CHEST

Learning a methodology for interpreting chest radiographs

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What modalities are used to image the chest?

The most commonly ordered X-ray is a chest X-ray, which is the quickest and most cost-effective way to begin imaging the thorax. Regardless of the diagnosis as it relates to cardiopulmonary disease, a PA and lateral chest X-ray gives valuable information and serves as a baseline to confirm the effectiveness of treatment. An AP chest is done when the patient is unable to be moved, usually because of the severity of his or her illness. As you will learn, the AP portable chest X-ray has definite diagnostic limitations. Sometimes viewing the lungs in expiration is helpful (please see section 4). A decubitus chest X-ray takes advantage of gravity. Air goes up and fluid goes down. This maneuver can help us be more specific with a diagnosis. CT, MRI, and PET have specific indications in the thorax, almost always to clarify or further characterize an abnormality seen on the PA and lateral chest X-ray.

Chest imaging modalities:

PA and lateral chest X-ray
AP portable chest X-ray
Expiratory PA chest X-ray
Lateral decubitus chest X-ray
Chest CT
Chest MRI
PET scanning

What is PA?

PA stands for *posterior to anterior*, which is the direction of the X-ray beam as it passes through the patient. As the patient stands with the anterior chest wall closest to the film, the technologist asks the patient to take in a deep breath and hold it. X-rays pass from posterior to anterior to expose the film. In this position, the heart is closer to the film than on an AP view and there is less magnification of the cardiac silhouette. For the lateral view, the patient stands with the left side closest to the film, again to reduce magnification of the heart shadow.

Normal PA chest

Normal lateral chest

When would I order an AP portable chest?

If a patient is too unstable or too ill to be transported to the radiology department, the only option is a single view with a portable X-ray machine brought to the bedside. This frequently occurs in the emergency department, in surgery, or in an intensive care unit. An AP portable chest is inferior to a PA or lateral. Problems with an AP chest include the following:

Magnification of the heart shadow
Artifacts from lead wires, lines, bedsheets, and skin folds
Patient motion artifacts
Patient rotation
Visualization of the chest in one plane only (a lateral is not performed mobile)
Variable exposure factors related to the equipment used

When would I order an expiratory PA chest?

The two most common indications for an expiratory PA chest are pneumothorax and foreign body aspiration. An expiratory phase film helps with the following:

Suspected pneumothorax: Forcing air out of the lungs allows the visceral pleura and the air in the pleural space to be observed to greater advantage. When the air inside the lung is forced out by expiration, the density of the lung increases. The air trapped in the pleural space remains low in density (air density shows as black). The trapped air in the pneumothorax then becomes easier to identify.

Suspected foreign body: If a patient, usually a child, aspirates a foreign body, it will commonly lodge in the right main stem bronchus. There it may act as a ball valve, allowing air to pass into the lung but not out. An expiratory film will demonstrate the persistent aeration of the obstructed lung, even if the foreign body is not opaque (visible). The obstructed lung will stay inflated on both inspiration and expiration, while the unaffected lung will inflate and empty.

What does a lateral decubitus chest X-ray show?

We often use gravity to help us differentiate between free-flowing pleural effusion and loculated fluid (fluid caught up in an area of pleural scarring) or pleural thickening. A transudate is a thin fluid collection that layers in the pleural space along the lateral thoracic wall when the affected side is down. The lateral decubitus film helps to demonstrate that the fluid is freely movable. We can thus better estimate the quantity of fluid and plan for thoracentesis (drawing off fluid for diagnosis or therapy). An exudate is a thick or viscous fluid collection. Exudates may be seen in infection (pyothorax) or in association with cancer (mesothelioma or metastatic disease). Exudates are slower to layer on a decubitus X-ray and may not layer at all.

TEST YOUR KNOWLEDGE:

You suspect a freely movable right pleural effusion (transudate). What X-ray study would you request?

Answer: PA and lateral chest with a right lateral decubitus view.

I'm looking at the PA and lateral chest. Now what? Where do I start?

1. Check the name and the date on the radiograph.
2. Examine the film for quality. Is it over- or underexposed? If you can see the disk spaces in the thoracic spine through the heart shadow on a PA radiograph, the film is overexposed. Is the patient rotated? Is there a good depth of inspiration? If you can count 8.5–11 posterior rib structures above the diaphragm, that's a good inspiration.

3. Use the mnemonic "MDPLOTS" as a guide:

M = Mediastinum
D = Diaphragm
P = Pleura
L = Lungs
O = Osseous structures
T = Trachea
S = Soft tissues

KEY POINT:

Any structure, normal or pathologic, should be analyzed for

1. Size
2. Shape and contour
3. Position
4. Density

How do I examine the mediastinum?

The boundaries of the mediastinum are noted below. If you understand what structures live there, you will understand what pathologies can occur there. The mediastinum has normal and predictable contours, and evaluating the mediastinum on a chest X-ray requires contour assessment.

On the PA view, superiorly, the right and left lateral margins of the mediastinum are slightly concave. The right border is created by the superior vena cava and the left border is created by the left subclavian artery. The trachea should be midline, except at the level of the aortic arch where the trachea descends to the right. As we move caudally, we will see a contour bulge on the left created by the aortic arch. A concavity called the aorticopulmonary window normally occurs between the undersurface of the aortic arch and the top of the left main pulmonary artery. On the right is a normal contour bulge where the azygos vein enters the superior vena cava. The hilar areas are located along both sides of the heart shadow. The vessels should resemble the branching of a tree trunk: three major branches on the right and two on the left. The pulmonary veins also enter the mediastinum at this location. Therefore, the hilar areas are a busy place and require close scrutiny on the radiograph. The ascending aorta can cause a normal, smooth convexity just above the right hilum leading to the aortic arch. On the left, there may be a subtle contour bulge made by the left atrium. The right heart border is created by the right atrium. The left heart border is created by a small segment of the left atrium but predominantly the left ventricle.

Divisions of the mediastinum:

1. Superior mediastinum: Contents of the chest above a line drawn between T5 and the sternal manubrium, fat, small lymph nodes, arteries, veins, and sometimes the thyroid gland.
2. Inferior mediastinum:
   a. Anterior: The anterior boundary of the anterior part is the posterior sternum. Its posterior boundary is the pericardium of the heart. It contains fat, small lymph nodes, and the thymus gland.
   b. Middle: The middle mediastinum is composed of the pericardium and the heart.
   c. Posterior: The anterior boundary of the posterior mediastinum is the posterior pericardial sac. The posterior boundary is the anterior surfaces of the bodies of thoracic vertebrae T5-T12. Neural tissue, the esophagus, and lymph nodes live here.

