Diagnostic Imaging: X-Ray and CT Scan in the Integrated Pulmonary Pathology

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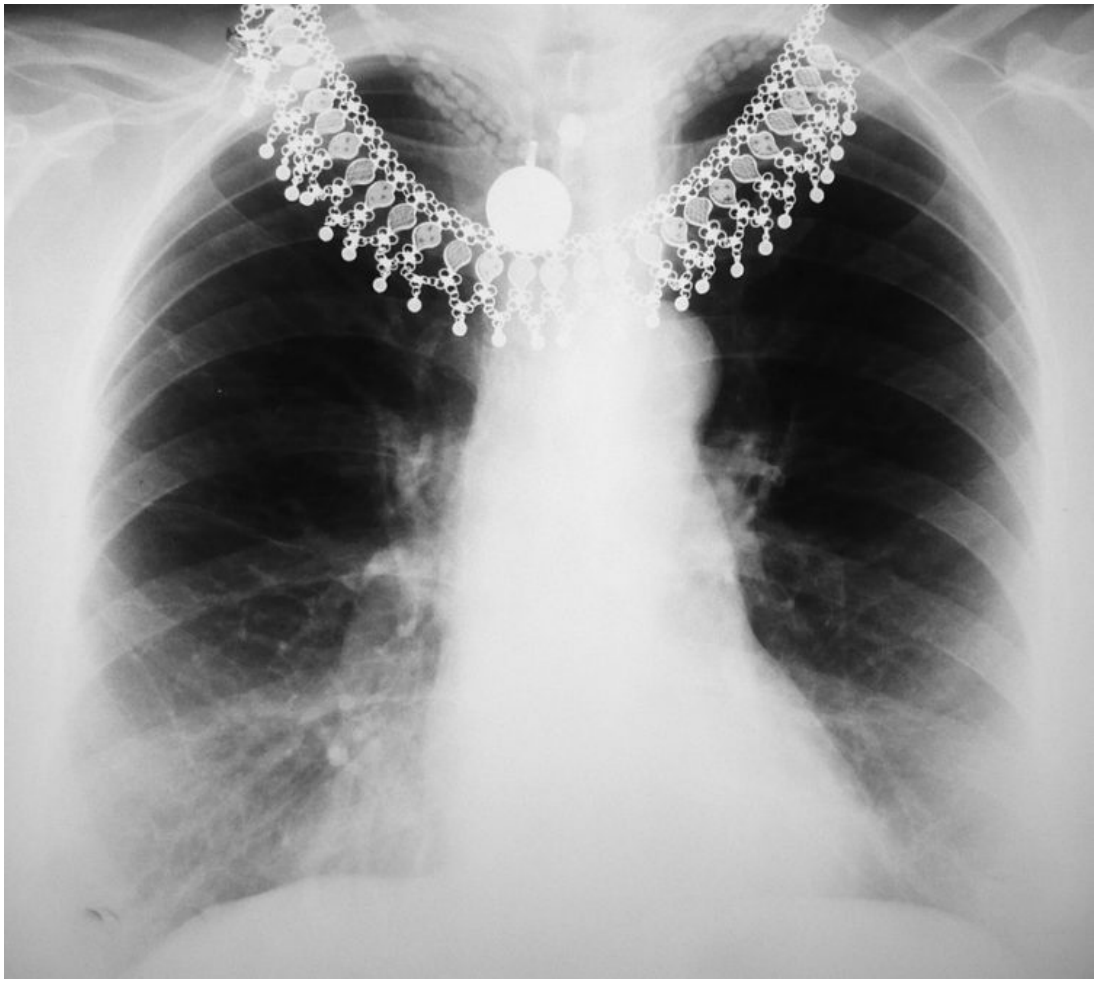
Radiological investigations like x-ray and CT scan are required for the confirmation of clinical findings. The field of radiology in the 21st century has become very advanced and through various radiological investigations, even the smallest calcifications and vascular pathologies can be diagnosed. The chest radiograph (CXR) is the most common radiological investigation.



