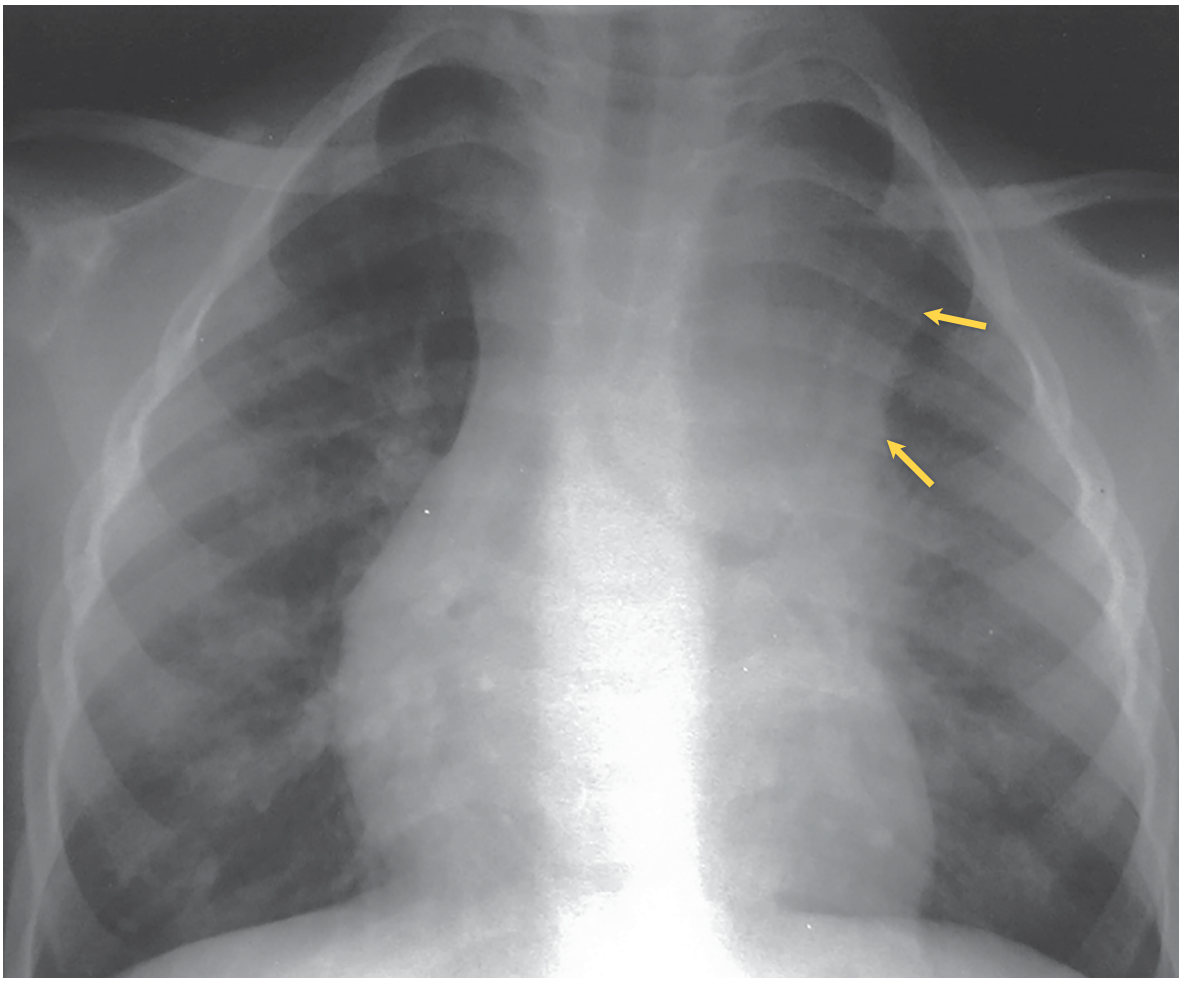


Figure 2.8 demonstrates left upper-lobe airspace opacification with atelectasis. The inferior margin of the airspace consolidation is straight and well visualized (arrows) against the air-containing lower lobe. This represents the major fissure separating the upper and lower lobes.

- Atelectasis caused by TB may result from obstruction of an airway from endobronchial disease or from extrinsic compression due to enlarged lymph nodes.
- The anterior segment of the upper lobe or the medial segment of the middle lobe is most often involved.
- Although less common in adults, segmental collapse is most likely to affect the anterior segment of the upper lobes.

Hilar and mediastinal lymphadenopathy

Early in the pathogenesis of TB, tubercle bacilli spread via lymphatics to draining lymph nodes in the hilar areas and mediastinum. Enlargement of these lymph nodes can sometimes be visualized on the chest radiograph. Lymphadenopathy is particularly common in children with primary TB and adults who are HIV positive.

FIGURE 2.9. **Lymphadenopathy: Example 1**

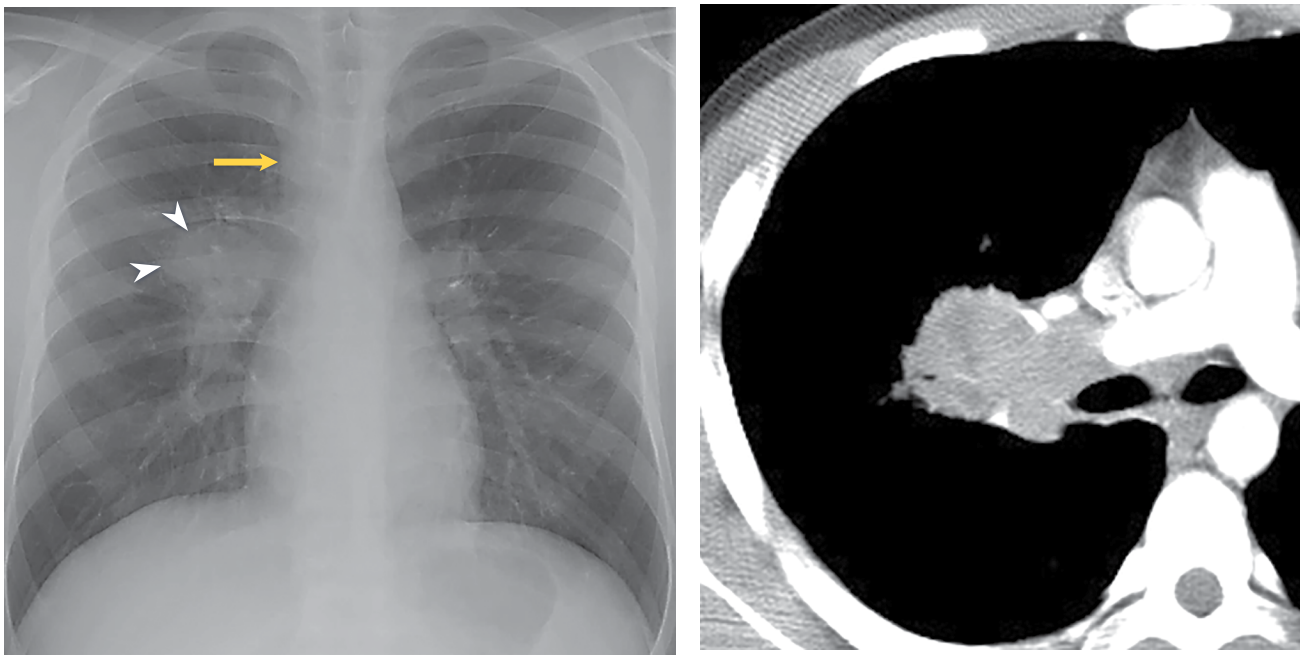


Figure 2.9. Radiograph of a 13-year-old boy (left) demonstrates right hilar (arrowheads) and paratracheal (arrow) lymphadenopathy. The bulky right hilar lymph node enlargement is well seen on CT (right).

- Lymphadenopathy is common among children and persons who are HIV positive.
- There is a predilection for the right side, especially in the paratracheal and hilar areas.
- The younger the child, the more often lymphadenopathy without associated parenchymal disease is seen.
- Enlarged lymph nodes may cause compression of airways leading to atelectasis.
- A lateral chest radiograph is often necessary to confirm the presence of hilar lymphadenopathy in young children. For this reason, two-view chest radiographs are recommended in the pediatric population.

FIGURE 2.10. **Lymphadenopathy: Example 2**

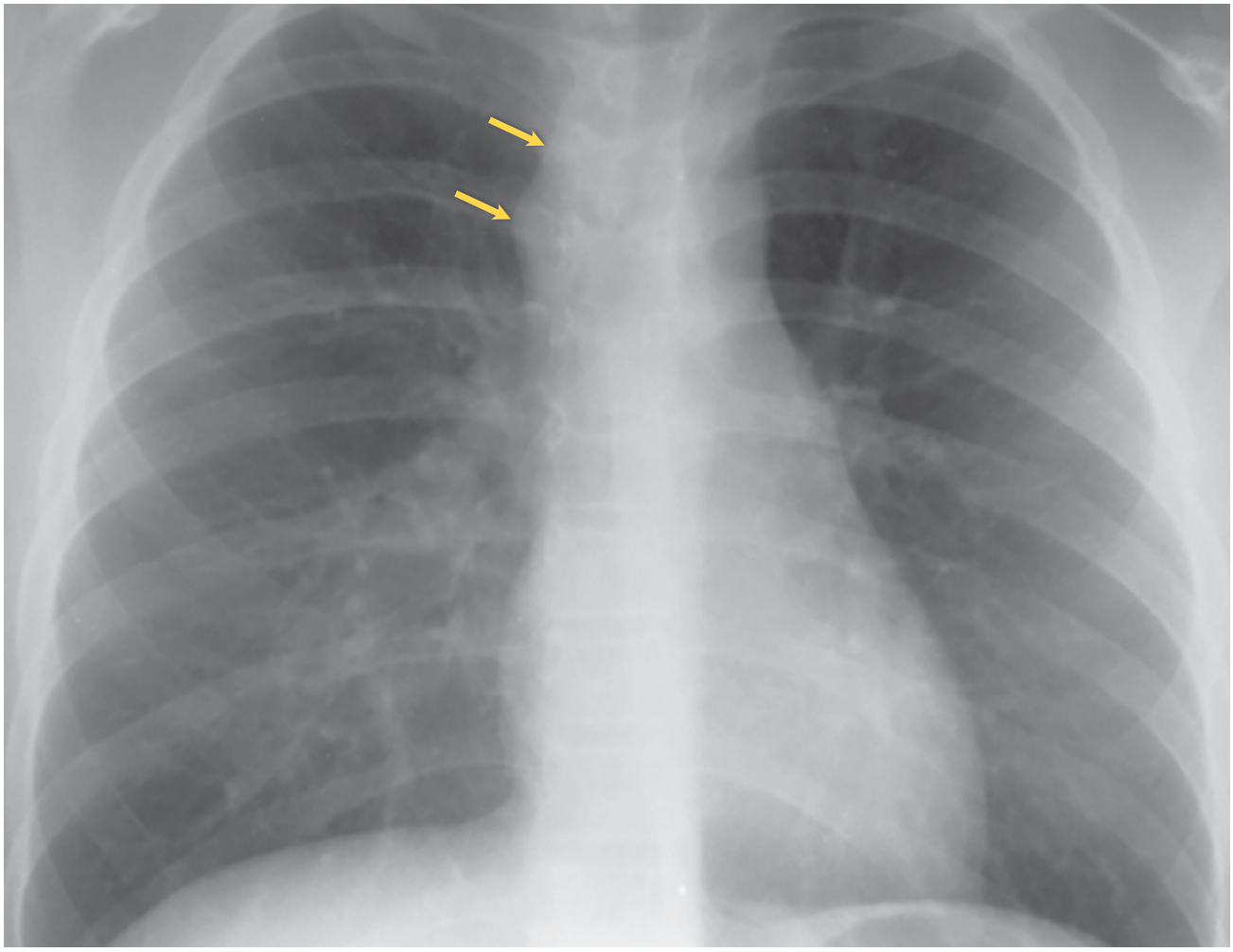


Figure 2.10. Chest radiograph of a 10-year-old child with TB shows thickening of the right paratracheal stripe (arrows) due to lymphadenopathy.

FIGURE 2.11. **Lymphadenopathy: Example 3**

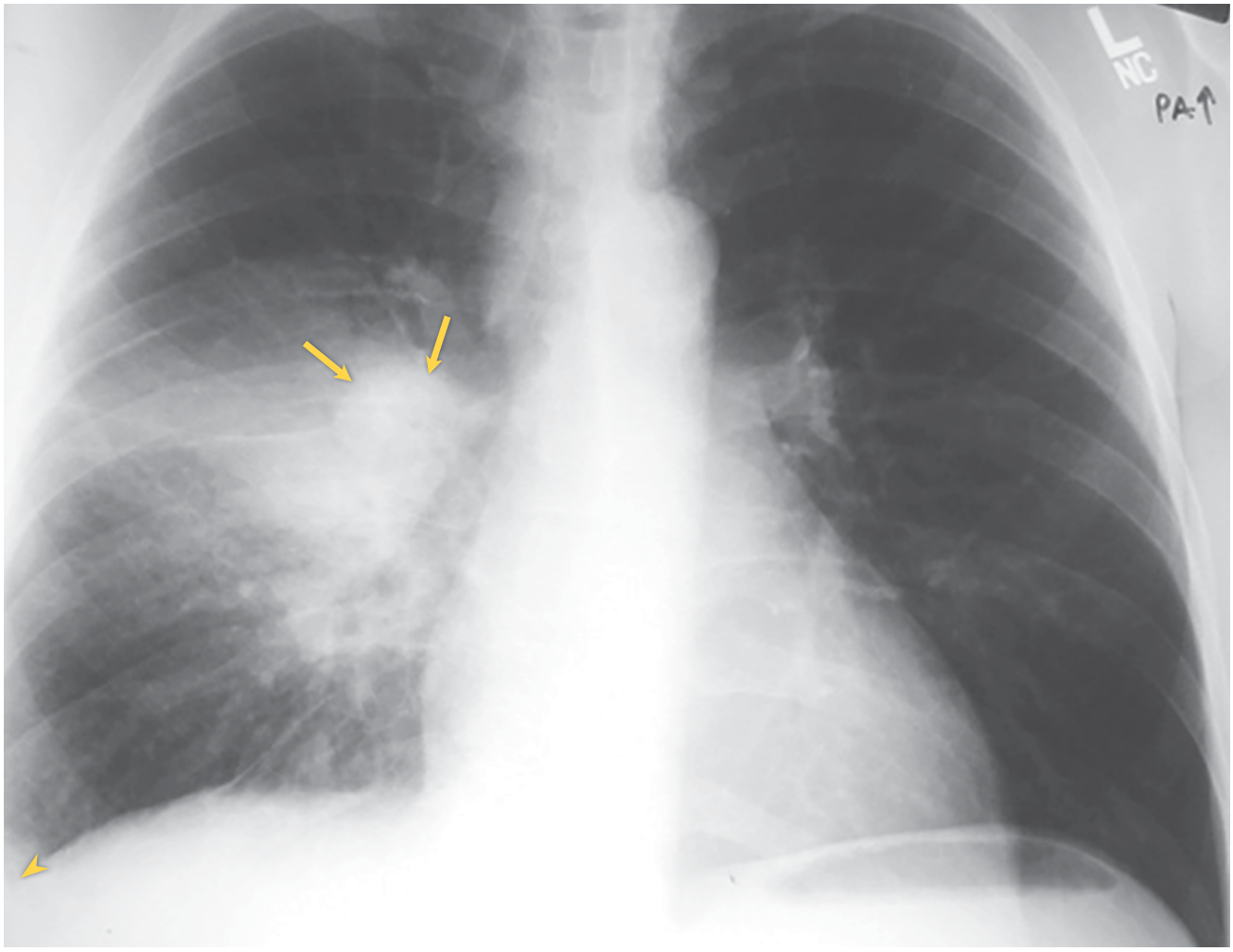


Figure 2.11. Frontal chest radiograph shows right hilar lymphadenopathy (arrows), right mid-lung airspace opacity, and blunting of the right costophrenic angle (arrowhead) consistent with a small pleural effusion. This HIV-negative patient had culture-confirmed primary TB.

Pleural disease

Pleural effusions that develop in the setting of primary disease are usually due to a delayed-type hypersensitivity reaction. These effusions can vary in size from small to large, sometimes occupying an entire hemithorax. In many cases, no parenchymal abnormality can be visualized on plain radiographs, although CT scans and autopsy studies have documented underlying parenchymal disease in most cases. Recognizing a pleural effusion is important so that pleural fluid can be aspirated for diagnostic studies.

FIGURE 2.12. **Pleural effusion**

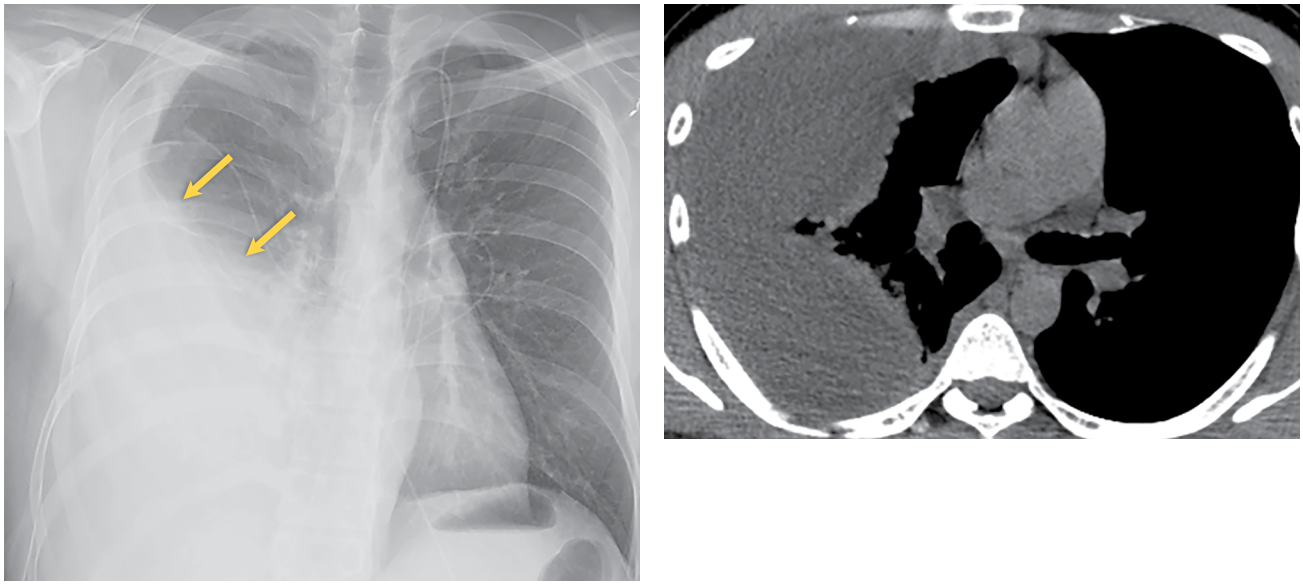


Figure 2.12 demonstrates a large right-sided pleural effusion (arrows), confirmed on CT. Note that the diaphragmatic border cannot be seen because the pleural liquid induces atelectasis in the right middle and right lower lobes, obscuring the right hemidiaphragm and right heart border (silhouette sign).

- Pleural effusions are uncommon in children (10%).
- Pleural effusions are very common in adults with primary TB (40%).
- Pleural effusions may represent the only manifestation of primary TB, particularly in adolescents and young adults.
- Pleural effusions are usually unilateral and may vary in size.

Reactivation (post-primary) TB

Reactivation* TB (also referred to as post-primary TB) is the most common form of disease in adults and occurs in individuals who have developed cell-mediated immunity to *M. tuberculosis*. In most individuals with latent TB infection, the immune system is able to control the infection. In some individuals, however, the organism can reactivate and proliferate, leading to reactivation TB.

Although the radiographic manifestations of reactivation TB overlap those of primary disease, there are several distinguishing features:

- Predilection for upper lobes
- Lack of lymphadenopathy
- Propensity for cavitation

Cavitation is an important characteristic of reactivation TB. In TB, cavities occur as the result of necrosis of lung tissue (caseous necrosis) and contain large numbers of mycobacteria. Hilar and mediastinal lymphadenopathy will not be discussed here because they are unusual in the setting of reactivation TB. As with the previous discussion of primary disease, this section will examine the radiographic manifestations of reactivation TB using the following categories:

- Distribution of parenchymal disease
- Patterns of disease

* The term “reactivated” is considered by some a misnomer as it implies prior “activity” but in most circumstances represents a progression from latent infection onward to active TB disease.

Distribution of parenchymal disease

As with primary TB, any lung segment can be involved with reactivation TB. However, reactivation TB typically involves apical and posterior segments of the upper lobes. If the lower lobe is involved, the superior segment is the most common site of disease. Isolated anterior segment involvement, without other segmental disease, is very unusual in reactivation TB. The predilection for the upper lobes is thought to be due to decreased lymph flow in the upper regions of the lung. An alternative explanation is the presence of higher oxygen tension in that region.

