Hemoptysis: what should you look for?

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Objectives

- Describe and illustrate the imaging findings of pulmonary, vascular and airway diseases which cause hemoptysis in computed tomography (CT), taking into account the age group.
- Explain the physiopathology of hemoptysis.

Introduction

- Hemoptysis is the expectoration of blood that originates from the lower respiratory tract.
- It may be a sign of a life-threatening disease or be large enough to need an immediate intervention.
- Knowledge of underlying diseases helps the clinician to guide therapy.

Causes

- Pulmonary, airways and thoracic vasculature diseases cause hemoptysis.
- CT allows assessment of these structures and frequently detects the responsible anomaly.
- Its main causes vary with the age group.

Causes

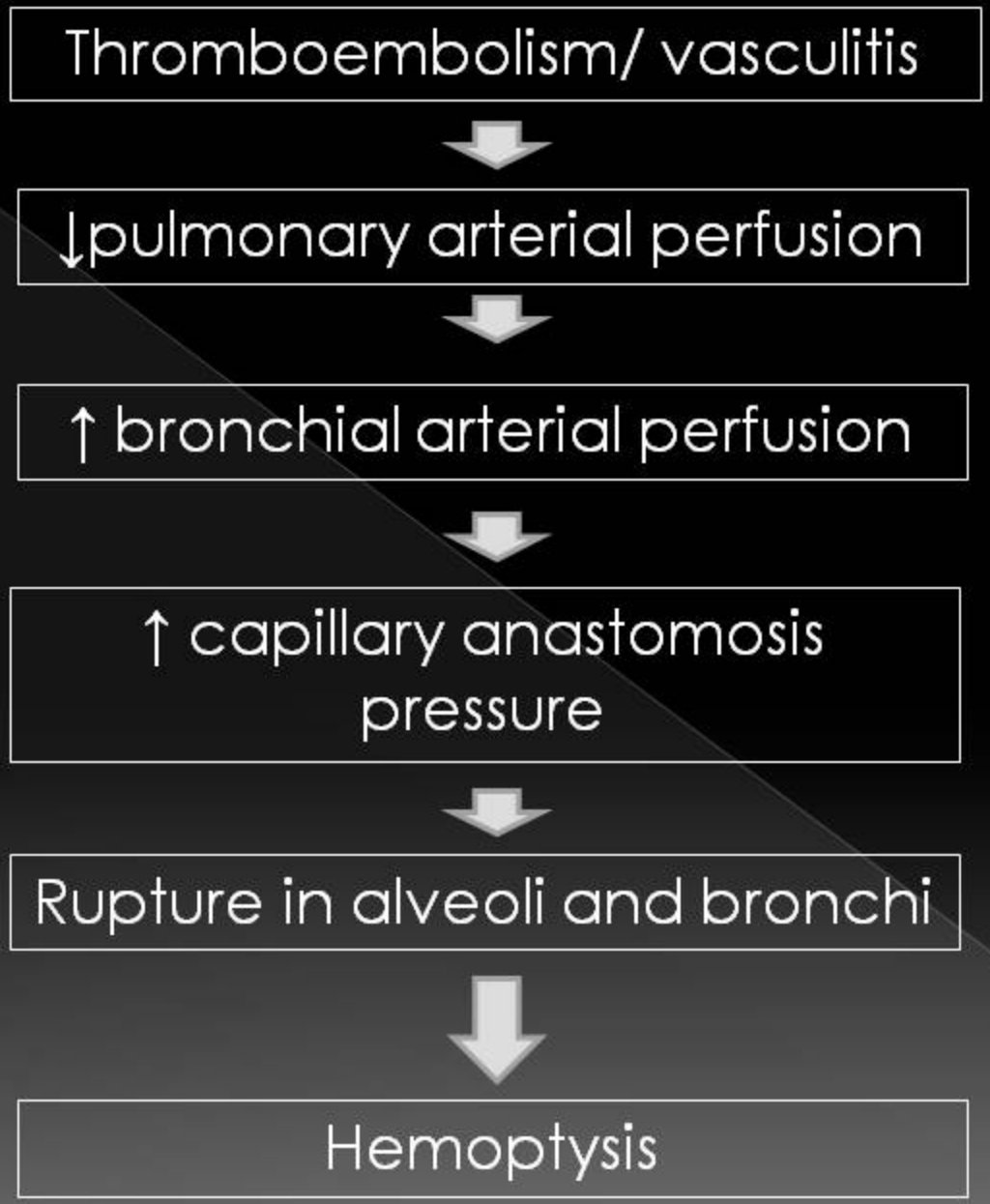
- Hemoptysis in young people is predominantly due to congenital diseases:
  - Pulmonary arteriovenous malformation (AVM)
  - Pulmonary artery atresia
  - Intralobar sequestration
  - Cystic fibrosis
  - LAM

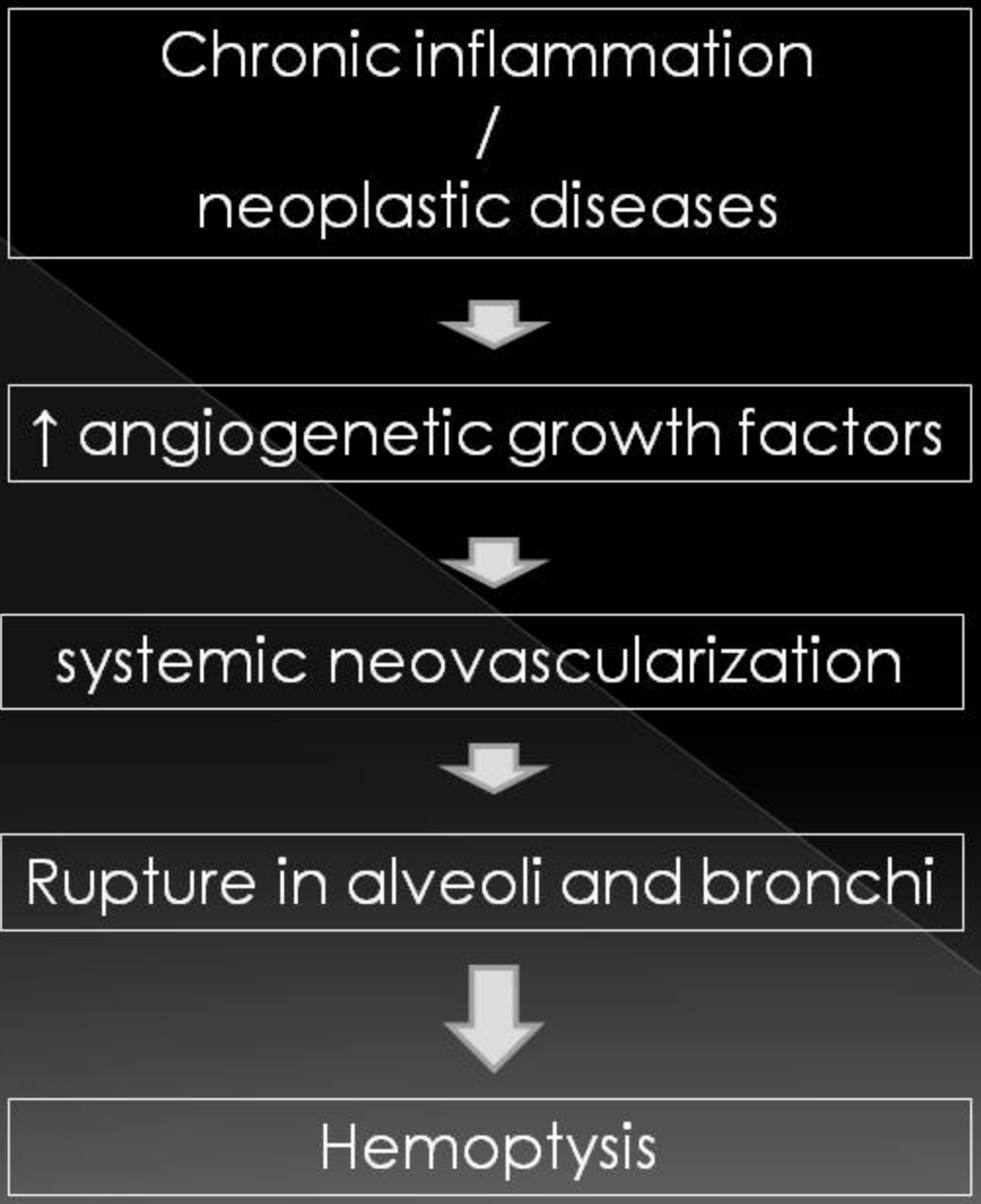
Causes

- In adults, acquired diseases are main causes of hemoptysis:
  - Bronchitis
  - Bronchiectasis
  - Infectious diseases (bacterial, mycobacterial and fungal)
  - Pulmonary neoplasm
  - Thromboembolism
  - Acute pulmonary edema
  - Vasculitis

Physiopathology

- Lungs are supplied by two arterial vascular systems with different functions: the pulmonary and bronchial arterial systems, which have a low and a high pressure, respectively.
- These, communicate with each other through fragile capillary anastomosis
- 90% of the cases of hemoptysis are due to damage in the bronchial arterial system.


Thromboembolism/ vasculitis
↓pulmonary arterial perfusion
↑ bronchial arterial perfusion
↑ capillary anastomosis pressure
Rupture in alveoli and bronchi
Hemoptysis


Chronic inflammation
/
neoplastic diseases
↑ angiogenetic growth factors
systemic neovascularization
Rupture in alveoli and bronchi
Hemoptysis

Others physiopathologic mechanisms

- Pulmonary infarction secondary to ischemic necrosis
  - Thromboembolism, vasculitis, infections with blood vessel invasion
- Pulmonary necrosis → cavitation
  - Tuberculosis and lung neoplasm
- Bronchial mucosal capillary erosions
  - Bronchiectasis and bronchitis

YOUNG PEOPLE

Pulmonary arteriovenous malformation (AVM)

- It is an abnormal dilatation of pulmonary capillaries resulting from a defect in the development of the capillary walls.
- Frequently seen in Osler-Weber-Rendu syndrome
- Manifests as hemoptysis or respiratory distress

Pulmonary arteriovenous malformation (AVM)

- AVM slowly enlarge over time and can closely mimic a lung tumor in chest radiography.
- May be uni or bilateral, simple or complex
  - Simple AVM: single feeding and draining vessels
  - Complex AVM: multiple feeding vessels

Pulmonary arteriovenous malformation (AVM)

- Thoracic CT: (Fig.1,2)
  - Smooth, sharply defined, round or elliptical nodule
  - Dilated and tortuous feeding artery and draining vein
  - Most common in lower lobes, in subpleural location
  - After iv contrast, these structures get enhanced markedly and rapidly

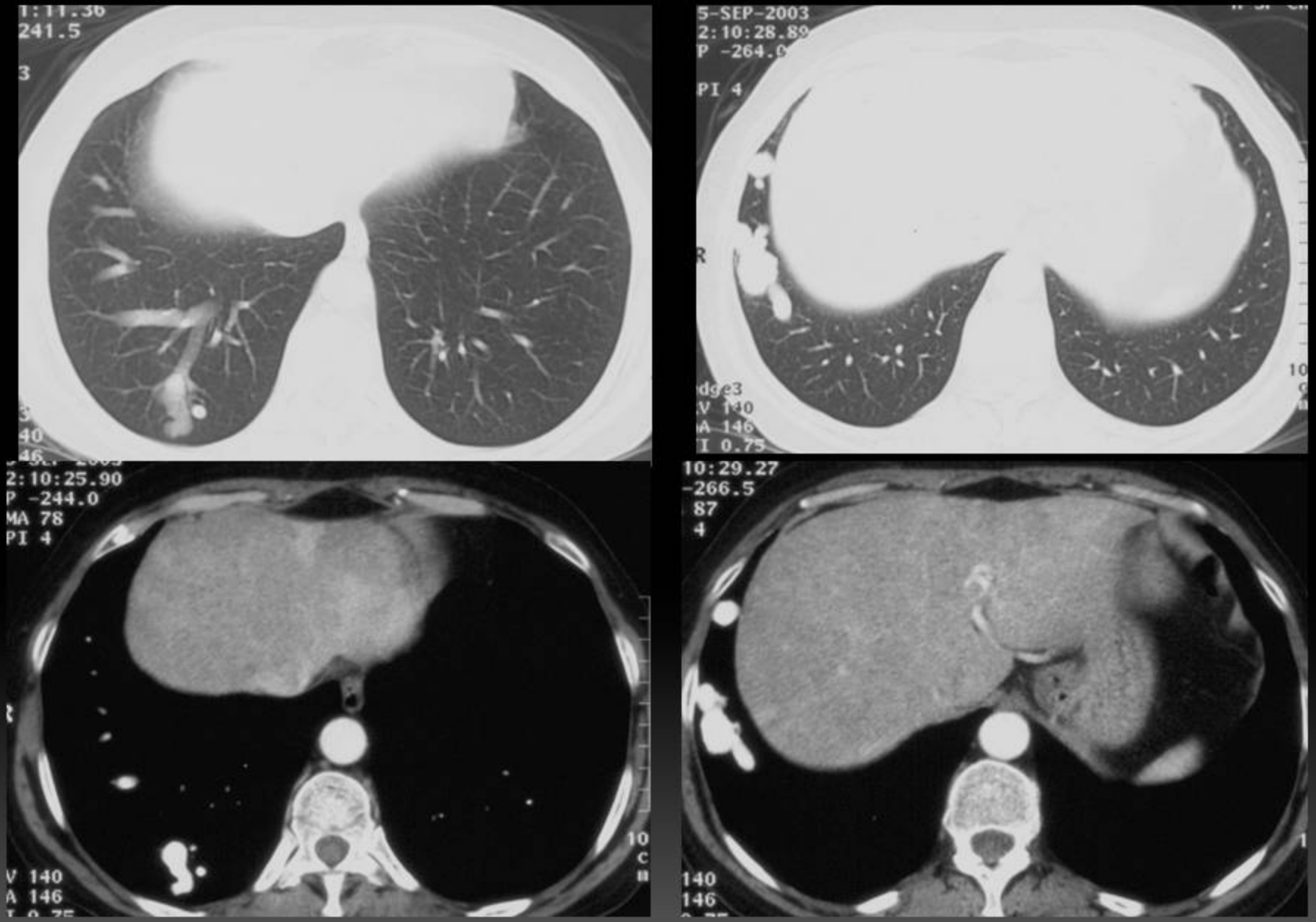


Fig.1: Man, 20 years old, with hemoptysis. Thoracic CT (axial planes) discloses multiple subpleural lobulated and well defined nodules in right lower lobe which strongly enhance after iv contrast, as well as aorta. First image shows a single dilated and tortuous feeding artery and vein in one of these nodules.

