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Lecture [5&6]

CHEST IMAGING

Learning objectives:

To overview of the standard CXR projections is followed by a brief outline of normal radiographic anatomy. Some notes on assessment of a few important technical aspects are then provided, as well as an outline of a suggested systematic approach. To understand indication each thoracic diagnostic imaging modalities and discuss the value of most important radiographic signs on chest X-ray and imaging findings of specific thoracic disorders.

IMAGING TECHNIQUES

1) Plain chest radiograph (CXR):

Indications:

- ✓ CXR is requested for virtually all patients with respiratory symptoms.
- ✓ Chest trauma
- ✓ Pre-operative assessment of the lungs and airways
- ✓ Staging of tumors.
- ✓ Localization of foreign body
- ✓ To check the position of endotracheal tube, CV-line and other thoracic prosthesis.
- ✓ Assessment of heart disorders.
- ✓ Post-operative follow-up.

2) Computed tomography (CT):

Indications:

- ✓ Evaluating abnormalities on a CXR.
- ✓ Investigating causes of breathlessness pulmonary artery thromboembolism
- ✓ Assessment of interstitial lung disease.
- ✓ Staging of cancer.
- ✓ Evaluation of vascular anatomy, e.g. thoracic aortic aneurysms/dissection.
- ✓ Performing CT-guided biopsy of a lung/pleural/mediastinal mass.

3) Magnetic resonance imaging (MRI)

MRI has only a very small role in the management of pulmonary, pleural or mediastinal disease, although it is playing an increasingly large part in the diagnosis of cardiac and aortic diseases. MRI can be useful in selected patients with lung cancers, particularly apical tumors, when the relevant questions cannot be answered by CT and MRI can show the intraspinal extent of mediastinal neural tumors.

4) Ultrasound (US)

Indications:

- ✓ Chest wall pathology such as lipoma, hematoma.
- ✓ Assessment diaphragm: normal vs. paralysis.

- ✓ Pleural effusion, thickening and mass.
- ✓ US-guided biopsy of peripheral lung/pleural mass.
- ✓ US-guided aspiration/drainage of pleural fluid collections.

5) Radionuclide lung scanning

The major indication for radionuclide lung scanning is to diagnose or exclude pulmonary embolism by using ventilation-perfusion scan, but this indication has been superseded by CT pulmonary angiography.

6) Positron emission tomography (PET)

It is used to stage lung cancer or lymphoma and to diagnose recurrent lung cancer. It is also increasingly used to diagnose the malignant nature of a solitary pulmonary nodule as well as pleural disease.

HOW TO READ A CXR

CXR Projections

In general, two radiographic views, posteroanterior (PA) and lateral, are used in the assessment of most chest conditions.

Exceptions where a PA view alone:

- ✓ Infants and children
- ✓ 'Screening' examinations, e.g. for immigration, insurance or diving medicals
- ✓ Follow-up of known conditions seen well on the PA, e.g. pneumonia following antibiotics.

PA Erect CXR

To obtain a PA erect CXR, the patient is positioned standing with his or her anterior chest wall up against the X-ray film. The X-ray tube lies behind the patient so that X-rays pass through in a posterior to anterior direction.

Reasons for performing the film PA:

- ✓ Accurate assessment of cardiac size due to minimal magnification
- ✓ Scapulae able to be rotated out of the way.
- ✓ Avoid direct radiation to the breasts in female.

Reasons for performing the film erect:

- ✓ Physiological representation of blood vessels of mediastinum and lung. In the supine position, mediastinal veins and upper lobe vessels may be distended leading to misinterpretation. A normal mediastinum may look abnormally wide on supine CXR
- ✓ Gas passes upwards: pneumothorax is more easily diagnosed, as is free gas beneath the diaphragm
- ✓ Fluid passes downwards: pleural effusion is more easily diagnosed.

Lateral CXR

Reasons for performing a lateral CXR:

- ✓ Further view of lungs, especially the hidden areas on the PA film, e.g. retrosternal, retrocardiac areas
- ✓ Further assessment of cardiac configuration
- ✓ Further anatomical localization of lesions
- ✓ More sensitive for pleural effusions
- ✓ Good view of thoracic spine.

Other projections

Indications of anteroposterior (AP)/supine X-ray:

- ✓ Acutely ill or traumatized patients, and patients in intensive care and coronary care units
- ✓ In infants.

Mediastinum and heart appear wider on an AP/supine film due to venous distension and magnification.

Indication of expiratory film:

- ✓ in small pneumothorax: in expiration the lung is smaller while the pneumothorax does not change in volume
- ✓ Suspected bronchial obstruction with air trapping, e.g. inhaled foreign body in a child: in expiration the normal lung reduces in volume while the lung with an obstructed airway remains inflated.

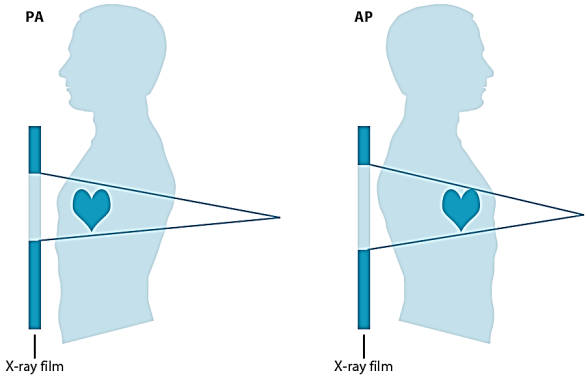
Indication of decubitus film:

Radiograph performed with the patient lying on their side, used occasionally in patients too ill to stand

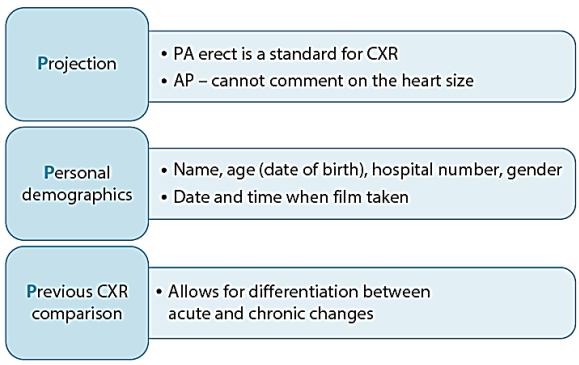
where pleural effusion or pneumothorax are suspected and not definitely diagnosed on an AP film.

Indication of oblique CXR

It may be used for suspected rib fracture, or to display other chest wall pathologies.



The size of the heart on the PA and AP CXR. Note on PA projection that the heart is closer to the X-ray film and thus less magnified by the divergent beam than on the AP view.



PPP (projection/personal demographics/previous CXR comparison).