FIGURE 2.13A. **Reactivation (post-primary) TB**

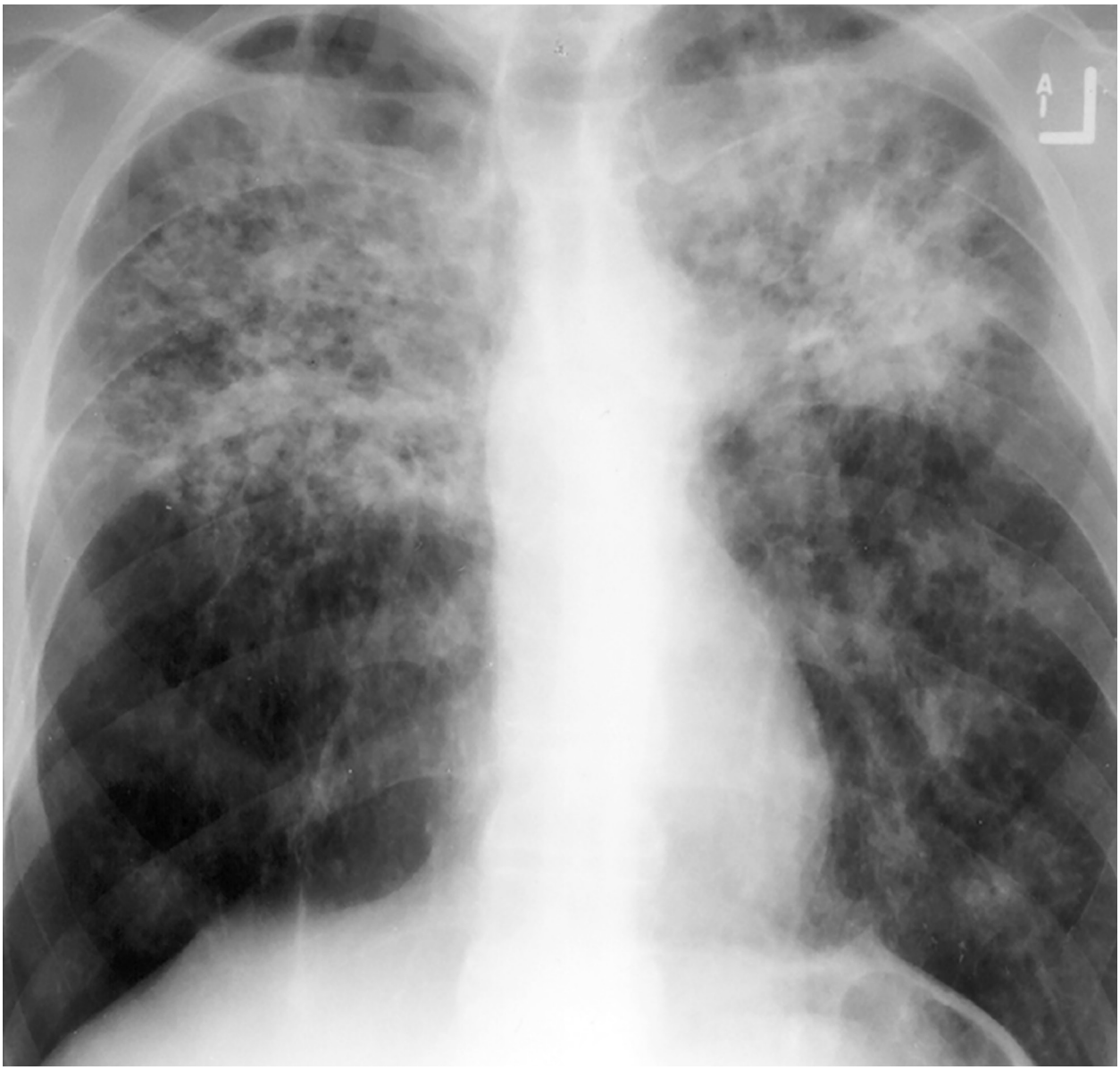


Figure 2.13A demonstrates consolidation in the apical and posterior segments of the right upper lobe and the apicoposterior segment of the left upper lobe, abnormalities characteristic of reactivation TB. Note the upward retraction of the hilar structures, an indication of volume loss.

FIGURE 2.13B. **Reactivation (post-primary) TB, lateral view**

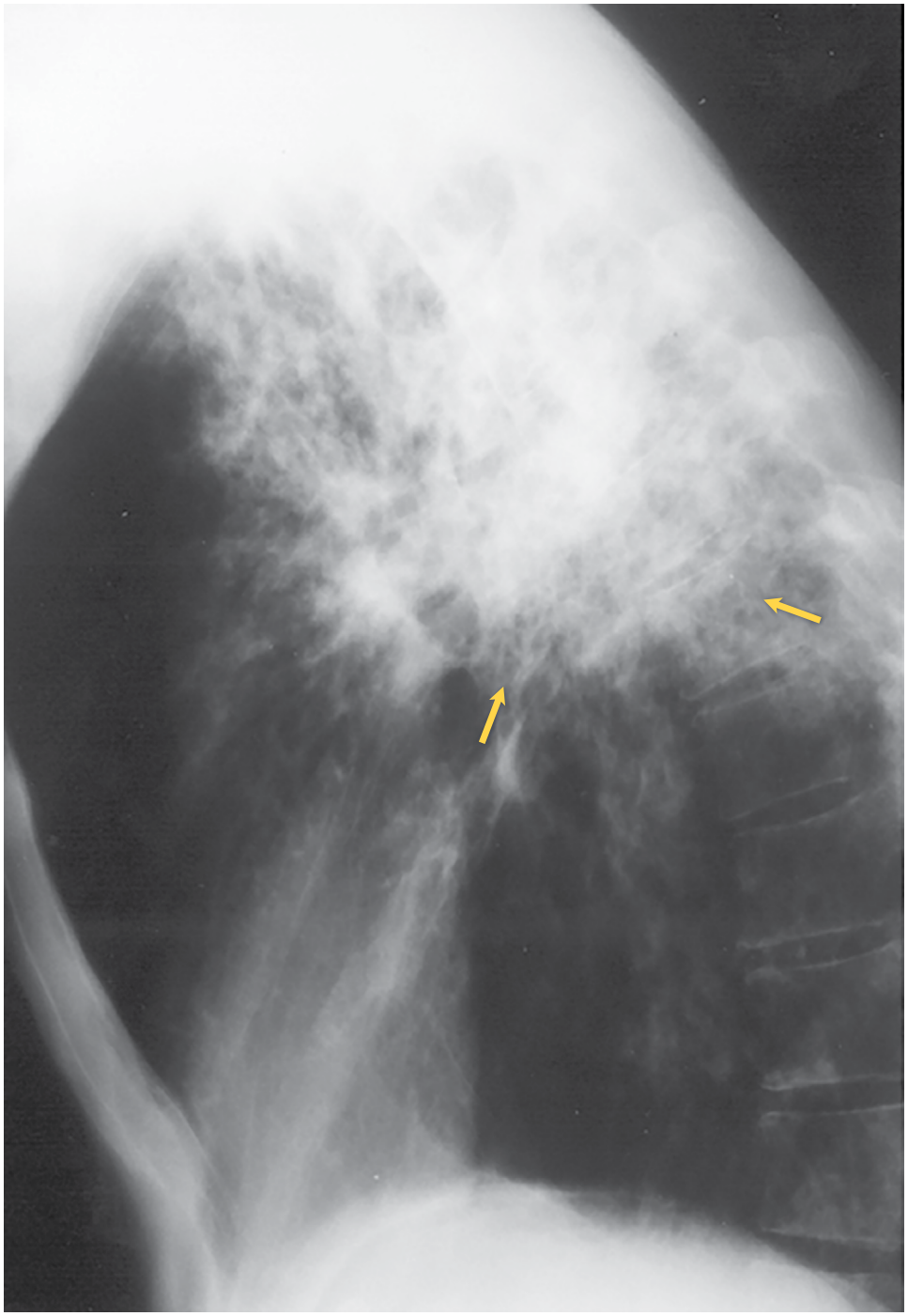


Figure 2.13B, a lateral view of the same patient in Figure 2.13A, shows the typical location of the apicoposterior segment of the left upper lobe, outlined by arrows.

- Reactivation TB characteristically involves the apical and posterior segments of the upper lobes or the superior segment of the lower lobes.
- This upper-lobe apical and posterior distribution is so typical that involvement of the anterior segment of the upper lobe without apical or posterior opacities makes the diagnosis of reactivation TB unlikely.
- In most cases, more than one pulmonary segment is involved.

Patterns of disease

Airspace consolidation is the most common pattern of reactivation disease, as in primary TB. In most cases, however, there is a mixture of radiographic patterns. Note: Disease activity cannot be determined based on the pattern of parenchymal involvement.

Airspace consolidation

FIGURE 2.14. **Airspace consolidation with cavitation: Example 1**

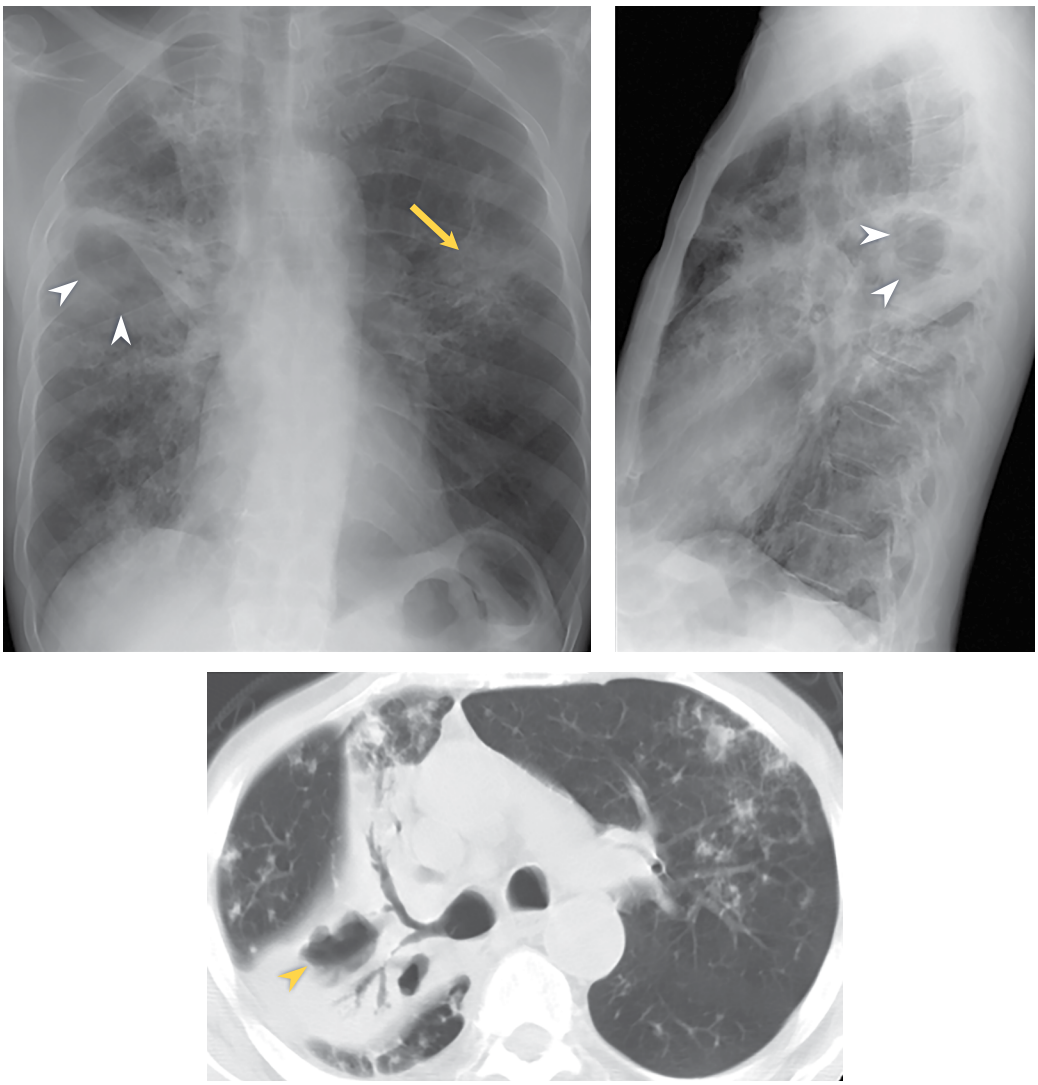


Figure 2.14 demonstrates airspace consolidation (arrow) in the bilateral upper lobes with areas of cavitary consolidation (arrowheads), particularly well seen on CT. Left upper-lobe nodules are also evident on CT.

- Airspace consolidation is the most common parenchymal pattern in reactivation disease.
- Consolidation may be patchy or confluent.
- Air bronchograms may be present within the area of consolidation.
- Cavitation is commonly seen within the consolidated lung.

FIGURE 2.15. **Airspace consolidation with cavitation: Example 2**

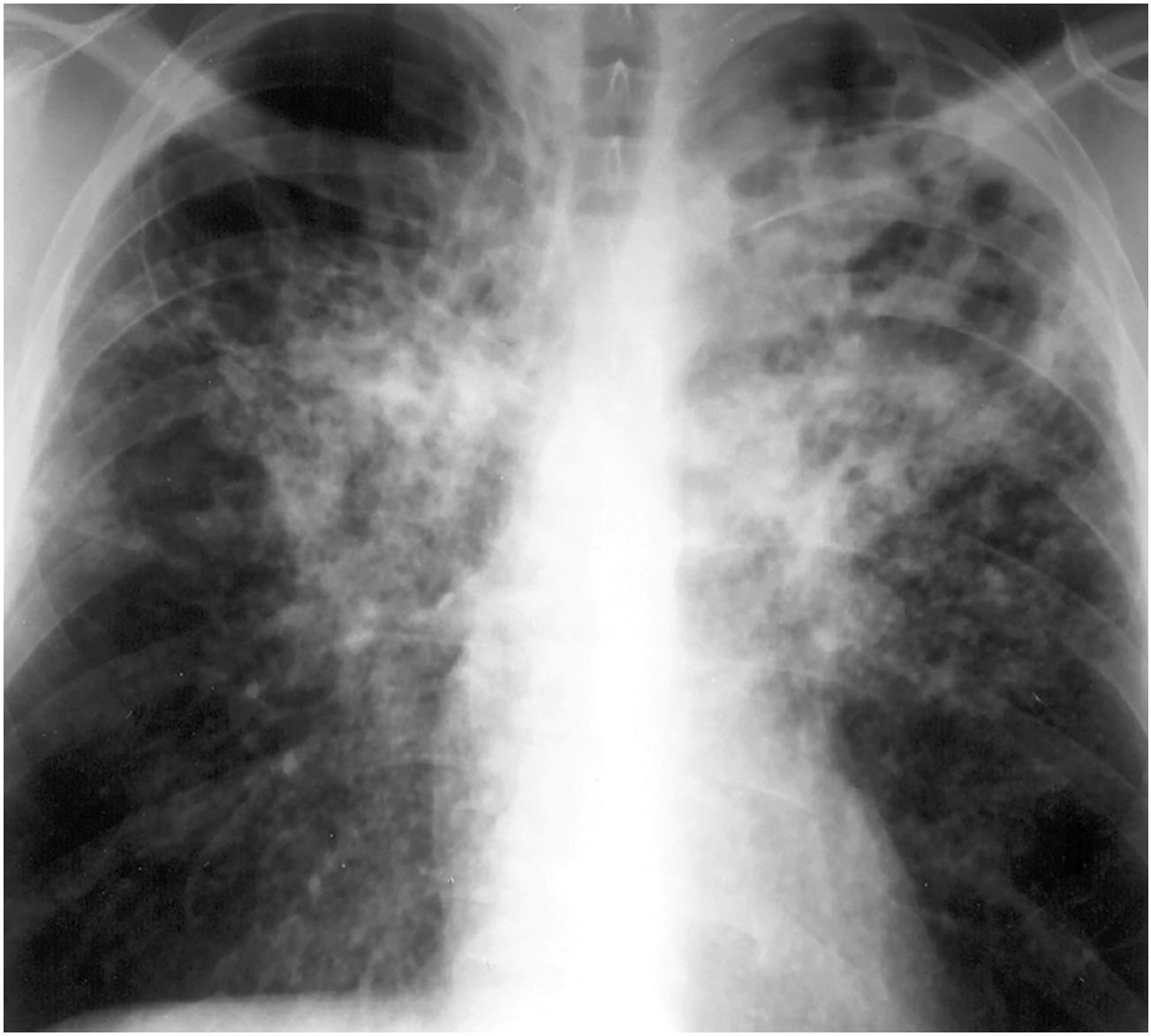


Figure 2.15 demonstrates bilateral airspace consolidation with multiple areas of lucency indicating cavitation.

- Important radiographic features of cavities include the thickness of the cavity wall (walls of cavities are thicker than those of cysts), the presence of fluid, and whether lesions are solitary or multiple.
- Cavitation on chest radiographs is present in more than half of reactivation cases, although it is uncommon in persons with immunosuppressive conditions such as HIV/AIDS.
- Air-fluid levels within cavities caused by TB are uncommon but may occasionally be seen.

FIGURE 2.16. **Airspace consolidation with bronchogenic spread: Example 3**

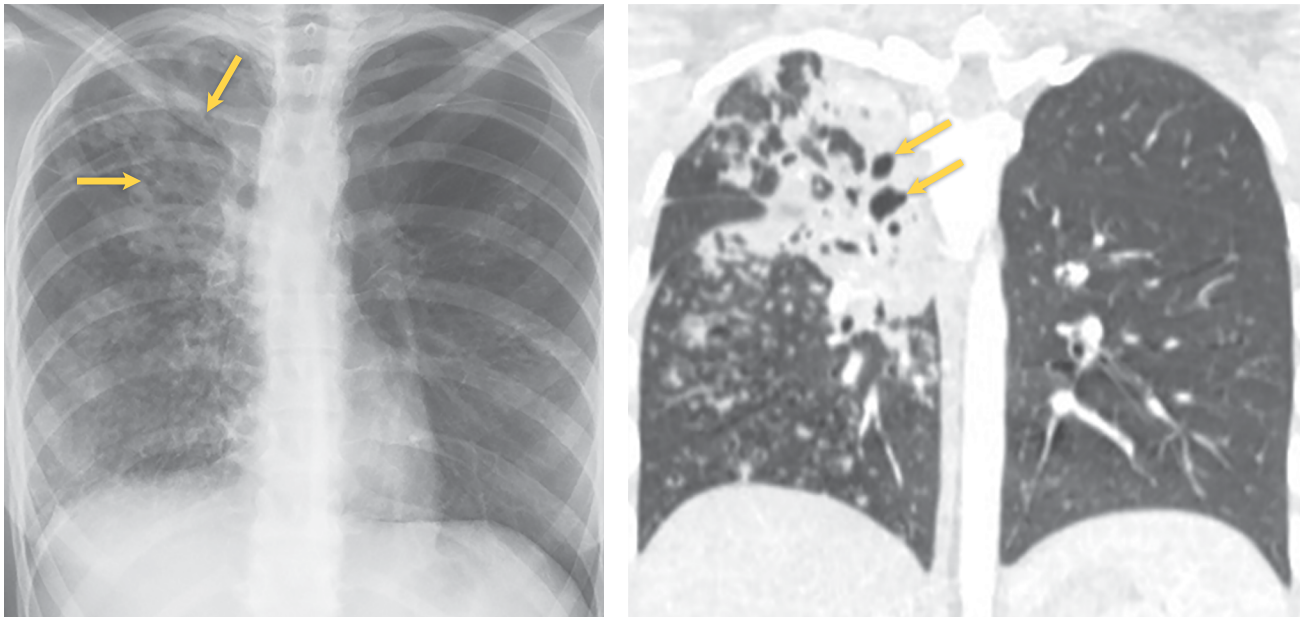


Figure 2.16 demonstrates bilateral (right greater than left) upper-lobe airspace consolidation. There is a large cavity in the right upper lobe (arrows). Note the nodular airspace opacities in the left upper lobe and throughout the right lung that represent bronchogenic spread of TB from the right upper lobe.

- In TB, a bronchogenic pattern results from the spread of infectious material within the bronchial tree, leading to new foci of infection in other bronchopulmonary segments, manifested as airspace nodules.
- Airspace nodules are 4-10 mm in diameter. They have poorly defined borders and multiple small lucent foci within their confines caused by air within bronchioles and alveoli.
- These nodules are best seen with high-resolution CT.

Lung volume loss

Volume loss (atelectasis) can be caused by fibrosis, endobronchial obstruction, or extrinsic compression of airways by enlarged lymph nodes. In the setting of reactivation TB, volume loss is usually due to fibrosis. In some cases, fibrosis leads to narrowing of an airway (bronchostenosis), which can result in segmental or lobar collapse.