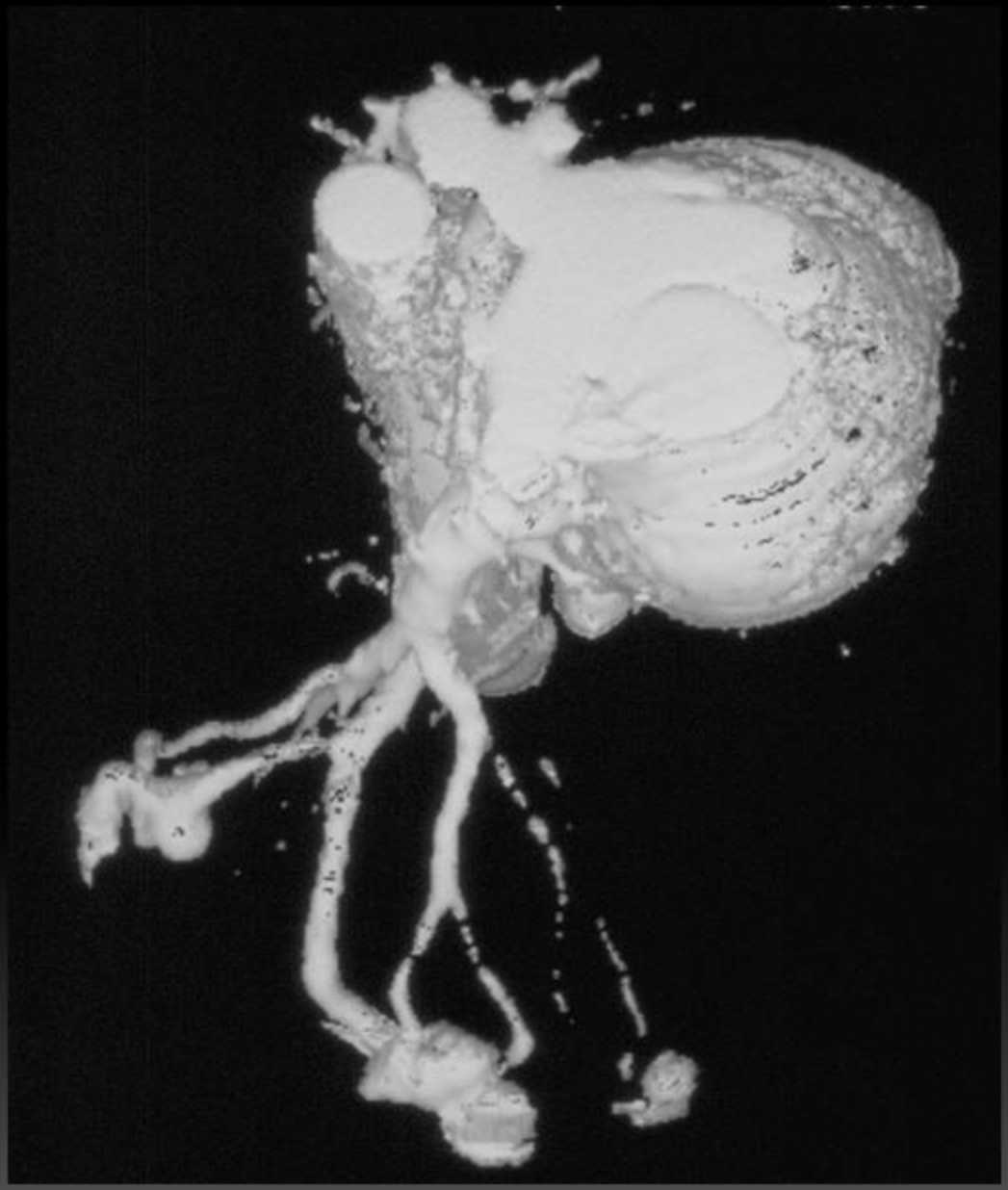


Fig. 2: Volume rendering technique confirms diagnosis of multiple simple AVM in this patient, showing better the draining and feeding vessels.

Pulmonary artery atresia

- Non – development of one of the main pulmonary arteries, frequently the one which is on the opposite site of the aortic arch
- Results in ipsilateral small lung and pulmonary vessels but compensatory hypertrofied bronchial arteries
- Commonly associated with congenital heart disease

Pulmonary artery atresia

- Manifests as hemoptysis or repeated respiratory infections.

- Thoracic CT: (Fig.3)
  - Lack of right or left main pulmonary artery
  - Small pulmonary vessels and hypertrofied bronchial arteries in the affected lung
  - Hypoplasia of the ipsilateral lung
  - Ipsilateral mediastinal shift
  - Normal tracheobronchial anatomy

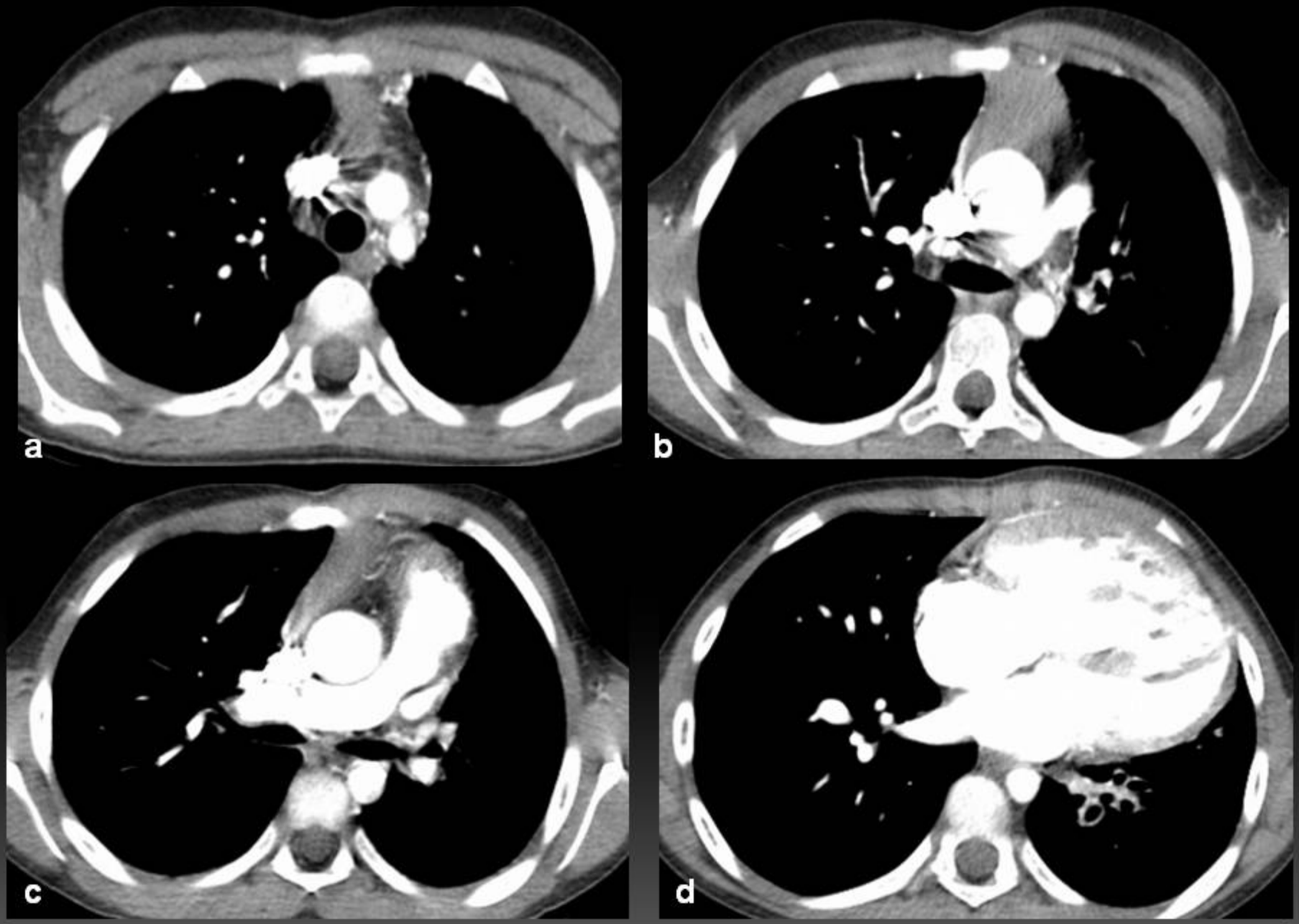


Fig.3: Boy, 7 years old, with recurrent left pneumonia and hemoptoic spuctum. Thoracic CT (axial planes) shows hypertrophy of left bronchial arteries (a,b), absence of left pulmonary artery and its branches (c,d), hypoplasia of ipsilateral lung and cardiomegaly (d).

Intralobar sequestration

- Portion of lung parenchyma, nonareated, without tracheobronchial communication and with systemic arterial supply.
- In 75% of cases, the arterial supply is from the descending thoracic aorta.
- Normal venous pulmonary drainage, absence of it own pleura or other thoracic anomalies distinguish it from an extralobar sequestration

Intralobar sequestration

- Localized more frequently in the left lower lobe
- Manifests as productive cough, recurrent pulmonary infections and hemoptysis
- Thoracic CT:(Fig.4,5)
  - Homogeneous and well-defined pulmonary mass of soft-tissue density
  - Homogeneous pulmonary consolidation

Intralobar sequestration

- Thoracic CT (continuation)
  - Uni or multilocular air and fluid-filled cystic lesion
  - Area of decreased lung attenuation
  - ++ lower lobes and left side
  - After iv contrast, it is visible in the affected pulmonary area, the supplying systemic artery and its origin as well as the normal pulmonary venous drainage.

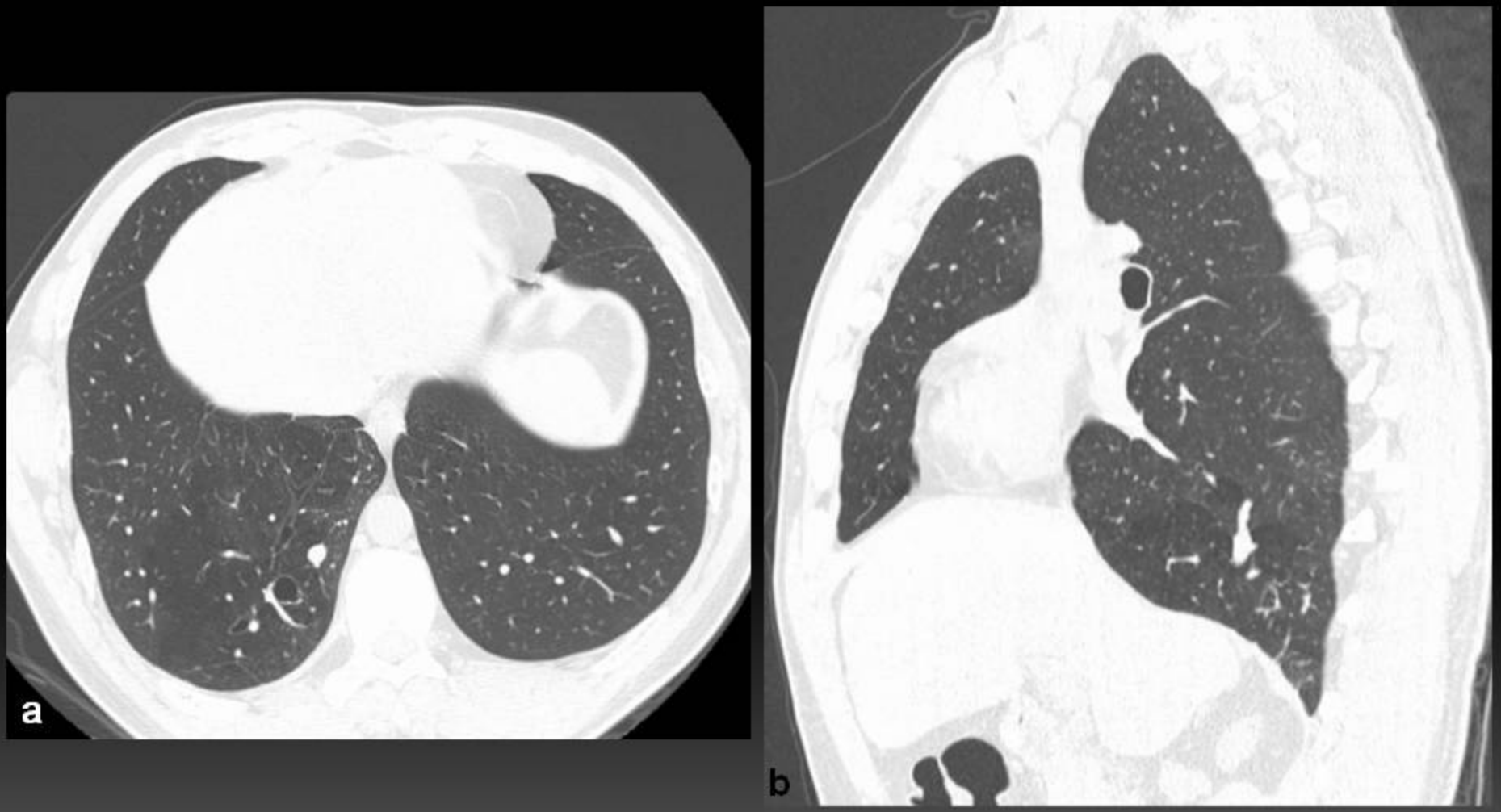


Fig.4: Man, 35 years old, with recurrent hemoptysis. Thoracic CT - axial (a) and sagittal planes (b) – discloses an area of decreased attenuation in the posterior segment of the right lower lobe. There is also a thickened tubular opacity crossing this area.