RADIOGRAPHIC ANATOMY

PA ERECT CXR

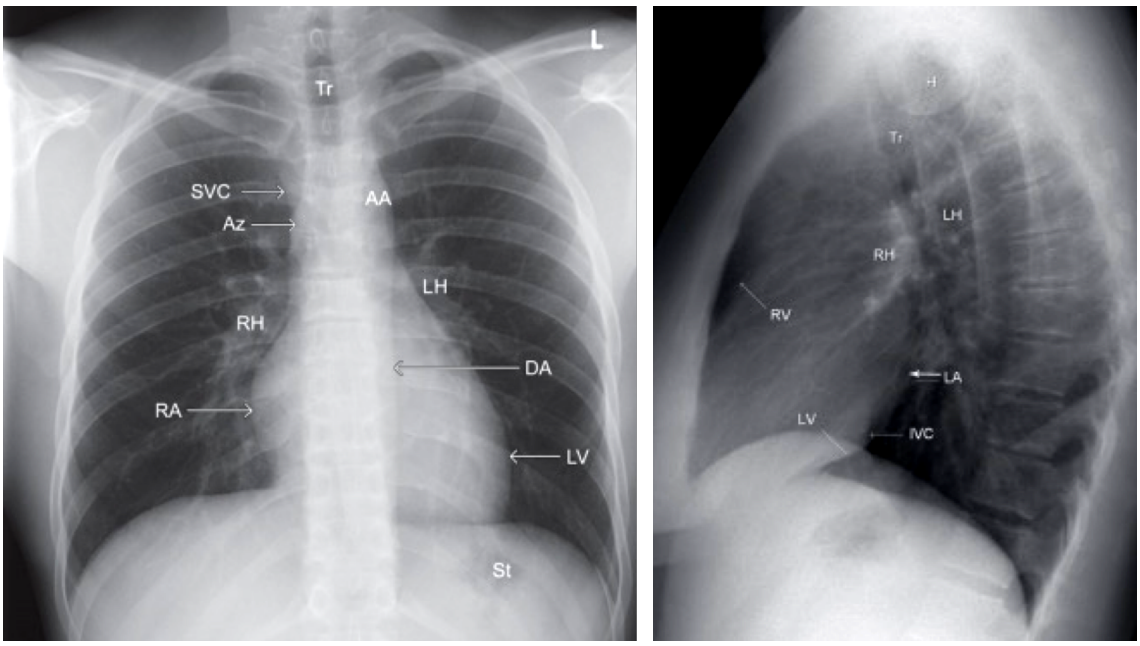
Look at a normal PA chest radiograph and try to identify the following features:

- **The trachea** in the midline, plus its division into right and left main bronchi
- **Right paratracheal stripe:** thin line on the right margin of the trachea, may be lost or thickened in the presence of lymphadenopathy
- **Superior vena cava (SVC):** straight line, continuous inferiorly with the right heart border
- **Right heart border:** formed by the right atrium, outlined by the aerated right middle lobe
- **Right hilum:** midway between the diaphragm and lung apex, formed by the right main bronchus and right pulmonary artery, and their lobar divisions
- **Aortic arch,** sometimes termed the **aortic 'knuckle'**
- **Descending aorta** can be traced downwards from aortic arch as a line to the left of the spine. Descending aorta may be obscured by a posterior mediastinal mass, or by pathology in the left lower lobe
- **Main pulmonary artery:** slightly convex line between aortic arch and left heart border
- **Left hilum:** posterior to main pulmonary artery and extending laterally, formed by left main bronchus and left pulmonary artery and their main lobar divisions Left heart border: formed by the left ventricle, except in cases where the right ventricle is enlarged
- **Left atrial appendage** lies on the upper left cardiac border; it is not seen unless enlarged.
- **Left heart border:** formed by the left ventricle, outlined by the aerated lingula.

Lateral CXR

The lateral view is usually performed with the patient's arms held out horizontally. Look at a normal lateral chest radiograph and try to identify the following features:

- **Anterior cardiac border:** formed by right ventricle
- **Posterior cardiac border:** formed by the left atrium superiorly and the left ventricle inferiorly
- **Trachea:** air-filled structure in the upper chest, midway between the anterior and posterior chest walls
- **Main bronchi** may be seen end-on as round lucencies
- **Posterior aspect of the aortic arch:** convexity posterior to the trachea
- **Main pulmonary artery** forms a convex opacity continuous with the right upper cardiac border.
- **Left main pulmonary artery** forms an opacity posterior and slightly superior to the carina
- **Right pulmonary artery** forms an opacity anterior and slightly inferior to the carina
- **Thoracic spine.**
- **Diaphragm.**



Normal lateral CXR (PA & Lateral views)

TECHNICAL ASSESSMENT

Rotation

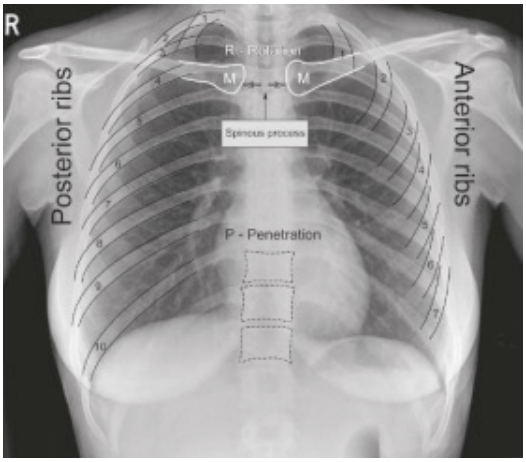
- ✓ To assess for rotation, find the medial heads of the clavicles and compare their distances away from the spinous process of the adjacent vertebral body.
- ✓ If the spinous process of the vertebral body is equidistant between both clavicle heads, then there is no rotation.
- ✓ If the gap is less on the right, then the patient is rotated to the right, and vice versa.

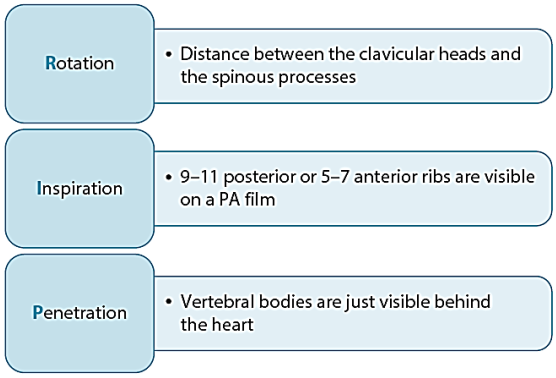
Inspiration

- ✓ Patients are asked to breathe in and hold their breath when a CXR is taken so that the lungs are optimally visualized.
- ✓ Poor inspiratory effort may be caused by pain, confusion or respiratory distress.
- ✓ Hyperexpanded lungs may be seen in COPD patients with obstructive airway disease, the diaphragms will appear flattened.
- ✓ Inspiratory effort is described as adequate when 9–11 posterior or 5–7 anterior ribs are seen.

Penetration

- ✓ The vertebral bodies should just be visible behind the heart for adequate penetration.
- ✓ If the CXR is either over- or underpenetrated, then you will not be able to fully assess all the structures and compare their densities accurately.
- ✓ An underpenetrated XR appears overly opaque/dense/white.
- ✓ An over penetrated XR appears too lucent/dark/black.