FIGURE 2.17. **Volume loss due to fibrosis**

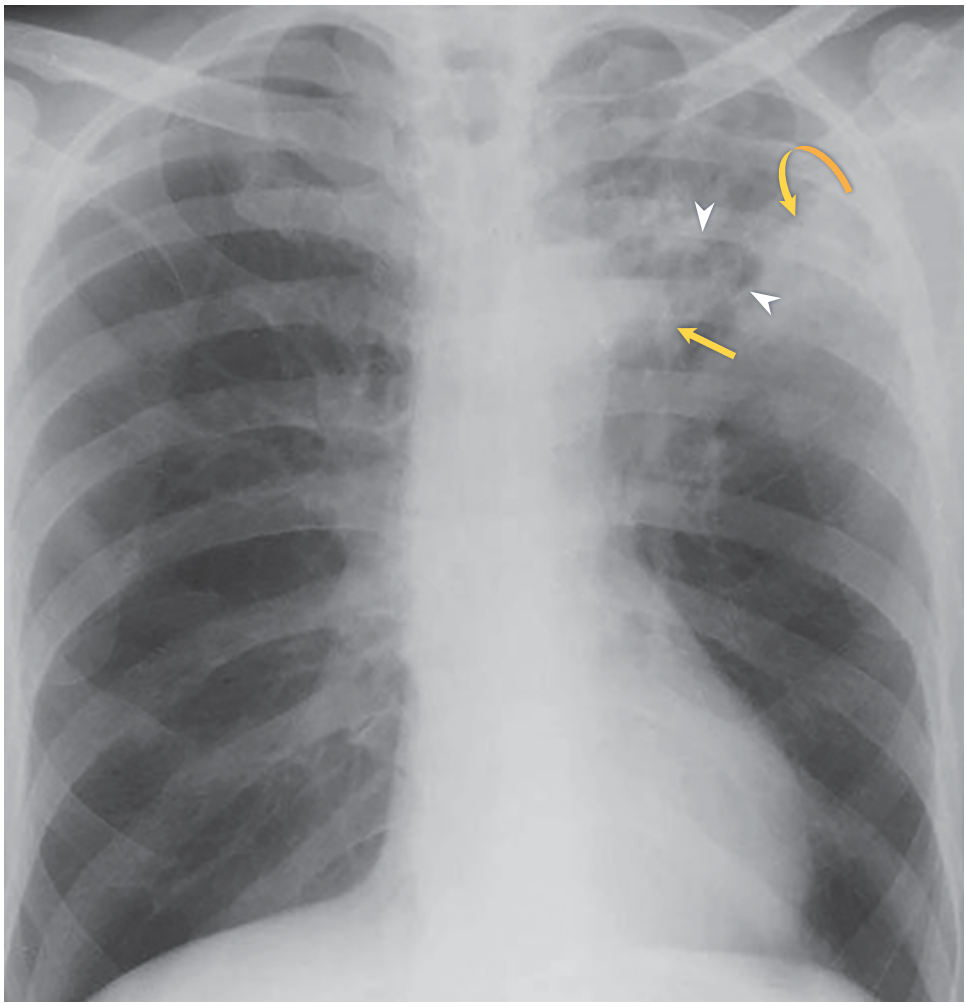


Figure 2.17 demonstrates airspace consolidation (curved arrow) and volume loss in the left upper lobe. The shift of the mediastinum and the left hilar elevation (arrow) are signs of volume loss or atelectasis. Note the area of cavitation (arrowheads).

- Post-primary TB is often associated with significant fibrosis. The resultant scarring can cause volume loss of the involved lung or lobe.
- Fibrotic lesions are often sharply defined and irregular in contour.
- These lesions are much more common in the upper lobes.
- Fibrotic lesions may be indicative of either active or prior TB, a distinction that can only be made by clinical and bacteriological evaluation.

FIGURE 2.18. **Left lower-lobe atelectasis due to bronchostenosis**

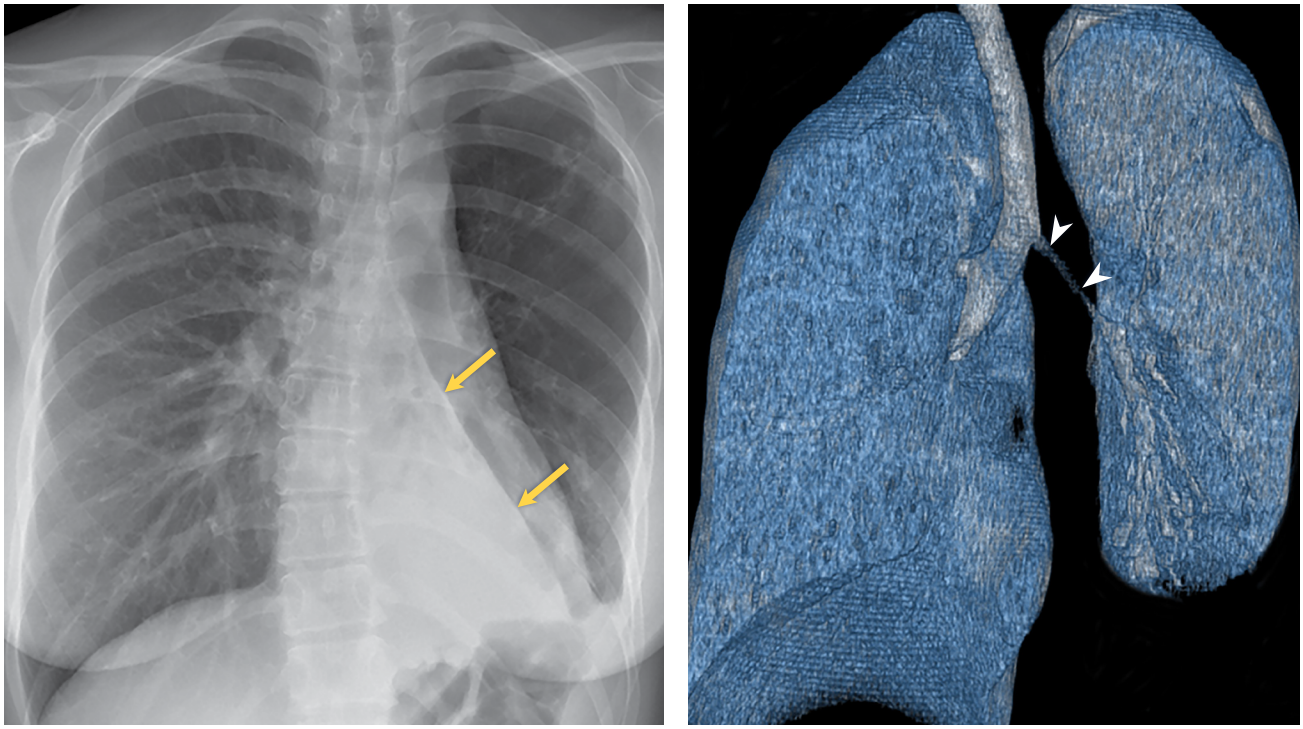


Figure 2.18. Frontal chest radiography (left) shows a left lower-lobe airspace opacity (arrows) obscuring the medial left hemidiaphragm and descending aorta. In addition, the left lung volume appears decreased, with relative hyperlucency of the left upper lobe and leftward shift of the trachea, due to left lower-lobe collapse and volume loss. Volume-rendered coronal CT (right) confirms left mainstem bronchostenosis (arrowheads). Bronchoscopy was performed to rule out a coexisting endobronchial tumor. This person with culture-confirmed TB was determined by bronchoscopy to have bronchostenosis.

FIGURE 2.19. **Right upper-lobe atelectasis due to bronchostenosis**

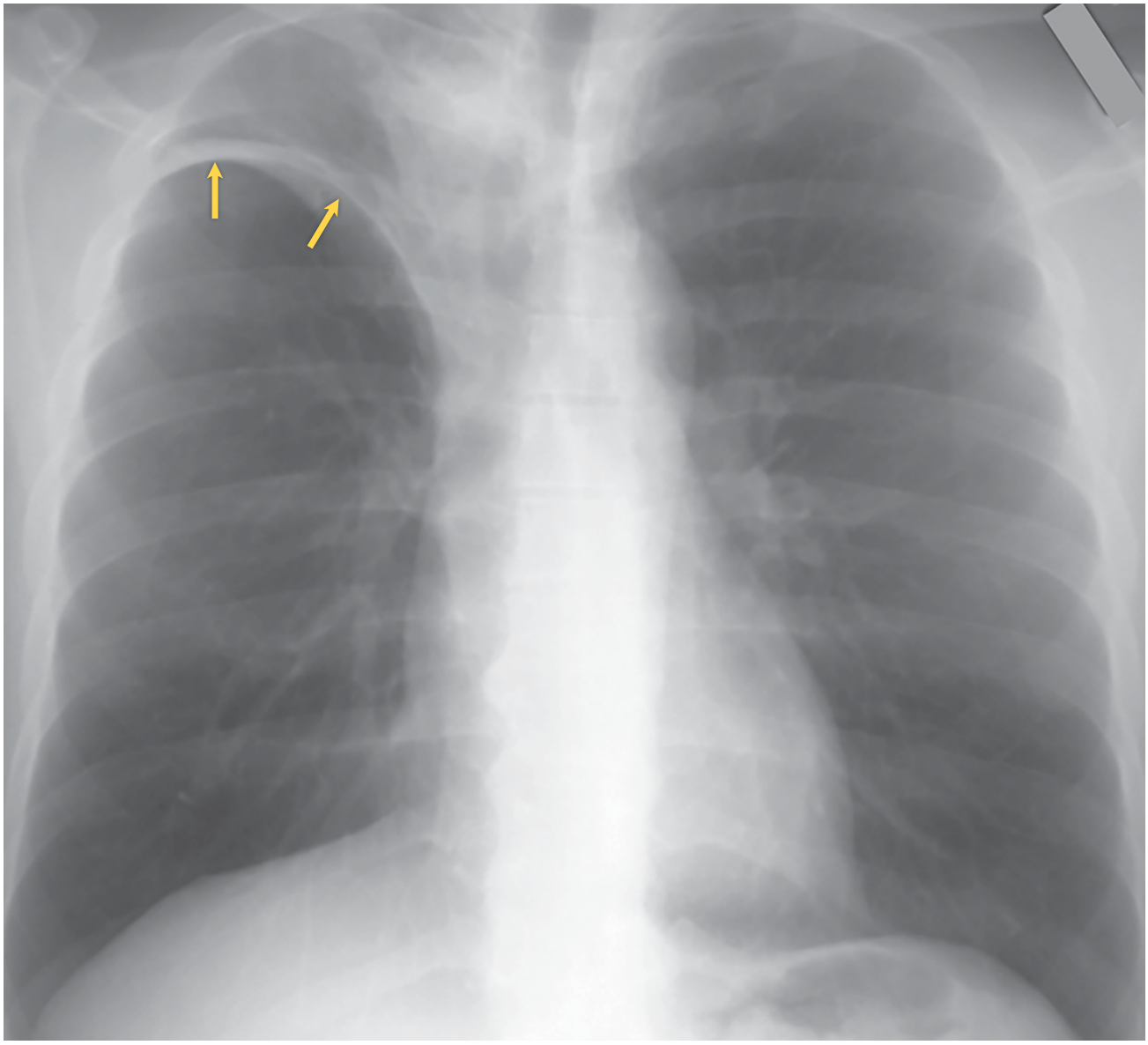


Figure 2.19. Frontal chest radiography shows right upper-lobe airspace opacity adjacent to the trachea with elevation of the minor fissure (arrows), indicating right upper-lobe collapse. This person with culture-confirmed TB was determined by bronchoscopy to have bronchostenosis.

Interstitial opacities (miliary)

FIGURE 2.20. **Miliary pattern**

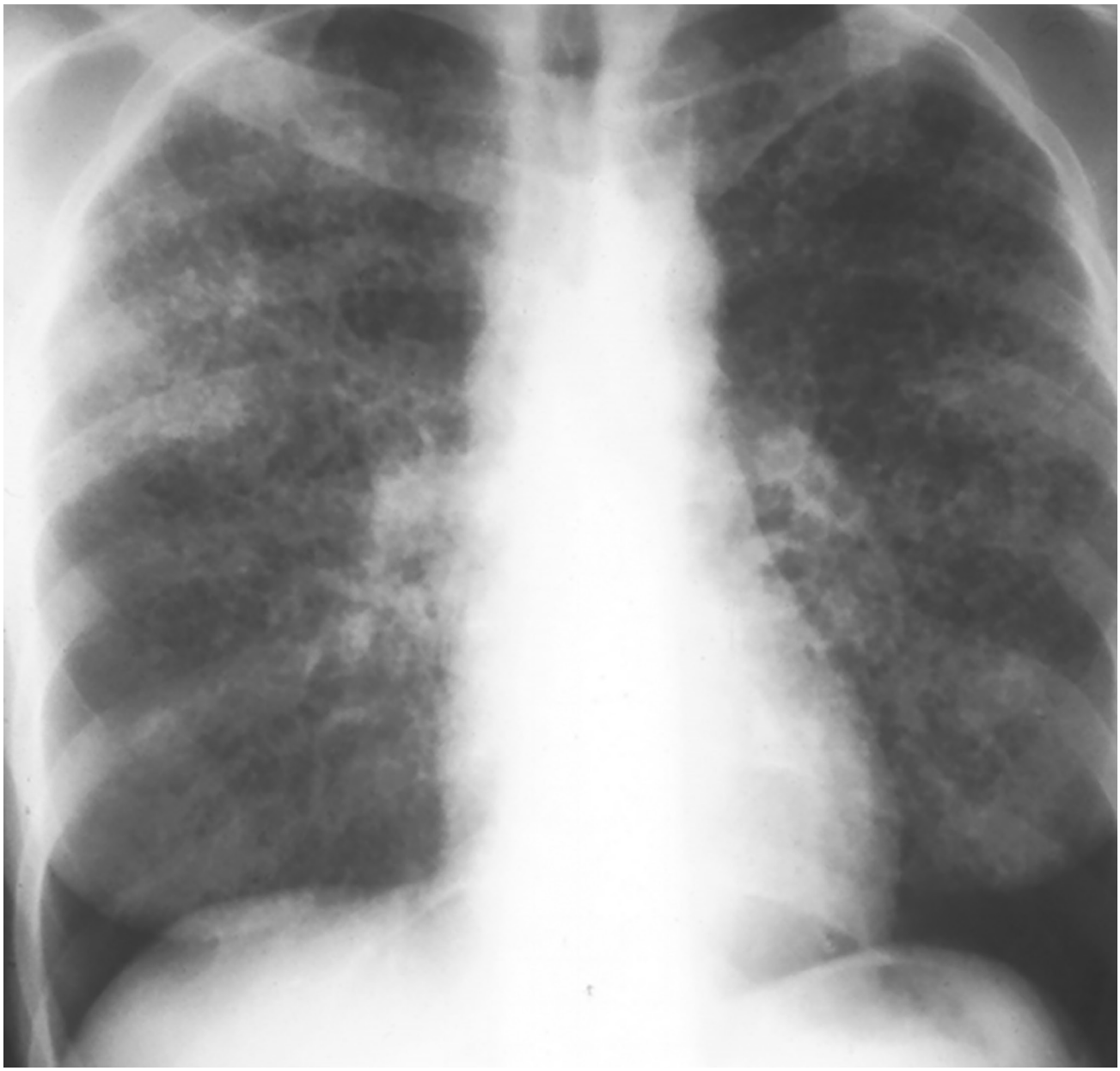


Figure 2.20 demonstrates bilateral diffuse small nodules characteristic of a miliary pattern.

- A miliary pattern results from hematogenous dissemination of tubercle bacilli.
- This dissemination leads to many nodules, initially present in the interstitium and ultimately involving the air spaces.
- Most of the nodules in miliary TB are 2-3 mm in diameter.
- Because miliary nodules result from hematogenous dissemination, more are present in the lower-lung zones due to greater blood flow to the bases compared with the apices of the lungs.

Tuberculoma

Tuberculomas are round or oval opacities, 1-5 cm in diameter, and usually found in the upper lobes. A tuberculoma is thought to be the residual of a healed primary infection. Although they may remain stable for many years, tuberculomas can be sites of disease reactivation, enlarging very slowly with the potential for cavitation.

FIGURE 2.21. **Tuberculoma**

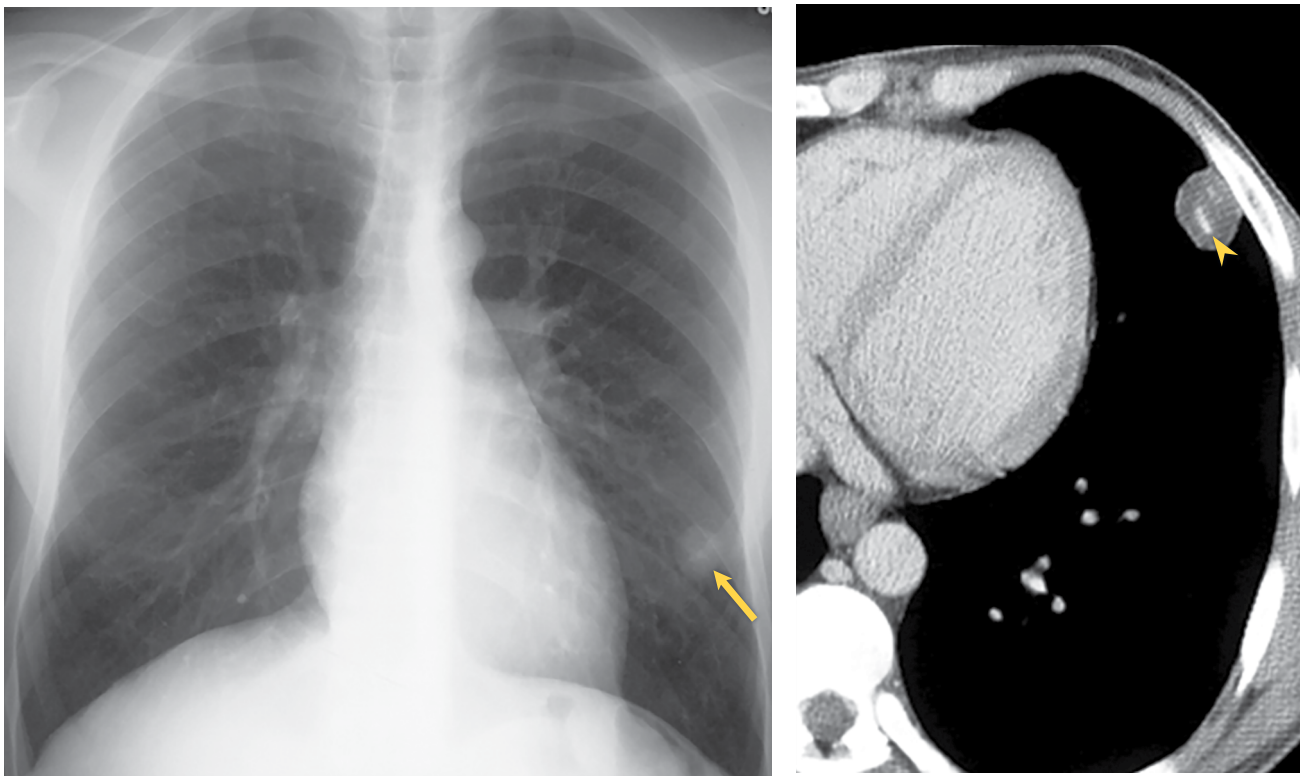


Figure 2.21 demonstrates a circumscribed nodule in the left lower lobe (arrow). Note the dense calcification (arrowhead) in the center of the nodule readily visualized on CT. Radiographically, tuberculomas can simulate a bronchogenic carcinoma.

- Tuberculomas are round or oval opacities, usually 1-5 cm in diameter, and usually found in the upper lobe.
- Tuberculomas are normally smooth and sharply defined.
- Satellite lesions, which are small, discrete nodules surrounding the tuberculoma, occur in 80% of cases and are clues to the diagnosis. However, they may only be visible on high-resolution CT.

Pleural disease

Pleural effusions can be a manifestation of primary or reactivation TB. However, in postprimary disease, the effusion is more likely to be associated with radiographically visible parenchymal abnormalities. Rarely, the effusion is a frank tuberculous empyema. See Figures 2.3 and 2.12 for previous examples of simple tuberculous pleural effusions.

FIGURE 2.22. **Tuberculous empyema**

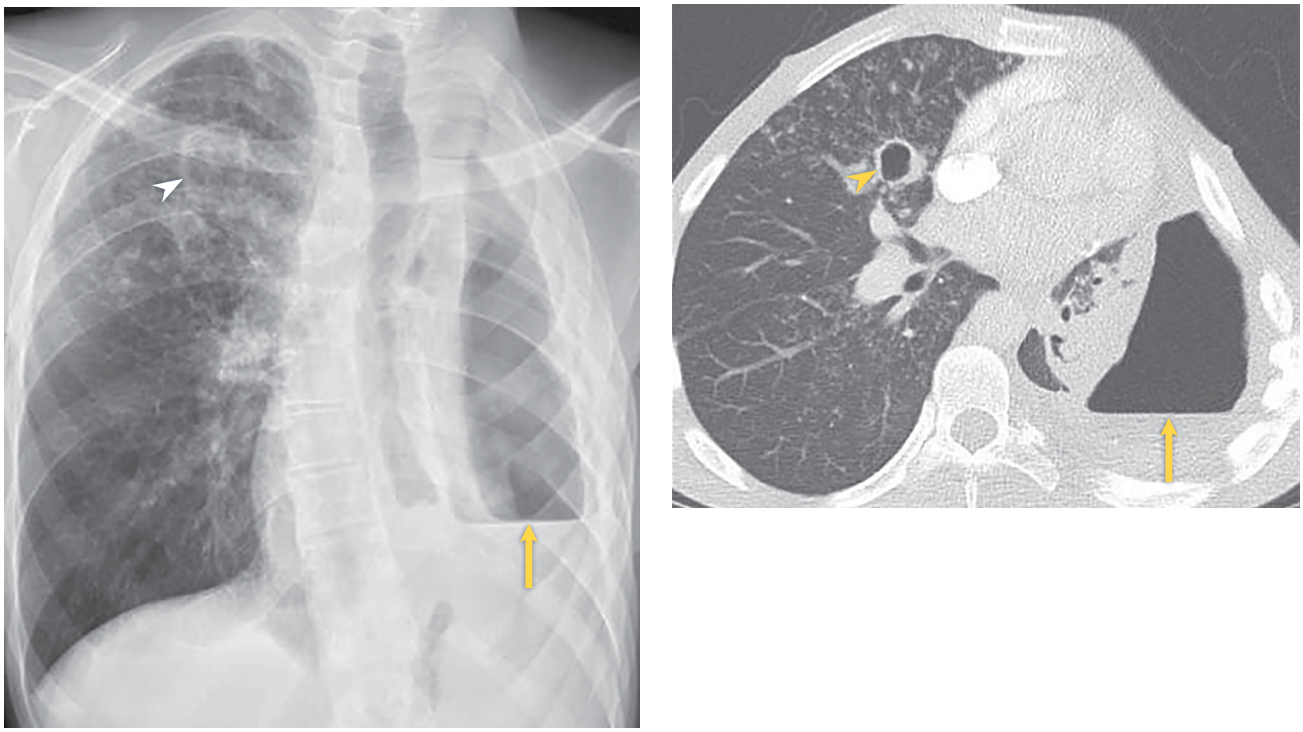


Figure 2.22 shows an example of a tuberculous empyema that developed when a cavitary tuberculous pneumonia ruptured into the left pleural space, creating a bronchopleural fistula. This case demonstrates a left pleural effusion with air-fluid levels (arrows) consistent with a hydropneumothorax. Right upper-lobe cavities (arrowheads) and nodules are present.