Role of Chest X-ray

Chest x-rays help **evaluate the lungs, heart, chest wall, airways, and diaphragm**. It can be used to help diagnose conditions with symptoms such as shortness of breath, persistent cough, fever, chest pain, traumatic injury, pneumonia, emphysema, pneumothorax, and lung cancer. It is particularly useful in medical emergencies because it is fast and cheap.

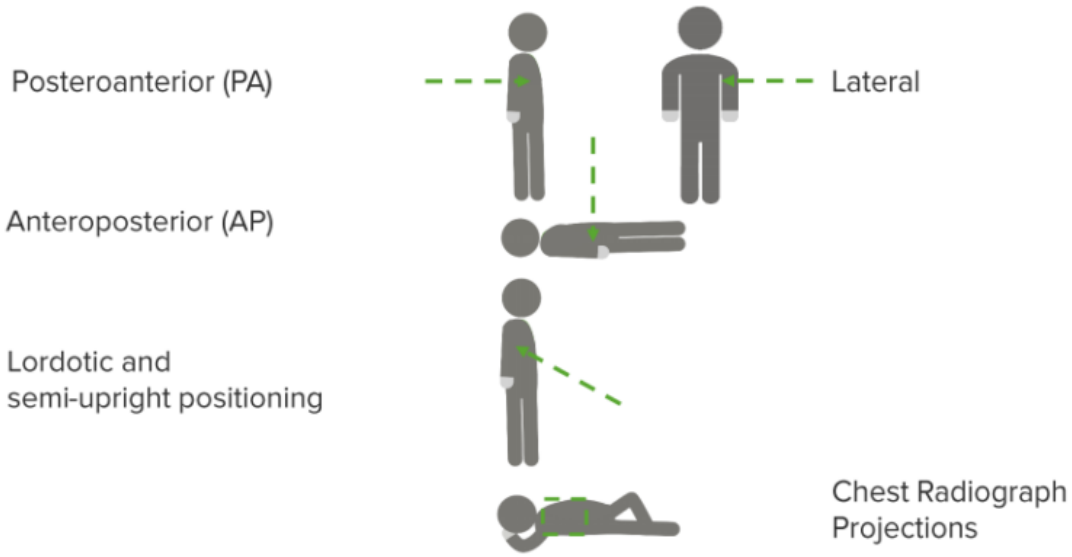
Physicians commonly order chest x-rays when the patients present with the following:

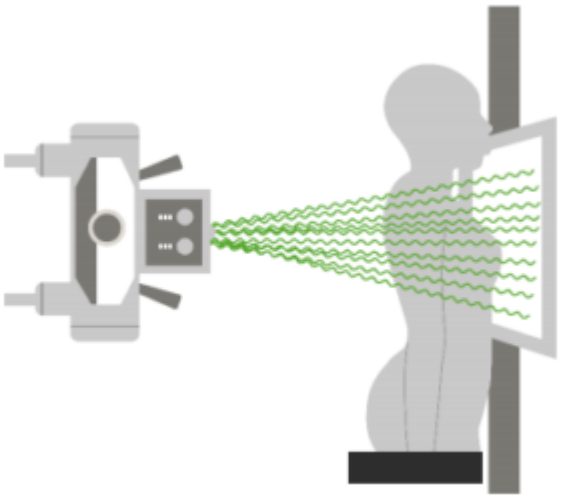
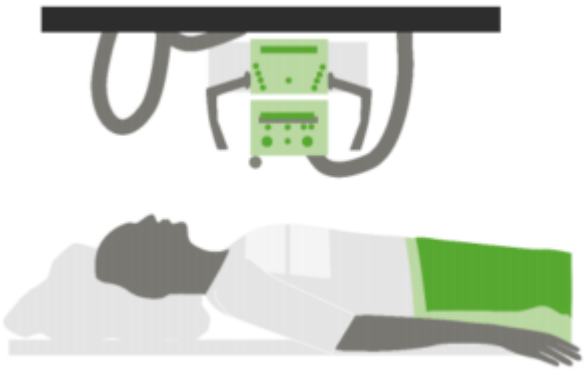
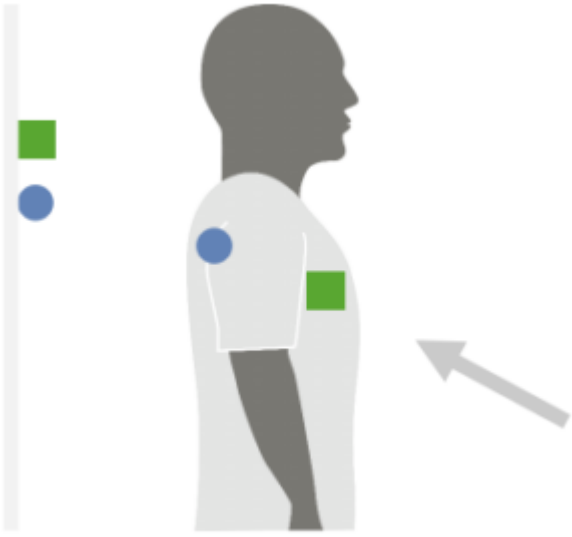
- Persistent cough with or without shortness of breath
- Dyspnea with or without exertion
- Persistent vomitus with blood
- A productive cough with respiratory distress
- Wheeze during respiration with or with a productive cough
- History of trauma to the chest during a roadside accident or any other blunt or sharp trauma to look for broken bones, lung anatomy, pneumothorax, and atelectasis of the lungs
- Pneumothorax
- Pleural effusion
- Cardiac conditions like CCF, pulmonary edema