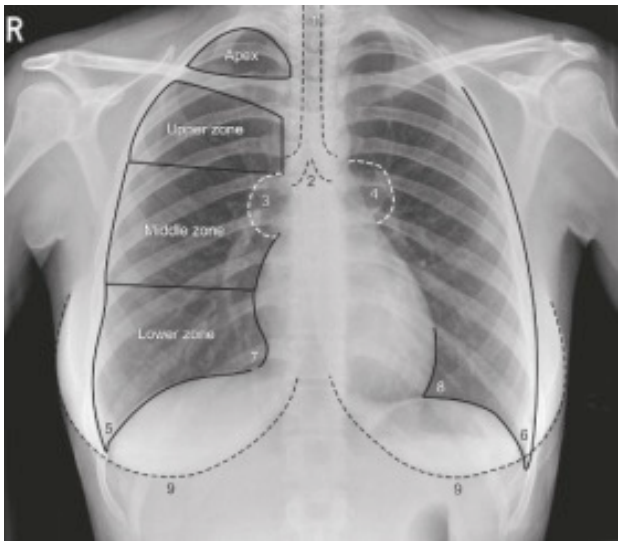


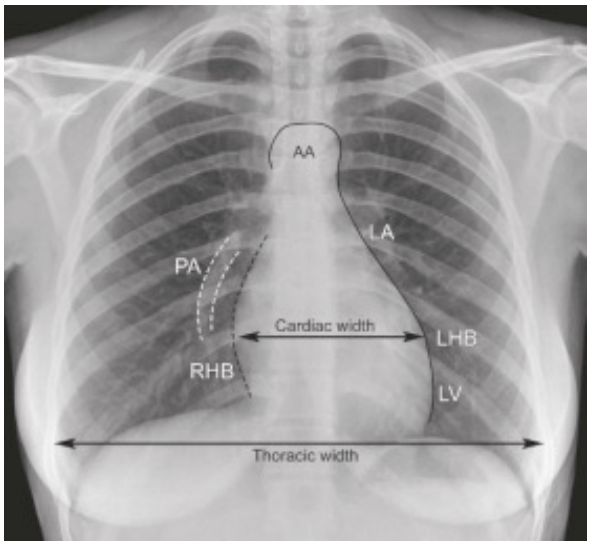


Technical factors: RIP (rotation/inspiration/penetration).

Assessing the technical quality of CXR (M = medial clavicle).

		Checklist for PA CXR
No.	**Structure/anatomical region**	**Specific features**
1	Patient data	Name, ID, age, sex, name of medical institute and date of exam
2	Technique	PA or AP, erect or supine, rotation, inspiration, side label
3	Trachea	Midline or deviated, patent or not.
4	Lung fields	Lung volume, abnormal opacity or lucency
5	Lung apices	Any abnormal opacity, calcification
6	Hilum	Position, shape and opacity
7	Heart	Site, size, shape and calcification
8	Mediastinum	Wide, narrow and contour abnormality
9	Diaphragm	Position and morphology
10	Costo-phrenic angle	Clear or obliterated
11	Cardio-phrenic angle	Clear or obliterated
12	Soft tissue	Mass, calcification or gas
13	Bone	Bone
14	Under the diaphragm	Gastric fundus gas, pneumoperitoneum
15	Tubes, lines & prosthesis	Endotracheal, nasogastric tubes, CV line, pacemaker





NORMAL CXR. Trachea (1), carina (2), right hilum (3), left hilum (4), right costophrenic angle (5), left costophrenic angle (6), right cardiophrenic angle (7), left cardiophrenic angle (8). bilateral, normal, symmetrical breast outlines (9). The left heart border (LHB) left ventricle (LV). The right heart border (RHB) is made up of the right atrium (dotted line), Aortic arch (AA), descending right pulmonary artery (PA). The CTR (cardiothoracic ratio) is the greatest cardiac width ÷ the intrathoracic width at its widest point (inner rib → inner rib), <50% in adults.

RADIOLOGICAL SIGNS OF LUNG DISEASE

AIR-SPACE OPACIFICATION

Definition:

Air-space opacification means the replacement of air in the alveoli by fluid or other materials (e.g. pus or blood). The fluid can be either an exudate (often called 'consolidation') or a transudate (pulmonary edema)

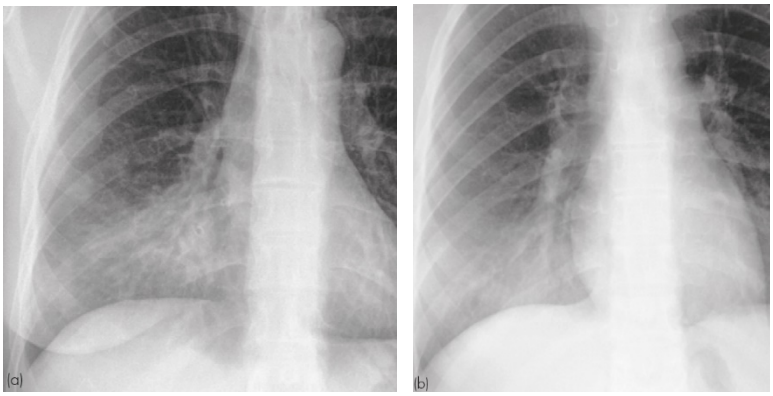
Radiological signs of consolidation:

- ✓ **An opacity with ill-defined borders**, except where the opacity is in contact with a fissure, in which case the opacity has a well-defined edge.
- ✓ **An air bronchogram**. Normally, it is not possible to identify air in bronchi within normally aerated lung, because the walls of the normal bronchi are too thin and air-filled bronchi are surrounded by air in the alveoli.
- ✓ **The silhouette sign**, namely loss of visualization of the adjacent mediastinal or diaphragm outline.

Types of consolidation:

- **Lobar consolidation:** it is virtually diagnostic of bacterial pneumonia. Lobar consolidation produces an opaque lobe, except for air bronchograms.
- **Patchy consolidation**: i.e. one or more patches of ill-defined opacifying, is usually due to:
  - Pneumonia
  - Infarction
  - Contusion
  - Immunological disorders.

Right upper lobe consolidation



Examples of the silhouette sign in the chest.

Part of lung that is non-aerated	Border that is obscured
Right upper lobe	Right border of ascending aorta; right mediastinal margin
Right middle lobe	Right heart border
Right lower lobe	Right diaphragm
Left upper lobe	Aortic arch, upper left cardiac border
Left lingula	Left heart border
Left lower lobe	Left diaphragm, descending aorta

Silhouette sign: presence or absence of visible radiographic borders can assist in the diagnosis and localization of pathology as illustrated in these two examples. (a) Consolidation of the right middle lobe obscures the right heart border. (b) Consolidation of the right lower lobe. The right heart border can still be seen.

PULMONARY COLLAPSE (ATELECTASIS)

Definition: loss of volume of a lobe or lung:

Types:

1) **Lobar or segmental collapse,** causes include:
   - **Bronchial obstruction**
     - ✓ Tumor
     - ✓ Foreign body
     - ✓ Mucous plug, e.g. asthma, cystic fibrosis
   - **Passive collapse due to external pressure on the lung**
     - ✓ Pneumothorax
     - ✓ Pleural effusion or hemothorax
     - ✓ Diaphragmatic hernia (neonate)
   - **Scarring or fibrosis**
     - ✓ TB (upper lobes)
     - ✓ Radiation pneumonitis (post-radiotherapy).• linear atelectasis.
2) **Linear or discoid atelectasis**, causes include:
   - Postoperative
   - Inflammatory or other painful pathology
   - beneath the diaphragm, e.g. pancreatitis, acute
   - cholecystitis
   - Pulmonary embolus
   - Following resolution of pneumonia.

General radiological signs of lobar collapse

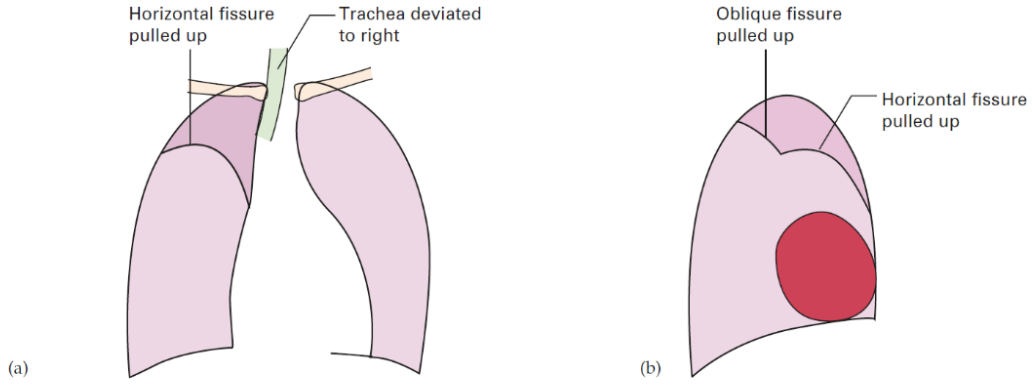
The most important initial sign for differentiating lobar collapse from consolidation is decreased volume of affected lung.