- Diagnosis of hydropneumothorax is based on the presence of a pleural effusion accompanied by an air-fluid level within the pleural space.
- The term hydropneumothorax signifies communication of the pleural space with the bronchial tree. Hydropneumothorax is often due to a necrotizing pneumonia such as TB.

TB and immunosuppression

The radiographic manifestations of TB in persons with immunosuppression vary depending on the degree of immunosuppression. In an HIV-positive person whose immune system is relatively intact (i.e., >200 CD4 cells/μL), the radiographic manifestations of TB are similar to those of reactivation disease in persons with intact immune systems.

As the CD4 lymphocyte count declines, the radiographic findings are more like those seen in primary disease.

- The radiographic opacities may be in the lower-lung zones or multilobar in nature.
- Thoracic lymphadenopathy is more common.

Diabetes mellitis is widely recognized as a risk factor for TB although the immunopathogenesis is not fully understood. In some case series of TB in patients with diabetes, an increased frequency of cavitation and lower-lobe involvement has been noted. However, in a large systematic review there was no difference in the radiographic distribution of abnormalities between persons with and without diabetes. There was, however, an increased frequency of cavitation.

Figures 2.23, 2.24, and 2.25 are three examples of unusual (atypical) radiographic manifestations of HIV-related TB.

FIGURE 2.23. **Bilateral diffuse opacities**

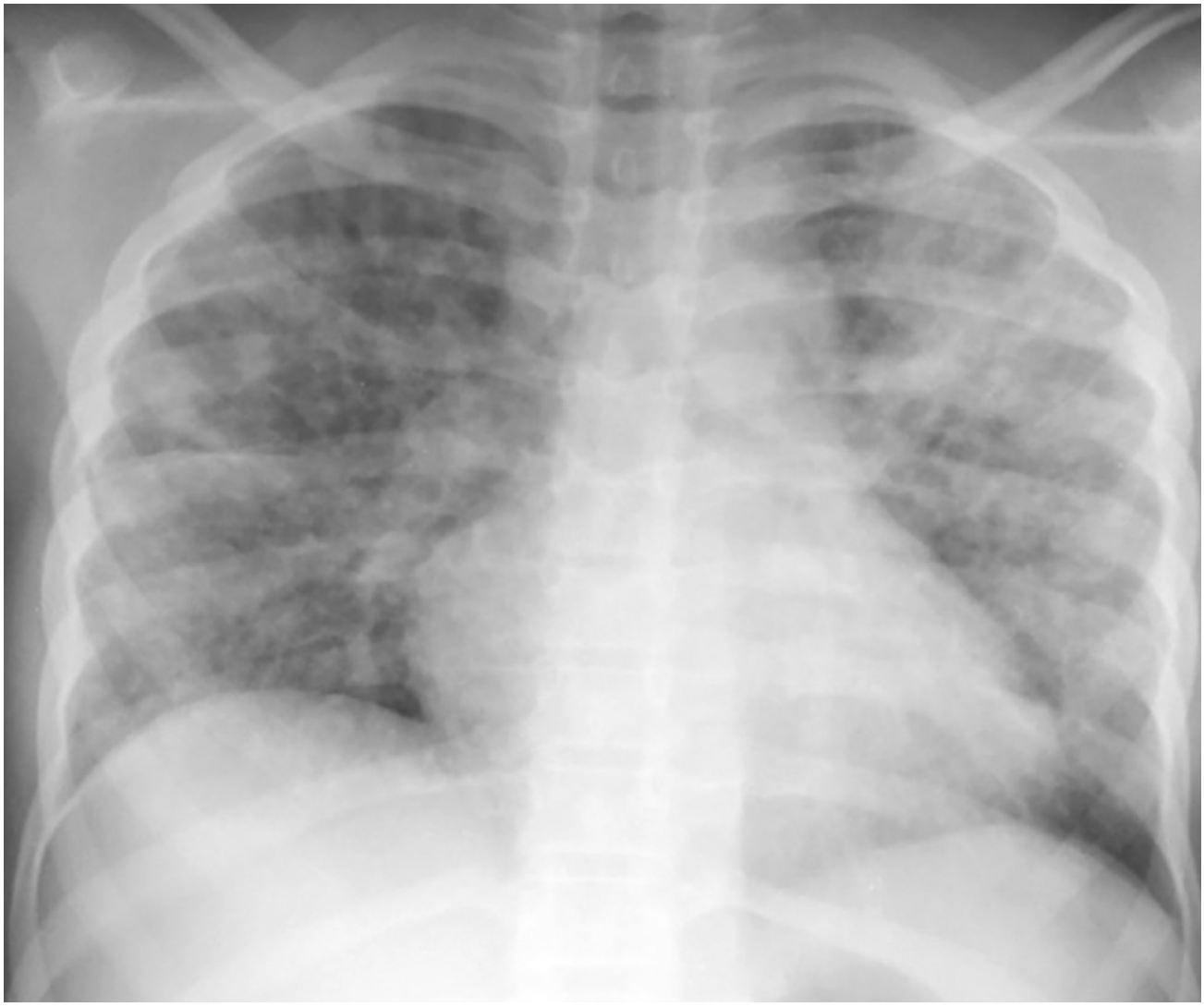


Figure 2.23. Frontal chest radiography shows bilateral diffuse airspace opacities with bilateral hilar enlargement. The patient had AFB smear-positive TB.

FIGURE 2.24. **Large paratracheal lymphadenopathy**

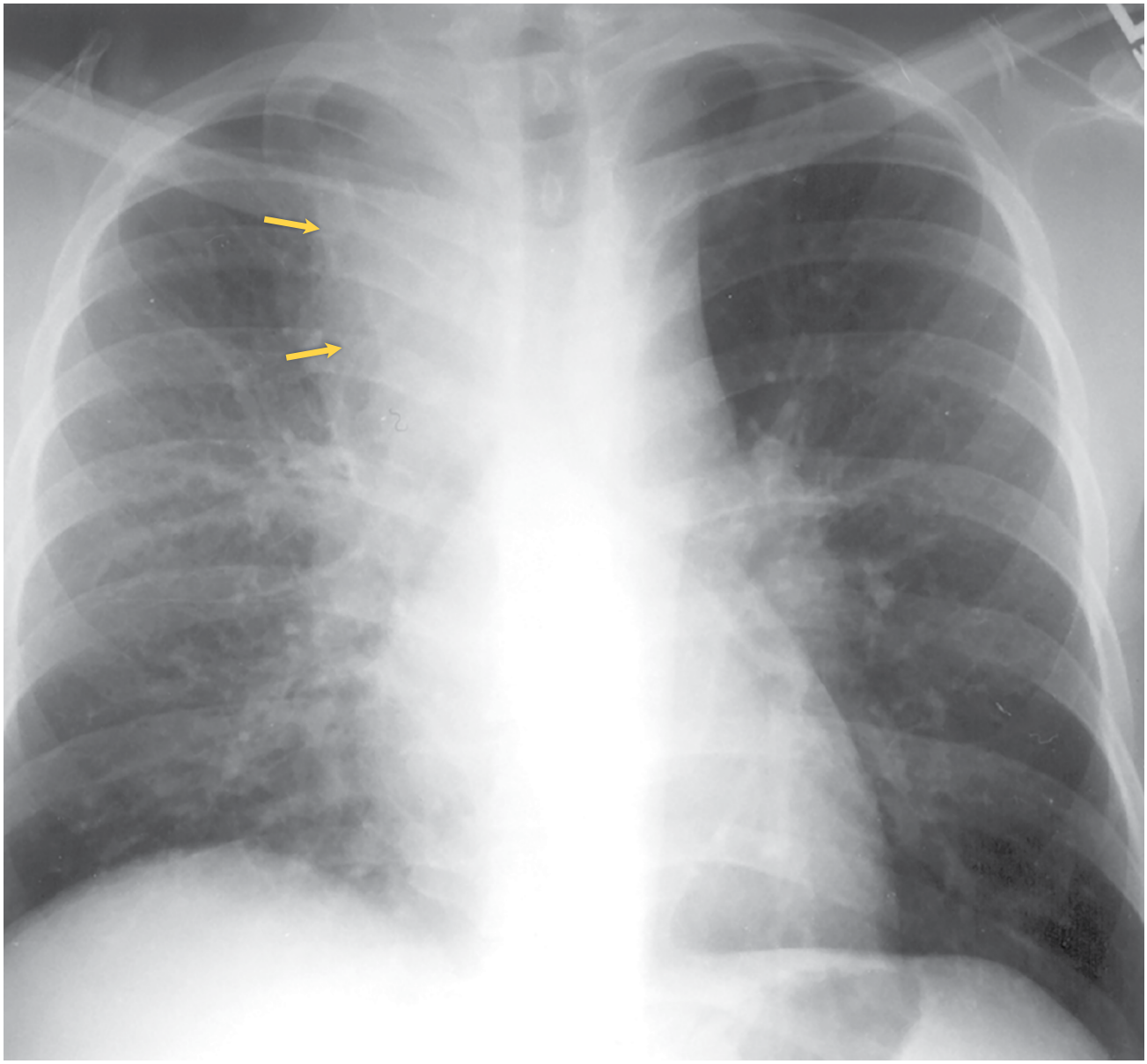


Figure 2.24 demonstrates large bilateral paratracheal lymphadenopathy, causing widening of the right superior mediastinum (arrows) with right middle- and lower-lung zone airspace and linear opacities. Note loss of the normal aortopulmonary window contour. Despite radiographically limited parenchymal disease, the patient was AFB smear-positive.

FIGURE 2.25. **Mediastinal lymphadenopathy**

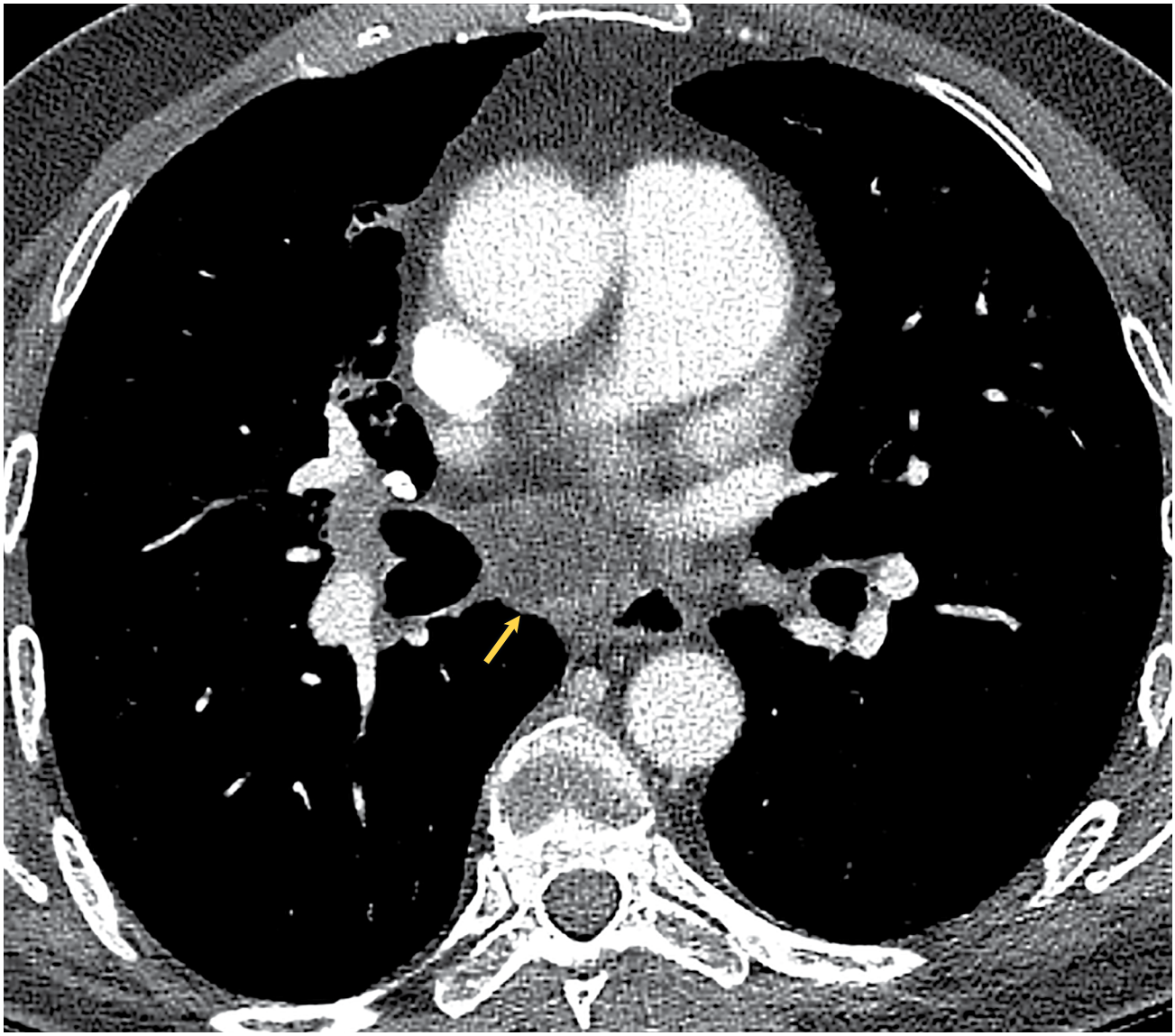


Figure 2.25. Contrast enhanced CT demonstrates subcarinal mediastinal lymphadenopathy (arrow) with central low attenuation ("darkening") due to necrosis. This finding is highly predictive of an infectious process, commonly TB.

Resolution of radiographic abnormalities and healed TB

The radiographic abnormalities in TB are slow to resolve. In some cases, parenchymal opacities and thoracic lymphadenopathy may actually worsen before improving. For this reason, the chest radiograph should be monitored together with the clinical assessment and bacteriological response in order to determine whether there is an appropriate response to treatment.

Primary TB

Healing of the primary complex, with or without therapy, can result in fibrosis and calcification of the Ghon focus. The Ghon focus is represented radiographically as a calcified nodular opacity (i.e., calcified granuloma). Calcified ipsilateral hilar or mediastinal lymph node calcifications (Ranke complex) may also be seen.

Primary TB typically resolves with minimal fibrosis and volume loss. However, patients who develop progressive primary disease with cavitation may have significant fibrosis and may develop bronchiectasis, similar to what may be seen in reactivation disease. Lymphadenopathy may take months to resolve and, in some cases, there may be prolonged enlargement of lymph nodes, particularly in children.

Reactivation TB

The degree of fibrosis and scarring varies considerably with reactivation TB. In general, the more extensive the disease and the worse the cavitation, the more likely it is that there will be fibrosis with associated volume loss. It is important to note that fibrosis and volume loss can occur in the presence of active TB, so these findings should not be used to dismiss a diagnosis of active disease. These residual radiographic abnormalities may be associated with ongoing respiratory symptoms and disability.

The following four figures are examples of healed primary and reactivation TB.

FIGURE 2.26. **Ranke complex**

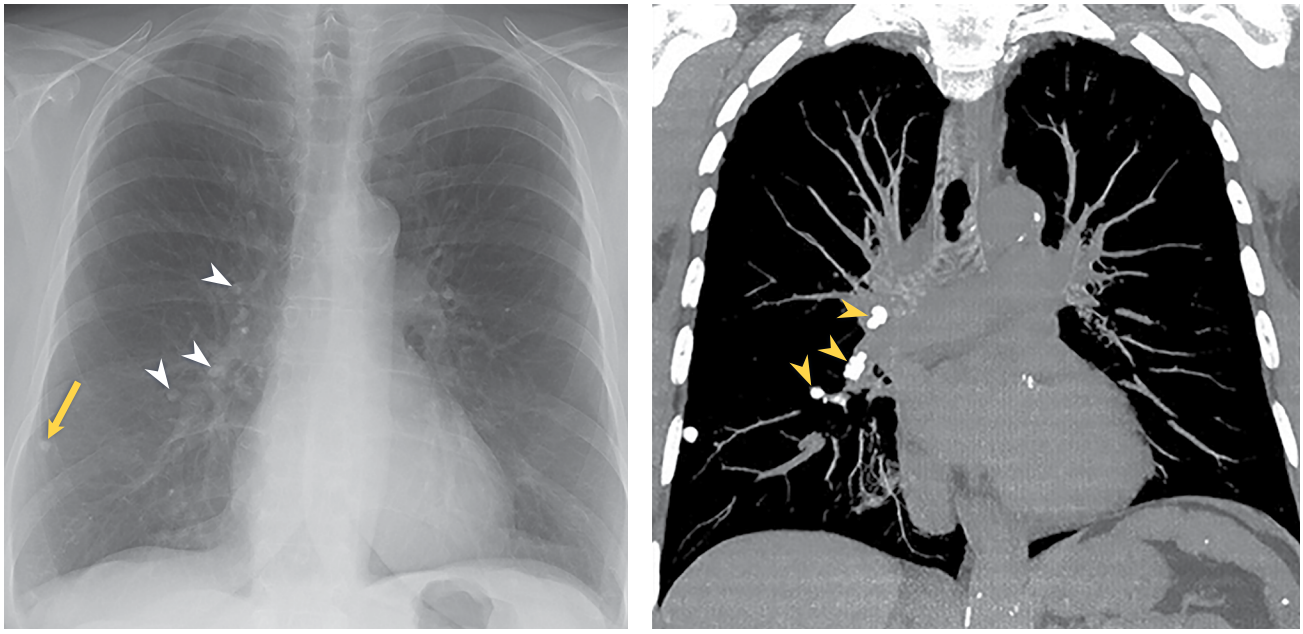


Figure 2.26. Frontal chest radiograph (left) demonstrates a calcified peripheral nodular opacity (arrow) consistent with a Ghon lesion. Calcified right hilar nodes (arrowheads) are also present, both confirmed on coronal CT (right). Together, these lesions are referred to as a Ranke complex.

- A Ghon lesion represents a calcified granuloma in the lung parenchyma.
- A Ranke complex is the combination of a Ghon lesion and an ipsilateral calcified hilar lymph node.
- Neither a Ghon lesion nor a Ranke complex represents active TB.
- Isolated calcified granulomas are not associated with an increased risk of progression to active disease in people with latent TB infection.

FIGURE 2.27. **Previously treated pulmonary TB**

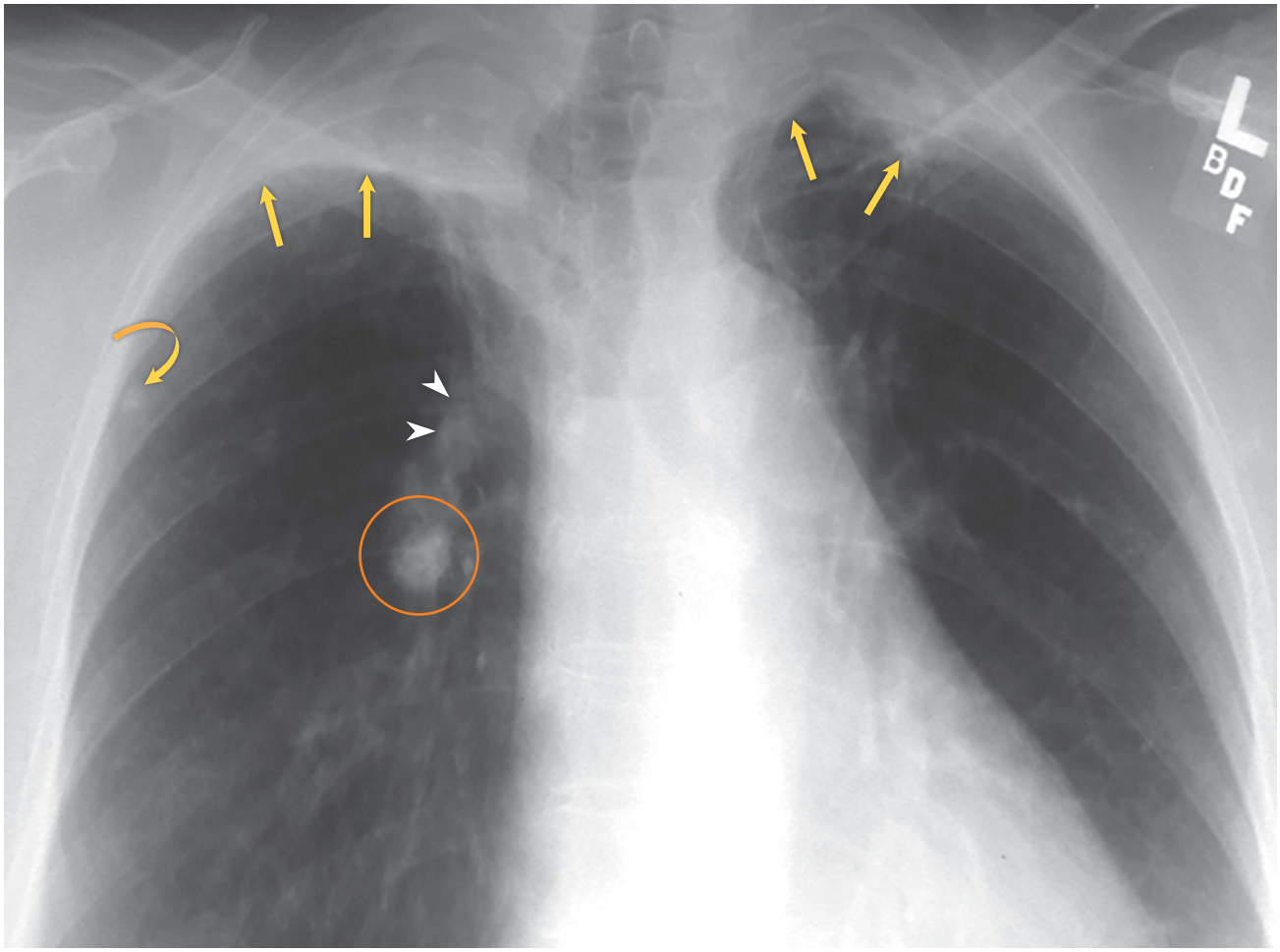


Figure 2.27. Frontal chest radiograph shows a person who had been treated previously for pulmonary TB. The patient has a right upper-lobe calcified granuloma (curved arrow) and calcified right peribronchial lymph nodes (circle). In addition, there is bilateral apical pleural thickening (arrows). Note upper-lobe volume loss evidenced by hilar retraction (arrowheads).