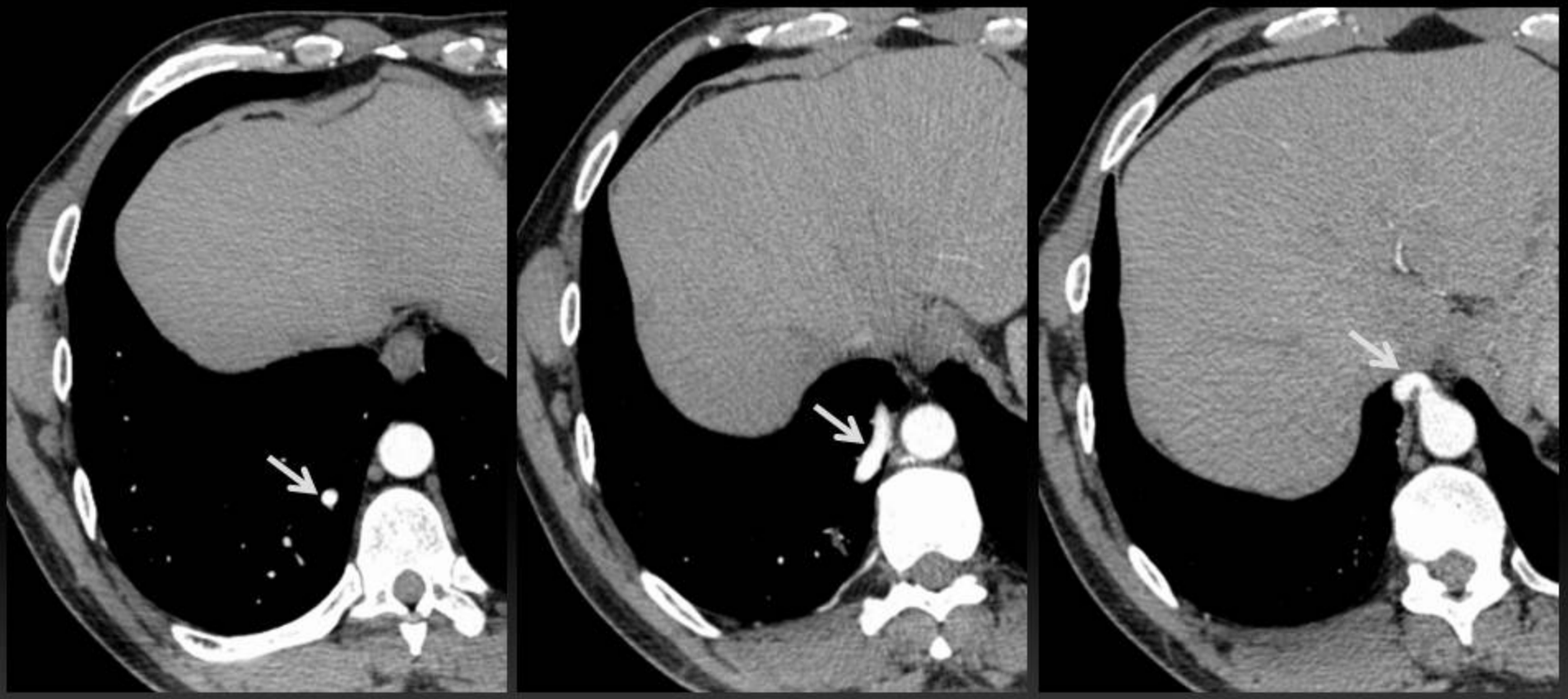


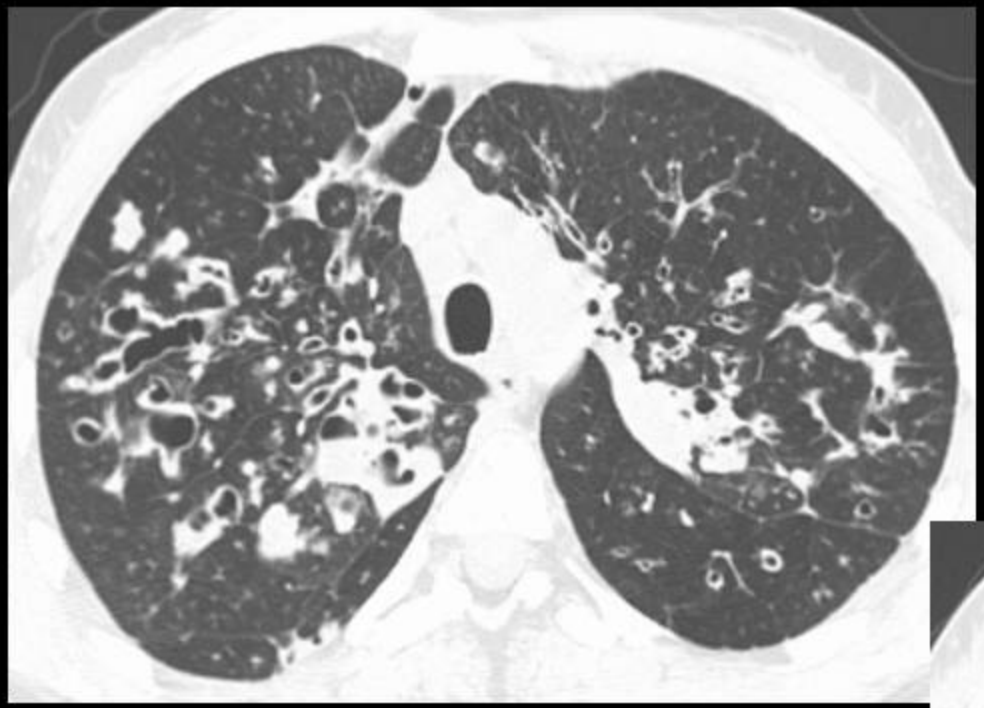
Fig.5: After iv contrast, CT reveals that the tubular structure (arrows) is an artery with abdominal aortic origin and that supplies the abnormal hypoattenuated area of lung. This is compatible with intralobar sequestration.

Cystic fibrosis

- Autosomal recessive disease in which an epithelial transmembrane protein abnormally transports chloride.
- In the lung, this genetic mutation leads to a thick mucus, difficult to clear.
- Mucous plugs predispose to airways infection and bronchiectasis.
- Manifests as recurrent pneumonia and hemoptysis

Cystic fibrosis

- Thoracic CT: (Fig.6)
  - bronchial wall thickening and central bronchiectasis, predominantly in the upper lobes
  - Bronchocele and tree-in-bud → collapse/consolidation
  - cystic lesions – bullae, abscess, cystic bronchiectasis
  - Mosaic pattern due to parenchymal areas of lower density
  - Hilar and mediastinal lymphadenopathies



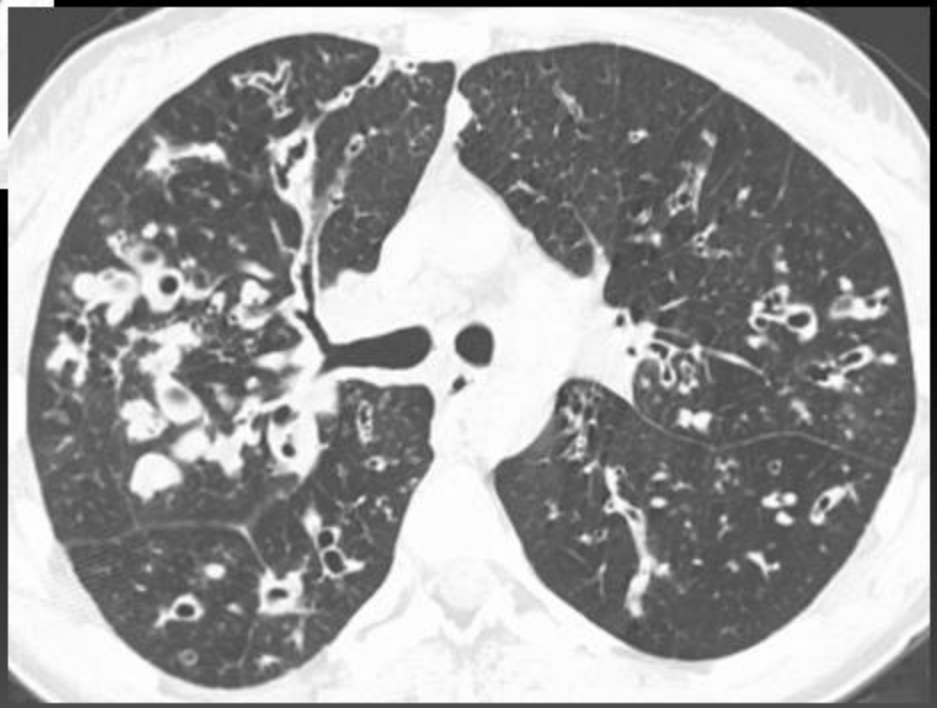


Fig.6: Woman, 24 years old, with cystic fibrosis, productive cough and blood streaked sputum. Thoracic CT shows multiple, diffuse and thickened cystic and varicose bronchiectasis, some with air-fluid level or completely filled.

Lymphangiomyomatosis (LAM)

- Cystic lung disease which affects almost only women.
- May be sporadic or associated with tuberous sclerosis
- Appears due to the abnormal proliferation of smooth muscle cells at the level of perivascular, peribronchial and perilymphatic areas.

Lymphangiomyomatosis (LAM)

- This abnormality causes lymphatic, bronchial and venous obstruction.
  - Bronchial obstruction → lung cysts, bullae and pneumothorax
  - Lymphatic obstruction → chilotorax
  - Venous obstruction → hemossiderosis, hemoptysis
- Manifests as dyspnea, cough, wheezing, fatigue and hemoptysis.

Lymphangiomyomatosis (LAM)

- Thoracic CT: (Fig.7)
  - Multiple lung cysts
    - Round
    - Thin wall
    - Diffusely distributed
  - Pneumothorax
  - Pleural effusion
  - Lymphadenopathy

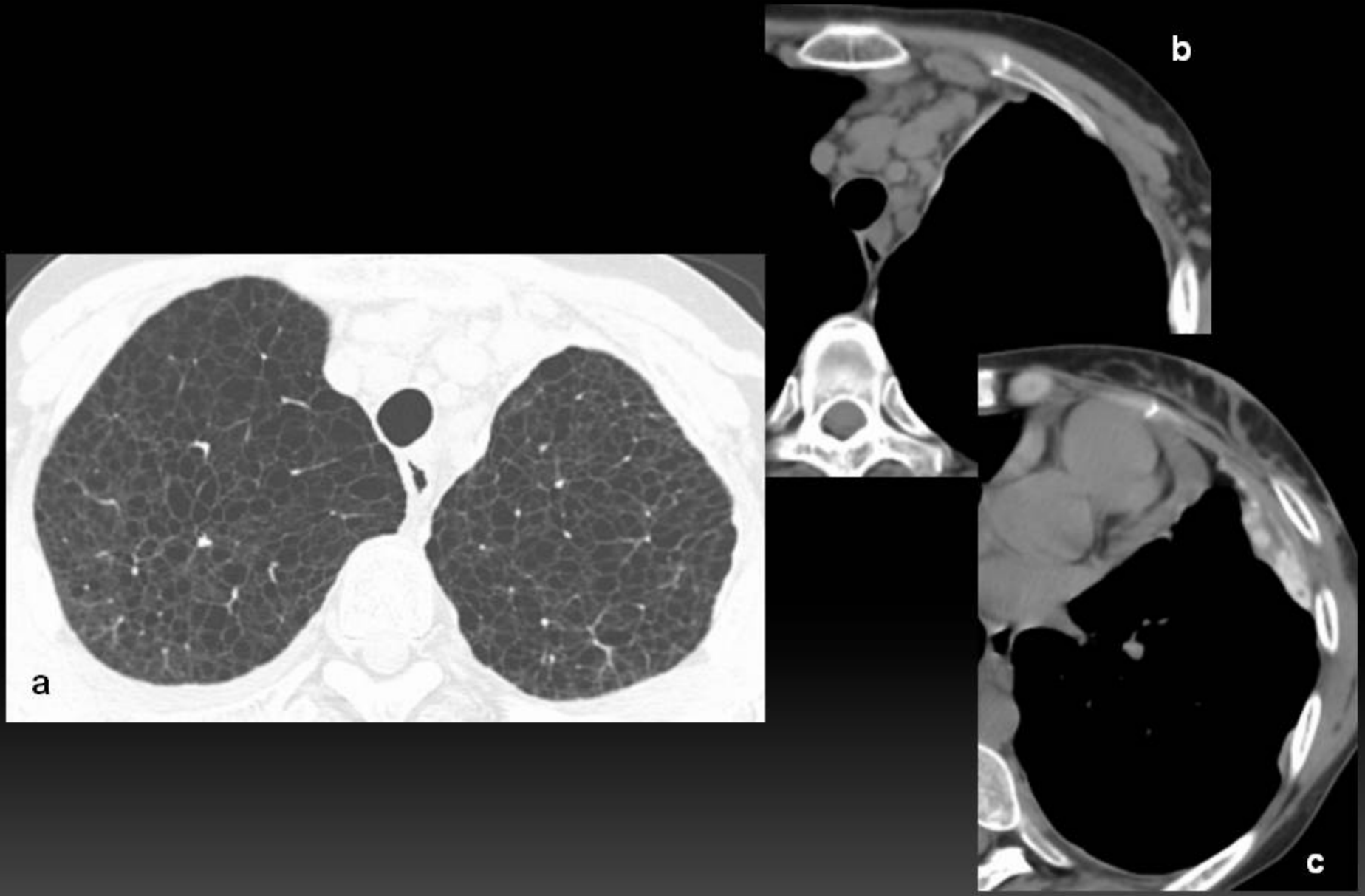


Fig.7: Woman, 31 years old with LAM and an episode of hemoptysis. Thoracic CT discloses uncountable lung cysts in both lungs with thin wall and round morphology(a), lymphadenopathy (b) and thickening of left pleura which have spontaneous high attenuation – talc (c).