Radiological signs of collapse include:

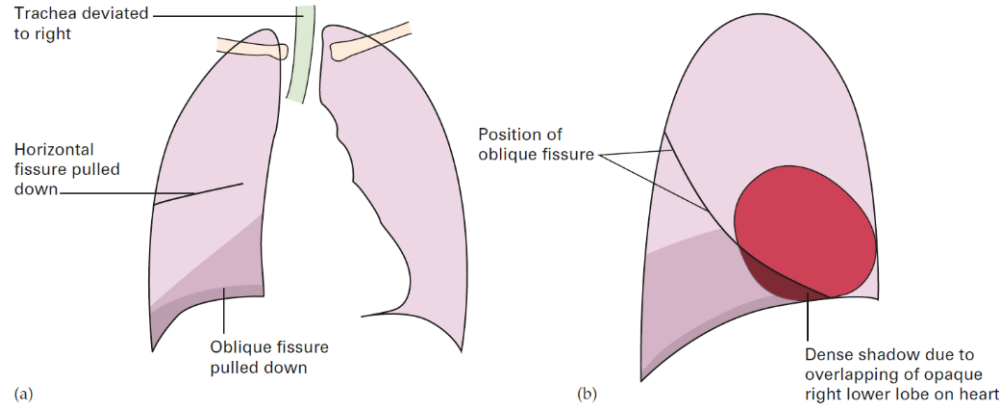
- ✓ Displacement of pulmonary fissures
- ✓ Local increase in density due to non-aerated lung
- ✓ Elevation of ipsilateral hemidiaphragm
- ✓ Displacement of hilum
- ✓ Displacement of mediastinum towards side of collapse
- ✓ Compensatory overinflation of adjacent lobes
- ✓ Loss of visualization of anatomical structures: silhouette sign.

Specific features of lobar collapse

Lobe	Direction of collapse	Hilum displacement	Increased density	Silhouette sign
Right upper	Upwards, anterior	Right, upwards	Right upper zone	Right mediastinum
Right middle	Anterior	None	PA: right midzone Lateral: triangular opacity overlying heart	Right heart border
Right lower	Downwards, posterior	Right, downwards	Triangular opacity right base	Right hemidiaphragm
Left upper	Upwards, anterior	Left, upwards	Left upper and midzone	Aortic arch[a] Upper left heart border
Left lower	Downwards, posterior	Left, downwards	Triangular opacity left base, behind heart	Left diaphragm, descending aorta



Collapse of the right upper lobe. (a) Posteroanterior and (b) lateral views. Note the opacification in the right apex and elevated horizontal fissure.



Collapse of the right lower lobe. (a) Posteroanterior and (b) lateral views. In this example the apical segment is relatively well aerated.

SOLITARY PULMONARY NODULE OR MASS

Solitary pulmonary nodule is a common incidental finding on CXR.
The definition of a **solitary pulmonary nodule** is a spherical lung opacity seen on CXR or CT, measuring less than 3 cm diameter, and not associated with pulmonary collapse or lymphadenopathy.

Opacities larger than 3 cm are referred to as **masses** and are more likely to be malignant.
Differential diagnosis of solitary pulmonary nodule:

- ✓ Bronchogenic carcinoma
- ✓ Solitary metastasis
- ✓ Granuloma including tuberculoma
- ✓ Hamartoma
- ✓ Carcinoid tumor
- ✓ Arteriovenous malformation.

The aim of investigation and follow-up of pulmonary nodules is to diagnose those that are malignant, and to facilitate early resection.

- **Features associated with a higher likelihood of malignancy:**
  - Evidence of rapid growth on serial CXR examinations
  - Ill-defined margin
  - Size >3 cm
  - No calcification.
  - Involvement of adjacent chest wall
  - Enhancement pattern on CT
  - Associated LAP, liver metastasis.

- **Features associated with a lower likelihood of malignancy:**
  - Calcification
  - Well-defined margin
  - Small size
  - Most granulomas measure 0.3–1.0 cm in diameter
  - Fat on CT
  - Unchanged on serial CXR examinations.

These benign features are present in a **minority** of solitary pulmonary nodules and most require further imaging investigations, particularly where there are underlying risk factors for lung cancer. Risk factors include cigarette smoking, exposure to asbestos, and a history of lung cancer in a first-degree relative. The two most used imaging investigations for solitary pulmonary nodule are **CT and FDG-PET**, with **CT the first investigation of choice in most instances.**

Role of computed tomography

The role of CT in patients with a solitary pulmonary nodule is primarily to characterize the nodule using the following steps.

- ✓ To demonstrate calcification in the nodule.
- ✓ To establish whether the nodule is solitary or multiple, when the lesion in question is likely to be a metastasis or when surgical resection of the mass is being considered.
- ✓ To localize the nodule accurately prior to bronchoscopy or percutaneous needle biopsy in cases where the position of the nodule is difficult to define on conventional films.

Role of positron emission tomography

FDG-PET may be useful to characterize solitary pulmonary nodules where other imaging is unhelpful. FDG-PET is particularly useful for lesions that are not amenable to biopsy. Neoplastic masses show increased uptake of FDG. FDG-PET is unable to accurately characterize lesions less than 1 cm in diameter. False-positive findings may occur in active inflammatory lesions.

Biopsy

Lesions that have positive findings for malignancy on CT or FDG-PET usually require biopsy. Biopsy may be performed via bronchoscopy, percutaneously with CT guidance, or by open surgical biopsy and resection.

MULTIPLE PULMONARY NODULES

Whereas solitary pulmonary nodule is commonly seen as an incidental finding, this is less often the case with multiple pulmonary nodules. More commonly, multiple pulmonary nodules are seen in symptomatic patients, or in patients with underlying pathology, such as immunosuppression or malignancy. The commonest exception to this would be multiple small, calcified granulomas, which may indicate previous infection including TB or chicken pox pneumonia.

Differential diagnosis of multiple pulmonary nodules:

- **Granulomas:** such as TB, fungal infection & collagen vascular disorders.
- **Metastases**
  - ✓ Usually well defined
  - ✓ Nodules of varying size
  - ✓ More common peripherally and in the lower lobes
  - ✓ Cavitation seen in squamous cell carcinomas, sarcomas and metastases from colonic primaries
- **Abscesses**
  - ✓ Cavitation: thick, irregular wall
  - ✓ Usually due to Staphylococcus aureus
- **Hydatid cysts**
  - ✓ Often quite large, i.e. 10 cm or more
- **Wegener's granulomatosis**
  - ✓ Cavitation of nodules common
  - ✓ Associated paranasal sinus disease
- **Multiple arteriovenous malformations.**

INTERSTITIAL OPACIFICATION

Three patterns of pulmonary opacification are seen in interstitial processes: linear, nodular and honeycomb pattern. These patterns may occur separately, or together in the same patient with considerable overlap in appearances

- **Linear pattern:**
  - ✓ Network of fine lines running through the lungs
  - ✓ Lines are due to thickened connective tissue septa
  - ✓ Kerley A lines: long, thin lines in the upper lobes
  - ✓ Kerley B lines: short, thin lines predominantly in the lower zones extending 1–2 cm horizontally inwards from the lung surface.