- Apical pleural thickening may be seen with or without surrounding apical parenchymal opacities.
- Apical pleural thickening is not associated with active TB unless there are accompanying parenchymal opacities such as airspace consolidation, nodules, or fibrosis.
- Isolated pleural thickening is not associated with an increased risk of progression to active disease in people with latent TB infection.

FIGURE 2.28. **Fibrotic scarring**

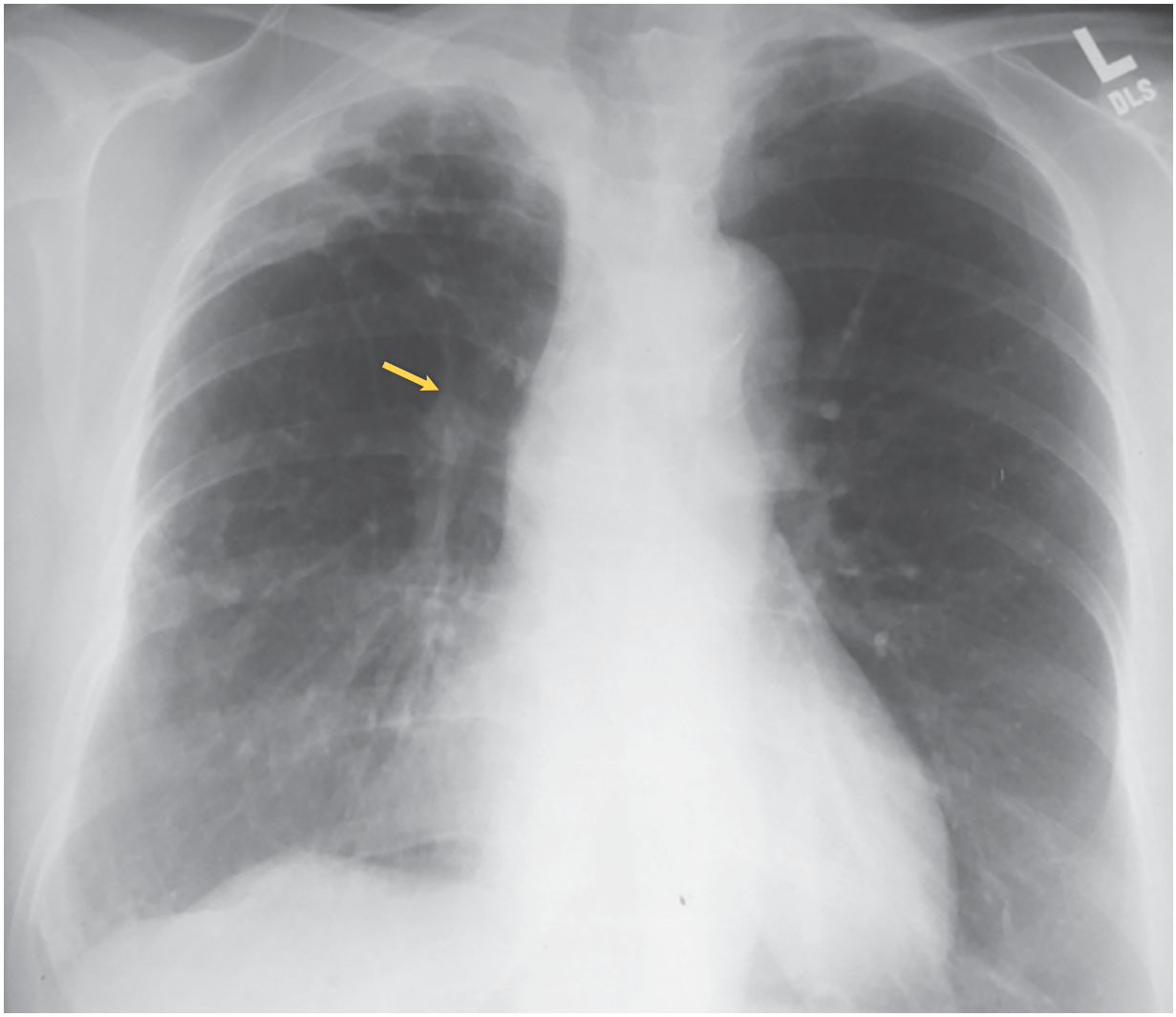


Figure 2.28 demonstrates right upper-lobe linear opacities, apical pleural thickening, and volume loss. Note the elevation of the right hilum (arrow) and hemidiaphragm. This person was asymptomatic and had negative AFB smears and cultures. However, the presence or absence of active infection cannot be determined on a single image. Patients with radiographic findings such as those shown in this example should be evaluated with sputum smear and culture unless there are earlier images showing stability of the abnormalities.

- Reactivation TB is often associated with significant fibrosis. The resultant scarring can cause volume loss of the involved lung or lobe.
- Fibrotic lesions may indicate either active or prior TB. This distinction can only be made by clinical and microbiological evaluation.
- Individuals who have parenchymal opacities suggesting “old TB” but who have not been treated for TB or who have had inadequate treatment are at increased risk of developing active TB. The presence of parenchymal opacities (representing old, healed TB) increases the risk of progression to TB in individuals who have received inadequate prior treatment for TB or latent TB infection.

Practice chest radiographs

Use the following three chest radiographs (Figures 2.29 – 2.31) to practice describing the findings. Check descriptions on pages 2.40 – 2.41.

Using a systematic approach, practice the following steps:

- Describe the abnormalities seen (location, size) using the descriptive terms from Chapter 1.
- Use lessons from Chapter 2 to propose what type of TB presentation may be included in the differential diagnosis of the radiographic abnormalities described.

Figure 2.29

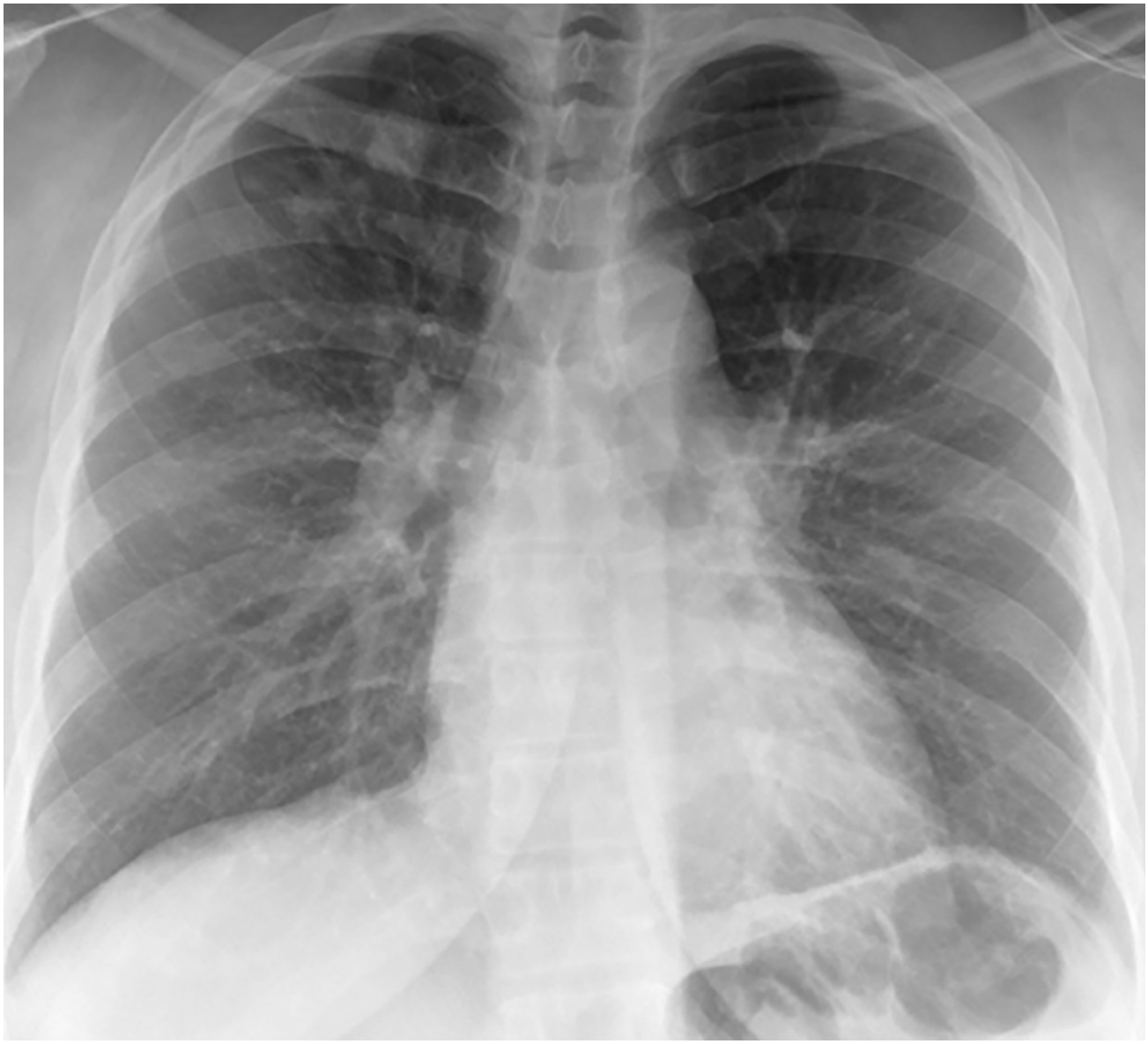


Figure 2.30

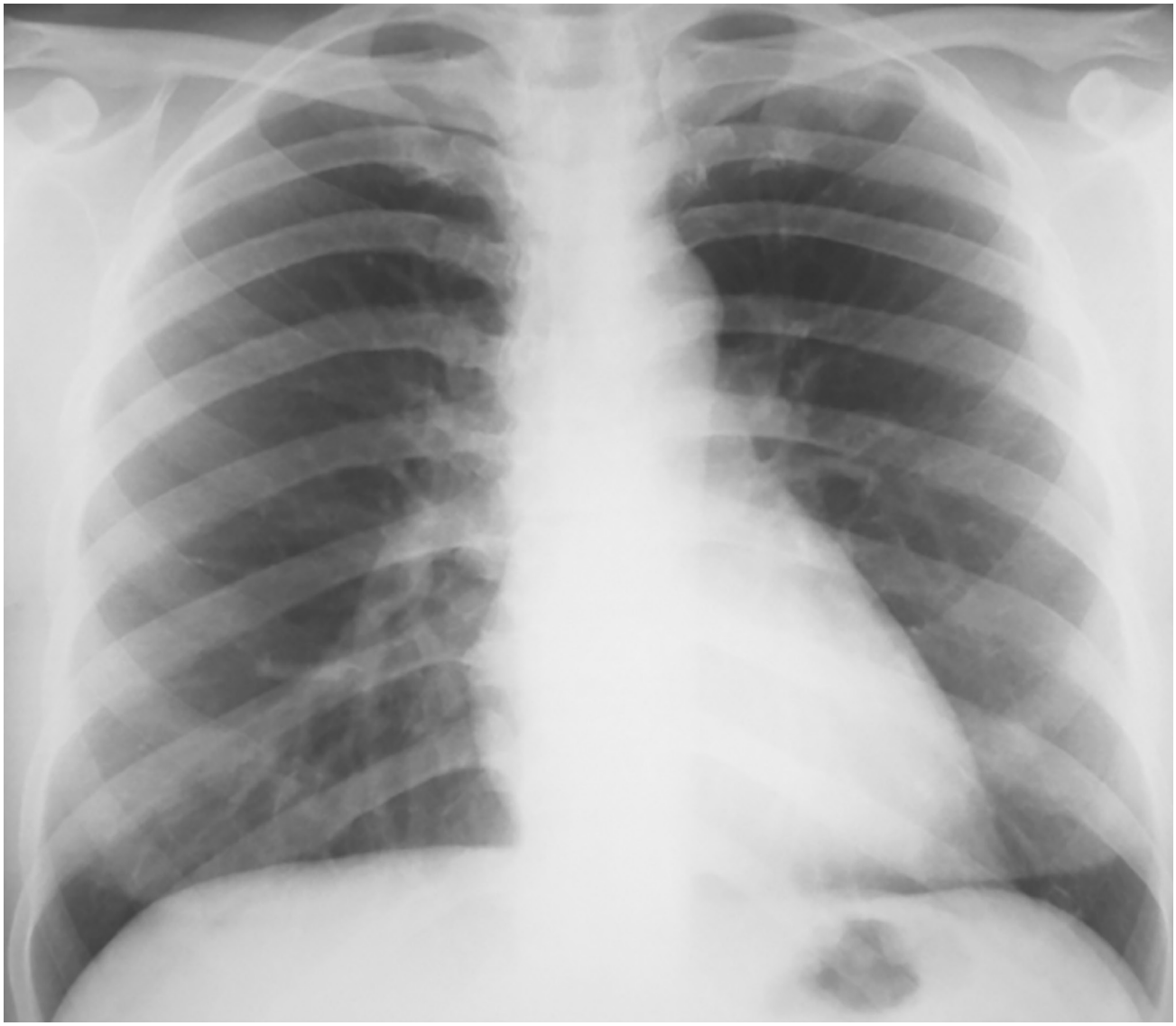
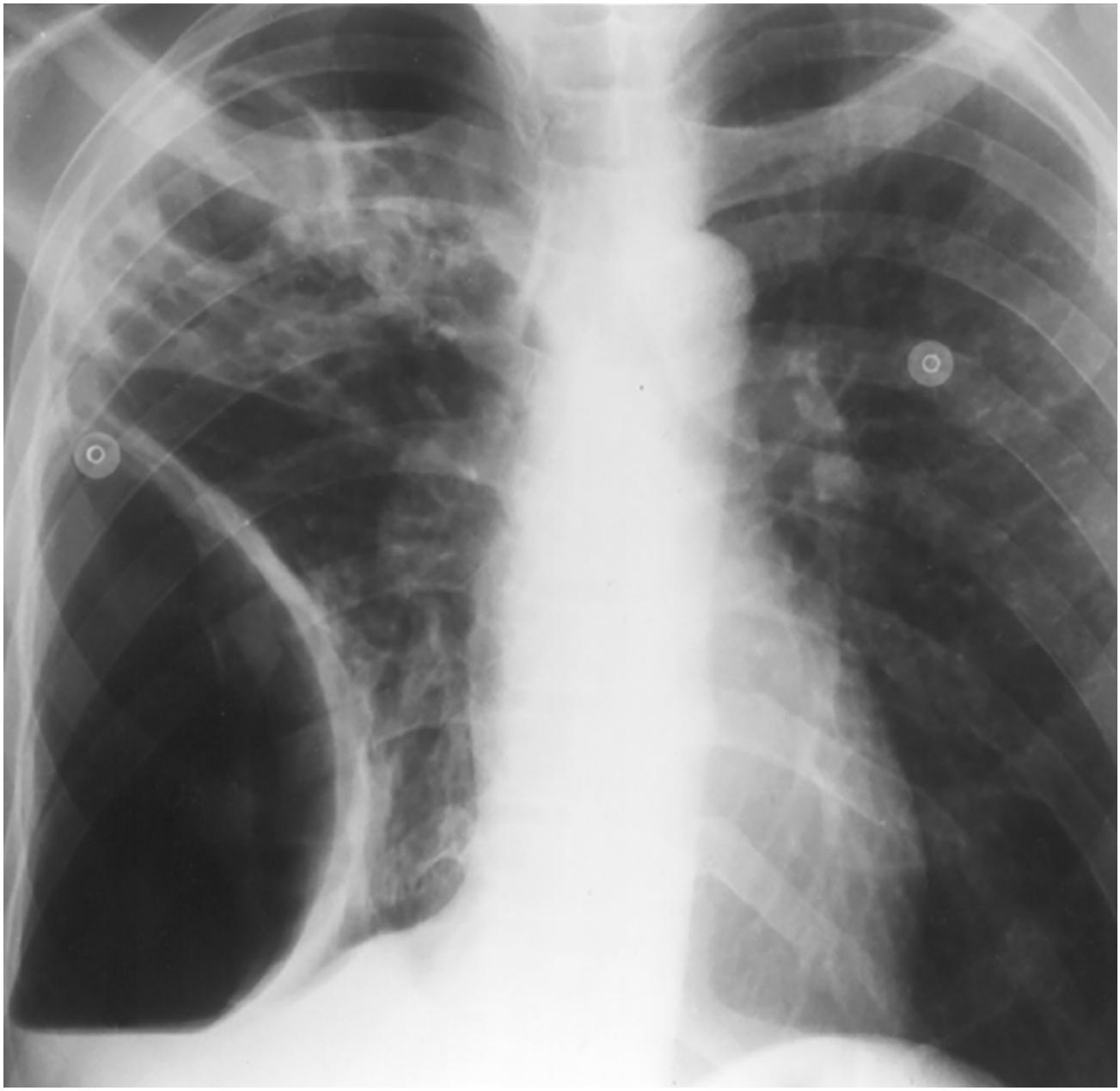


Figure 2.31



Descriptions: Practice chest radiographs

Figure 2.29 description

Imaging findings: There is a 14 mm right apical opacity posterior to the right clavicle in Figure 2.32 (see arrow), confirmed on CT.

Final clinical diagnosis: Culture-confirmed TB

FIGURE 2.32.

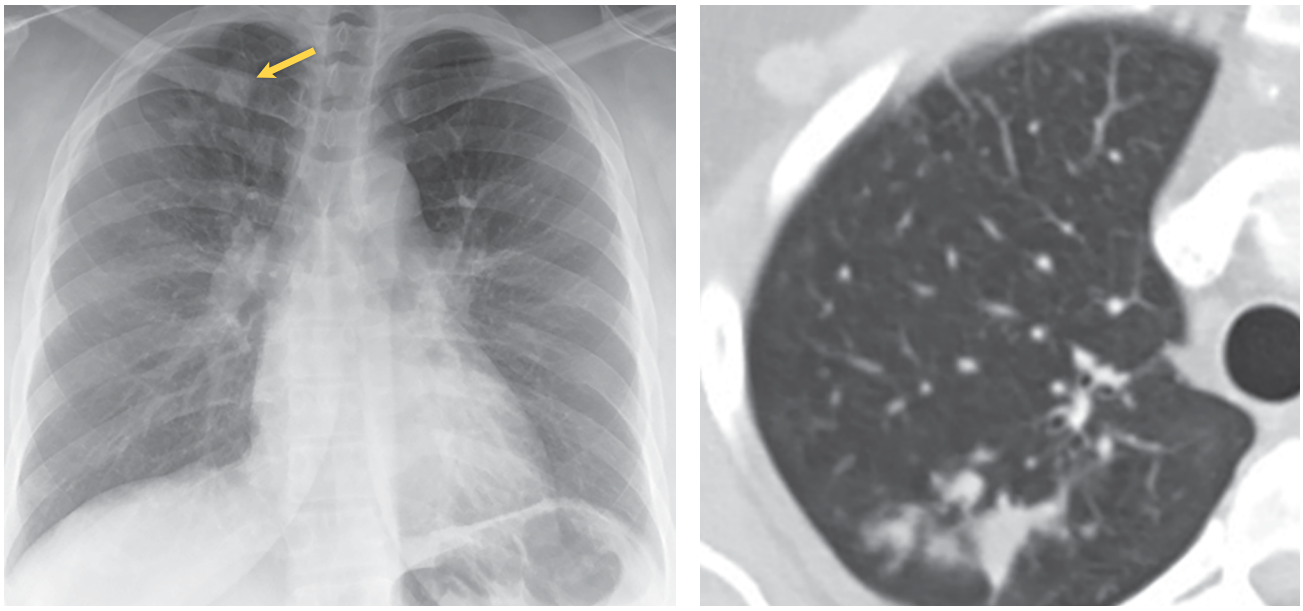


Figure 2.30 description

Imaging findings: Frontal chest radiograph shows a faint 15 mm left apical nodule (arrow, Figure 2.33A), obscured by overlap with the left first rib, confirmed with a lordotic projection (arrow, Figure 2.33B).