ADULTS/ELDERLY

Bronchiectasis

- Defined as an irreversible bronchial dilatation
- Focal or diffuse
- Main causes are acquired:
  - Acute, chronic or recurrent infection
    - Bacterial
    - Mycobacterial → tuberculosis
    - Fungal → aspergilosis

Bronchiectasis

- Bronchitis
- Rejection of lung transplantation
- Bronchial obstruction

- Manifests as recurrent respiratory infections and hemoptysis
- Hemoptysis is due to hypertrophy of bronchial artery

Bronchiectasis

- Thoracic CT: (Fig.8)
  - Bronchial dilatation:
    - Internal bronchial diameter > artery diameter
      - → signet-ring sign
    - Lack of bronchial tapering
      - → visible within 1 cm of thoracic wall.
    - Airways visible peripherally
  - Bronchial wall thickening

Bronchiectasis

- Thoracic CT
  - Bronchial contours – morphologic classification:
    - Cylindrical type:
      - Regular parallel walls → tubular morphology
      - lack of bronchial tapering
    - Varicose type:
      - Irregular parallel walls → "string of pearls" appearance

Bronchiectasis

- Thoracic CT
  - Saccular/cystic type:
    - Saccular dilatation of distal bronchi → "cluster of grapes" appearance
  - +/- bronchial artery enlargement
  - Bronchocele and "tree-in-bud"

→ Imaging findings of infection

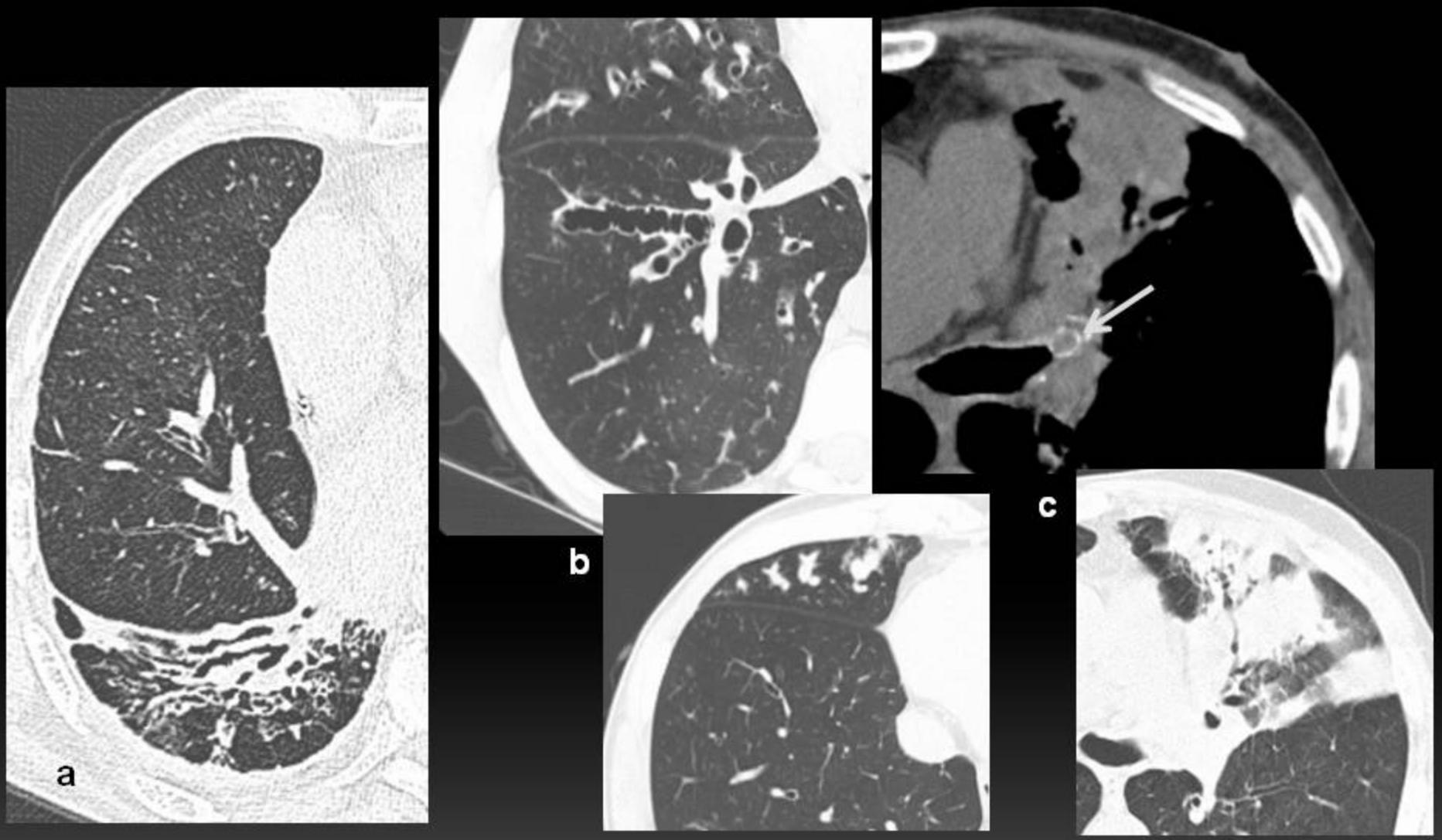


Fig.8: a – Man, 60 years old with bronchitis and hemoptysis. CT shows cylindrical bronchiectasis in superior segment of right lower lobe. b- Man, 65 years old with recent pneumonia and hemoptysis. CT reveals varicose bronchiectasis in right lower lobe and broncoceles in middle lobe. c – Man, 65 years old and blood streaked sputum. CT discloses a foreign body partially calcified (arrow) in lingular bronchus, cylindrical bronchiectasis and lung collapse/consolidation.

Bacterial infection

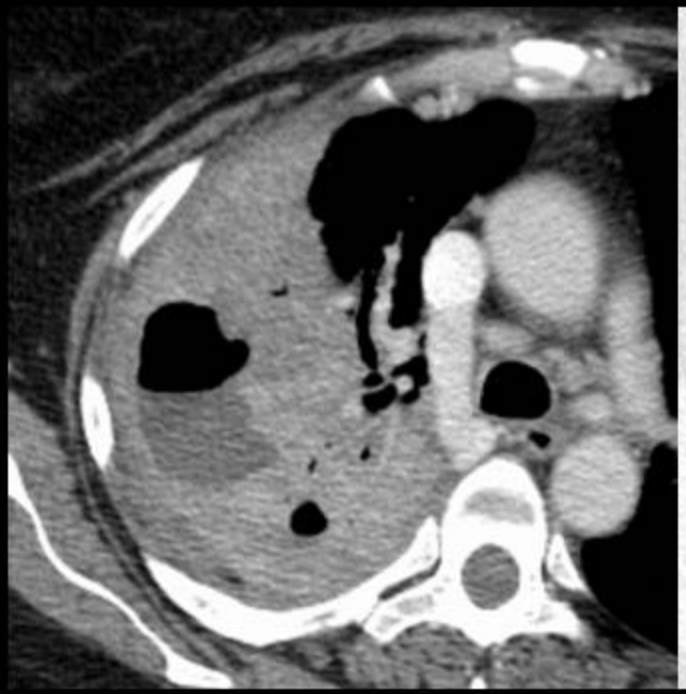
- Necrotizing pneumonia is the type of bacterial infection most frequently associated with hemoptysis, beyond fever and purulent sputum.
- *Staphylococcus aureus, Klebsiella, Pseudomonas* and anaerobic bacteria are commonly implicated.
- Immunosupression, aspiration and chronic disease are the main risk factors.

Bacterial infection

- Thoracic CT: (Fig.9,10)
  - Necrotizing pneumonia
    - Pulmonary consolidation with multiple areas of reduced enhancement or cavitations.
    - Cavities:
      - thick smooth or irregular wall, which enhance after iv contrast.
      - air-fluid level when in communication with traqueobronchial tree.

Bacterial infection

- Thoracic CT:
  - Pleural effusion/empiema
  - Lymphadenopathy



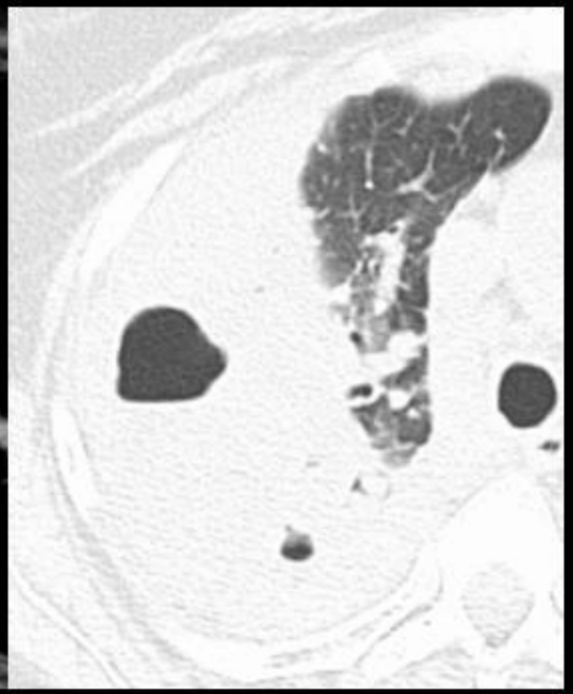
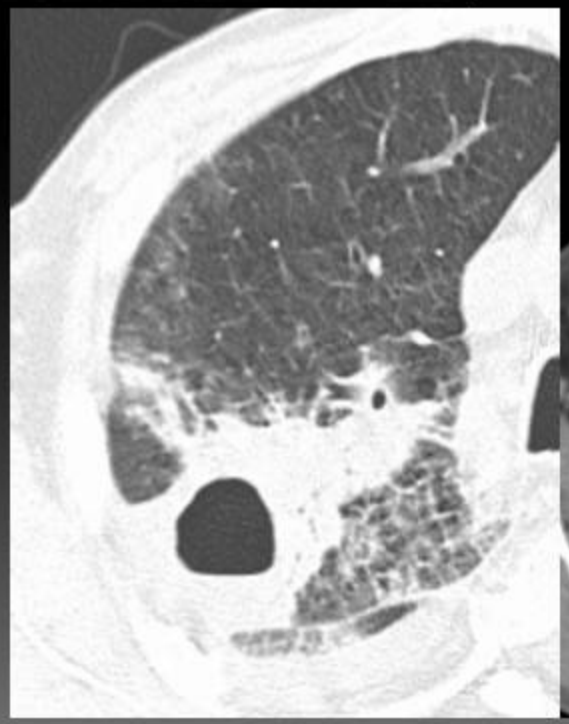
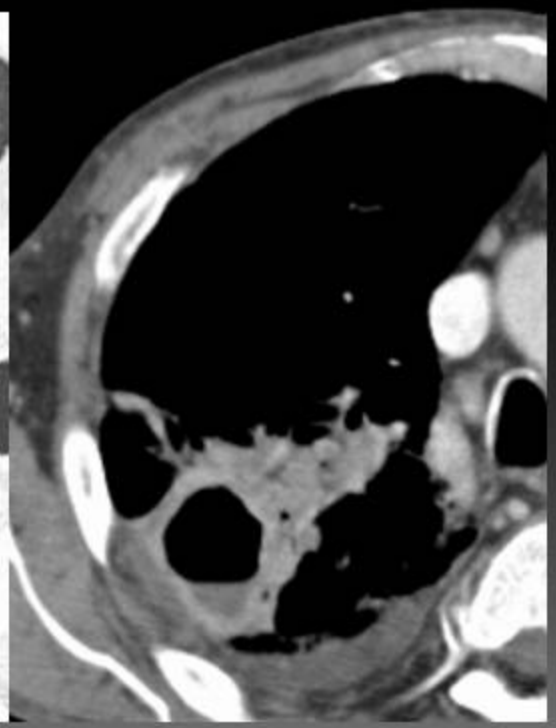


Fig.9: *Woman*, 51 years old with dyspnea, fever, productive cough and hemoptysis. Thoracic CT discloses consolidation with two cavitations. These have air - fluid level (lung abscesses).

Fig.10: Man, 50 years old with same symptoms. Thoracic CT shows a cavitation with a thick wall and an air-fluid level (lung abscess). Its wall enhances and is surrounded by small consolidation.
Ipsilateral pleural effusion.





Mycobacterial infection Tuberculosis

- May be primary or post primary, depending if it is or is not the primary exposure.
- Manifests as low-grade fever, night sweats, anorexia, loss of weight and cough in active disease.
- In active disease, cavities are responsible for hemoptysis while traction bronchiectasis are its principal cause in inactive disease.

Tuberculosis

- Rasmussen's aneurysm, a dilated bronchial artery in the wall of a tuberculous cavity is rare and causes massive hemoptysis.

- Infection affects preferentially apical and posterior segments of upper lobes and superior segment of inferior lobes.