Summary of mediastinal evaluation:

1. The *width* of the mediastinum
2. The shape or *contour*
3. The *midline position* of the mediastinal structures
4. The *density* of the mediastinum (i.e., calcium density in mediastinal teratoma)

Common causes of abnormally widened superior mediastinum:

1. Distention of the superior vena cava in CHF
2. Mediastinal hemorrhage following blunt chest trauma
3. Aneurysm of any of the three aortic arch branches (brachiocephalic, left common carotid, and left subclavian arteries)
4. Excessive mediastinal fat (Cushing's disease, steroid use)
5. Lymphadenopathy
6. Metastatic disease
7. Tumors such as thymoma, teratoma, or substernal goiter
8. Air (pneumomediastinum)

Causes of widened superior mediastinum with smooth contours:

1. Distension of the superior vena cava
2. Hemorrhage
3. Fat

Causes of lobulated superior mediastinal contour:

1. Aneurysms
2. Masses
3. Lymphadenopathy

Causes of shift of the mediastinum:

1. Toward pathology: volume loss (atelectasis), postoperative lobectomy or pneumonectomy, scarring or fibrosis
2. Away from pathology: lung mass, tension pneumothorax, large pleural effusion, pulmonary consolidation (rare)

Chest X-ray: left superior mediastinal mass

CT: thyroid mass

What can I tell about the mediastinum based on density?

Calcification is the most helpful density to identify when looking at the mediastinum.

Calcium density can be seen in

> Teratomas
> Granulomatous lymph nodes (histoplasmosis)
> Calcified walls of an aneurysm
> Goiters (rare)

How do I examine the hemidiaphragms?

Analyzing the hemidiaphragms involves primarily assessing diaphragmatic position and contour. The right hemidiaphragm is usually higher than the left, probably because of the liver being below the right hemidiaphragm and the heart being above the left hemidiaphragm. If specific information about diaphragmatic motion is required, ask for chest fluoroscopy. The radiologist can watch the hemidiaphragms move during expiration, inspiration, sniffing, and Valsalva maneuvers.

What causes elevation of the diaphragm?

The diaphragm can be pushed or pulled. What can push the diaphragm down?

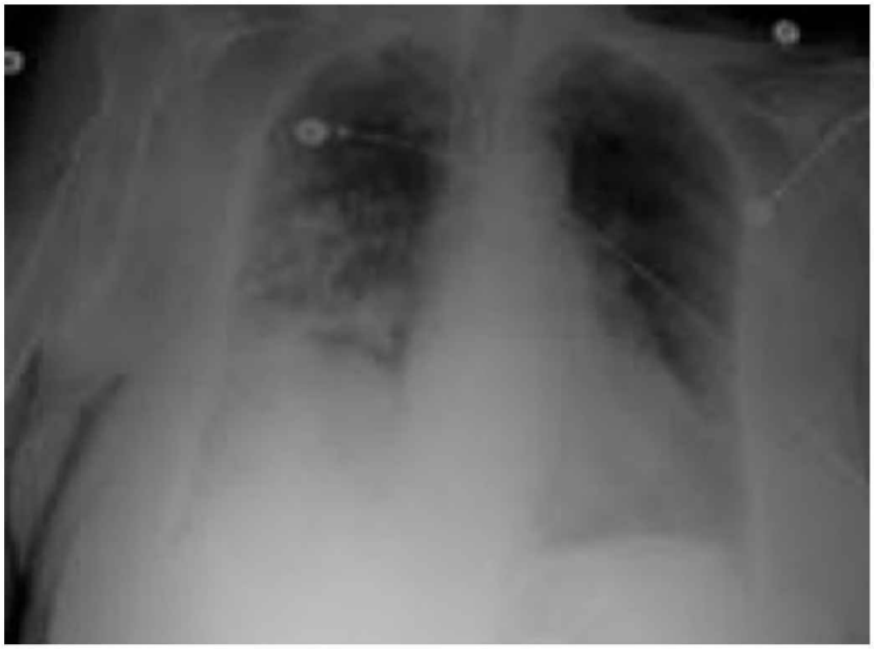
> Pressure buildup in the pleural space in tension pneumothorax
> Large pleural effusions
> Air trapping in the lungs, such as with emphysema or asthma
> Tumors, pleural and pulmonary
> Consolidating pneumonia or lung abscess

What can push the diaphragm up?

> Hepatic enlargement
> Ascites
> Splenomegaly
> Air buildup in the hepatic flexure, transverse colon, or splenic flexure

What can pull the diaphragm up?

> Scar tissue in a lower lobe of the lung
> Atelectasis in a lower lobe
> Previous pneumonectomy or lobectomy; with loss of volume, the diaphragm rises to fill the void



Elevated right diaphragm consistent with RLL volume loss

Note: Masses arising from the diaphragm itself are rare.

How do I examine the pleura?

The pleural space is actually a potential space between the parietal pleura, which lines the inside of the chest wall and the visceral pleura, which covers the lungs. A small amount of fluid and a slight negative pressure keep the pleural linings together. When examining the pleura, begin at the medial aspect of the right diaphragm, follow the diaphragm laterally, examine the lateral chest wall from bottom to top, and continue down the mediastinum to the point where you began. Repeat the process on the left side. If the pleura is visible, it is abnormal.

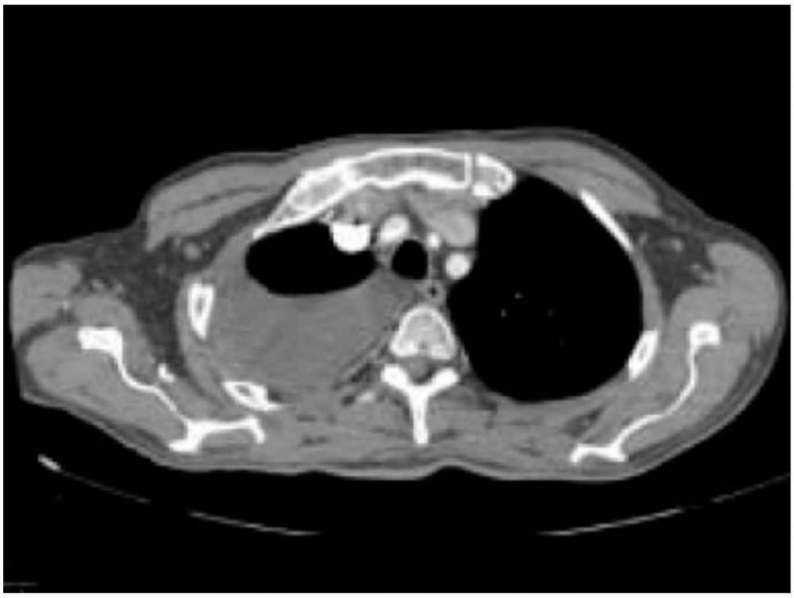
What can go wrong in the pleural space?

Typically, what can go wrong in the pleural space is that something else fills it, such as

> Air in the case of pneumothorax
> Lymph in chylothorax
> Pus (pathogens and inflammatory cells) in empyema
> Serous (thin) fluid in pleural effusion
> Exudative (thick) fluid in pleural effusion
> Cancer cells in malignant effusion
> Blood in hemothorax
> Scar tissue (pleural thickening) in diseases such as asbestosis and tuberculosis

The two most common conditions resulting in an abnormal pleural space are pneumothorax and serous pleural effusion.