Final clinical diagnosis: Culture-confirmed TB following percutaneous biopsy

FIGURE 2.33A.

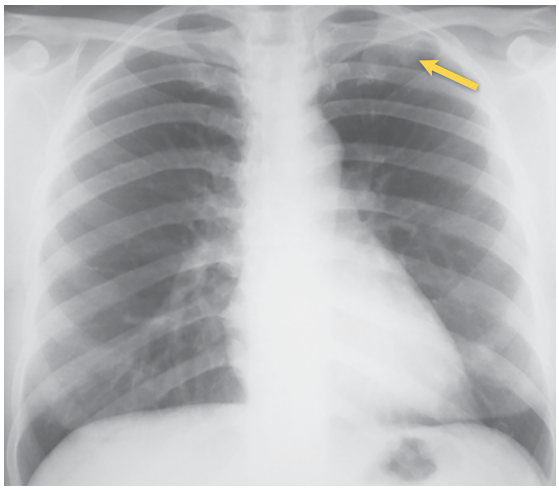


FIGURE 2.33B.

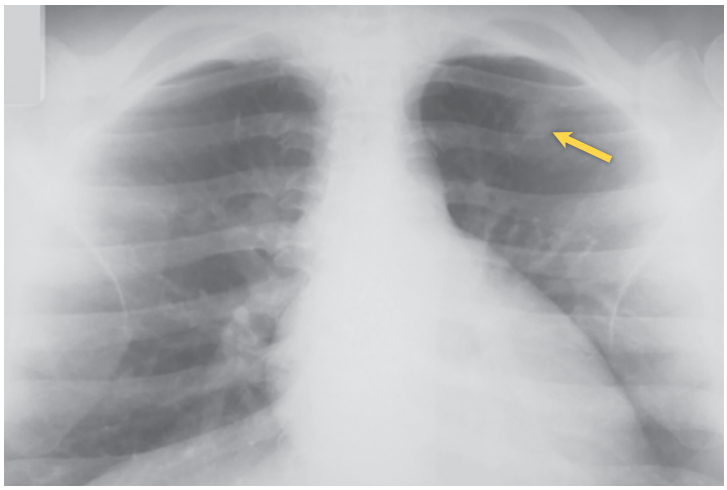
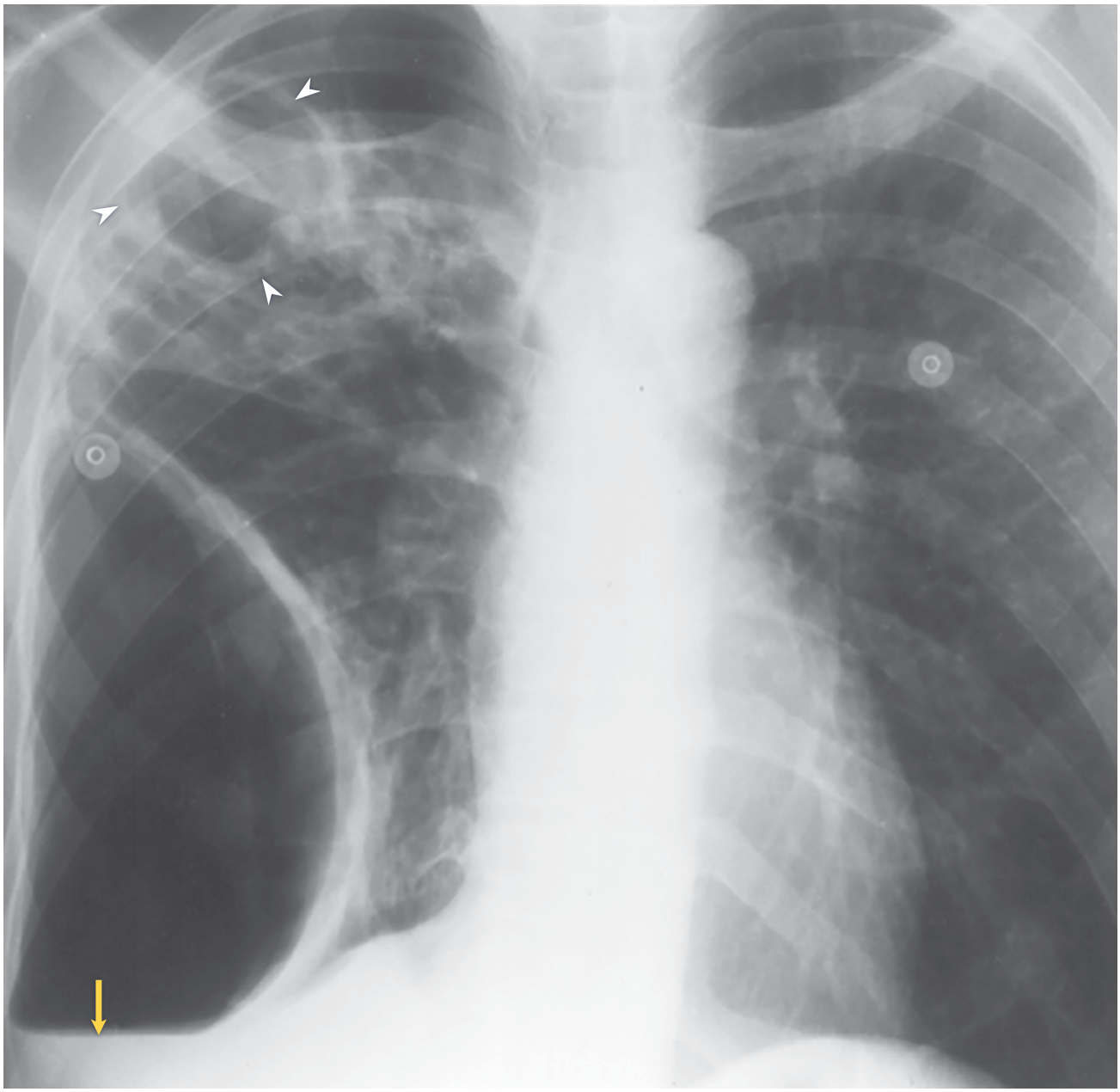


Figure 2.31 description

Imaging findings: Right upper-lobe airspace opacity with cavitation. Note the large cavity (32 mm, arrowheads, Figure 2.34). There is also a large right hydropneumothorax with an air-fluid level (arrow).

Final clinical diagnosis: Smear-positive pulmonary TB with tuberculous empyema

FIGURE 2.34.



Take-home points

- Clinical (or "active") TB commonly develops in a two-stage process. "Primary" TB occurs soon after infection with *M. tuberculosis*. "Post-primary" or "reactivation" TB occurs after cell-mediated immunity develops, often many years after infection.
- The radiographic features of these two stages tend to differ. Primary TB is more common in the lower-lung zones with associated intrathoracic lymphadenopathy and no cavitation. Reactivation TB tends to occur in the apical and posterior upper-lung zones and is associated with cavitation and no lymphadenopathy.
- Radiographic abnormalities cannot be used to make a diagnosis of either active or inactive ("healed" or "old") TB. However, the pattern of radiographic abnormalities can move the diagnosis either up or down in the list of possible diagnoses under consideration and can guide the choices of diagnostic tests.
- Almost any pattern of radiographic abnormalities may occur with TB. Three clues that an abnormality may be caused by TB are:
  1. The presence of intrathoracic (mediastinal and/or hilar) lymphadenopathy
  2. Parenchymal cavitation
  3. Predominant upper-lobe involvement, especially in the apical and posterior segments
- TB may cause lung volume loss due to lymphadenopathy causing airway compression and fibrosis causing lung retraction.
- TB occurring in the presence of immunosuppression is associated with "atypical" radiographic features.

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3

Clinical Cases

Introduction

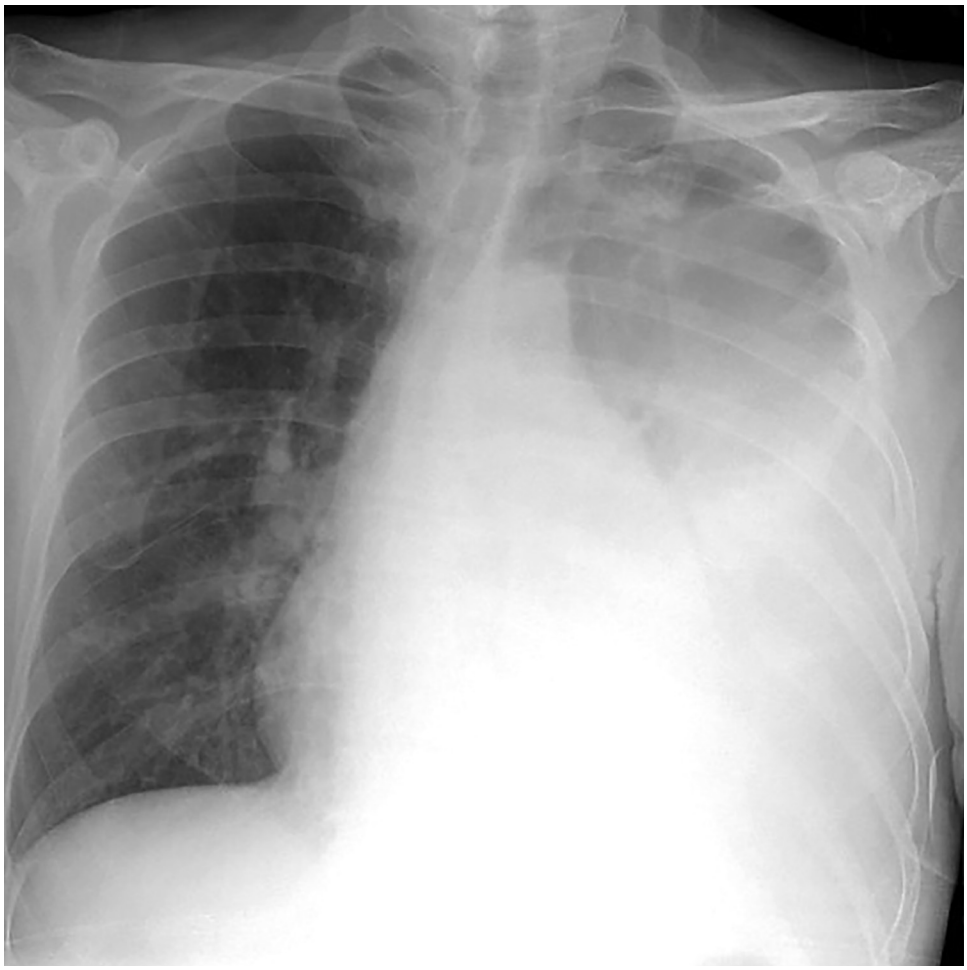
Chapter 1 provided a framework for interpreting chest radiographs and characterizing abnormalities using standard terminology. Chapter 2 illustrated the many chest radiographic abnormalities that can be caused by tuberculosis (TB). In Chapter 3, the goal is to integrate lessons learned thus far and apply that knowledge to clinical cases.

These cases are adapted from presentations gathered from U.S.-based practice but include examples of clinical problems and decision-making challenges that are applicable to any clinician diagnosing and treating TB. For each case, describe the radiographic abnormalities and answer questions relevant to the next steps in the medical evaluation and care based on the radiographic interpretation. The answers to the questions and a summary immediately follow each case.

Case #1

The patient is a 27-year-old woman who was born in Pakistan and moved to the United States at age 3. She reported 2 weeks of pleuritic chest pain, fevers, night sweats, and 5 days of a nonproductive cough. The patient had spent the previous 2 years working in Ethiopia. Two years ago, her tuberculin skin test was 3 mm and now measures 14 mm. Her chest radiograph is shown in Figure 3.1.

FIGURE 3.1.



1. **Describe the chest radiograph using standard terminology.**
2. **Which of the following should be done next?**
   - **A.** Bronchoscopy
   - **B.** Thoracoscopic lung biopsy
   - **C.** Thoracentesis
   - **D.** Treatment of latent TB infection (LTBI)

Case #1 answers

1. Homogeneous opacity occupying more than one-half of the left hemithorax and extending up the lateral chest wall. The opacity is obscuring the left hemidiaphragm and the left heart border.
2. The correct answer is **C**. Because the patient's radiograph demonstrates a large left pleural effusion, the first procedure to be done should be a diagnostic thoracentesis in addition to sputum for smears, cultures, and nucleic acid amplification test (NAAT; e.g., Xpert MTB RIF, line probe, or PCR).
    - Pleural liquid should be obtained for measurement of glucose, protein, lactate dehydrogenase, adenosine deaminase, cell counts, cytology, and microbiological studies. Consider a pleural biopsy if the diagnosis is not evident from the studies listed or if there is concern for drug-resistant TB.
    - Sputum tests remain useful for suspected pulmonary TB with pleural effusions, as the effusion may often hide the presence of parenchymal involvement.

Case #1 summary

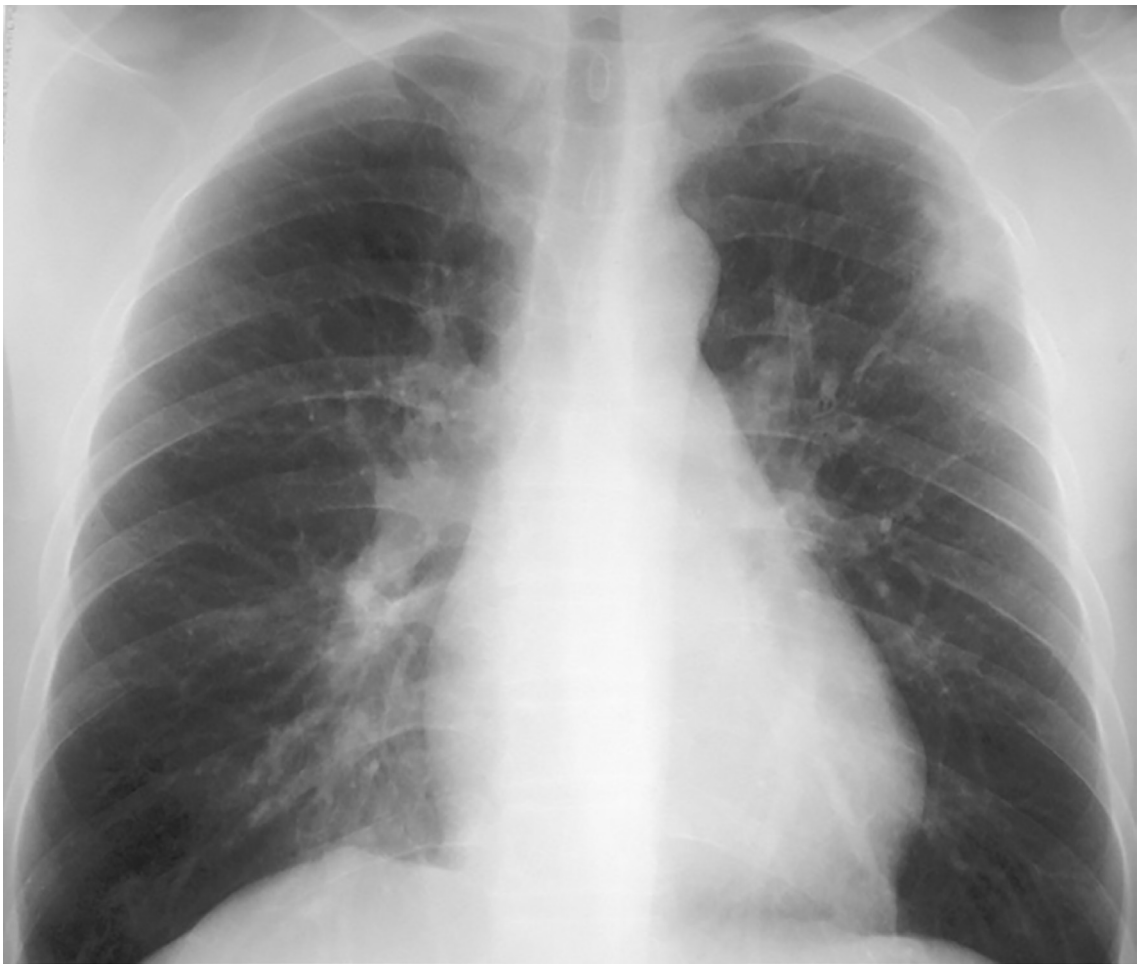
Based on the current radiographic findings, there is no immediate indication for either bronchoscopy or a thoracoscopic lung biopsy. Never start treatment for LTBI (typically with one or two medications) until active disease has been ruled out.

Pleural TB represents one of the most common forms of extrapulmonary TB. TB effusions are often unilateral and paucibacillary resulting from a hypersensitivity reaction to TB bacilli but can, on rare occasions, progress to empyema. The fluid is characterized by an exudative, lymphocyte-predominate pleural fluid. The diagnosis can be difficult to establish because pleural liquid cultures are often negative (culture yield 23-58%). In this case example, sputum and pleural fluid smear and cultures were all negative (NAAT not obtained). Culture of the pleural biopsy later revealed *M. tuberculosis* resistant to isoniazid (INH).

Case #2: Part 1

The patient is a 30-year-old woman from the Philippines who was noted to have an abnormal chest radiograph (Figure 3.2) when she underwent TB screening prior to employment in a healthcare facility. She had a documented positive IGRA test several years earlier and received 6 months of INH treatment. She denies having symptoms, has no underlying medical conditions, and is a non-smoker.

FIGURE 3.2.



1. **How would you describe the chest radiograph?**
2. **Based on your interpretation of the chest radiograph, which of the following are appropriate next steps?** (Choose all that apply)
   - **A.** Collect 3 sputum specimens for acid-fast smears, NAAT, and mycobacterial cultures
   - **B.** Begin treatment for LTBI
   - **C.** Repeat the IGRA
   - **D.** Look for the records and radiographs from her previous evaluation to determine if the radiographic abnormality was present at that time

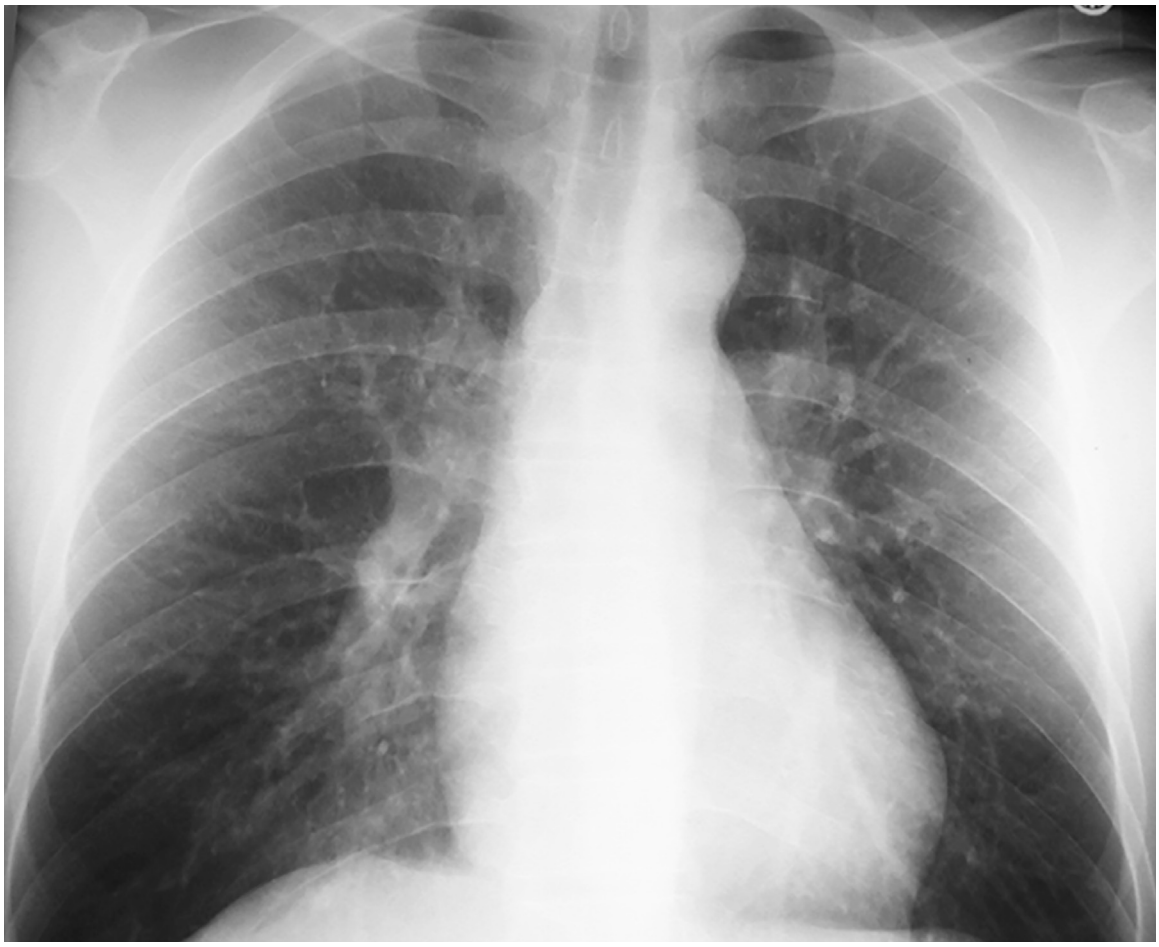
Case #2 answers: Part 1

1. Left upper-lobe peripheral airspace opacity.
2. The correct answers are **A** and **D**. When a patient has a positive TB skin test or IGRA and an abnormal chest radiograph consistent with TB, the first step should always consist of collecting sputum (if not already done) to assess the possibility of active TB. Based on the information provided, chest imaging should have been done when she was evaluated for the previous positive IGRA. An image showing that the lesion was unchanged might lessen the need for additional evaluation, whereas progression of the lesion would indicate the need for further evaluation. Even if the lesion is stable, obtain sputum for microbiological evaluation to confirm no active disease is present, particularly if LTBI treatment is indicated.