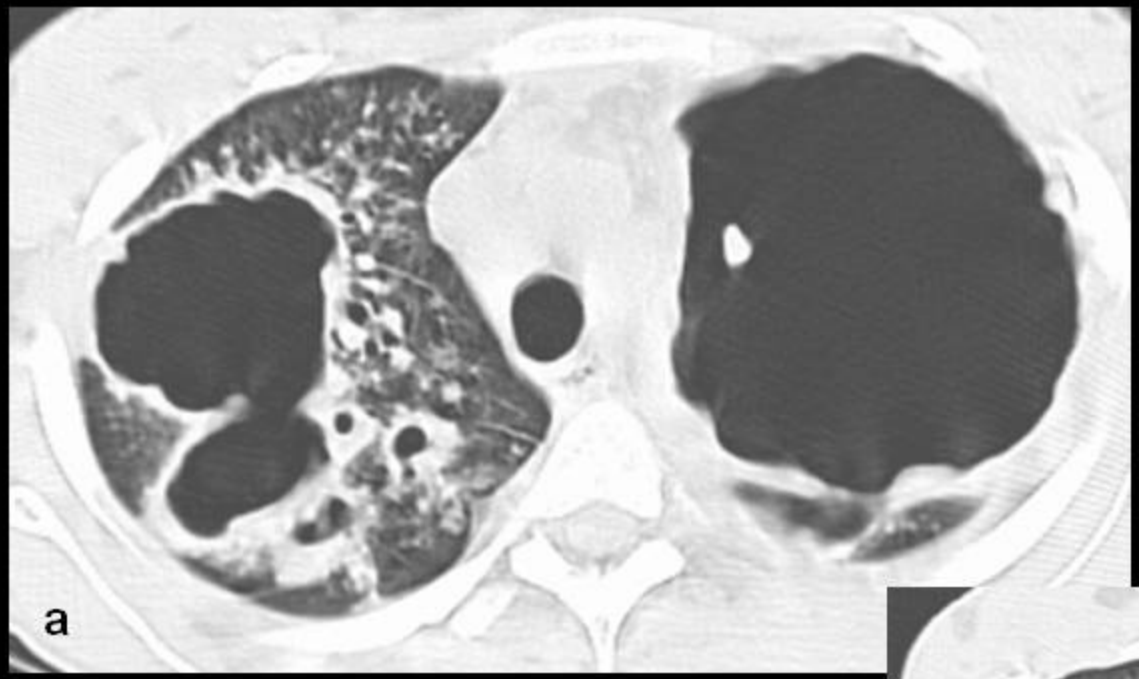
Tuberculosis

- Thoracic CT – active disease (Fig.11)
  - Parenchyma consolidation with air bronchogram
  - Cavities:
    - Thick wall
    - air-fluid level is uncommon

→ Satellites poor - defined micro – nodules

Tuberculosis

- Thoracic CT:
  - Tree-in-bud
    - Sign of endobronchial dissemination
  - Miliary pattern and solitary pulmonary nodule in upper lobes – tuberculoma – rarely cause hemoptysis
  - Necrotic thoracic lymphadenopaty
  - Pleural effusion



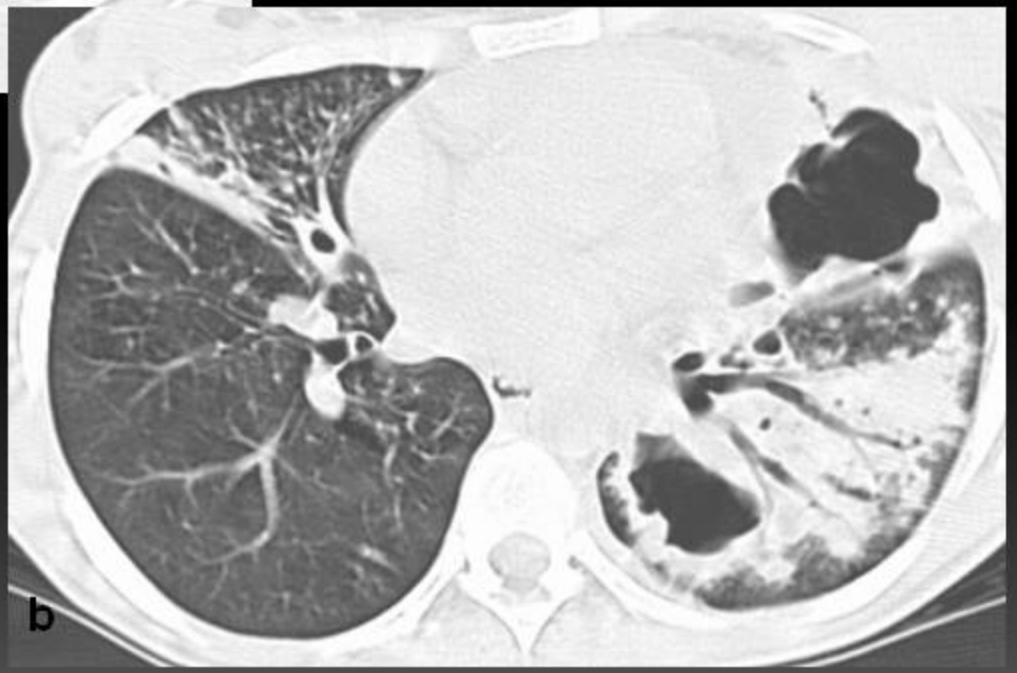
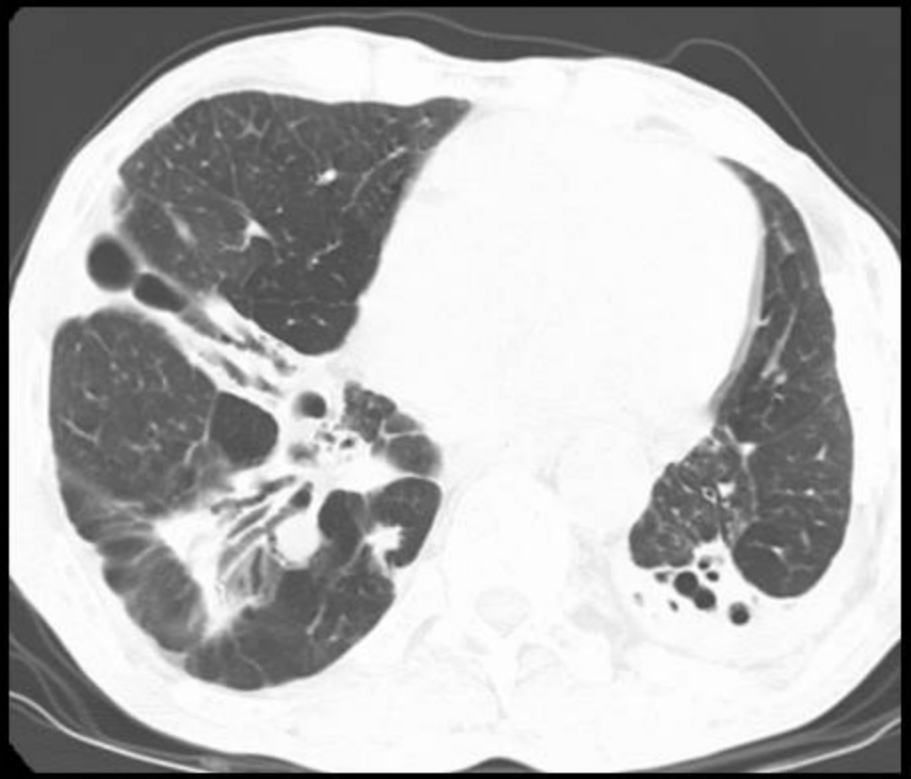


Fig.11: Woman with dyspnea, fever, hemoptysis and weight loss. Thoracic CT reveals two big cavities with thick wall in the upper lobes (a), tree-in-bud and ill-defined micronodules in the middle lobe, cavitations and consolidation with air broncogram in the left lower lobe (b). Sputum analysis positive for *M. tuberculosis*.

Tuberculosis

- Thoracic CT – inactive disease (Fig.12,13)
  - Cavities
    - Thin wall
  - Calcified nodules – granuloma
  - Linear opacities
  - Traction bronchiectasis
  - Thickening of pleura
  - Loss of lung volume



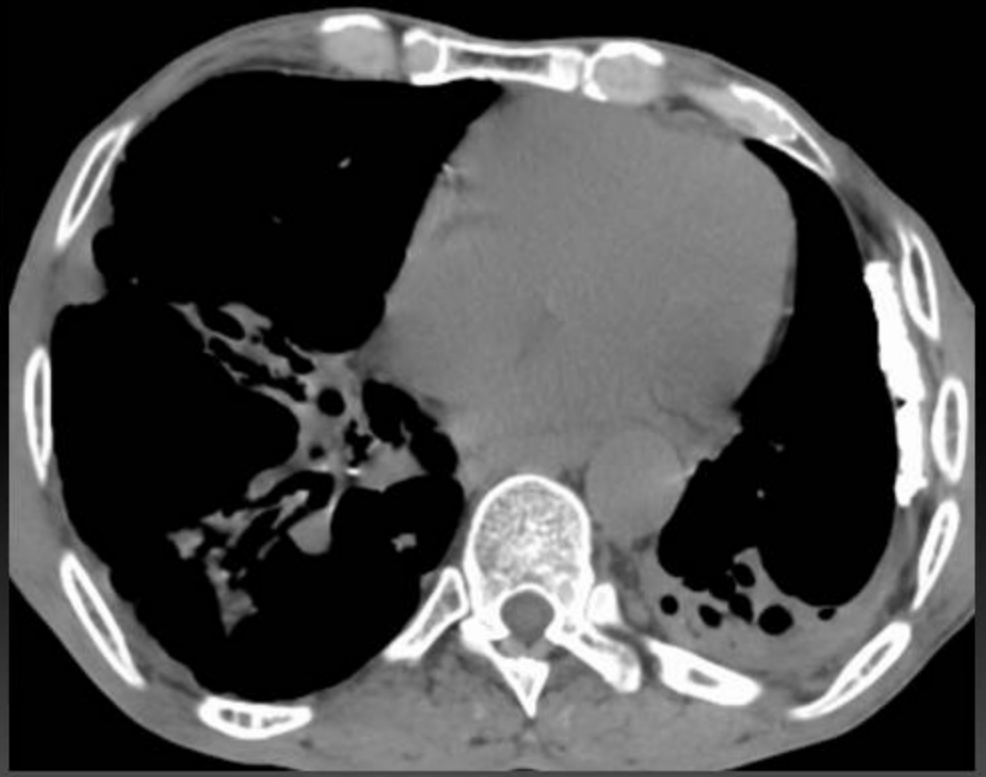


Fig.12: Man, 62 years old, with hemoptysis and history of pulmonary tuberculosis. Thoracic CT shows bilateral traction bronchiectasis (lower and middle lobes), left paquipleuritis and loss of volume of the left lung with ipsilateral mediastinal shift.

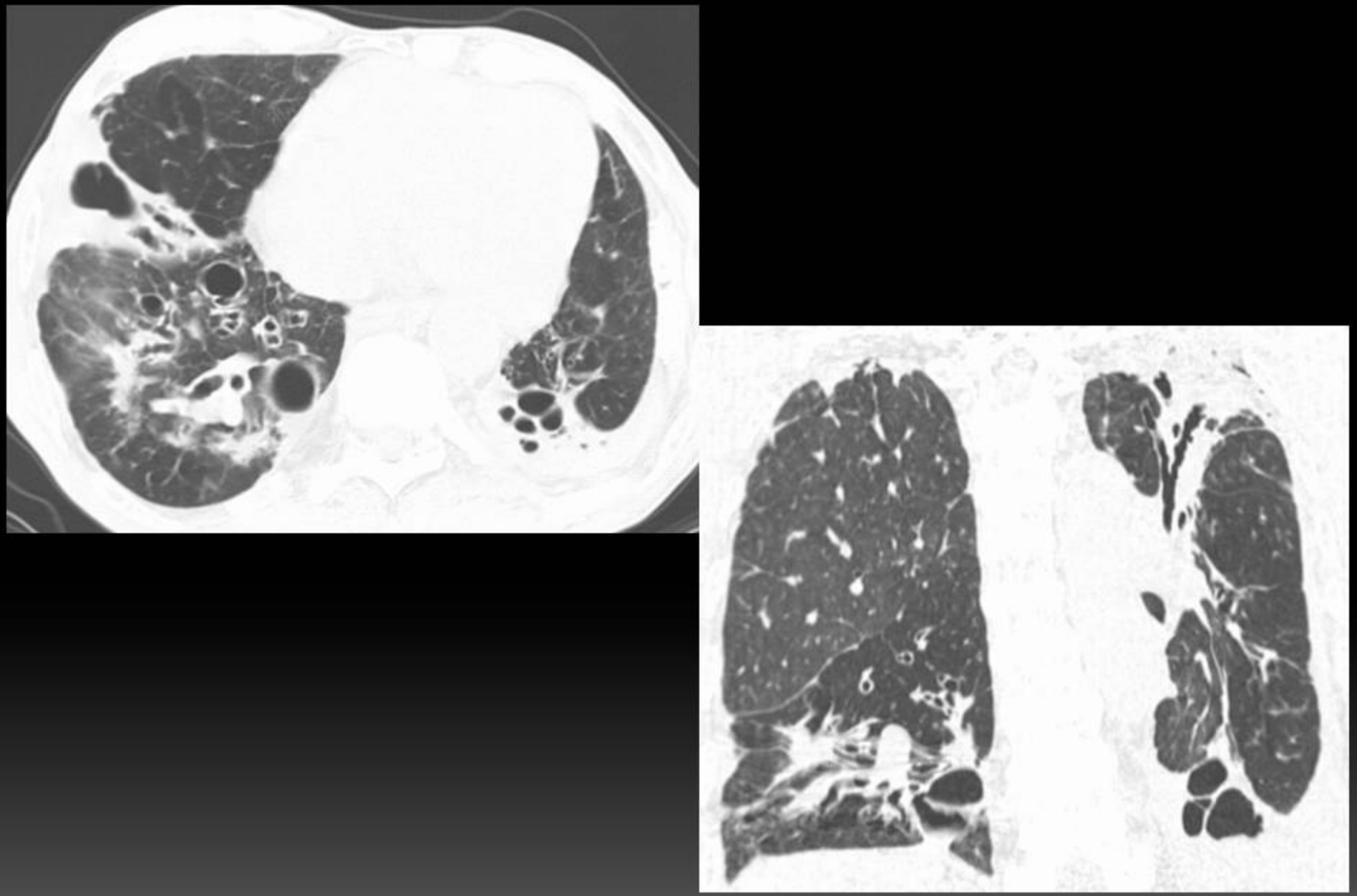


Fig.13: In the same patient, thoracic CT shows bilateral thin-walled cystic lesions corresponding to cavities and cystic bronchiectasis. There are also cylindrical bronchiectasis in the left upper lobe and pleural thickening.