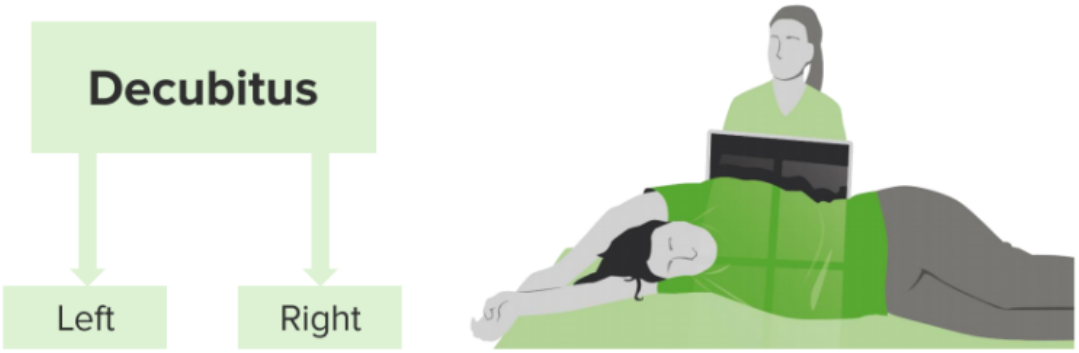
Another use of the chest x-ray is to rule out any heart pathology and to check for the position of the nasogastric/feeding/endotracheal tracheostomy tube after placement in the body. The chest x-ray is required after endotracheal intubation to determine proper tube placement.

Standard Projections

- PA view is performed while standing and in full inspiration. It examines the lungs, bony thoracic cavity, mediastinum, and great vessels.
- **The lateral view is performed in an erect left lateral position, for locating suspected lung lesions.**



Posteroanterior (PA) and Lateral		Upright (X-ray beam perpendicular to cassette)
Anteroposterior (AP)		Supine (X-ray beam perpendicular to cassette) Semi-upright (X-ray beam angled towards the head)
Lordotic and semi-upright positioning	 	Results in anterior structures appearing to be superior to posterior structures



Types of Opacities

Lung abnormalities mostly present as **“opacities”** due to increased densities. Opacities can be divided into four types:

- **Consolidation:** A pathologic process that leads to accumulation of fluid, pus, blood or cells (including tumor cells) or other substances in the air sacs. Pneumonia is the most common example of consolidation.
- **Interstitial changes:** Changes seen in the supporting tissue of the lung parenchyma
- **Nodules or masses:** A space-occupying lesion in the lungs can be single or many
- **Atelectasis:** Collapse of a part of the lung when the amount of air in the alveoli decreases due to some pathology