- **Nodular pattern:**
  - ✓ Nodules due to interstitial disease are small (1–5 mm), well defined and no air bronchograms.
  - ✓ Nodules tend to be very numerous and are distributed evenly throughout the lungs.

- **Honeycomb pattern:**
  - ✓ Honeycomb pattern represents the end stage of many of the interstitial processes listed below.
  - ✓ May also be seen with tuberous sclerosis, amyloidosis, neurofibromatosis and cystic fibrosis.
  - ✓ Honeycomb pattern implies extensive destruction of pulmonary tissue.
  - ✓ Cysts that range in size from tiny up to 2 cm in diameter replace the lung parenchyma. These
    cysts have very thin walls.
  - ✓ Normal pulmonary vasculature cannot be seen.
  - ✓ Pneumothorax is a frequent complication of honeycomb lung.

CXR appearances of interstitial disease processes are often non-specific. Short differential diagnosis lists of the more common disorders may be based on whether clinical presentation and CXR findings are acute, subacute or chronic. Chronic diseases may be further subdivided based on their distribution in the lungs, i.e. whether upper or lower zones are predominantly involved.

Causes of interstitial opacification

- Acute interstitial pneumonia: usually viral.
- Lymphangitis carcinomatosis:
- TB: upper lobe fibrosis; associated calcification in cavities.
- Sarcoidosis: often associated with hilar lymphadenopathy
- Silicosis: associated with hilar lymph node calcification and enlargement.
- Extrinsic allergic alveolitis
- Bronchopulmonary aspergillosis
- Usual interstitial pneumonia (UIP)
- Asbestosis: may be associated with pleural plaques and calcification, mainly of the diaphragmatic pleura.
- Connective tissue disorders: e.g. systematic lupus erythematosus (SLE) & scleroderma.

INCREASED TRANSLUCENCY OF THE LUNGS

- **Generalized increased transradiancy of the lungs:** it's one of the signs of emphysema.
- **Localized increased transradiancy of the lungs:** when only one hemithorax appears more transradiant than normal the following should be considered:
  - ✓ **Compensatory emphysema** occurs when a lobe or lung is collapsed or has been excised and the remaining lung expands to fill the space.
  - ✓ **Emphysematous bullae**
  - ✓ **Pneumothorax.**
  - ✓ **Reduction in the chest wall soft tissues** e.g. mastectomy, Poland syndrome.
  - ✓ **Air-trapping due to central obstruction**: foreign body inhalation particularly in children.

PLEURAL DISORDERS

PLEURAL EFFUSION

- **Definition:** accumulation of fluid in the pleural space, between the visceral and parietal pleural layers.
- **Causes:**
  - ✓ **Cardiac failure:** bilateral pleural effusions, right usually larger than left
  - ✓ **Malignancy:** Bronchogenic carcinoma, Metastatic, Mesothelioma
  - ✓ **Infection:** bacterial pneumonia, TB ..
  - ✓ **Pulmonary embolus with infarct**
  - ✓ **Pancreatitis:** effusion is usually left-sided
  - ✓ **Trauma:** associated with rib fractures
  - ✓ **Connective tissue disorders**

- **Radiographic signs of pleural effusion:**
  - ✓ The radiographic appearances of pleural effusion are generally the same regardless of the nature of the fluid, which may include transudate, exudate, blood, pus (empyema) or lymph (chylothorax).
  - ✓ Homogeneous dense opacity at the base of the lung
  - ✓ Concave upper surface higher laterally than medially, producing **a meniscus sign.**
  - ✓ Small pleural effusions produce blunting of the costophrenic angle.
  - ✓ Large pleural effusions displace the mediastinum towards the contralateral side.
  - ✓ The lateral view is more sensitive to the presence of small pleural effusions than the PA view. It is estimated that about **300 mL of fluid** is required to show costophrenic angle blunting on the PA, whereas only **100 mL** is required to produce this sign (posteriorly) on the lateral view.
  - ✓ **Signs of pleural fluid on supine CXR** include opacity over the lung apex (pleural cap) and increased opacity of the hemithorax, through which lung structures can still be seen. There is often loss of definition of the hemidiaphragm and blunting of the costophrenic angle.

- **Ultrasound**
  - ✓ Ultrasound is a simple method of determining whether pleural fluid is present.
  - ✓ Pleural fluid can be recognized as a hypoechoic area between the lung and diaphragm or the chest wall.
  - ✓ It is only rarely possible to determine the nature of the fluid, e.g. in empyema multiple echoes may be seen due to the pus in the fluid.
  - ✓ Ultrasound is particularly useful in defining the presence, size and shape of any pleural collection loculated against the chest wall or diaphragm.
  - ✓ It is a convenient method of imaging control to guide procedures such as pleural fluid aspiration or drainage.

- **Computed tomography**
  - ✓ Pleural effusions are usually seen as an area of homogeneous fluid density between the chest wall and lung.
  - ✓ CT is particularly useful for showing loculated pleural effusions.
  - ✓ If the fluid is due to recent hemorrhage it will show the high density of blood.

- ✓ Free pleural fluid moves to the dependent portion of the chest CT can be used to distinguish between lung abscess and empyema.
- ✓ Like ultrasound, CT can be used to direct the placement of drainage tubes.

PNEUMOTHORAX

- **Definition:** accumulation of air in the pleural space, between the visceral and parietal pleural layers.
- **Causes:**
  - ✓ Spontaneous: tall, thin males, Smokers
  - ✓ Iatrogenic: percutaneous lung biopsy, pacemaker insertion …
  - ✓ Trauma: associated with rib fractures
  - ✓ Emphysema
  - ✓ Malignancy: high incidence with osteogenic sarcoma metastases
  - ✓ Lymphangiomyomatosis (LAM): interstitial disease of young women
  - ✓ Cystic fibrosis, bronchiectasis.

- **Radiographic signs of pneumothorax:**
  - ✓ Pneumothorax is usually well seen on a normal inspiratory PA film.
  - ✓ The diagnosis of small pneumothorax may be easier on an expiratory film. This is due to reduced volume of the lung in expiration, which makes the pneumothorax look relatively larger.
  - ✓ Whether the film is performed in inspiration or expiration, the sign to look for is the lung edge outlined by air in the pleural space with the absence of vessel opacities outside visceral pleural line.
  - ✓ Tension pneumothorax occurs with continued air leak from the lung into the pleural space. This results in increased pressure in the pleural space with expansion of the hemithorax and further compression and collapse of the lung.
  - ✓ **CXR signs of tension pneumothorax:**
    - Marked collapse and distortion of the lung
    - Increased volume of hemithorax
    - Displacement of the mediastinum to the contralateral side
    - Depressed diaphragm
    - Increased space between the ribs.

  - ✓ **Supine AP CXR** may have to be performed in ICU patients or following severe trauma. Pleural air lays anteromedially and beneath the lung so that the usual appearance of a pneumothorax as described for an erect PA film is not seen.
  - ✓ **Signs of pneumothorax on a supine CXR:**
    - Mediastinal structures including heart border, inferior vena cava (IVC), SVC are sharply outlined by adjacent free pleural air
    - Upper abdomen appears lucent due to overlying air
    - Deep lateral costophrenic angle.