Fungal infection Aspergillosis

- Fungal infection caused by *Aspergillus fumigatus*
- Manifests in 3 forms dependent on the status of immunity
  - Invasive aspergillosis
  - Semi-invasive aspergillosis
  - Aspergilloma

IMMUNITY

Very low

low

normal

Aspergillosis

- Invasive and semi-invasive aspergillosis are the result from invasion and thrombosis of pulmonary arteries by this fungus originating subsequently pulmonary infarct

- Aspergilloma results from the colonization of a preexisting cavity – tuberculosis, sarcoidosis, cystic bronquiectasis or bullae – by *Aspergillus*, causing wall inflammation.

Aspergillosis

- This fungus also causes a hypersensitivity reaction in asthmatics, named allergic bronchopulmonary aspergillosis.
- All forms may be present with hemoptysis, cough and dyspnea.

Aspergillosis

- Thoracic CT: (Fig.14)
  - Invasive aspergillosis
    - Dense nodular opacities surrounded by a halo of ground-glass opacity – the halo sign
    - Crescentic cavitation – the air-crescent sign
  - Semi-invasive aspergillosis
    - Mimics tuberculosis

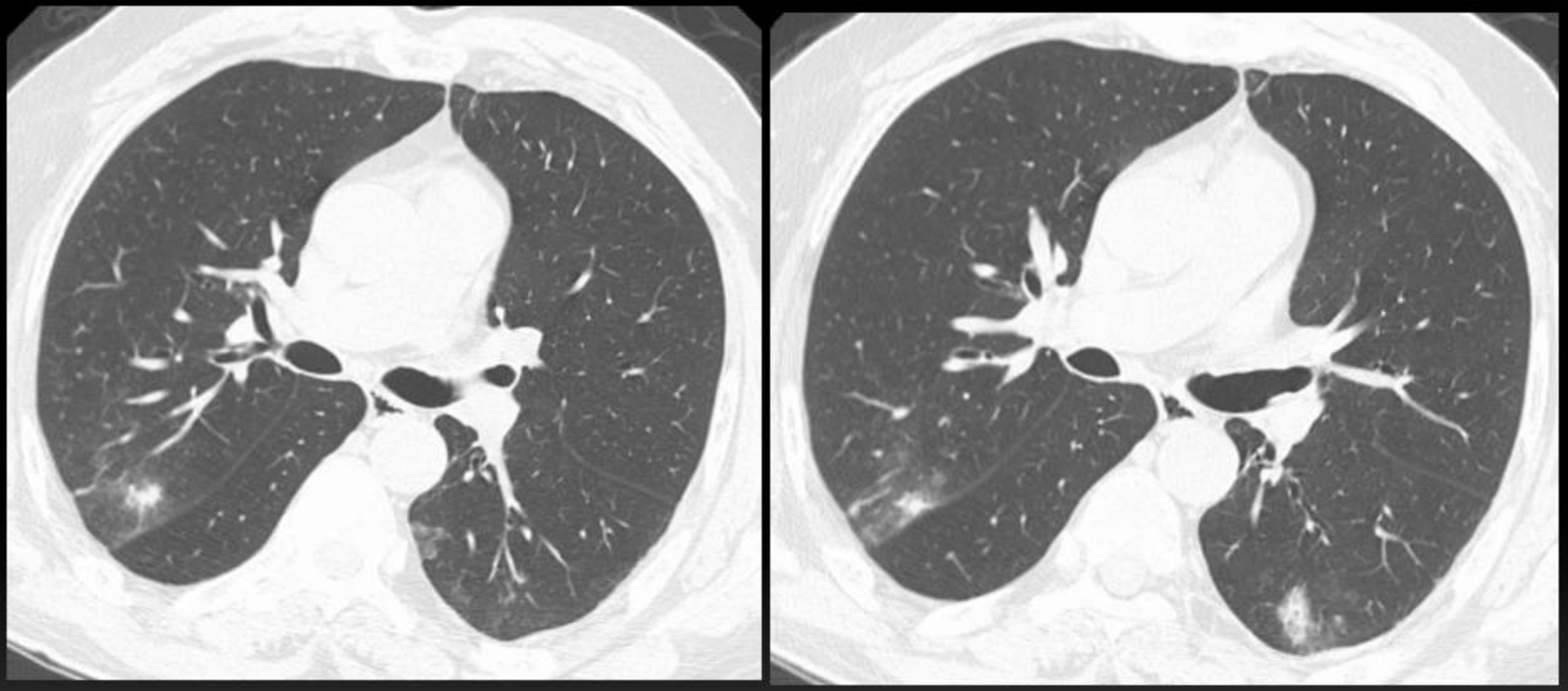


Fig.14: Man, 40 years, immunocompromised cough and hemoptysis. Thoracic CT discloses nodular opacities surrounded by a halo of ground-glass opacity in the posterior segment of right upper lobe and superior segment of the left lower lobe. BAL positive for *Aspergillus*.

Aspergillosis

- Thoracic CT: (Fig.15)
  - Aspergilloma
    - Thickening of cystic wall
    - Intracavitary round mass – fungus ball – in the dependent aspect of the cavity which moves with patient position change

      ➡ Air crescent sign

    - Mass may exhibit areas of high attenuation ⇔ calcium

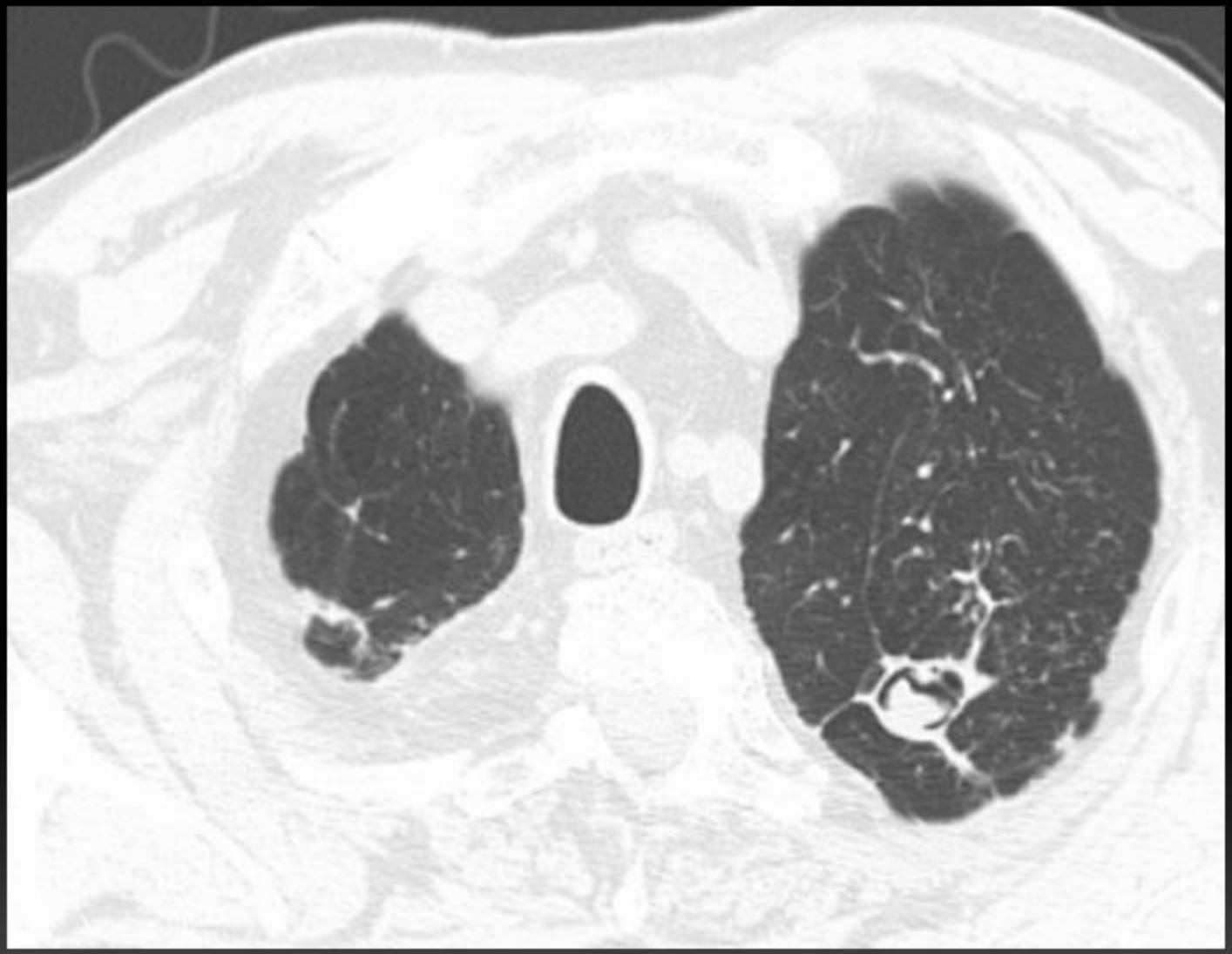


Fig.15: Man, 73 years old, with history of pulmonary tuberculosis, cough and hemoptysis. Thoracic CT reveals a mass in the dependent portion of a cavity localized in the left upper lobe, compatible with aspergilloma. Right pleural thickening.

Aspergillosis

- Thoracic CT:
  - Allergic bronchopulmonary aspergillosis
    - Affects preferentially the upper lobes
    - Central varicose and cylindrical bronchiectasis
    - Mucous plugs sometimes with high attenuation due to the avidity of *Aspergillus* for calcium
    - +/- consolidation/collapse/cavitation

Lung cancer

- Smoking is the major risk factor for its development
- May be central or peripheral, both causing hemoptysis.
- Other symptoms: dyspnea, cough, chest pain, recurrent pneumonia, anorexia and loss of weight

Lung cancer

Thoracic CT

Peripheral tumor

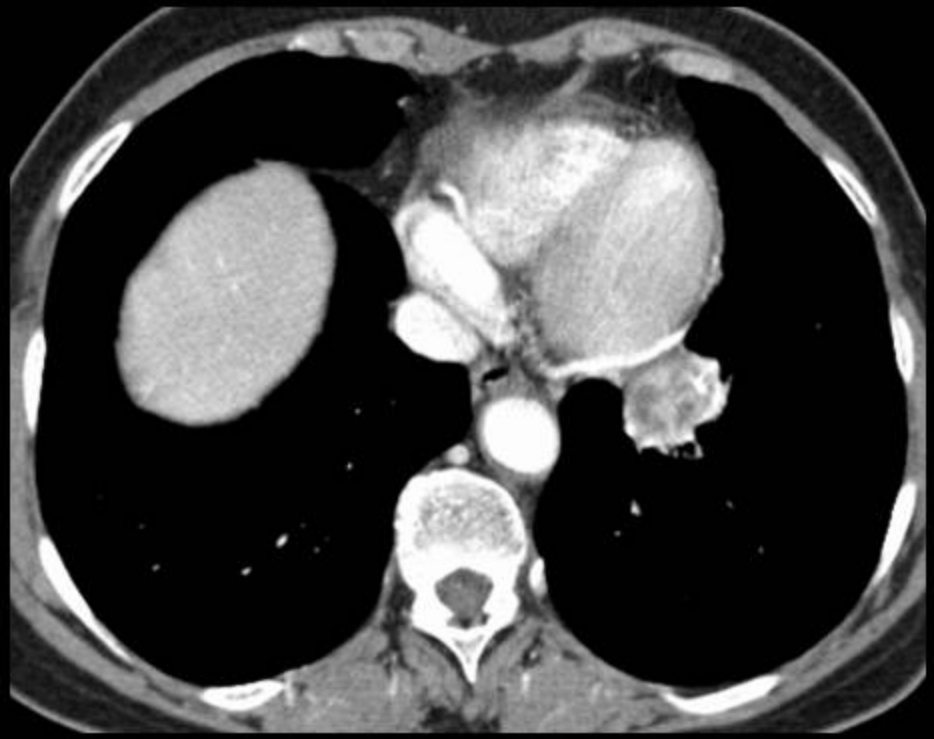
- Peripheral round or lobulated mass
- "Pleural tail" sign
- Ground-glass opacities
- Air bronchograms / pseudocavitation (patent bronchi)

Central tumor

- Hilar or endobronchial mass
- Pulmonary collapse or/and consolidation
  → "Golden's S" sign
- Dilated mucus-filled bronchi distally to the tumor

Lung cancer

- Thoracic CT - **Both**:
  - Cavitation - irregular and thick wall
  - "Corona radiata" – a spiculated pulmonary mass
  - Solid compounds enhance after iv contrast
  - Lymphadenopathy
  - Pleural effusion
  - Lymphangitic spread – thickening of interlobular septa and peribronchovascular interstitium
  - Invasion of thoracic structures



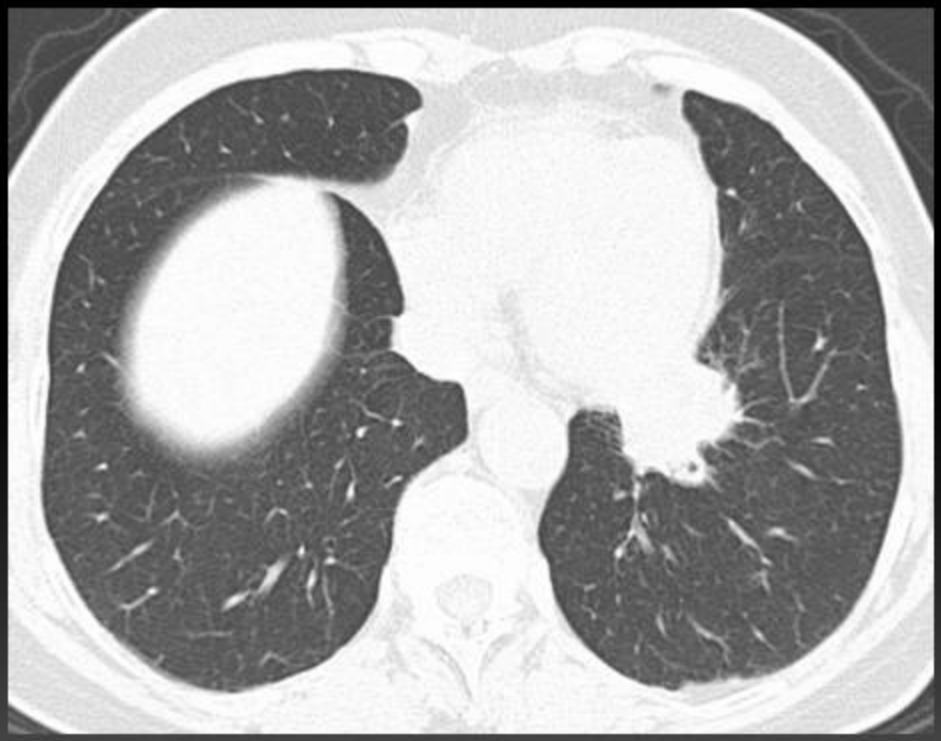


Fig.16: Man, 68 years old, ex-smoker and with hemoptysis. Thoracic CT shows a left justamediastinal mass with heterogeneous enhancing and spiculated contours (corona radiata). Biopsy confirms the diagnosis of lung cancer.