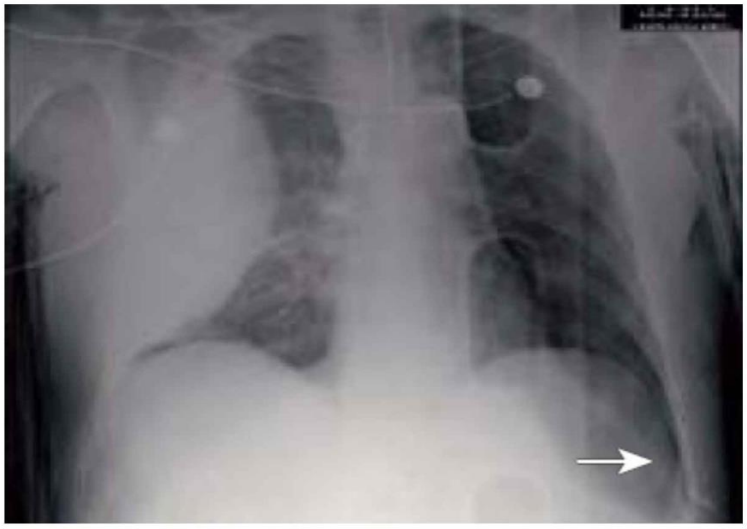
Right pleural effusion



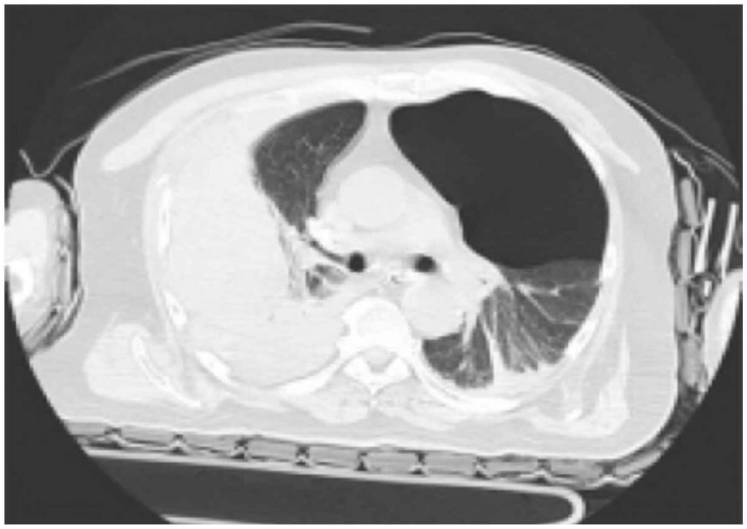
CT: right pleural effusion

How can I recognize a pneumothorax on a chest X-ray?

If you carefully examine the most gravity-independent portion of the chest (the apices on an upright PA radiograph), you will note that the lung markings (composed of blood vessels and bronchial structures) do not extend all the way to the chest wall. You will be able to see the thin visceral pleura. The abnormally accumulated air in the pleural space is clear and devoid of any markings. To exaggerate this appearance, request an expiratory phase PA chest X-ray, which is taken with the patient at end exhalation. The markings in the lungs become accentuated in expiration, and therefore the density difference between the partially empty lung tissue and the air in the pleural space becomes more obvious.