HYDROPNEUMOTHORAX, HAEMOPNEUMOTHORAX AND PYOPNEUMOTHORAX

Fluid in the pleural cavity, whether it be a pleural effusion, blood or pus, assumes a different shape in the presence of a pneumothorax. The diagnostic feature is the air–fluid level

PLEURAL THICKENING

Causes:

- Secondary to trauma
- Following empyema
- TB
- Asbestos exposure
- Mesothelioma
- Pancoast tumor
- Pleural metastases

Radiographic signs of pleural thickening:

- Blunting of costophrenic angles, mimicking pleural effusion
- Soft tissue thickening over the lungs, including the lung apices
- Calcification of the pleural surfaces due to previous pleural hemorrhage or infection
- Pleural plaques
- Convex, pleural-based opacities when seen in profile
- Less well-defined opacities when not in profile
- May be calcified, especially with a history of exposure to asbestos.

PLEURAL TUMORS

- The commonest pleural tumors are metastatic carcinomas.
- Primary pleural tumors, such as mesotheliomas, are relatively uncommon.
- Many patients with malignant mesotheliomas give a history of asbestos exposure and may show the other features of asbestos-related disease.
- Pleural tumors produce lobulated masses based on the pleura.
- Malignant pleural tumors, both primary (malignant mesothelioma) and secondary, frequently cause
  pleural effusions which may obscure the tumor itself.

PLEURAL CALCIFICATION

- Irregular plaques of calcium may be seen with or without accompanying pleural thickening.
- When **unilateral** they are likely to be due to either an old empyema, usually tuberculous, or an old hemothorax.
- **Bilateral** pleural calcification is often related to asbestos exposure.

HILAR DISORDERS

- ✓ Each hilar complex as seen on the PA and lateral chest radiographs comprises the proximal pulmonary arteries, bronchus, pulmonary veins and lymph nodes.
- ✓ Hilar lymph nodes are not visualized unless enlarged.
- ✓ In assessing hilar enlargement, be it bilateral or unilateral, one must decide whether it is due to enlargement of the pulmonary arteries, or some other cause like lymphadenopathy or a mass.
- ✓ If the branching pulmonary arteries are seen to converge into an apparent mass, this is a good sign of enlarged main pulmonary artery (hilum convergence sign).

- **Causes of unilateral hilar enlargement:**
  - Bronchial carcinoma
  - Lymphadenopathy
    - ✓ infection
    - ✓ Lymphoma
    - ✓ Sarcoidosis
  - Causes of enlargement of a single pulmonary artery
    - ✓ Post-stenotic dilatation on the left side due to pulmonary stenosis
    - ✓ Massive unilateral pulmonary embolus
    - ✓ Pulmonary artery aneurysm (often calcified).

- **Causes of bilateral hilar enlargement:**
  - Bilateral pulmonary artery enlargement (Pulmonary arterial hypertension)
  - Lymphadenopathy
    - ✓ Lymphoma: often asymmetrical
    - ✓ Metastatic malignancy (Bronchogenic carcinoma, non-pulmonary primary, e.g. testis)
    - ✓ Sarcoidosis.

MEDIASTINAL DISORDERS

MEDIASTINAL MASSES

- **Signs on CXR that a central opacity or mass lies within the mediastinum rather than the lung include:**
  - ✓ Continuity with the mediastinal outline
  - ✓ Sharp margin
  - ✓ Convex margin
  - ✓ Absence of air bronchograms.

Logical classification and differential diagnosis of mediastinal masses is based on localization to the anterior, middle or posterior mediastinum.

❖ **Anterior mediastinal mass**
- **Causes of an anterior mediastinal mass:**
  - Retrosternal goiter
  - Thymic tumor

- Lymphadenopathy
- Hodgkin's disease
- Metastases
- Aneurysm of ascending aorta.

- **CXR signs of an anterior mediastinal mass:**
  - Merge with cardiac border
  - Hilar structures can be seen through the mass
  - Masses passing upwards into the neck merge radiologically with the soft tissues of the neck and so are not seen above the clavicles
  - This is known as the cervicothoracic sign; a lesion seen above the clavicles must lie adjacent to aerated lung apices, i.e. posterior and within the thorax
  - Displaced trachea.

❖ Middle mediastinal mass

- **Differential diagnosis of a middle mediastinal mass includes:**
  - ✓ Lymphadenopathy, mediastinal or hilar
    - Bronchogenic carcinoma, less commonly other tumors
    - Lymphoma
  - ✓ Bronchogenic cyst
  - ✓ Aortic aneurysm.

- **CXR signs of a middle mediastinal mass:**
  - ✓ Opacity that merges with the hilar structures and cardiac borders.

❖ Posterior mediastinal mass

- **Differential diagnosis of a posterior mediastinal mass:**
  - ✓ Hiatus hernia
    - Round opacity located behind the heart
    - May contain a fluid level
  - ✓ Neurogenic tumor
    - Well-defined mass in the paravertebral region
    - May be associated with erosion or destruction of vertebral bodies or posterior ribs
  - ✓ Anterior thoracic meningocele: Associated with neurofibromatosis
  - ✓ Neurenteric cyst: Associated with vertebral abnormalities
  - ✓ Aneurysm of descending thoracic aorta
  - ✓ Paravertebral lymphadenopathy.

- **CXR signs of a posterior mediastinal mass:**
  - ✓ Does not obscure heart and middle mediastinal structures
  - ✓ Cardiac borders and hila clearly seen
  - ✓ Posterior descending aorta obscured
  - ✓ May be underlying vertebral changes.

PNEUMOMEDIASTINUM

- **Definition:** it refers to air leak into the soft tissues of the mediastinum.
- **Causes**:
  - ✓ Spontaneous: following severe coughing or strenuous exercise
  - ✓ Asthma
  - ✓ Foreign body aspiration in neonates
  - ✓ Chest trauma
  - ✓ Esophageal perforation: tumor, severe vomiting and endoscopy.

- **Radiographic signs of pneumomediastinum are due to air outlining the normal mediastinal structures:**
  - ✓ A strip of air outlining the left side of the mediastinum
  - ✓ Air around the aorta, pulmonary arteries and pericardium
  - ✓ Subcutaneous air extending upwards into the soft tissues of the neck

DIAPHRAGM

- **Elevation of the diaphragm** may be bilateral or unilateral, and secondary to abdominal distension/pathology (such as an abdominal mass or a subphrenic abscess), volume loss in the adjacent lung or a phrenic nerve palsy.
- It should always be borne in mind that subpulmonary effusion may mimic elevation of a hemidiaphragm.
- Marked elevation of one hemidiaphragm with no other visible abnormality suggests either paralysis or eventration.
- Paralysis results from disorders of the phrenic nerves, e.g. invasion by carcinoma of the bronchus or damage following thoracic surgery.
- The signs are elevation of one hemidiaphragm, which on fluoroscopy or ultrasound shows paradoxical movement, i.e. it moves upward on inspiration.
- **Eventration of the diaphragm** is a congenital condition in which the diaphragm lacks muscle and becomes a thin membranous sheet. Except in the neonatal period it is almost always an incidental finding and does not cause symptoms. Eventration may involve all (usually the left) or part of one hemidiaphragm, resulting in a smooth 'hump'.

PNEUMONIA

BACTERIAL PNEUMONIA

- The basic radiological feature of pneumonia is one or more areas of **consolidation**, varying from a small, ill-defined opacity to a large opacity involving the whole of one or more lobes.
- Consolidation may be accompanied by **loss of volume of the affected lobe**, a feature that is particularly common in children.
- **Cavitation** may occur within the consolidated areas. Cavitation is a particular feature of infections with staphylococci, Gram negative and anaerobic bacteria and tuberculosis.
- The differentiation between pneumonia and pulmonary edema or pulmonary infarction may, at times, be difficult or impossible radiographically. The clinical features usually decide the issue.