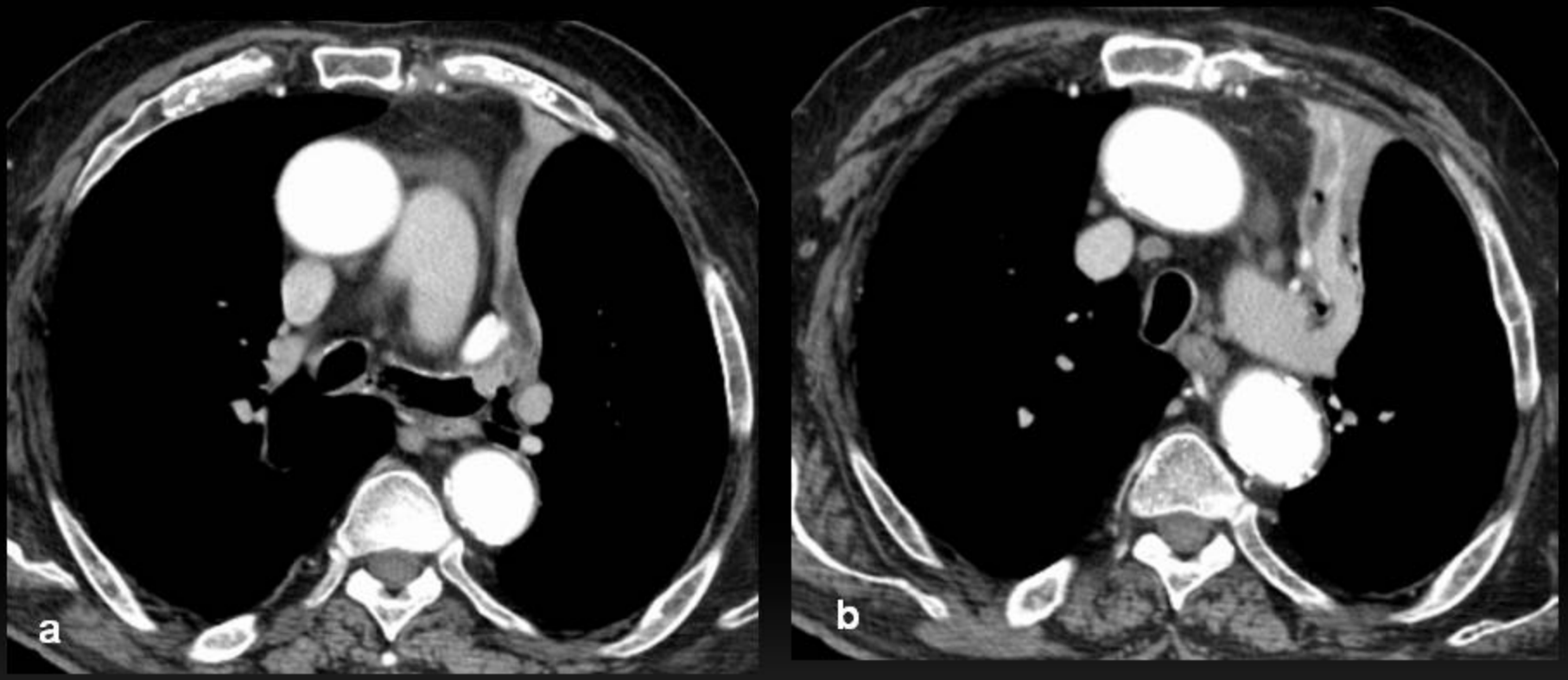


Fig.17: Man, 76 years old, ex-smoker and with dyspnea and hemoptysis. Thoracic CT discloses an endobronchial mass (a) conditioning collapse of the left upper lobe(b).

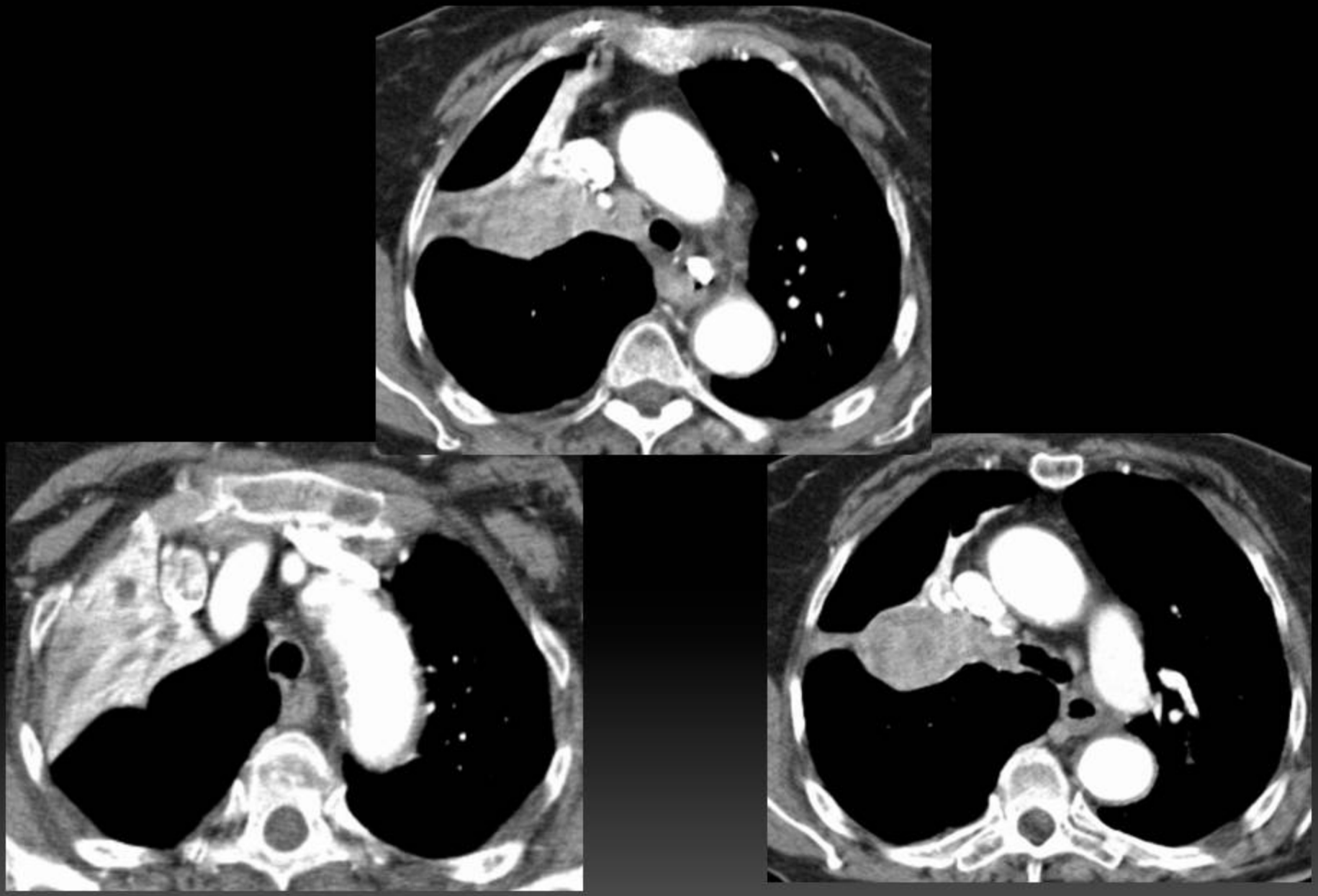
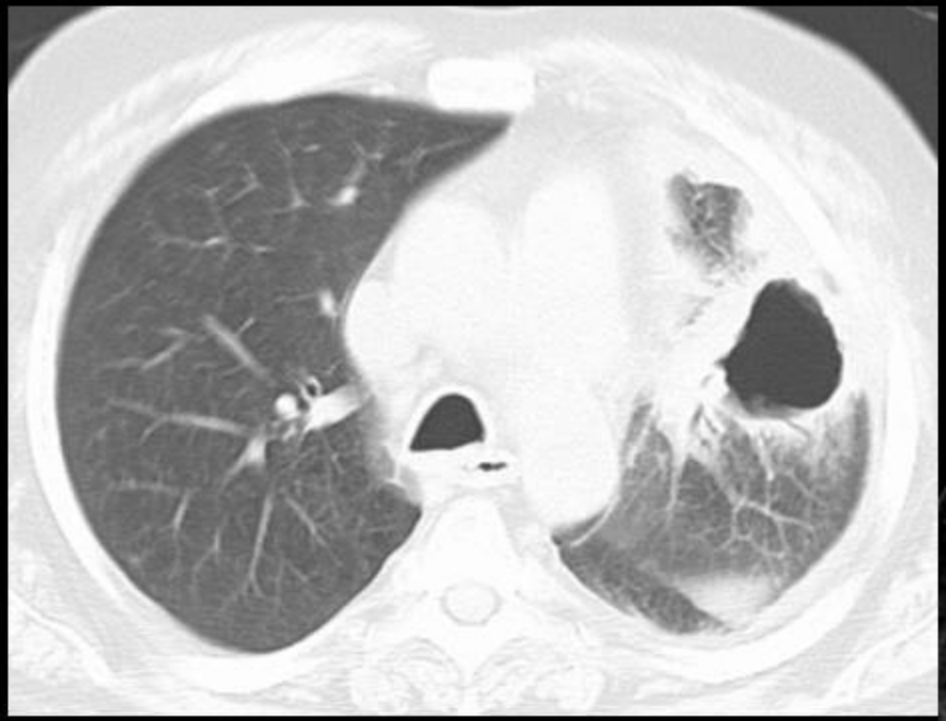


Fig.18: Man, 82 years old with hemoptysis and dyspnea. Thoracic CT shows a hilar mass which invades the right upper lobe and causes collapse of the respective lung segment. The posterior border becomes convex due to the tumor (Golden´s S sign).



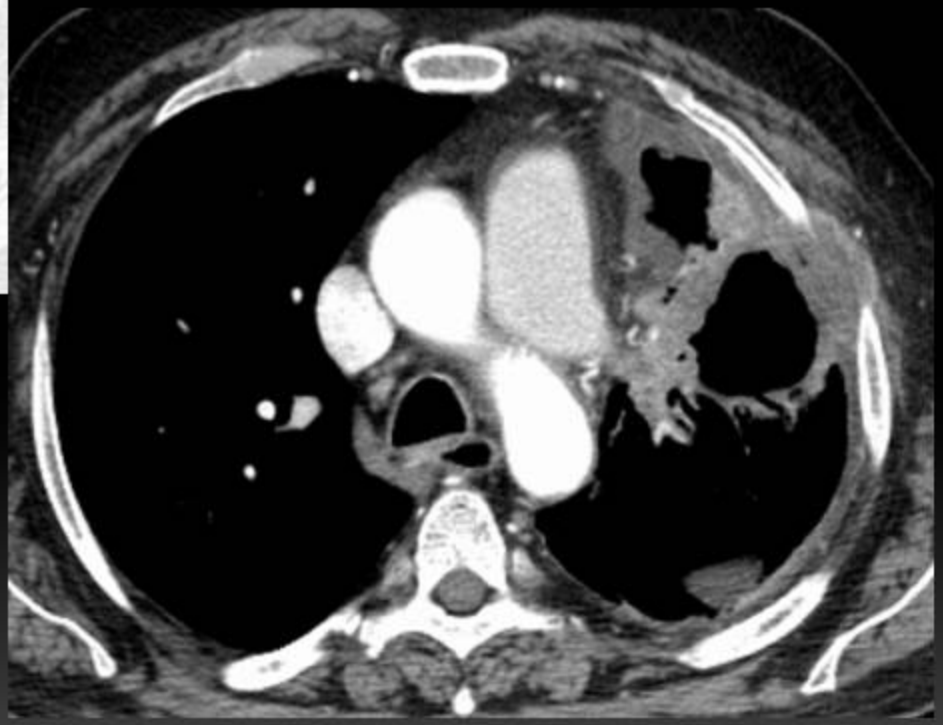


Fig.19: Man, 58 years old, with chest pain and hemoptysis. Thoracic CT shows a thick walled cavitation in the anterior segment of the left upper lobe. It invades the ipsilateral pleura and thoracic wall. Loculated pleural effusion is seen adjacent to the cavitated lung neoplasm.

Vasculitis

- It is a systemic inflammation of blood vessel walls
- Classification is based in the diameter of the vessels affected
  - Large-vessel
  - Medium –vessel
  - Small-vessel

Vasculitis

- Small-vessel vasculitis more frequently are responsible by pulmonary hemorrhage and so hemoptysis.