Deep sulcus sign (left pneumothorax)/right hemothorax

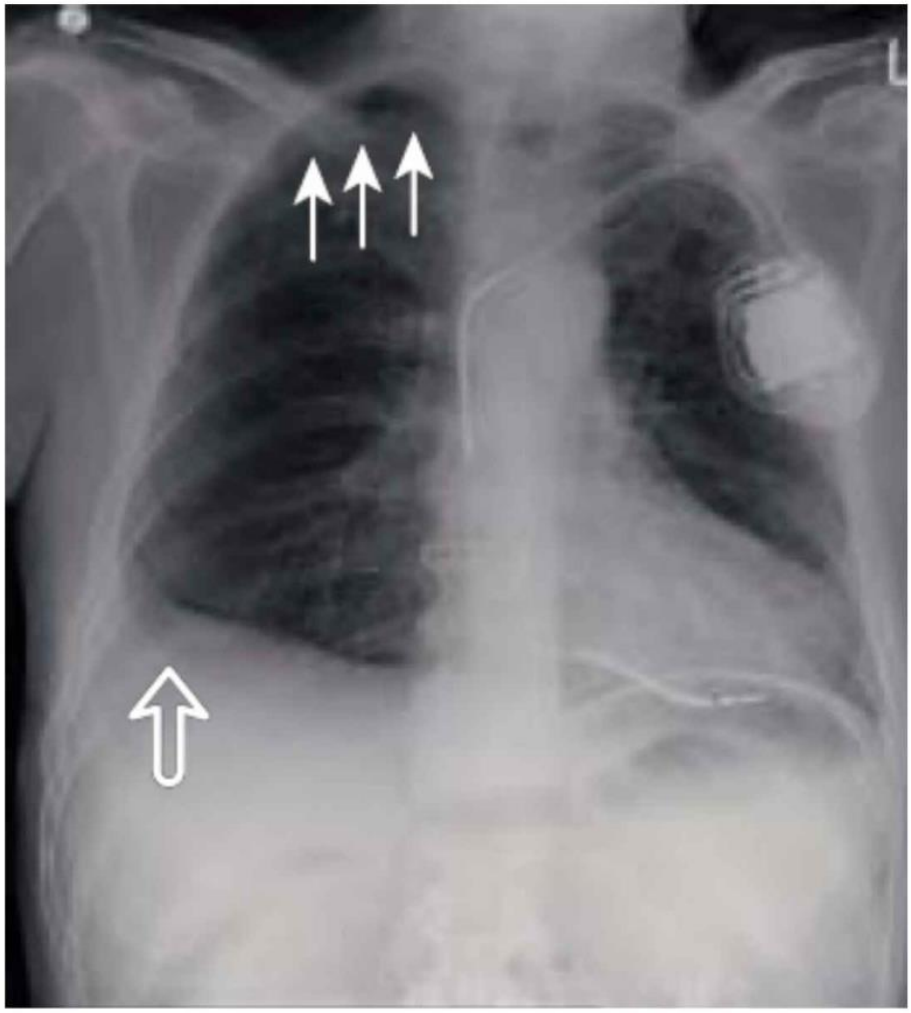


Right hemothorax/left pneumothorax on CT

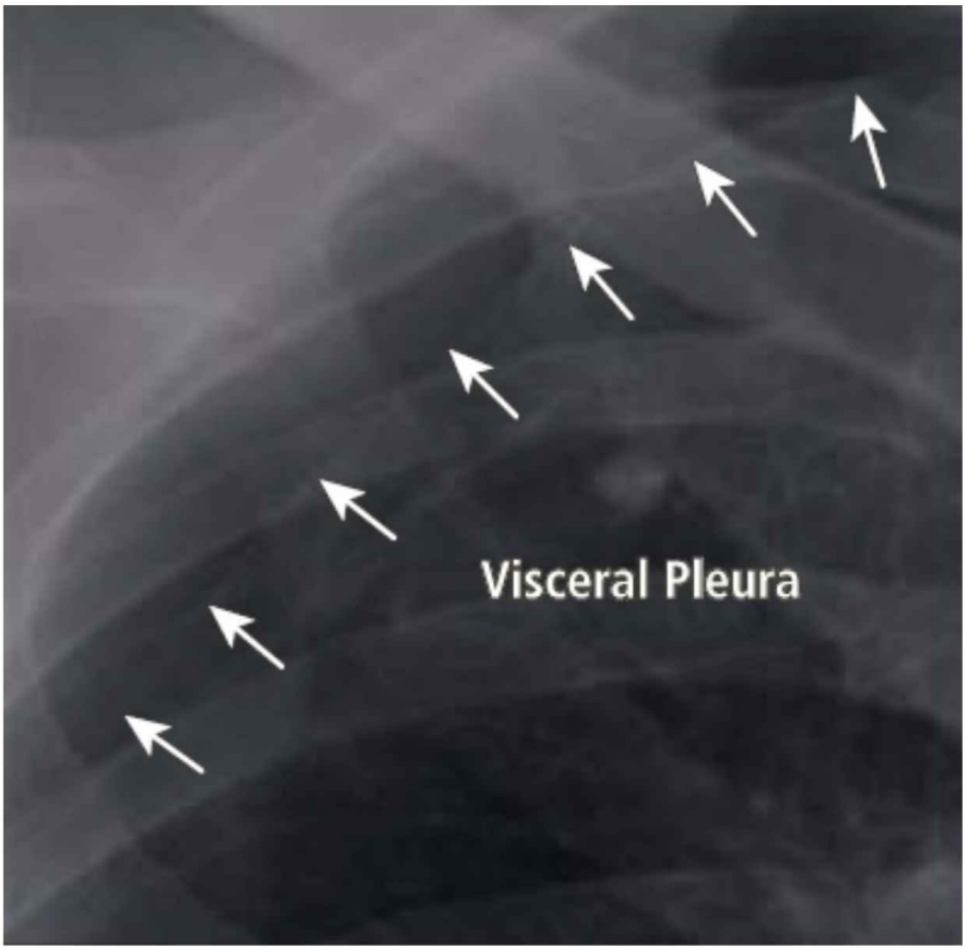
What does pleural effusion look like?

Fluid falls to fill the most gravity-dependent portion of the pleural space. This occurs adjacent to the diaphragms in the posterior and lateral costophrenic angles. The costophrenic angles are the key to the diagnosis. The apex of the sharp angle between the chest wall and the diaphragm should be pointing down. When this space fills with fluid, the angles are filled in (blunted). Fluid clinging to the edges of the costophrenic angle creates a meniscus (cup shape).

A useful maneuver to determine if the fluid is serous and free to flow in the pleural space is to place the patient on his or her side with the effusion side down. The chest X-ray will show the fluid layering along the lateral chest wall. Doing this will provide two important pieces of information: first, you will know that the fluid is thin enough to move, and second, you will know that it is not loculated or trapped. A film can be obtained with the patient lying in a lateral decubitus position, that is, on his or her side. If you suspect a right pleural effusion, order a right lateral decubitus chest X-ray.



Arrows: right apical pneumothorax Block arrow: pleural effusion



Visible visceral pleura = pneumothorax

How do I examine the lungs?

The lungs are most often the primary reason for obtaining a chest X-ray. The right side of the chest should be compared to the left side from top to bottom. I like to compare the top thirds of the lungs first, then the middle thirds, and finally the bottom thirds. As always, a global or overall impression of both lungs helps to give an initial impression. Pathology in the lungs can be broken down into conditions that fill the lungs and those that collapse the lungs.

What things can fill the lungs?

> Excessive air, such as with emphysema or asthma
> Blood, pus, or fluid in the alveolar spaces
> Thickened connective tissue (the interstitial portions) of the lungs
> Tumors

What are the findings in emphysema?

Emphysema and asthma are common forms of chronic obstructive pulmonary disease.

Air gets into the alveolar spaces but has trouble getting out because of chronic inflammatory narrowing, spasm, or mucus within the bronchi. Because air is black on an X-ray, when there is excess air, the lungs look darker than normal (hyperlucent). As the chest accommodates more volume, the anterior to posterior diameter increases (barrel chest) and the space behind the sternum widens (increased retrosternal clear space). You may notice that the rib spaces are wider and the diaphragms, normally convex superiorly, are flattened or depressed. Pressure from the increased air volume compresses the peripheral veins such that the pulmonary vasculature appears tapered. The heart also has to pump against this increased pressure, resulting in enlargement of the central pulmonary arteries with peripheral arterial narrowing.

Summary of findings in chronic obstructive pulmonary disease:

> Pulmonary overaeration (dark-looking lungs)
> Increased AP diameter of the chest
> Widened retrosternal clear space
> Widened intercostal spaces
> Flattening of the hemidiaphragms
> Tapering of the peripheral pulmonary vasculature
> Engorgement of the central pulmonary arteries