- Common infecting organism in community-acquired lobar pneumonia is Streptococcus pneumoniae (pneumococcal pneumonia). In pneumococcal pneumonia, there is usually dense consolidation of a considerable portion of one lobe, usually without loss of volume referred as **lobar pneumonia**. There may be an associated pleural effusion.
- When the consolidation is patchy, involving one or more lobes, it is commonly referred to as **bronchopneumonia.** The most frequent causes of community acquired bronchopneumonia are Staphylococcus aureus,
- Various Gram-negative and anaerobic bacteria and Mycoplasma pneumoniae.
- Pneumonia may be secondary to obstruction of a major bronchus, carcinoma being a common cause of obstruction.

VIRAL AND MYCOPLASMA PNEUMONIA

- Viral pneumonia and pneumonia due to Mycoplasma pneumoniae may produce widespread ill-defined consolidation and loss of clarity of the vascular markings,
- Pleural effusions are rare.
- The radiological abnormality may persist for many weeks after clinical recovery.

LUNG ABSCESS

- **Definition:** lung abscess is a localized suppurative lesion of the lung parenchyma
- **Causes:**
  - ✓ Aspiration of food or secretions. Such abscesses are usually in the apical (superior) segments of the lower lobes or in the posterior segments of the upper lobes.
  - ✓ Infection beyond an obstructing lesion in the bronchus.
  - ✓ Infected emboli, particularly in drug addicts.

- **CXR signs:**
  - ✓ A lung abscess is usually seen as a spherical opacity containing a central lucency due to air within the cavity.
  - ✓ An air–fluid level may be present.
  - ✓ It can be difficult or impossible to distinguish an infective lung abscess from a cavitating lung neoplasm or cavitation in Wegener's granulomatosis.

PULMONARY TUBERCULOSIS

- Pulmonary tuberculosis is usually divided into primary and post primary forms
- Primary tuberculosis is the result of the first infection with Mycobacterium tuberculosis and usually occurs in childhood.
- Post primary tuberculosis, the usual form in adults, is believed to be re-infection, the patient having developed relative immunity following the primary infection.
- Tuberculosis (and atypical mycobacterial infections) is seen commonly in patients with acquired immune deficiency syndrome (AIDS).

PRIMARY TUBERCULOSIS

- An area of consolidation, known as the **Ghon focus**, develops in the periphery of the lung usually in the mid or upper zones.
- Usually, the pulmonary opacity is small, but it may occasionally involve most of the lobe. Sometimes the pulmonary consolidation is so.
- The consolidation is often accompanied by visibly enlarged hilar or mediastinal lymph nodes. This combination known as **the primary complex.**
- Primary tuberculosis may present with a pleural effusion.
- **Miliary TB** occurs due to hematogenous dissemination, which may occur at any time following primary infection. On CXR, Miliary TB appears as tiny densities of approximately 2 mm diameter spread evenly through both lungs.

POST PRIMARY TUBERCULOSIS

- Post primary tuberculosis is usually confined to the apico-posterior segments of the upper lobes and the apical segments of the lower lobes.
- The initial lesions are multiple small areas of consolidation and are often bilateral.
- Pleural effusions are frequent and may be the only radiographic abnormality.
- mediastinal and/or hilar lymphadenopathy.
- areas of consolidation may enlarge and frequently undergo cavitation.
- Cavities are seen as rounded airspaces (translucencies) surrounded by pulmonary opacification
- As with the primary form, post primary tuberculosis may spread to give widespread bronchopneumonia or Miliary tuberculosis.
- Healing occurs by fibrosis, often with calcification
- Pleural effusions often leave permanent pleural thickening which may, on occasion, calcify.

Tuberculoma

- The term tuberculoma refers to a tuberculous granuloma in the form of a spherical mass, usually less than a centimeter or two in diameter, and mostly much smaller. The edge is usually sharply defined, and the lesions are often partly calcified.
- CT may be needed to demonstrate the calcification. Tuberculomas are almost invariably inactive even though viable tubercle bacilli may be present deep within the lesions.

Mycetoma

- The fungus Aspergillus fumigatus may colonize old tuberculous cavities to produce a ball of fungus (mycetoma) lying free within the cavity.
- Air is seen between the mycetoma and the wall of the cavity.
- Cavities containing mycetoma are usually surrounded by other evidence of old tuberculous infection, particularly fibrosis and calcification of the adjacent lung.
- CT often allows a specific diagnosis of mycetoma to be made.

Is the tuberculosis active?

Valuable diagnostic signs of activity are:

- development of new lesions on serial films
- demonstration of cavities.

FUNGAL AND PARASITIC DISEASES

The radiological appearances vary with the particular fungus, but two broad divisions can be made:

1) **Infection of an otherwise normal patient.** Organisms such as histoplasmosis, coccidioidomycosis and blastomycosis, produce lung lesions that are very similar and often identical to tuberculosis. Cavitation is a particular feature. Healing by fibrosis and calcification is frequent.
2) **Infection in an immunocompromised host.** With impaired immunity, fungi such as Candida albicans and Aspergillus fumigatus, may cause widespread pneumonia. HRCT include multiple nodularities with surrounding ground glass appearances.

Aspergillus fumigatus affects the lung in three ways:

- it may colonize a pre-existing cavity forming a fungus ball (mycetoma)
- it may infect the lung in an immunocompromised patient causing severe pneumonia
- it may be responsible for allergic bronchopulmonary aspergillosis.

Hydatid disease

- Pulmonary infection with Echinococcus granulosus may result in cysts in the lung or pleural cavity.
- These cysts may be solitary or multiple and are seen as spherical opacities with very well-defined borders.
- Hydatid cysts occasionally rupture to produce complex cavities with undulated air fluid level called waterlily sign.

DISEASES OF THE AIRWAYS

ASTHMA

The chest film in asthma is usually normal or shows only air-trapping with flattening of the diaphragm. Bronchial wall thickening may be seen.

The main purpose of the CXR in asthma is:

- to determine complications, e.g. atelectasis
- to detect associated pneumonia
- to exclude other causes of acute dyspnea, e.g. pulmonary edema, pneumothorax or, rarely, tracheal obstruction.

Allergic bronchopulmonary aspergillosis results from hypersensitivity to Aspergillus fumigatus. Asthma is the cardinal clinical feature of this disease. The radiological signs are allergic consolidations in the lung and proximal bronchiectasis, particularly in the mid and upper zones. The thickened walls of the dilated bronchi may be visible on a CXR.

ACUTE BRONCHITIS

Acute bronchitis in adults and older children does not produce any radiological abnormality unless complicated by pneumonia.

CHRONIC OBSTRUCTIVE PULMONARY DISEASE

Chronic bronchitis: CXR in uncomplicated chronic bronchitis is normal.

EMPHYSEMA

- **Definition:** refers to enlarged airspaces secondary to destruction of the alveolar walls.
- **Types:**

  - ✓ **Centrilobular emphysema** is the most common form; it occurs in smokers and predominantly affects the upper lobes.
  - ✓ **Panlobular emphysema** is seen in association with alpha-1 antitrypsin deficiency; it tends to predominantly affect the lower lobes.

- **CXR signs of emphysema:**

  - ✓ Over expanded lungs
  - ✓ Flattening of the diaphragms, best seen on lateral CXR
  - ✓ Diaphragms lie below anterior end of sixth rib on frontal view
  - ✓ Increased retrosternal airspace on lateral film
  - ✓ Beware incorrect diagnosis of pulmonary overexpansion in a young, athletic patient capable of a large inspiration
  - ✓ Decreased vascular markings in lung fields
  - ✓ Increased AP diameter of the chest, with in some cases kyphosis and anterior bowing of the sternum
  - ✓ Bulla formation: bullae are seen as thin-walled air-containing cavities
  - ✓ Pulmonary arterial hypertension: prominent main pulmonary arteries.