Case #2: Part 2

An earlier chest radiograph could not be found and initial test results revealed negative smears and a negative NAAT. She was started on 4 antituberculosis medications pending the results of sputum cultures. After 2 months, the culture results were negative. A repeat chest radiograph was obtained (Figure 3.3).

FIGURE 3.3. **After 2 months of treatment for TB**



3. **How would you describe the chest radiograph?**
4. **Which of the following would be the most appropriate next step?**
   - **A.** Continue multidrug therapy for TB
   - **B.** Obtain a chest CT scan
   - **C.** Perform a fine-needle aspiration of the nodule
   - **D.** Perform bronchoscopy to obtain a better respiratory specimen

Case #2 answers: Part 2

3. Left upper-lobe peripheral opacity is nearly resolved compared with the chest radiograph from 2 months ago.
4. The correct answer is **A**. Because the radiographic abnormality decreased in size and there was no other etiology identified, the patient is considered a clinical (culture-negative) case of TB. Therefore, the multidrug regimen should be continued and the patient treated for active disease.

Case #2 summary

In a patient at increased risk for TB who has an abnormal chest radiograph consistent with TB, the first step should be to obtain sputum for acid-fast smears, NAAT, and mycobacterial cultures. Sputum examination for mycobacteria is necessary because it is not possible to determine if the lesion is residual scarring from previous TB or currently active TB on the basis of a single radiograph.

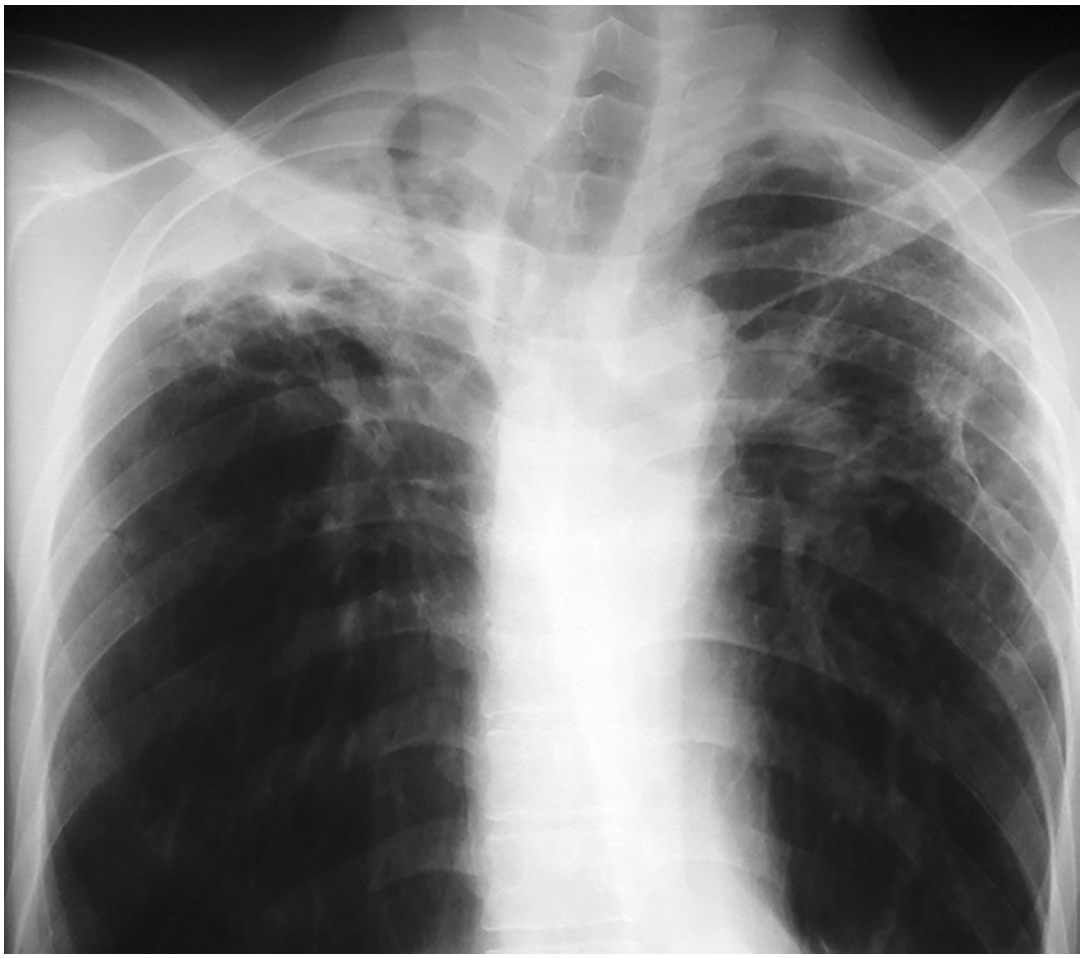
Negative cultures do not necessarily exclude a diagnosis of active TB; usually 15-20% of reported cases in the United States each year are culture negative. Presumably, the negative microbiological tests are due to a low bacillary load. These cases are best managed by follow-up clinical and radiographic evaluation after 2-3 months of multidrug therapy to determine if there has been a response.

If a patient exhibits either a clinical response or significant improvement in the radiograph after 2-3 months of treatment and no other etiology is identified, treatment should be continued for a total of 4 months for culture-negative, active TB. However, in some individuals a 6-month regimen may be indicated.

Case #3

A 60-year-old woman, who immigrated from China 1 month ago, is screened for TB She denies symptoms and has no history of previous TB treatment or other significant medical history. Her IGRA, done as part of her immigration evaluation before arriving to the U.S., was positive. Her immigration chest radiograph done 6 months ago in China is shown in Figure 3.4.

FIGURE 3.4.



1. **How would you describe the chest radiograph?**

Pre-immigration acid-fast smears and cultures of sputum (x 3) were documented as negative in her immigration forms. A repeat chest radiograph now remains unchanged.

2. **What would be the most appropriate next step?**
   - **A.** Obtain sputum for smear, NAAT, and culture. If all tests return as negative for *M. tuberculosis*, treat for LTBI
   - **B.** Treat as culture-negative TB disease with a multidrug regimen for 4 months
   - **C.** Monitor chest radiograph every 3-6 months for 2 years
   - **D.** Obtain chest CT

Case #3 answers

1. Right greater than left upper-lobe fibronodular opacities with volume loss and bilateral hilar retraction. Pronounced right apical pleural thickening.
2. The correct answer is **A**. While the abnormalities described may represent residual damage from prior TB, diagnostic sputum tests should still be done to investigate for active TB disease. Current U.S. TB program practices vary regarding whether overseas sputum results are relied upon before starting LTBI treatment or are repeated when a new immigrant arrives with abnormal chest radiographic findings. Empiric multidrug treatment or a CT scan are not currently indicated given the lack of clinical symptoms and the reassuring lack of interval radiographic change compared to image taken 6 months ago.

Case #3 summary

Patients with a positive IGRA or TB skin test who have radiographic evidence of prior TB and who have not received prior treatment are at increased risk for the subsequent progression to active TB.

- The radiographic findings that constitute evidence of prior TB are upper-lobe opacities or fibrosis, often with volume loss. Other radiographic findings due to prior TB may include bronchiectasis or pleural thickening. In many instances of resolved TB, the chest radiographic findings revert to normal.
- Individuals with LTBI and limited radiographic findings of healed primary TB (e.g., calcified solitary pulmonary nodules, calcified hilar lymph nodes, and pleural thickening without associated parenchymal opacities or fibrosis) are not at increased risk for progression to active TB compared with persons with LTBI and normal chest radiographs.

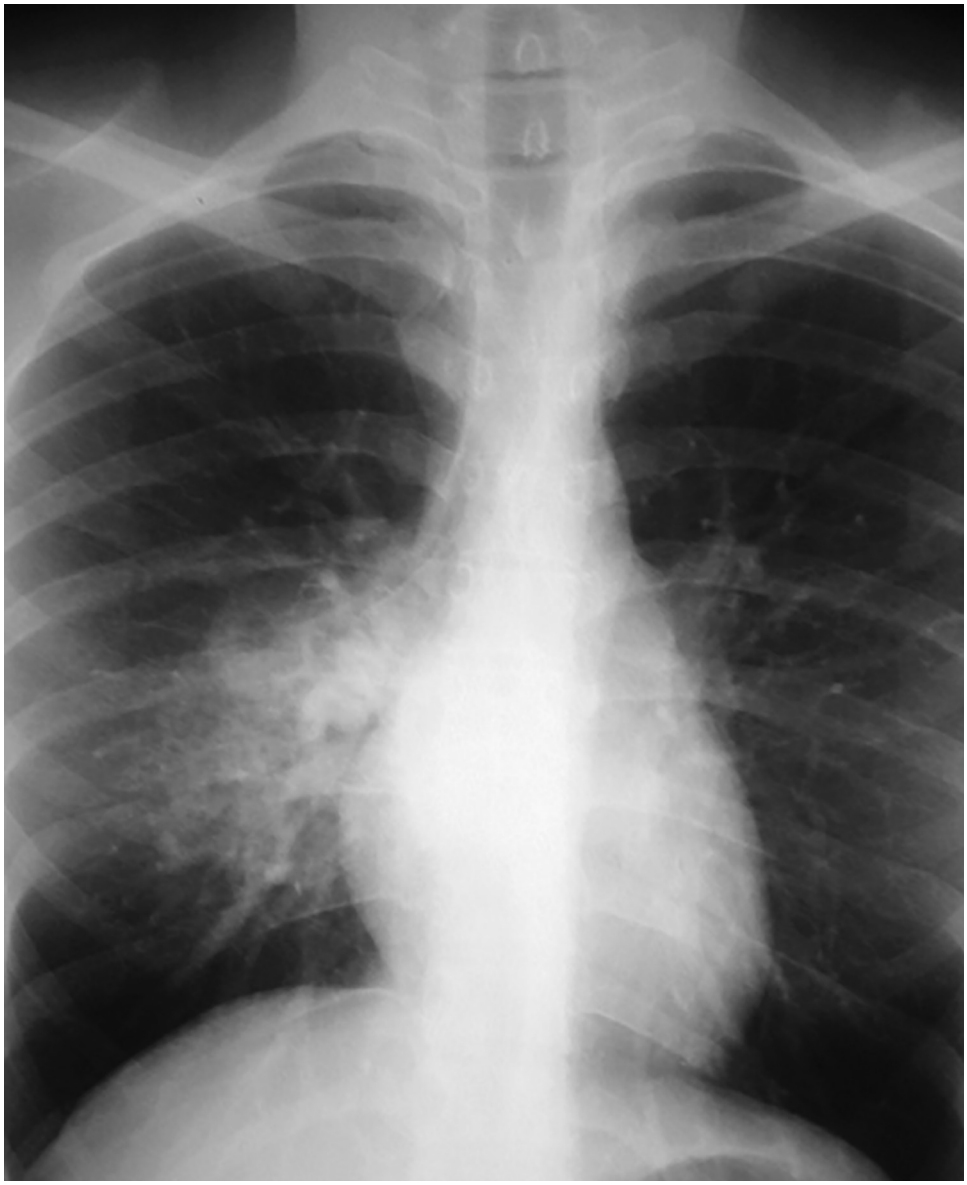
Disease activity cannot be determined from a single chest radiograph. Unless previous radiographs show that the abnormality has not changed, sputum examination should be performed to assess the possibility of active TB. Once active TB has been excluded, consider LTBI treatment for individuals who have not had prior treatment.

The decision to initiate multidrug antituberculosis treatment at the initial evaluation should be based on the degree of clinical suspicion for active TB. If suspicion is high, multidrug therapy should be initiated before smear/culture results are known. If suspicion is low, treatment can be deferred until additional data have been obtained to clarify the diagnosis.

Case #4

A 32-year-old male patient with AIDS presents with a history of fever, cough, dyspnea, and night sweats for the past 3 weeks. His last CD4 lymphocyte count was 550 cells/μL. His radiograph is shown in Figure 3.5.

FIGURE 3.5.



1. **How would you describe the chest radiograph?**
2. **Based on the clinical presentation and your reading of the chest radiograph, what would be the least likely diagnosis?**
   - **A.** TB
   - **B.** Fungal infection
   - **C.** *Pneumocystis jirovecii* pneumonia
   - **D.** *Mycobacterium avium* disease

Case #4 answers

1. Right perihilar consolidation with a focus of cavitation and possible right hilar lymphadenopathy.
2. The correct answer is **C**. Infection with *P. jirovecii* does not usually cause lymphadenopathy, although cavitation can occur. TB is a classic cause of cavitation and lymphadenopathy, but nontuberculous mycobacteria such as *M. avium* may on occasion present with identical radiographic findings. Finally, fungal infections like cryptococcus can cause cavitation and lymphadenopathy and thus need to be included in the differential diagnosis as well.

Case #4 summary

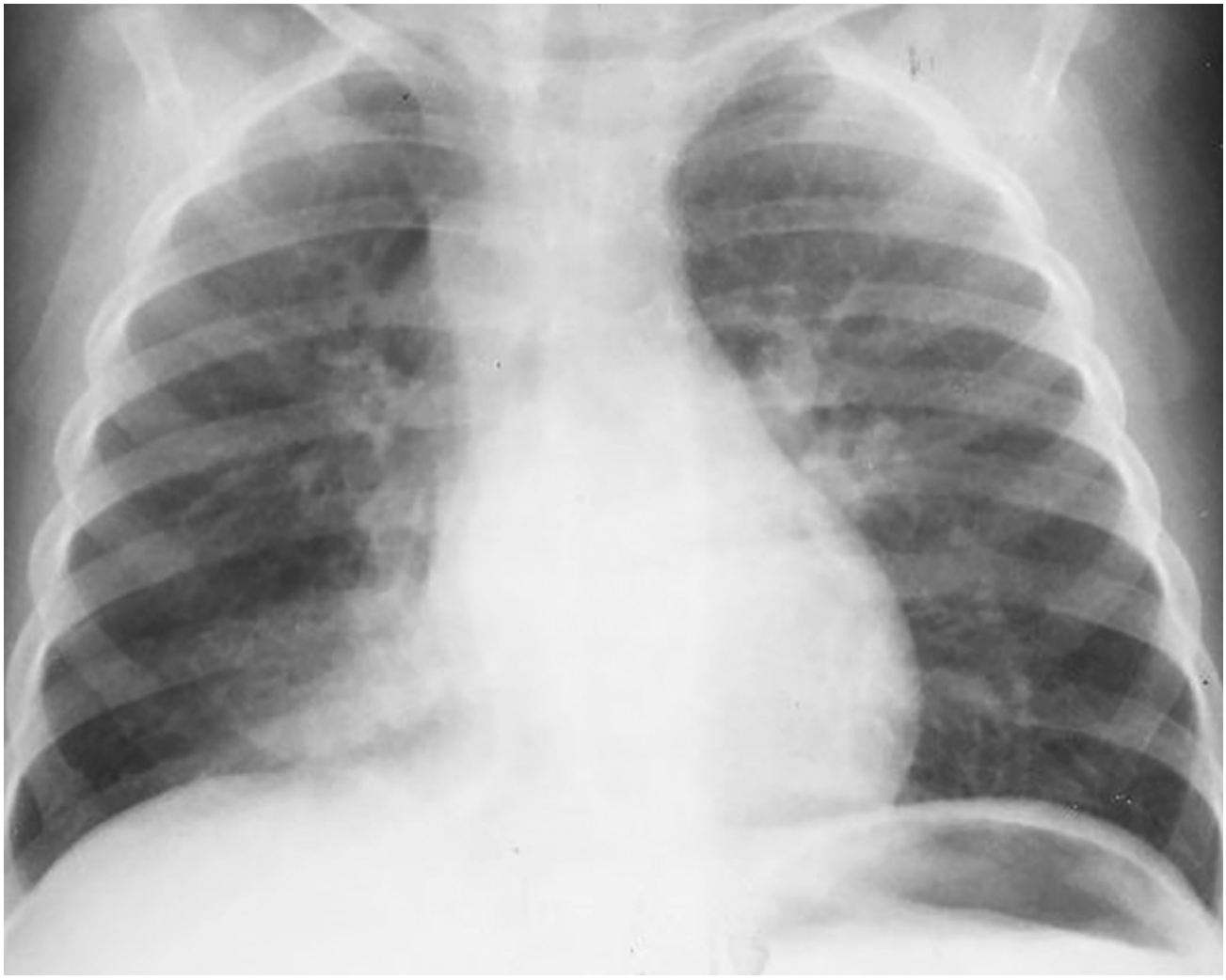
The patient had 3 acid-fast smears which were positive, a positive NAAT for *M. tuberculosis* without rifampin resistance, and was started on directly observed therapy with 4 antituberculosis medications. Final cultures grew *M. tuberculosis.*

Patients with HIV who develop pulmonary disease often present challenging diagnostic dilemmas to clinicians. One reason is the myriad radiographic appearances that the same infection can take in an HIV-positive individual. For example, TB in a person with HIV can appear as lower-lung zone involvement, lymphadenopathy, and pleural effusion instead of the more typical post-primary reactivation pattern of upper-lobe cavitary disease. As a general rule, the more immunosuppressed the patient, the more atypical the chest radiograph findings with respect to TB. Proper interpretation of the chest radiograph is critical in such patients to help guide the diagnostic evaluation. The presence of cavitation and lymphadenopathy in this patient made TB and other mycobacterial and fungal infections much more likely than *P. jirovecii* pneumonia.

Case #5

The patient is a 4-year-old child who presents to a local hospital with fever, cough, and wheezing. The child has no underlying medical conditions. He was recently exposed to 2 family members with culture-positive TB. The organisms are pan-susceptible. His chest radiograph is shown in Figure 3.6.

FIGURE 3.6.



1. **How would you describe the chest radiograph?**
2. **What would be the most appropriate next step?**
   - **A.** Perform bronchoscopy to obtain a good respiratory specimen
   - **B.** Collect sputum specimens for acid-fast smears, NAAT, and cultures
   - **C.** Begin a broad-spectrum antibiotic for community-acquired pneumonia
   - **D.** Begin multidrug antituberculosis therapy

Case #5 answers

1. Right paratracheal and hilar lymphadenopathy and right lower-lung zone consolidation with probable middle-lobe collapse. The right heart border and medial portion of the right hemidiaphragm are not seen (silhouette sign). Note: The image is a lordotic projection (the clavicles are not seen in the image). This projection tends to make objects in the lower half of the thorax appear larger.
2. The correct answer is **D**. Generally, any child with lymphadenopathy on the chest radiograph and recent exposure to adults with TB should be started on antituberculosis therapy. The yield from bronchoscopy is low, and the procedure is not always readily available. It can be very difficult to obtain sputum specimens from a young child. The presence of lymphadenopathy is unlikely to be due to community-acquired pneumonia. Definitive microbiological diagnosis is best made in young children by obtaining aspirates of gastric secretions.

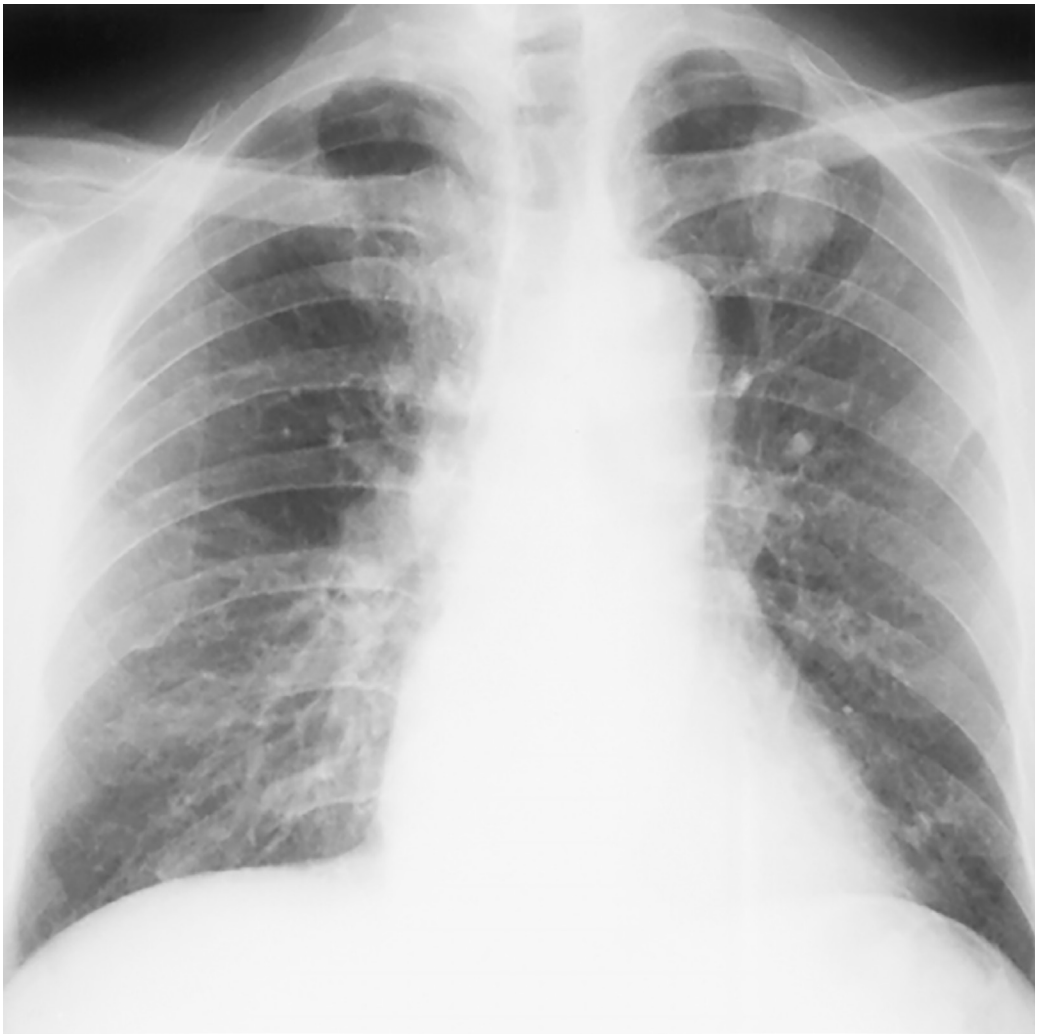
Case #5 summary

It is often challenging to establish a diagnosis of TB in children because it is difficult to obtain sputum or other diagnostic specimens. However in this instance, the epidemiological evidence plus the radiographic findings that are most consistent with TB are sufficient to make a diagnosis of TB, even though microbiological proof from the child is unlikely.