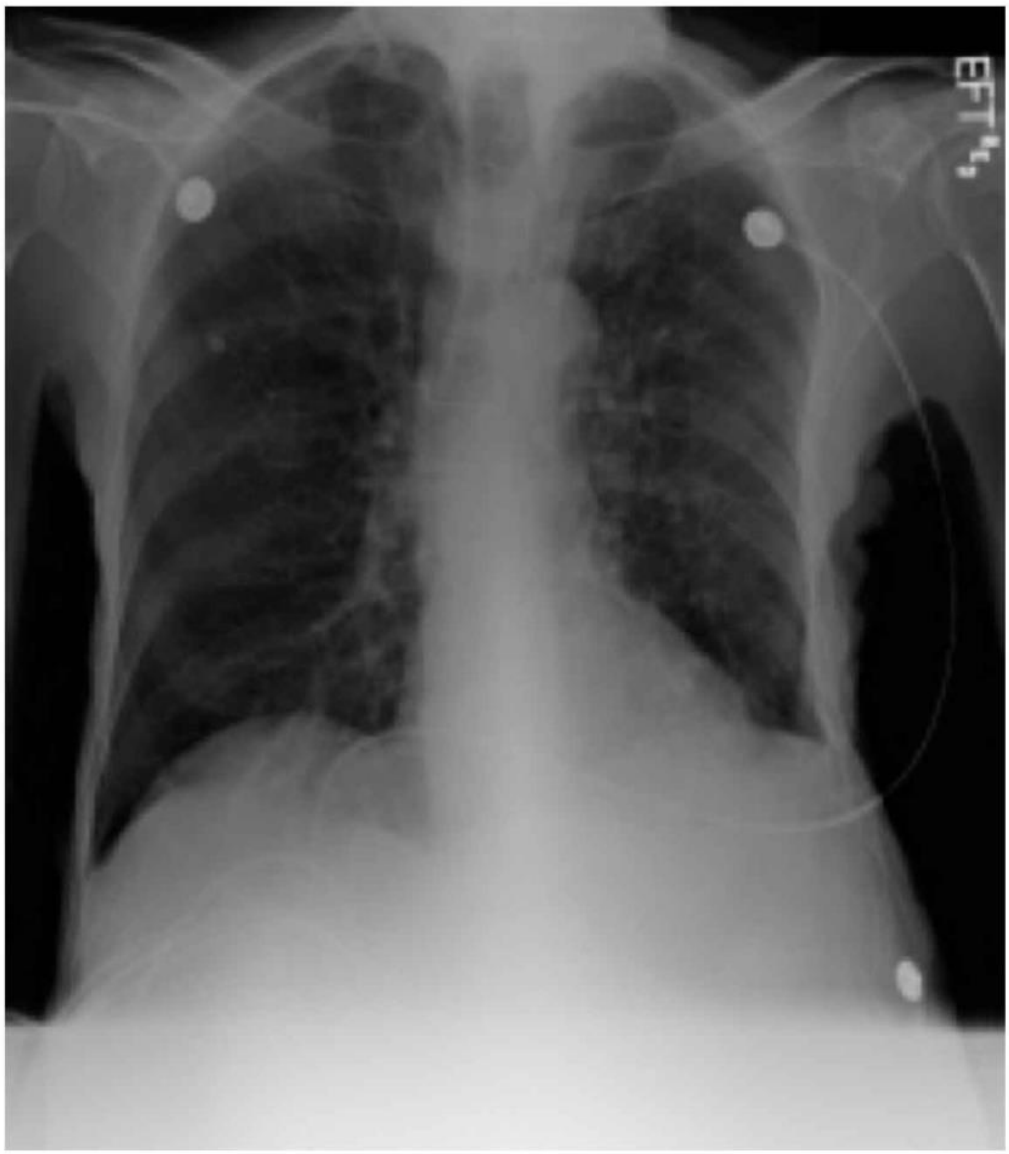
Chronic obstructive pulmonary disease

What are the causes of alveolar lung disease?

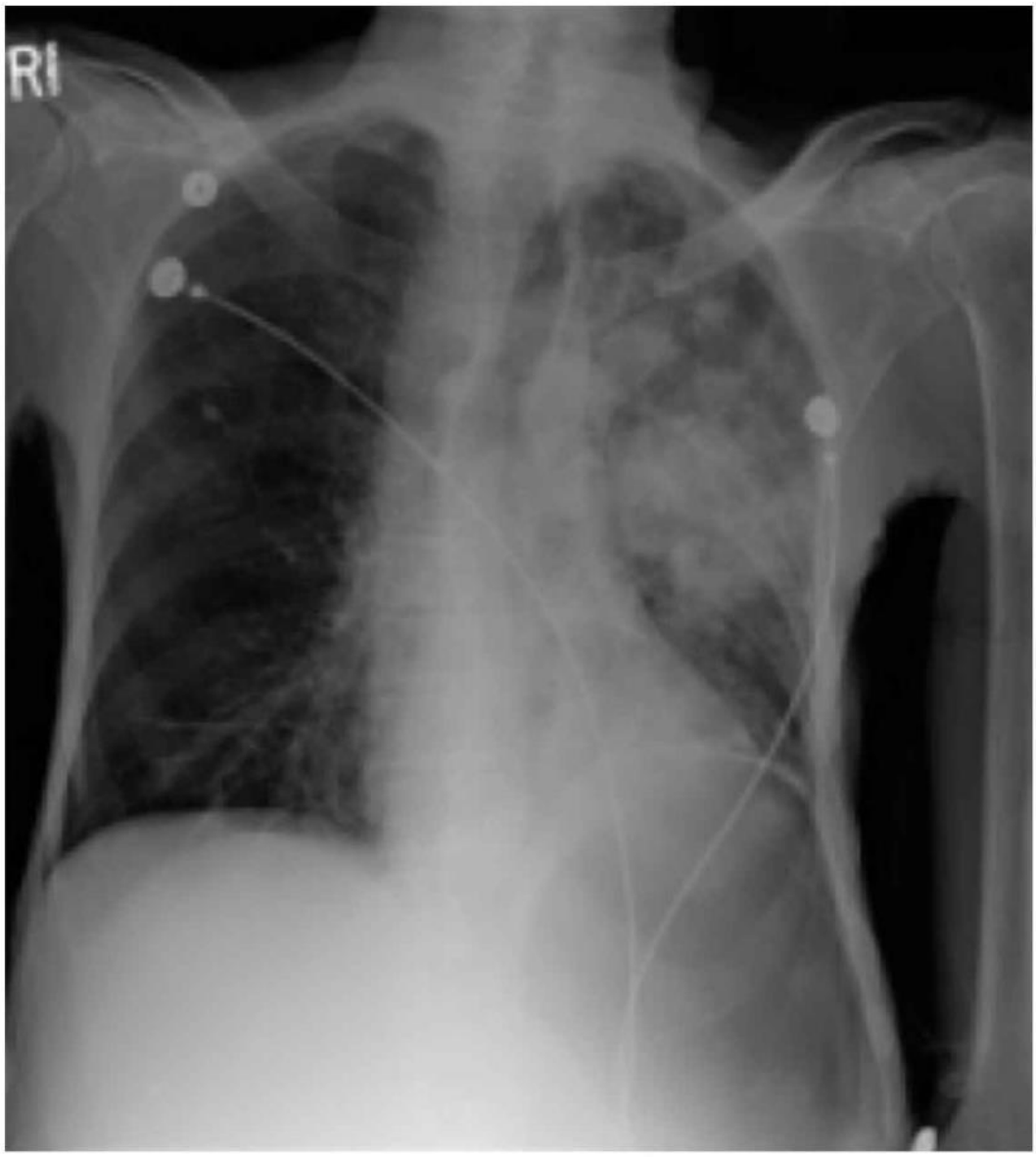
In the pure form of alveolar lung disease (also called air space disease), fluid of some type is occupying the air sacs. The three types of fluid responsible for the vast majority of alveolar lung disease are pus (pneumonia), water (pulmonary edema), and blood (pulmonary hemorrhage). On a chest X-ray, alveolar lung disease appears as a cumulus cloud. The opacity is coalescent and can vary in density from wispy to dense. *Consolidation* is the term applied to the densest type of alveolar lung disease. The air bronchogram is the hallmark of alveolar lung disease. This important sign occurs when the alveolar sacs within the acini of the lung fill with blood, pus, or fluid, allowing us to see the air-filled bronchi. Without alveolar disease, the bronchi are not visible because the alveoli and the adjacent bronchi are filled with air and cannot be distinguished from one another.