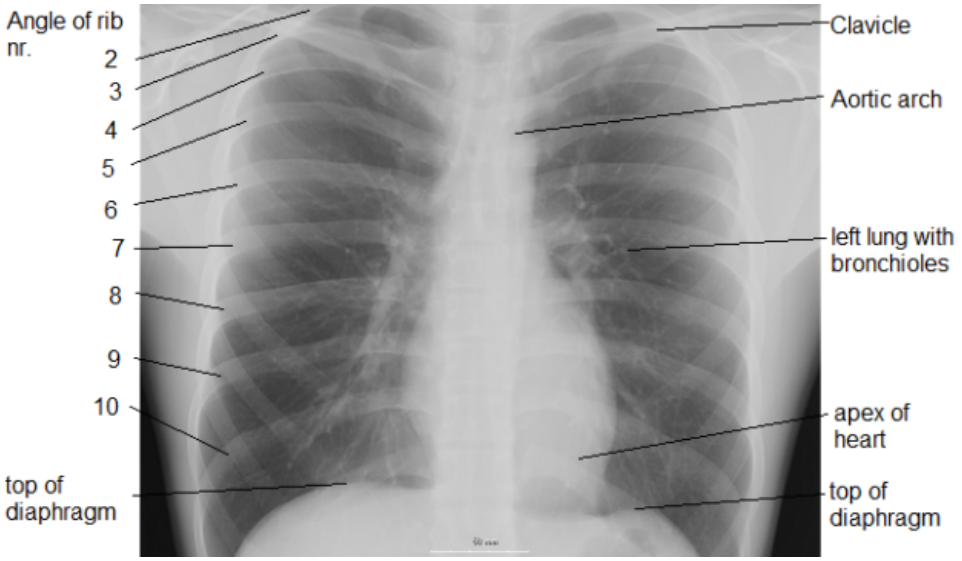


Image: “An X-ray of a human chest area, with some structures labeled” by Chikumaya and Mikael Häggström. License: CC BY-SA 3.0

Zones on the Chest X-ray

The chest radiograph is a **two-dimensional picture of a three-dimensional structure**; the four-zone technique is helpful for the location of the pathology:

- **Apical zone:** Above the clavicles
- **Upper zone:** Below the clavicles and above the cardiac silhouette

- **Mid zone:** Level of the hilar structures
- **Lower zone:** Bases of the lungs

Limitations, Benefits, and Risks of X-rays

Limitations of chest x-ray

Although cheap and fast, conventional chest x-ray still **fails to diagnose a few conditions** like small cancers, blood clots, and pulmonary embolisms.

Benefits of chest x-ray

X-rays usually have **no side effects** in the typical diagnostic range and the equipment is **relatively cheap and widely available** in emergency rooms, physician offices, ambulatory care centers, and nursing homes, making it convenient for both patients and physicians.

Risks of x-rays exposure in chest x-ray

There is always a slight **chance of cancer from excessive exposure to radiation**. However, the benefit of an accurate diagnosis far outweighs the risk. The effective **radiation dose** for this procedure **varies**. Sperms in males and ova (eggs) in females can be damaged by radiation exposure and women should always inform their physician about their pregnancy status.