Case #6

A 71-year-old man is evaluated because of a 1-month history of a cough with occasional bloodstreaked sputum. He denies fever or weight loss. He previously smoked cigarettes but stopped 23 years ago. He thought he was treated for TB in the past, but he is unable to provide any details. Eight months ago, he arrived in the United States from China on an immigrant visa. The physical exam is unremarkable. An IGRA test is positive. No prior radiographs are available. Three sputum smears are negative for acid-fast bacilli, but the NAAT is positive (negative rifampin resistance), and cultures are pending. His chest radiograph is shown in Figure 3.7.

FIGURE 3.7.



1. **How would you describe this chest radiograph?**
2. **Which of the following would you do next?**
   - **A.** Begin INH for treatment of LTBI
   - **B.** Begin multidrug TB treatment and obtain a chest CT
   - **C.** Repeat chest radiograph in 6 months

Case #6 answers

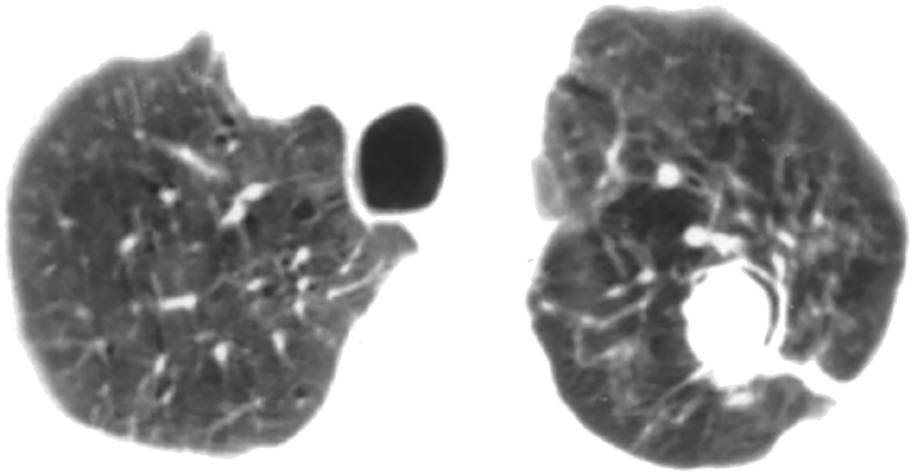
1. Left upper-lobe focal rounded mass with crescent-shaped air collection in its superior aspect.
2. The correct answer is **B**. INH alone should not be started in someone suspected of having potential active TB. A repeat chest radiograph in 6 months would be too long an interval for follow-up.

Case #6 summary

The first step in approaching a patient with a positive IGRA and an abnormal chest radiograph is to obtain sputum for acid-fast smears, NAAT, and cultures. The positive NAAT suggests active disease is likely and multidrug therapy is indicated. An air crescent within the cavity suggests a mycetoma and can be better visualized with a chest CT.

The CT scan (Figure 3.8) indicates that the radiographic abnormality is a mycetoma, which is a fungus ball that develops in a preexisting cavity (in this case, due to prior TB). When a patient with a mycetoma develops massive hemoptysis, embolization or lung resection may be considered for definitive treatment of the hemoptysis. This patient will require treatment for both his active TB and the mycetoma.

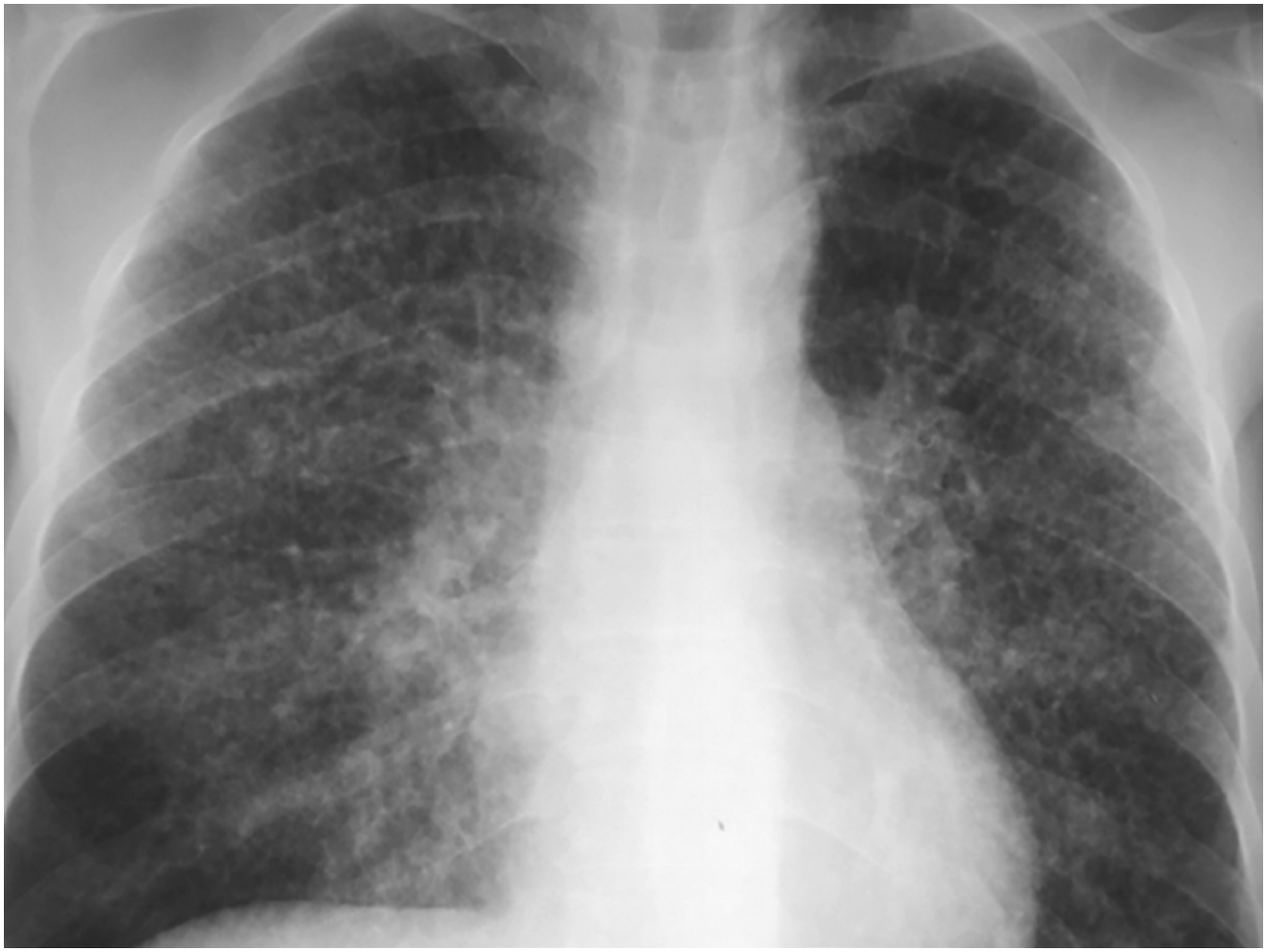
FIGURE 3.8.



Case #7

The patient is a 62-year-old man from India with a 3-month history of fevers, night sweats, intermittent cough, and a 10-kilogram weight loss. His chest radiograph is shown in Figure 3.9.

FIGURE 3.9.



1. **How would you describe this chest radiograph?**
2. **Which of the following diagnostic tests has the highest sensitivity for identifying *M. tuberculosis* in this patient?**
   - **A.** Mycobacterial cultures of blood
   - **B.** Mycobacterial cultures of sputum
   - **C.** Mycobacterial cultures of transbronchial biopsies
   - **D.** Mycobacterial cultures of bronchoalveolar lavage fluid

Case #7 answers

1. Miliary pattern of multiple well-defined, small nodules, mostly 2-3 mm in diameter, that are widespread in distribution.
2. The correct answer is **C**. The diagnostic yield of tuberculosis from transbronchial biopsy (combining both histology and culture) is 50-70% in patients with miliary disease. This pattern is found in patients with disseminated TB and can also be seen in disseminated fungal infections and some malignancies.

Case #7 summary

A miliary pattern is indicative of disseminated disease. It consists of diffuse small nodules the size of millet seeds, about 2 mm in diameter. In TB, the miliary pattern results from hematogenous dissemination of tubercle bacilli, which explains its widespread distribution. A miliary pattern is not specific for TB and can also be seen in disseminated fungal infections and some malignancies (e.g., renal cell carcinoma). Because the miliary pattern is an example of an interstitial pattern, transbronchial tissue provides the highest diagnostic yield. Transbronchial tissue should be examined for the presence of granulomas and cultured for mycobacteria (yield: 50-70%). Sputum samples should be collected as part of the initial evaluation, but more extensive sampling is usually required. Because miliary TB almost always involves other organs, diagnostic alternatives include biopsies of bone marrow (especially in patients with cytopenias) and liver (especially in patients with elevated serum alkaline phosphatase), and cultures of urine. Given the high mortality of disseminated TB, evaluation should occur without delay.

Case #8

The patient is a 54-year-old woman with a 5-week history of fever, night sweats, and a cough productive of foul-smelling sputum. Medical problems include a history of chronic obstructive pulmonary disease and heavy alcohol use. Her last tuberculin skin test 3 years ago had 13 mm of induration. Her chest radiographs are shown in Figures 3.10A and 3.10B.

FIGURE 3.10A. **Frontal**

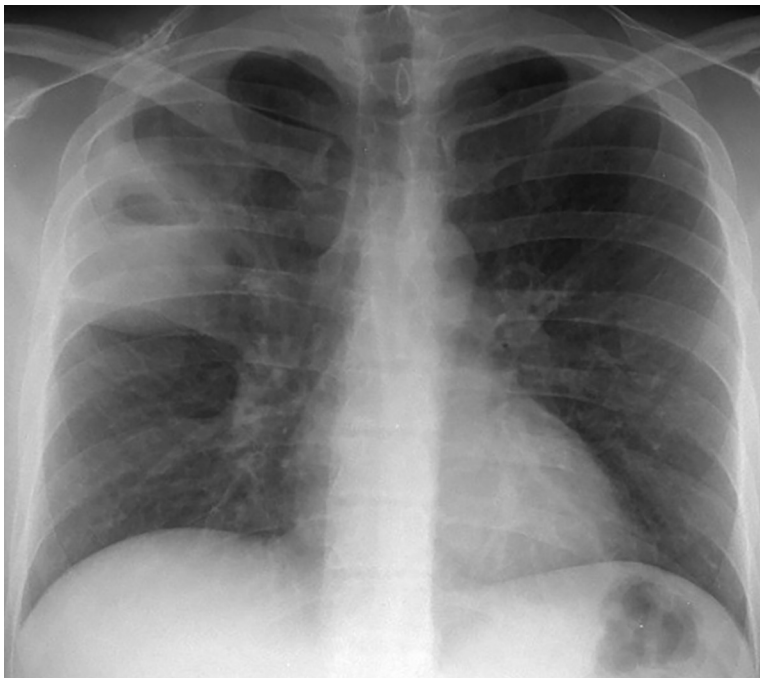
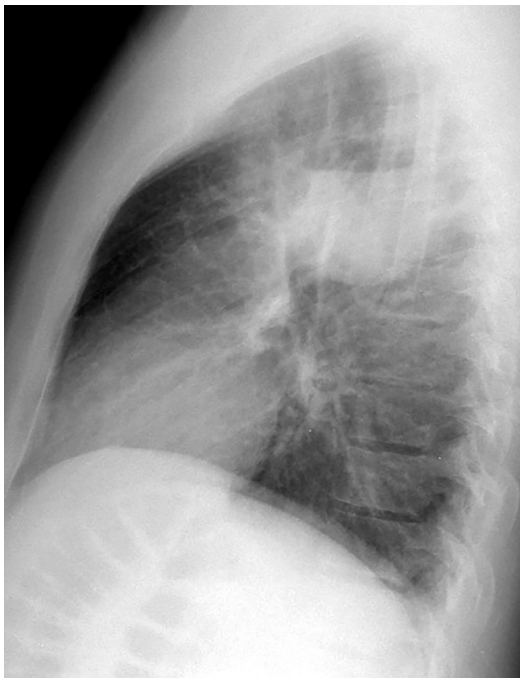


FIGURE 3.10B. **Lateral**



1. **How would you describe these chest radiographs?**
2. **Which of the following would be the most appropriate treatment for this patient?**
   - **A.** Doxycycline
   - **B.** Treatment for anerobic infection
   - **C.** Isoniazid, rifampin, pyrazinamide, and ethambutol
   - **D.** Fluconazole

Case #8 answers

1. Large air-filled spherical density in the right upper lobe that has an air-fluid level.
2. The correct answer is **B**. The differential diagnosis of an air-fluid level in the chest includes lung abscess and other pyogenic infections; hemorrhage into a bulla or cyst; bronchogenic cancer; and noninfectious cavitary lung disease (e.g., Wegener's granulomatosis). Although TB is on the list of diseases associated with cavitation, the presence of an air-fluid level is uncommon. In this case, lung abscess is more likely than the other diagnostic possibilities given the symptom of foul-smelling sputum, and radiographic findings of a thick-walled cavity with an air-fluid level and absence of surrounding infiltrate. Antibiotics like doxycycline do not provide sufficient anaerobic bacterial coverage to be useful for treating a lung abscess. Fluconazole (choice D) should not be used unless a fungal infection is found to be the cause.

Case #8 summary

It is important to identify and properly characterize focal lucent areas on the chest radiograph. There are many causes of focal lucent lesions, but diseases that result in cavitation are among the most important. Causes of pulmonary cavitation include TB, lung abscess, pulmonary infarction, bronchogenic cancer, and non-infectious inflammatory diseases (e.g., Wegener's granulomatosis). These diseases have different clinical presentations, so obtaining a good history is an important first step. The next step in the diagnostic evaluation is usually collecting sputum for microbiologic studies and cytologic examination. Patients should also be placed in respiratory isolation if TB is suspected on the basis of either the radiographic findings or clinical examination.

Take-home points

Proper interpretation of the chest radiograph is an essential component of the diagnostic evaluation of any person with potential TB. The radiographs and clinical case scenarios in this chapter intend to illustrate common patterns associated with pulmonary TB and to very briefly discuss how the findings fit into the sequence of diagnostic and/or therapeutic approaches. Importantly, the cases highlight some basic principles related to the role of radiography in the diagnosis of pulmonary TB. Some of these principles are:

- Chest radiographs cannot establish a diagnosis of TB, but they are highly influential in suggesting or guiding clinicians' diagnostic approaches that can confirm a diagnosis.
- An exception to this rule can occur in persons with radiographic findings consistent with pulmonary TB but with negative microbiologic tests who have positive IGRAs or TB skin tests and are given multidrug treatment empirically. If no alternate diagnosis is established and a follow-up radiograph 2-3 months after starting anti-TB treatment shows improvement, a clinical diagnosis of TB is strongly inferred.
- In general, while there are differences in the radiographic patterns of "primary" and "post-primary" TB, there is considerable overlap.
- Radiographic findings of healed primary TB (e.g., calcified solitary pulmonary nodules, calcified hilar lymph nodes, and pleural thickening without associated parenchymal opacities or fibrosis) are not indicative of an increased risk for progression to active TB.
- It is essentially impossible to diagnose "old, inactive TB" from a single chest radiograph. Appropriate specimens for microbiological testing should be obtained from any patient with an abnormal chest radiograph in whom a diagnosis of TB is being considered.
- Prior radiographs, if available, should be sought. They can help to determine if a given lesion is active (progressing) or inactive (unchanging).
- Clinical suspicion for TB in children is often based on a positive tuberculin skin test or IGRA and an abnormal chest radiograph showing lymphadenopathy as well as parenchymal abnormalities.
- People with immunocompromising conditions or treatments commonly have "atypical" chest radiographic findings with lower-lobe opacities, hilar and mediastinal lymphadenopathy, and little or no cavitation.

Although not explicitly stated, the clinical scenarios imply that communication/discussion between radiologists and clinicians is highly desirable, if not essential, to get the most information from chest radiographs.

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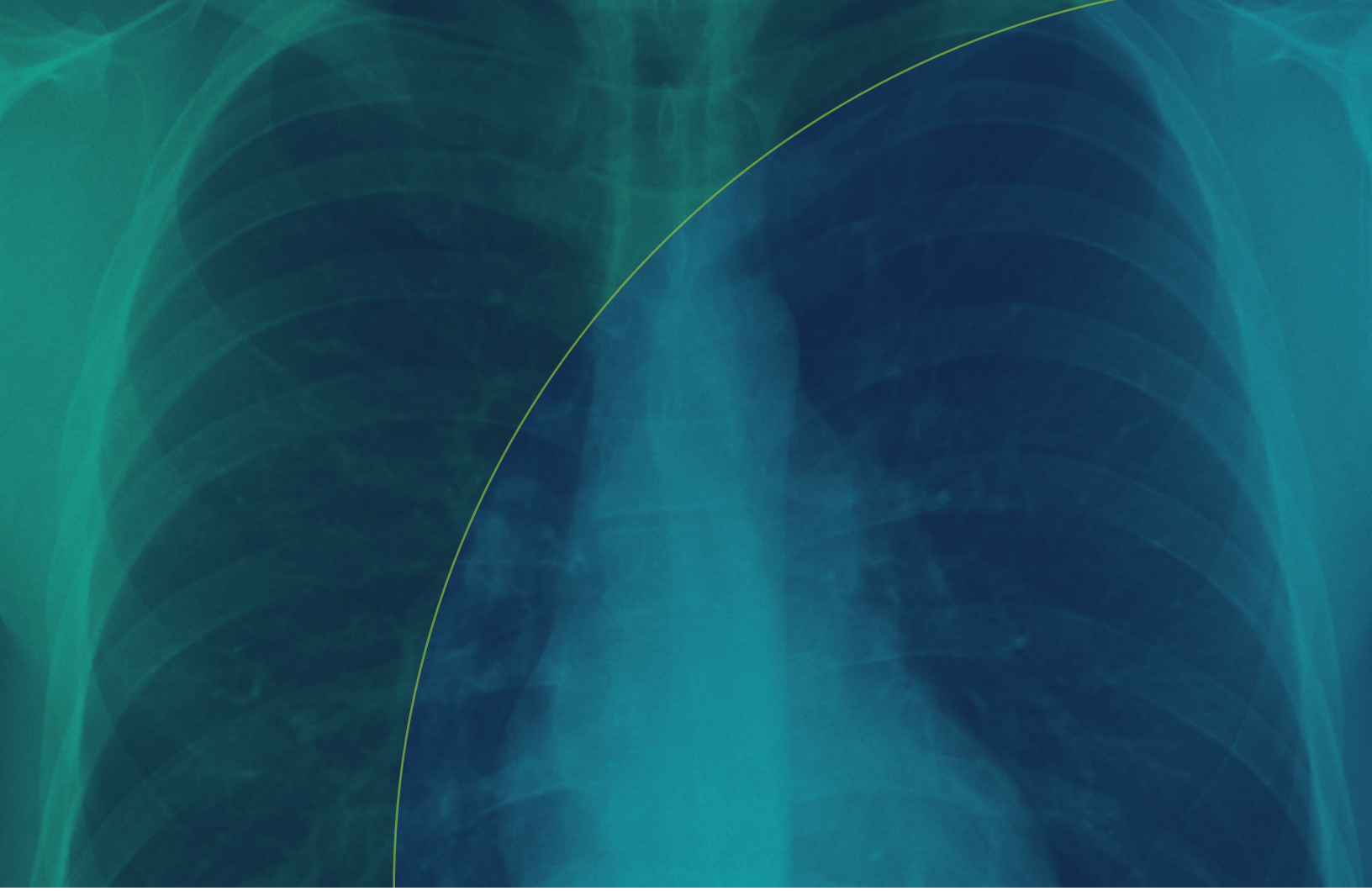

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