Summary: Causes of alveolar lung disease

Blood = Pulmonary laceration, contusion, Goodpasture's syndrome
Pus = Any pneumonia, but especially bacterial pneumonia
Fluid = Pulmonary edema from any cause, congestive heart failure, near-drowning, high-altitude pulmonary edema



Chest X-ray: prepneumonia



Left upper lobe pneumonia

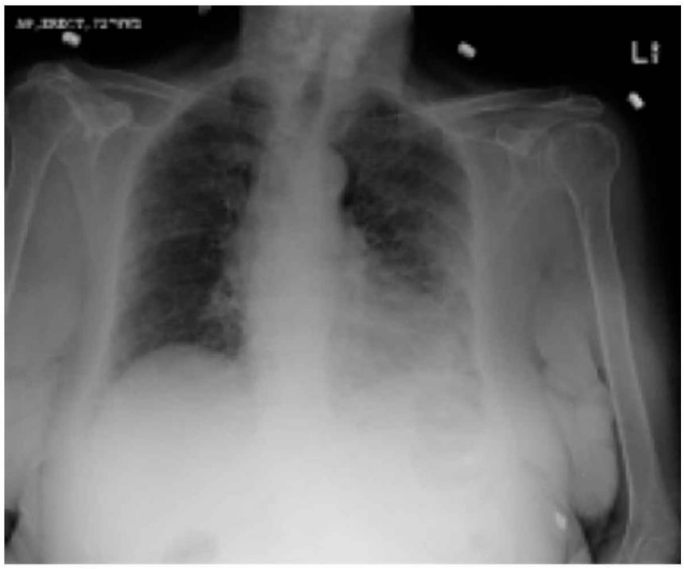
What is interstitial lung disease?

Interstitial lung disease encompasses a large number of pathologic conditions. The interstitium of the lung is the connective tissue support structure and the lymphatics, which make up a network of linear and weblike tissues akin to the highways, streets, and alleys of a city. When these structures become congested with fluid, tumor cells, or inflammatory cells, or when they become overgrown and thickened, they show up on a chest X-ray as thickened linear or weblike opacities or small nodular opacities. Interstitial lung disease can be reticular (all linear), nodular (all small nodular opacities), or reticulonodular (both).

Mnemonic for interstitial lung disease: "CAT HIDES"

C = Collagen vascular diseases
A = Arthritis (rheumatoid lung, ankylosing spondylitis)
T = Tuberculosis
H = Hemosiderosis
I = Infection (TB, fungal or viral), Irradiation treatment
D = Drug-induced

E = Eosinophilic granuloma, Edema
S = Sarcoidosis, Scleroderma



Interstitial pneumonia

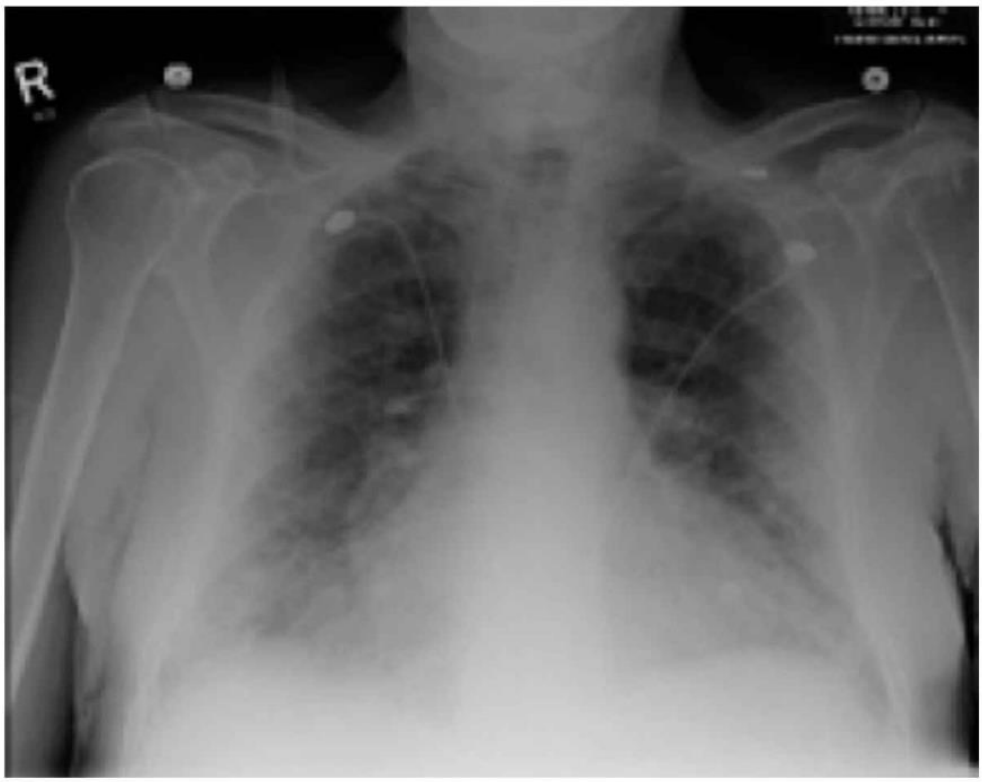
Close-up: interstitial disease

What are the findings in congestive heart failure (CHF)?

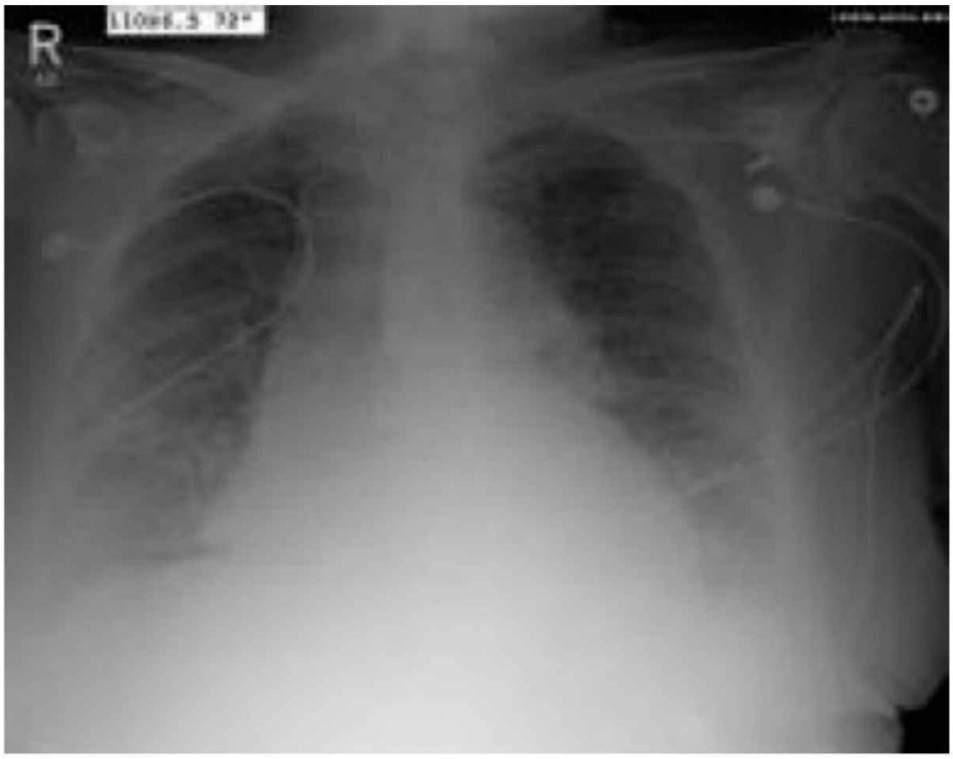
Cardiac enlargement with a cardiac-to-thoracic (C/T) ratio of 0.50 or greater is often seen in left heart failure. A subtle finding in early congestive heart failure is engorgement of the upper lobe pulmonary veins. This is called *cephalization* in reference to the upper lobe venous congestion. The mediastinum may appear widened due to engorgement of the superior vena cava (widening of the vascular pedicle). Kerley B lines are small linear opacities that typically occur in the lateral aspect of the lower lobes at right angles to the pleura. These thin, approximately 2 cm-long opacities represent perilymphatic fluid resulting from volume overload. Eventually, fluid can distend the interstitial lung structures (interstitial pulmonary edema) and/or the alveolar spaces (alveolar pulmonary edema). As CHF progresses, there is often increasing bilateral pleural effusion.