Chest X-ray in Various Conditions

Chest infections

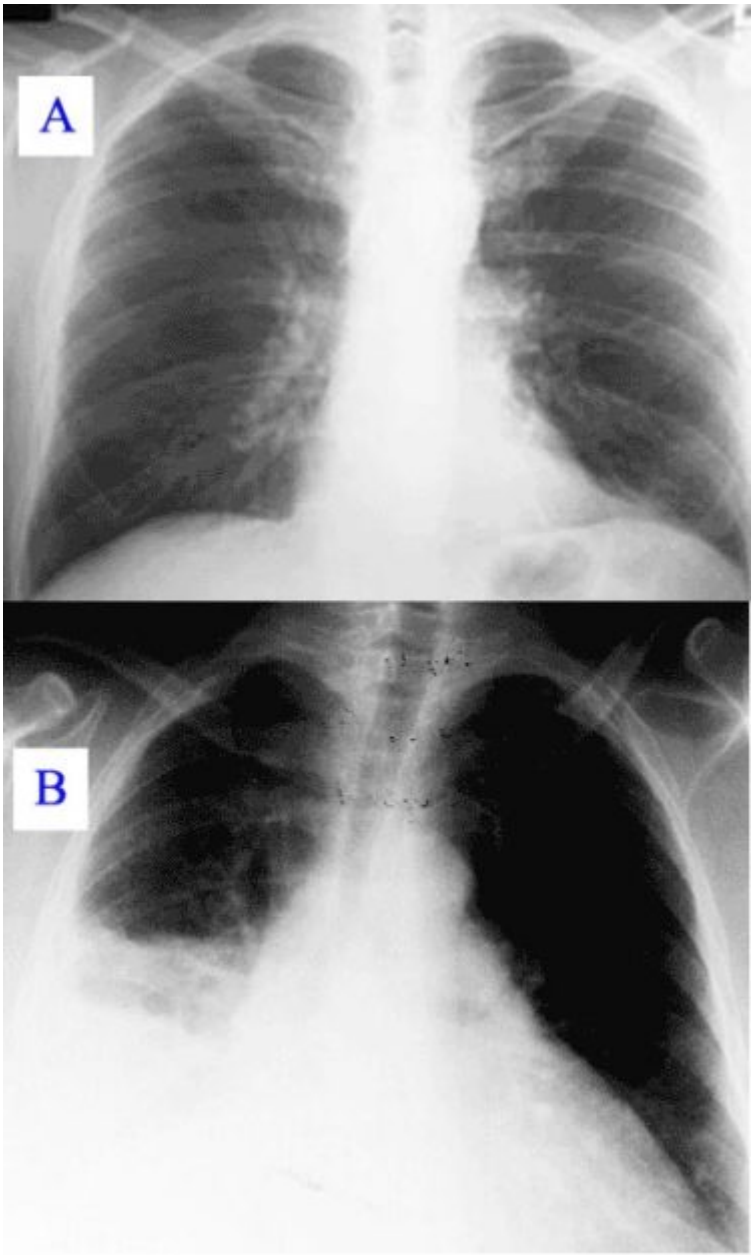


Image: “Image A: A normal chest radiograph. Image B:Q fever pneumonia.” by CDC. License: Public Domain

Pneumonia can be either lobar pneumonia, which involves complete lobe of the lungs or bronchopneumonia, which occurs in the entire lungs in patches. The chest x-ray of a patient with lobar pneumonia shows **consolidation** of the involved lobe of the lung. While in bronchopneumonia patches of **alveolar infiltrates** are seen as random patches in the lungs.

Severe lower respiratory tract infection can cause the enlargement of the hilar lymph nodes, which appears **as hilar infiltrates** on the chest x-ray. In **tuberculosis**, usually upper zones of the lungs are involved. Chronic inflammation leads to granulomatous inflammation in the lungs seen as rounded or randomly shaped consolidation/complex along with hilar infiltrates. In **asthma**, hyperinflation of the chest due to longer inspiration as compared to expiration causes the air to stay in the lungs. This is seen as relatively darker lung fields along with inflated lungs.

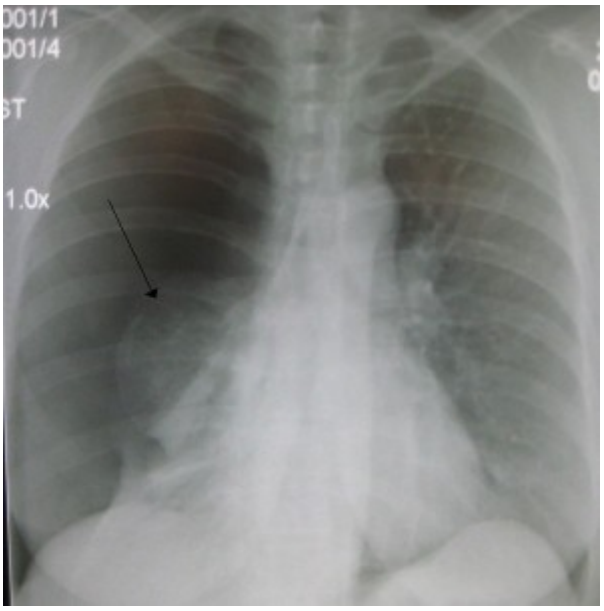
Calcification of lymph nodes in chronic chest infections:

- In patients with chronic chest infections, **bacteria infiltrate the lymph**

nodes in the hilum (lymphadenopathy) which later calcify due to the chronic inflammatory response of the body. These calcified lymph nodes are seen on the x-ray in the hilum as hyper-dense white opacities.