- **High resolution CT of the lungs (HRCT)** may be used to assess accurately the severity and distribution of emphysema, quantitate the percentage of residual healthy lung, and identify associated findings such as bronchogenic carcinoma.

BRONCHIECTASIS

- **Definition:** it is defined as irreversible dilatation of the bronchi, often accompanied by impairment of drainage of bronchial secretions leading to persistent infection.
- **Causes:**
  - ✓ Pulmonary infection in childhood, cystic fibrosis and longstanding bronchial obstruction.

- **The radiological features:**
  - ✓ Visibly dilated bronchi. If they contain air, the thickened walls of the dilated bronchi may be seen as tubular or ring opacities [honeycomb appearance]. If filled with fluid, the dilated bronchi are either opaque or contain air–fluid levels.
  - ✓ Loss of volume of the affected lobe or lobes is almost invariable.
  - ✓ A proportion of patients with symptomatic bronchiectasis have a normal CXR.
- **High resolution CT** is very useful both to diagnose bronchiectasis and to assess its extent

CARCINOMA OF THE BRONCHUS

Carcinoma of the bronchus is one of the most common primary malignant tumors.

- **Signs of a central tumor**
  - ✓ The tumor itself may present as a hilar mass with or without narrowing of the adjacent major bronchus.
  - ✓ Collapse and/or consolidation of lung beyond the tumor.

- **Signs of a peripheral tumor**
  - ✓ A peripheral tumor usually presents as a solitary pulmonary nodule/mass on plain films or chest CT.
  - ✓ It is very unusual to see a lung carcinoma of less than 1 cm in diameter on a CXR.
  - ✓ Much smaller cancers, some even as small as a few millimeters may be discovered on CT.
  - ✓ The signs of a peripheral primary carcinoma are:
    - o A rounded opacity with an irregular border. Lobulation, notching and infiltrating edges are common.
    - o Cavitation within the mass. The walls of the cavity are classically thick and irregular, but thin-walled, smooth cavities due to carcinoma do occur.

- **Spread of bronchial carcinoma**
  - ✓ Evidence of the spread of bronchial carcinoma may be visible on plain chest radiography.
  - ✓ CT has made a major contribution to the staging of lung cancer.
  - ✓ FDG-PET/ CT scanning is now used routinely to stage potentially operable tumors.
  - ✓ MRI is only used for highly specific indications.

- **The following features should be looked for.**
  - ✓ **Hilar and mediastinal lymph node enlargement due to lymphatic spread of tumor.**
    - o Enlargement of lymph nodes does not necessarily mean metastatic involvement because reactive hyperplasia to the tumor or associated infection can be responsible for nodal enlargement, as can pre-existing disease – notably previous granulomatous infection.
    - o FDG-PET/CT is used to identify neoplastic nodes
    - o If there is any doubt on imaging, prior to resection of the primary tumor, biopsies can be obtained via mediastinoscopy or endobronchial ultrasound.
  - ✓ **Pleural effusion** in a patient with lung cancer is usually due to malignant involvement of the pleura, but it may be secondary to associated infection of the lung or coincidental, as in heart failure.

Invasion of the mediastinum is best assessed by CT because the neoplasm is directly visualized, and the detailed anatomy is displayed.

- ✓ **Invasion of the chest wall.** Destruction of a rib immediately adjacent to a pulmonary opacity is virtually diagnostic of bronchial carcinoma with chest wall invasion. CT (and MRI) can demonstrate rib and soft tissue invasion.
- ✓ **Rib metastases.** Carcinoma of the lung frequently metastasizes to the ribs, where it produces bone destruction. Sclerotic secondary deposits from lung carcinoma are rare.
- ✓ **Pulmonary metastases.** Primary lung carcinoma may metastasize to other parts of the lungs. The rounded opacities
- ✓ **Lymphangitis carcinomatosa** is the term applied to blockage of the pulmonary lymphatics by carcinomatous tissue. The lymphatic vessels become grossly distended and the lungs become edematous. The signs can be identical to those seen in interstitial pulmonary edema (septal lines, loss of vessel clarity and peribronchial thickening). CT, particularly HRCT, has proven very valuable in demonstrating lymphangitis carcinomatosa.

METASTATIC NEOPLASMS

Metastases from extra thoracic primary tumors may be seen in the lungs, the pleura or the bones of the thoracic cage or, very rarely, in hilar and mediastinal lymph nodes.

- **Pulmonary metastases**
  - ✓ Pulmonary metastases are, typically, spherical and well defined, although irregular borders are occasionally seen. Usually, they are multiple and vary in size.
  - ✓ Metastases have to be almost a centimeter in diameter, or larger, to be visible on a CXR. CT can demonstrate metastases as small as 3–6 mm.
- **Pleural metastases**
  - ✓ Pleural metastases usually give rise to pleural effusion; but metastatic adenocarcinoma can present with diffuse thickening of the pleura.
- **Metastases to ribs**
  - ✓ Rib metastases are common with those primary tumors that metastasize to bone, notably bronchus, breast, kidney, thyroid and prostate.
  - ✓ All except prostatic and breast cancers produce mainly or exclusively lytic metastases. With lytic metastases, the most reliable sign is destruction of the cortex, particularly of the upper border of a rib.

TRAUMA TO THE CHEST

In major trauma CT is often needed, but a CXR is usually enough following minor trauma.

Findings to look for on the CXR of a trauma patient:

- **Pneumothorax**
- **Pneumomediastinum**
- **Subcutaneous emphysema**
  - Streaky gas lucency in the soft tissues of the chest wall
  - Commonly tracks superiorly into soft tissues of the neck
- **Hemothorax**
- **Hemopneumothorax**
- **Pulmonary contusion:** Focal area of alveolar shadowing that appears within hours of the trauma and usually clears after 4 days; usually associated with rib fractures.

- **Mediastinal hematoma**
- **Ruptured diaphragm:** CXR signs of ruptured diaphragm include herniation of abdominal structures into the chest, apparent elevation of the hemidiaphragm and contralateral mediastinal shift
- **Rib fractures**
  - ✓ Fractures of the upper three ribs indicate a high level of trauma, though there is no proven increase in the incidence of great vessel damage
  - ✓ Fractures of the lower three ribs have an association with upper abdominal injury (liver, spleen and kidney)
  - ✓ **Flail segment** refers to segmental fractures of three or more ribs, flail segment produces paradoxical movement of a segment of the chest wall with respiration
- **Fractures of the clavicle, scapula, sternum and humerus** may also be seen in association with chest trauma.
- **Aortic injury:**
  - ✓ Rupture of the thoracic aorta is the most catastrophic injury associated with chest trauma.
  - ✓ Full thickness or complete aortic rupture is usually fatal.
  - ✓ If left untreated, incomplete aortic rupture has a high mortality rate
  - ✓ Most aortic injuries occur at the aortic isthmus, just distal to the left subclavian artery.
  - ✓ **CXR signs of aortic rupture are due to the associated mediastinal hematoma:**
    - Widened mediastinum
    - Obscured aortic knuckle and other mediastinal structures
    - Displacement of trachea and nasogastric tube to the right
    - Depression of left main bronchus
    - Left hemothorax causing pleural opacification, including depression of the apex of the left lung.
    - Ruptured aorta is a surgical emergency and is best diagnosed by CT angiography.

Further readings: Diagnostic imaging, seventh edition