Summary of findings in CHF:

> Cardiac enlargement (C/T ratio of 0.50 or greater)
> Cephalization
> Widening of the vascular pedicle
> Kerley B lines
> Interstitial and/or alveolar pulmonary edema
> Bilateral pleural effusion



Congestive heart failure



Moderate congestive heart failure

How do I examine the osseous structures of the thorax?

The only way to do a complete assessment of bones is to examine them one by one. Start with the right shoulder, examine the right clavicle, the right ribs, the cervical spine and mandible, the left clavicle, the left shoulder, the left ribs, and finally the thoracic spine. You will be looking for signs of osseous destruction or fracture.

How do I examine the trachea?

The trachea is usually easy to see. It should be midline except where it deviates to the right at the level of the aortic arch. Because neck and mediastinal masses often displace the trachea, it is important to examine the trachea for position. There are also a few abnormalities relating to tracheal size. Weakening of the tracheal cartilage can result in a dilated trachea. Chronic inflammation, trauma, or infection can cause tracheal stenosis (narrowing).

How do I examine the visible soft tissues of the thorax and upper abdomen?

Start with the stomach bubble. Because all of us have at least some air in our stomachs, the stomach bubble is a constant finding in the left upper quadrant. If the bubble is displaced medially or toward the right side, consider splenomegaly or splenic hematoma. If the bubble is overly distended, consider bowel obstruction. After checking the stomach, scan all of the other visible soft tissues in a clockwise fashion.

You will be looking for signs of mass, opaque foreign bodies, evidence of previous surgery, and areas of asymmetry that may reflect swelling or tumors. Your last stop is beneath the hemidiaphragms, where you will specifically look for free air in the abdomen. You will most likely see it on the right side because the right diaphragm is higher than the left and the liver serves as a solid background of density for comparison of air density to soft tissue density.

How do I evaluate tubes and lines on a chest X-ray?

An endotracheal tube should terminate at the top of the aortic arch. This will be at approximately the T4 level and will place the end of the tube about 4 cm above the carina. Placement below this level raises the risk that the tube could enter the right or left main stem bronchus (usually the right because it is a straighter shot). If this happens, the opposite lung may collapse and the lung on the affected side may become hyperinflated, leading to pneumothorax and/or pneumomediastinum. Placement above the T2 level raises the risk of inflating the balloon cuff too high.

Chest tubes are used to remove something from the pleural space. In the case of pneumothorax, the chest tube is on suction to remove air from the pleural space. In this instance the tube should be in the most gravity-independent position, the apical region of the chest. If the tube is placed to remove blood, pus, or fluid, it should be in the most gravity-dependent area of the chest, posterior and inferior in the thorax. If the fluid is loculated in a different area, the chest tube should be placed in the most gravity-dependent part of the collection.

When would I order a chest CT?

CT is generally the imaging procedure of choice after chest X-ray. CT provides excellent anatomic detail of the mediastinum, hemidiaphragms, pleura, lungs, osseous structures, trachea, and soft tissues.

VITAMINS D and C mnemonic for general medical differential diagnosis:

V = Vascular diseases:
- Suspected pulmonary embolism (order as computed tomography angiogram [CTA])
- Suspected thoracic aortic aneurysm, dissection, or coarctation
- Anomalous pulmonary venous return

I = Infection, Inflammation, Inhalation disease:
- Lung abscess
- Pyothorax (infection in the pleural space)
- Refinement of the differential diagnosis in interstitial lung disease

T = Trauma:
- Pulmonary laceration
- Aortic disruption
- Traumatic esophageal rupture

A = Allergic or Autoimmune disease:
- Rheumatoid lung
- Bronchiolitis obliterans

M = Metabolic disease:
- Substernal goiter

I = Idiopathic disease:

Sarcoidosis

N = Neoplasia:
- Evaluation of pulmonary nodule(s)
- Evaluation of a pulmonary mass (defined as a nodule 3 cm or larger)
- Metastatic disease
- Mediastinal mass (teratoma, lymphoma, neurogenic tumors, thymoma)

D = Developmental:
- Pulmonary sequestration
- Diaphragmatic hernia

C = Cardiac:
- Left ventricular aneurysm
- Valvular calcification
- Coronary calcium scoring
- Coronary CTA

What are the indications for chest MRI?

MRI is a modality best saved for specialized situations. The heart and great vessels can also be studied to great advantage. Because CT is effective, quick, and readily available, I suggest before requesting an MRI of the chest, you first check with the radiologist. Doing so will dramatically improve information sharing and facilitate the best use of resources for arriving at the correct diagnosis.

When would I order a PET scan of the chest?

Indications for PET imaging:

> Evaluation of a focal pulmonary abnormality, as in diagnosis of a solitary pulmonary nodule (SPN)
>
> Preoperative staging for bronchogenic carcinoma, which includes mediastinal and hilar staging as well as extrathoracic staging
>
> Staging of recurrent tumor

How can I distinguish bacterial from viral pneumonia?

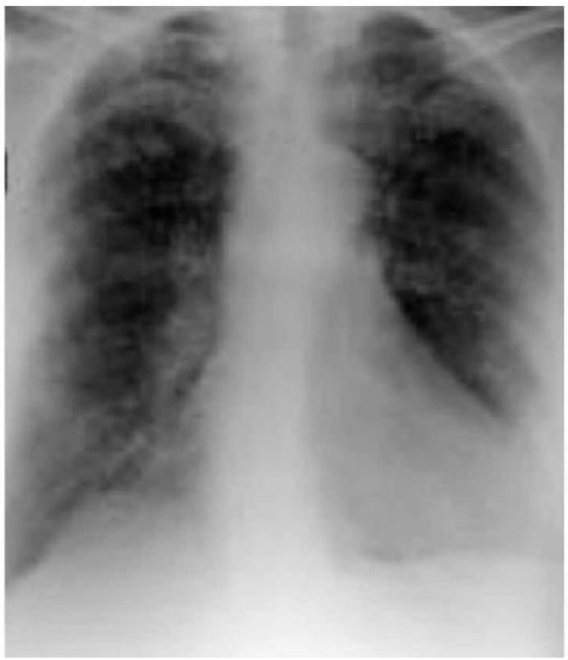
In general, bacterial pneumonia produces air space (alveolar) lung opacities while viral pneumonia produces interstitial lung disease.