- Sometimes the infection causes the formation of **pneumatoceles**, small false pockets containing air. These are seen on the chest x-ray as rounded membranous pouches with darker center due to air.

Pneumothorax



Chest X-ray showing a pneumothorax on the right (left in the image), where the absence of lung markings indicates that there is free air inside the chest

Air sometimes accumulates in the pleural cavity as a result of direct trauma to the chest and causes the lungs to collapse. This can be observed by the absence of interstitial lung markings and smooth black space/air where the collapsed lung should in the chest cavity. With a pneumothorax, the mediastinum can shift toward the affected side. With a tension pneumothorax, the mediastinum will shift toward the unaffected side due to pressure buildup on the affected side.

Alveolar infiltration

Consolidation is caused by the alveolar infiltration by fluid, pus or blood. There are many causes of this infiltration. Fluid can be **transudate** due to edema (caused by CCF, ARDS, renal failure) or an **exudate** (e.g pus) as in pneumonia. Blood accumulation occurs due to hemorrhage after trauma or with cancer or autoimmune diseases like SLE.

Acute onset of consolidation can be due to pulmonary edema, pneumonia, aspiration, hemorrhage, while few chronic conditions lead to chronic consolidation e.g lung cancer, lymphoma, sarcoidosis, etc.

Lung nodules and lung carcinomas

Benign lung nodules or lung tumors can be seen on the chest x-ray as **densities/opacities in the lung fields or near the hilum**. Calcification of the benign tumors can also be seen.

Nodularity of sarcoidosis is seen in the lower zone, near the bases of the lungs. Adenocarcinomas, large cell carcinoma of the lungs are seen mostly as peripherally located lung nodules, while small cell lung carcinoma and squamous cell lung cancer are located centrally on the chest x-ray.

Solitary pulmonary nodules

Single densities found radiological images can be benign or malignant.

- Density < 1 cm size are usually benign nodules.
- Density > 1 cm size are usually malignant tumors.

Benign tumors/nodules are usually seen as calcified lesions while malignant lesions are non-calcified, invasive and metastatic (multiple).

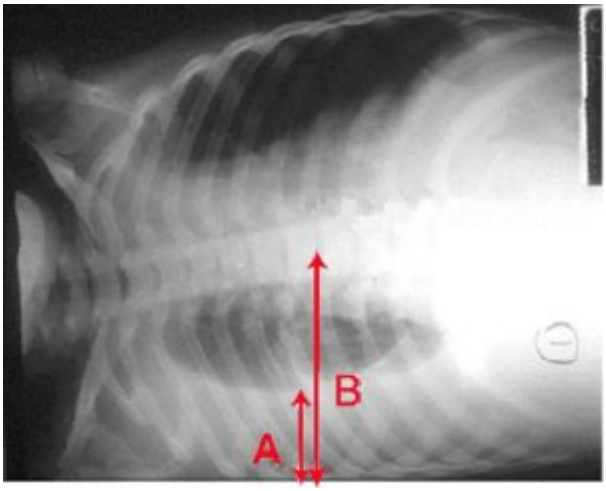


Image: “Chest x-ray of a pleural effusion. The arrow A shows fluid layering in the right pleural cavity. The B arrow shows the normal width of the lung in the cavity” by Centers for Disease Control and Prevention. License: Public Domain

Pleural effusion

Accumulation of fluid in the pleural space is called pleural effusion. Pleural effusion is seen in the lower zone, above the shadow of the diaphragm. Mild effusion leads to the loss of a **costodiaphragmatic angle**, severe effusion leads to loss of **a costophrenic angle**.