- ANCA-associated small vessel vasculitis are the most common primary systemic vasculitis in adults and include:
  - Wegener's granulomatosis
  - Microscopic polyangiitis
  - Churg-Strauss syndrome

Vasculitis

- Thoracic CT: (Fig.20)
  - Pulmonary hemorrhage
    - Patchy or diffuse consolidation/ground – glass opacities
      → sometimes, spare lung periphery, apices and costophrenic angles
    - Ill - defined centrilobular nodules
    - +/- thickening of interlobular septa

Resolve completely in 2 weeks

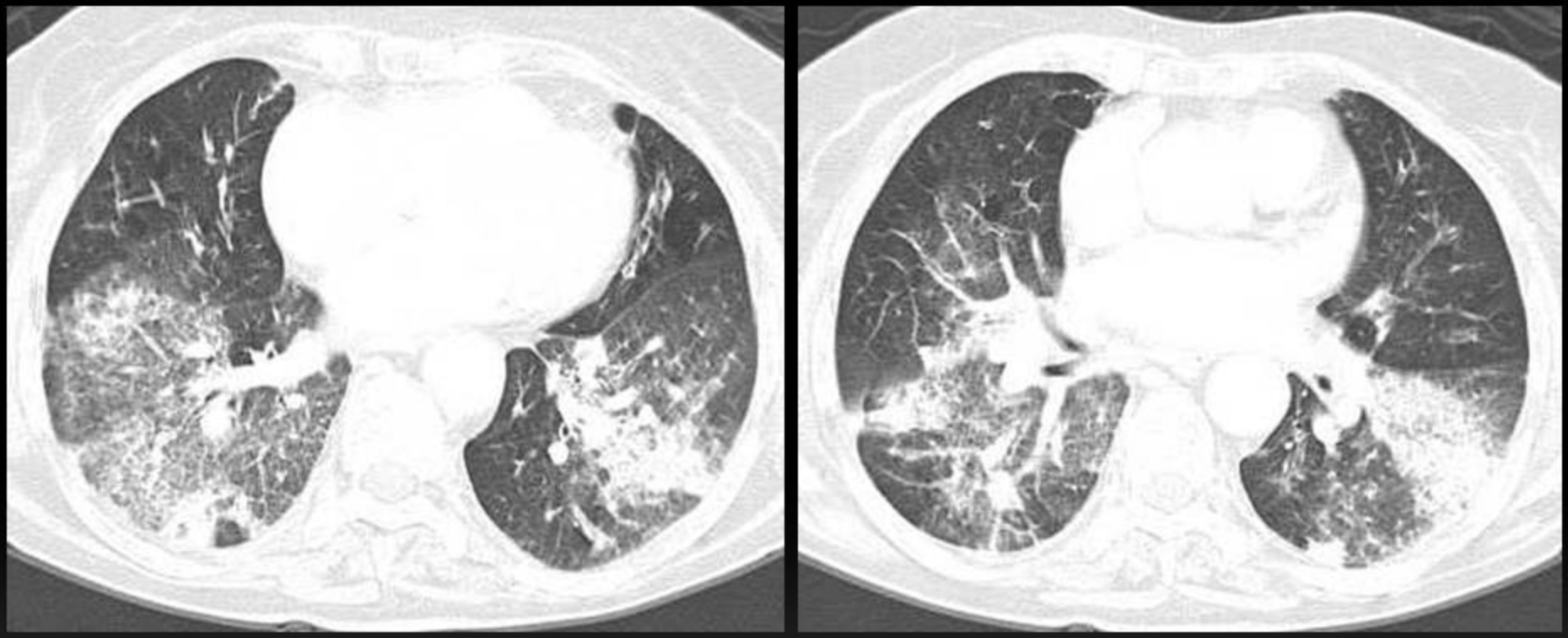


Fig.20: Woman, 78 years old with history of Wegener's granulomatosis and hemoptysis. Thoracic CT shows bilateral patchy ground-glass opacities, thickening of interlobular septa and a consolidation with air bronchogam in the left lower lobe, suggesting of diffuse alveolar hemorrhage.

Acute thromboembolism

- Results of a embolus that migrates to a central or peripheral pulmonary artery, leading to reduction or absence of distal perfusion.

- Predisposing factors:
  - Malignant tumor
  - Pregnancy/postpartum
  - Trauma/recent surgery/ long immobilization
  - Hypercoagulopathy
  - Oral contraceptives

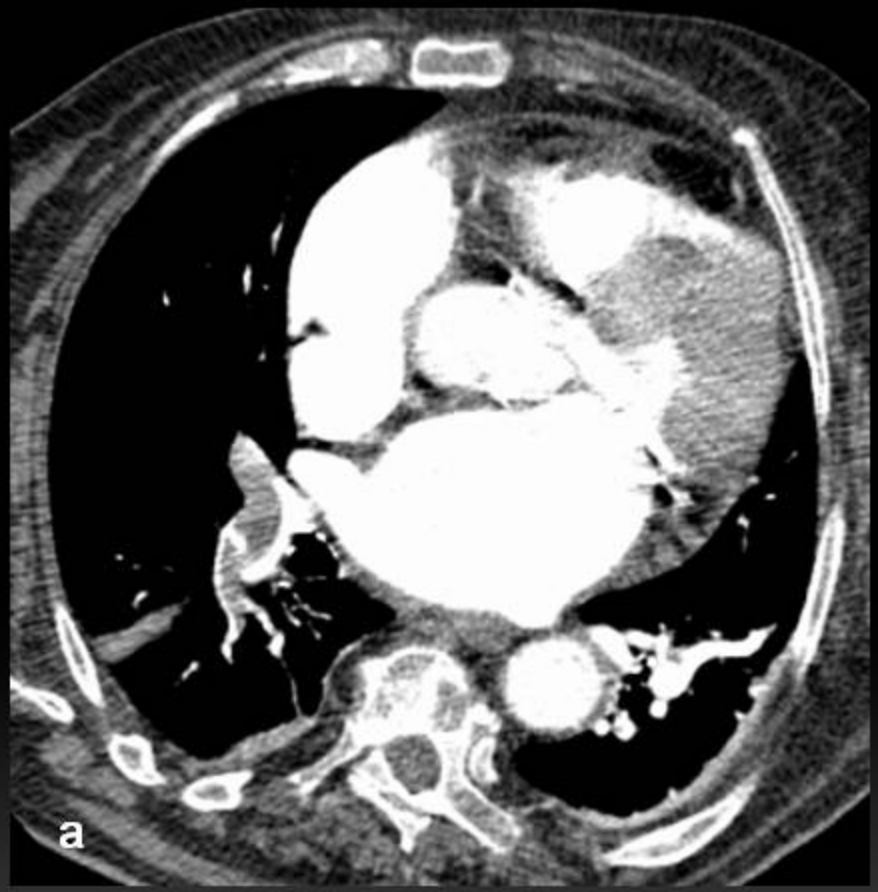
Acute thromboembolism

- Manifests as dyspnea, chest pain and hemoptysis.
- In severe cases, it presents as syncope
- When therapy doesn´t dissolve completely the embolus, patient may develop chronic thromboembolic pulmonary hypertension.

Acute thromboembolism

- Thoracic CT (CT angiography) (Fig.21)
  - Complete or partial filling defects (⇔ emboli) in the main, segmentar ou subsegmentar opacified pulmonary arteries
  - +/- a wedge-shaped area of pulmonary consolidation, with base in pleura and apex toward hilum ⇔ pulmonary infarct
  - Dilatation of right cardiac chambers

    → sign of severity



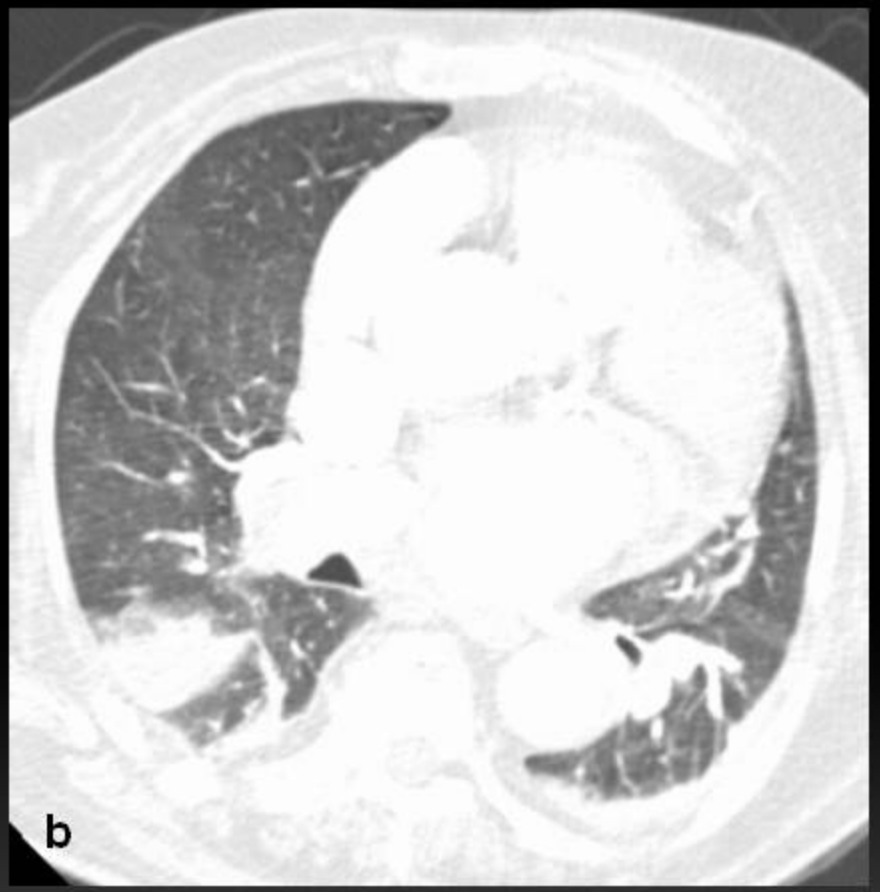


Fig.21: Man, 80 years old, with acute respiratory distress and hemoptysis. Thoracic CT shows cardiomegaly and filling defects (thrombi) in the right lower lobe artery and its branches (a). In lung windows (b), there is a wedge shaped opacity in the right lower lobe, surrounding by a ground - glass opacity (pulmonary infarct surrounded by hemorrhage).

Acute pulmonary edema

- Results of fluid transudation into pulmonary interstitium and aveoli, in setting of left ventricular failure and mitral stenosis
- It is reversible
- Manifests as hemoptysis, orthopnea and peripheral edema.

Acute pulmonary edema

- Thoracic CT: (fig.22)
  - Diffuse and peri-hilar ground-glass opacities
  - Thickening of interlobular septa
  - Thickening of bronchial wall
  - Bilateral pleural effusion
  - Cardiomegaly

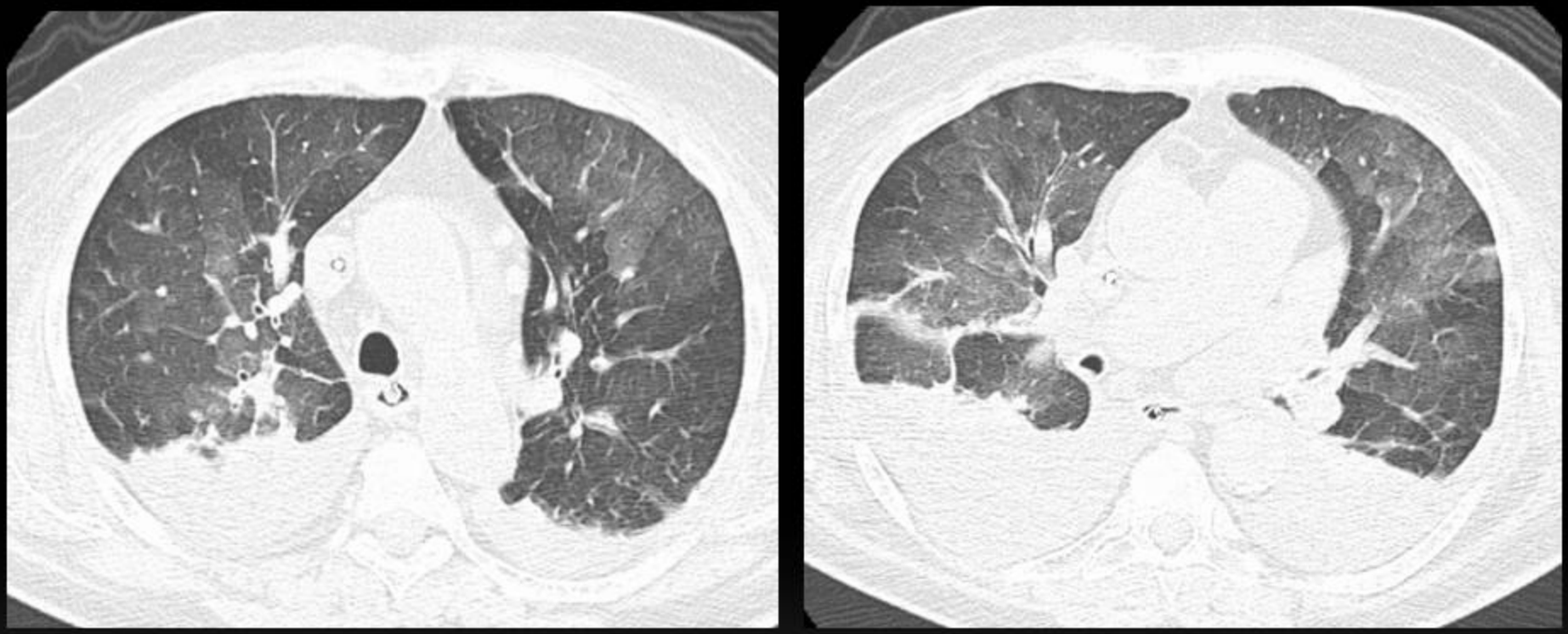


Fig.22: Man, 70 years old, with acute dyspnea and hemoptysis. Thoracic CT discloses diffuse ground-glass opacities sparing relatively the lung periphery, thickening of bronchial wall and bilateral pleural effusion. Cardiomegaly (not show here)

Conclusion

- Knowledge of the principal causes of hemoptysis by radiologist and the correlation with the patient age increase his diagnostic ability.
- CT is a rapid and non-invasive technique which allows the study of pulmonary parenchyma, thoracic vasculature and airways.
- In most cases, CT diagnoses the cause of the hemoptysis and gives an orientation for its treatment.

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