Bacterial pneumonia often presents with alveolar opacity confined to a lobe or segment of a lobe. Pneumococcal pneumonia is the pathogen most frequently associated with lobar alveolar disease. Klebsiella pneumonia is often associated with alveolar disease that produces bowing of adjacent fissures. Staphylococcal pneumonia can be very aggressive, presenting with dense consolidation that is not stopped by fissures. Staphylococcal pneumonia tends to create cavities (abscesses) and is a common cause of empyema.

Viral pneumonia is more common in children but can occur in any age group. Occasionally there is associated hilar lymph node enlargement. A common finding in viral infections is peribronchial thickening (thickening of the bronchial wall). Peribronchial thickening is easiest to recognize when a bronchus is viewed end on. Fungal pneumonia may produce interstitial lung disease, alveolar disease, or a

combination of both. Fungi are a common cause of cystic cavitation in the lungs.

Bacterial pneumonia



Viral pneumonia

How will I recognize lung cancer?

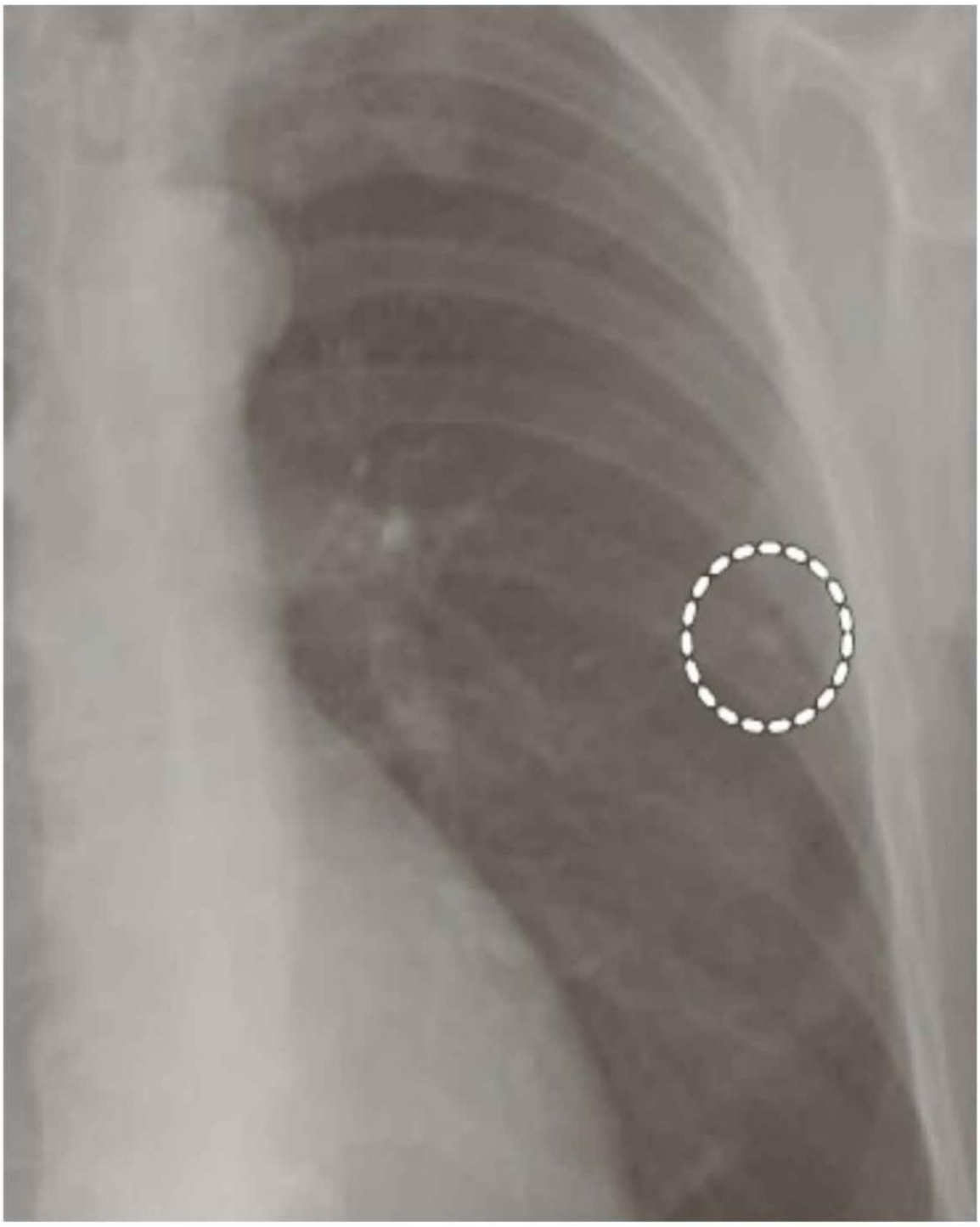
Lung cancer can present on a chest X-ray in multiple ways. Any nodule or mass within the lung that is noncalcified must be considered possible lung cancer. A solitary density is considered to be a nodule if it is smaller than 3 cm and a mass if it is larger

than 3 cm. Biopsy is the only definitive means for confirming cancer. If the nodule is over 1 cm, a PET scan can help determine whether the nodule requires biopsy. Increased metabolic activity of a nodule on the PET scan would prompt a biopsy, while a negative PET scan would lead to imaging surveillance. Nodules less than 1 cm are most often followed by surveillance, unless there is strong suspicion of malignancy based on imaging appearance (stellate margins) or clinical grounds.

Surveillance of lung nodules is most often completed with chest X-ray and chest CT performed at 3, 6, 12, and 24 months following the discovery of the nodule. If the nodule has remained stable for 2 years, the chance of malignancy is slim.

Imaging characteristics of a malignant lung nodule include irregular or stellate margins, lack of calcification, increasing size from previous examinations, and lymphadenopathy. Multiple noncalcified lesions, even if they are smoothly marginated, strongly suggest metastatic disease. Lung cancer can often present as pneumonia. Before the patient is deemed healthy, it is important that follow-up chest X-rays document complete resolution of pneumonia. A pulmonary malignancy may produce bronchial obstruction, leading to pneumonia and often slow or incomplete resolution of the resulting air space disease. For the same reason, malignancy can present as an area of atelectasis or volume loss in lungs. In these cases, if volume loss does not resolve over a period of two to four weeks, CT and/or bronchoscopy should be considered.

CT: lung cancer



Calcified granuloma