CT Scan of the Chest in various Pulmonary Pathologies

Usually, HRCT (high-resolution CT) chest is preferred over plain CT scan of the chest. Numerous patterns are seen on the HRCT in various diseases. While studying a CT image:

1. **Identify the pattern**. It can be...
2. ...reticular
3. ...nodular
4. ...ground glass appearance
5. ...low attenuation (in emphysema,cystic lesions)

- What is the **location of the abnormality** in the lungs in the secondary

lobules?

1. Centrilobular
2. Peri-lymphatic
3. Random
4. Where is the **predominance of the abnormality** in the lungs?
    1. Upper versus lower zone predominance
    2. Central versus peripheral predominance
    3. **Any other findings in the CT?**
    4. Traction bronchiectasis
    5. Lymphadenopathy
    6. Pleural effusion

Reticular Pattern on CT

In this pattern, many **honeycomb-like lines** are seen in the lungs due to fibrosis or thickening of the interlobular septa. Honeycombing is due to cystic spaces in the lung with thickened, fibrosed walls. This is a feature of interstitial pneumonia. Septal thickening occurs after fluid accumulation, fibrosis or cellular infiltration. These findings can be **focal or general and unilateral or bilateral**.

Septal thickening is **smooth** as seen in pulmonary edema (Karley B lines on the chest X-ray), lymphatic spread of carcinoma or lymphoma and in alveolar proteinosis or **nodular/irregular as** seen in sarcoidosis, silicosis, and lymphatic metastasis of carcinoma or lymphoma.

Nodular Pattern on CT

Peri-lymphatic nodules are seen near the pleural surfaces, interlobular septa and in the peribronchovascular interstitium. Nodules are particularly seen in the fissures. These nodules are most commonly seen in sarcoidosis, silicosis, coal worker's pneumoconiosis, and lymphatic metastasis of cancer.

Centrilobular nodules are mostly present in the center of the lobules in the lung mostly 5–10 mm away from the fissures and pleural surface. They are found in hypersensitivity pneumonitis, bronchiolitis in smokers, infectious airways diseases. The **'tree-in-bud'** pattern can be helpful in following differentials:

- Endobronchial spread of infection (TB, MAC, any bacterial bronchopneumonia)
- Disease of the lungs associated with infection (cystic fibrosis, bronchiectasis)
- An airway disease associated with mucus retention (allergic bronchopulmonary aspergillosis, asthma)

Nodules can be distributed randomly, commonly involving the pleural surfaces and fissures, not the sub-pleural areas which is seen in patients of peri-lymphatic distribution. Small random nodules are seen in hematogenous metastasis, miliary tuberculosis, miliary fungal infections when extensively distributed sarcoidosis may mimic this pattern and Langerhans cell histiocytosis (early nodular stage).

Abnormalities seen in the **ground glass pattern** are located in different zones in different conditions:

- Upper zone predominance: Respiratory bronchiolitis, PCP
- Lower zone predominance: UIP, NSIP, DIP
- Centrilobular distribution: Hypersensitivity pneumonitis, respiratory bronchiolitis

Low Attenuation Pattern on CT

The fourth pattern includes conditions that can lead to decreased lung attenuation or air-filled lesions. These include:

- Emphysema
- Lung cysts (LAM, LIP, Langerhans cell histiocytosis)
- Bronchiectasis
- Honeycombing

Review Question

The correct answer can be found below the references.

A 26-year-old male with a history of a sore throat previously now came with difficulty breathing and productive cough for the last 3–4 days. On examination, he had a high-grade fever and bilateral crepitations in the chest more on the right side. He has no history of weight loss or hemoptysis. He is vaccinated against tuberculosis. His chest x-ray shows an opacity on the right middle lobe of the lungs. Which of the following is the most common cause of such findings?

A. Lung abscess
B. Foreign body intake
C. Pneumonia
D. Tuberculosis

References

X-ray (Radiography) – Chest via radiologyinfo.org

Chest X-ray via healthline.com

Chest radiograph zones via radiopaedia.org

Lung – HRCT Basic Interpretation by Robin Smithuis, Otto van Delden and Cornelia Schaefer-Prokop

Understanding HRCT of the Lungs by Zafar Sajjad

Correct answer: 2C

Notes