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Interpretation of High-Resolution CT (HRCT) in Interstitial Lung Disease Patients

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Contents

01

Technique for ILD Imaging

CT Technique for ILD Detection, Characterization and Quantification

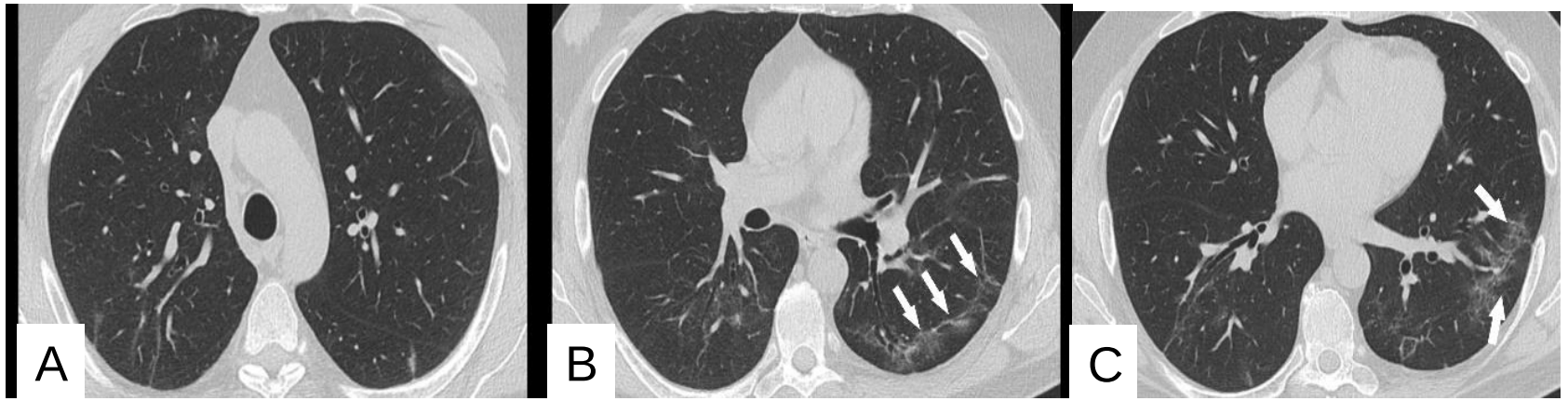
- Thin-section CT (TSCT); thin (1.0–1.5 mm) slice thickness, 80–120 kVp, < 250 mA, ≤ 0.5/sec gantry rotation time, 1.0–1.5 beam pitch, and high-frequency reconstruction algorithms
- Helical CT scanner with volumetric acquisition of entire thorax with near-isotropic resolution; raw data for reconstructed thin-sectional axial, sagittal and coronal images
- Obtained with patient in supine and at end inhalation; additional images in prone position or at full exhalation for dependent lung abnormalities or air trapping (mosaic attenuation)
- Texture pattern analyses; emphysema, ground-glass opacity (GGO), reticulation, honeycombing (HC), consolidation and normal lung parenchyma
- Quantification of total lung abnormality and of fibrotic lung facilitates initial ILD and ILA diagnosis, as well as informs determination of functional and clinical status and prognostication. Also, longitudinal changes help predict patient survival

Lee KS et al. *AJR Am J Roentgenol* 2024 Feb;222(2):e2329119.

Paired Inspiratory and Expiratory CT

47M, Long-COVID; 70 days after admission

Arrows = consolidation



A-C) Inspiratory CT

Arrows = air trapping, Arrowheads = consolidation

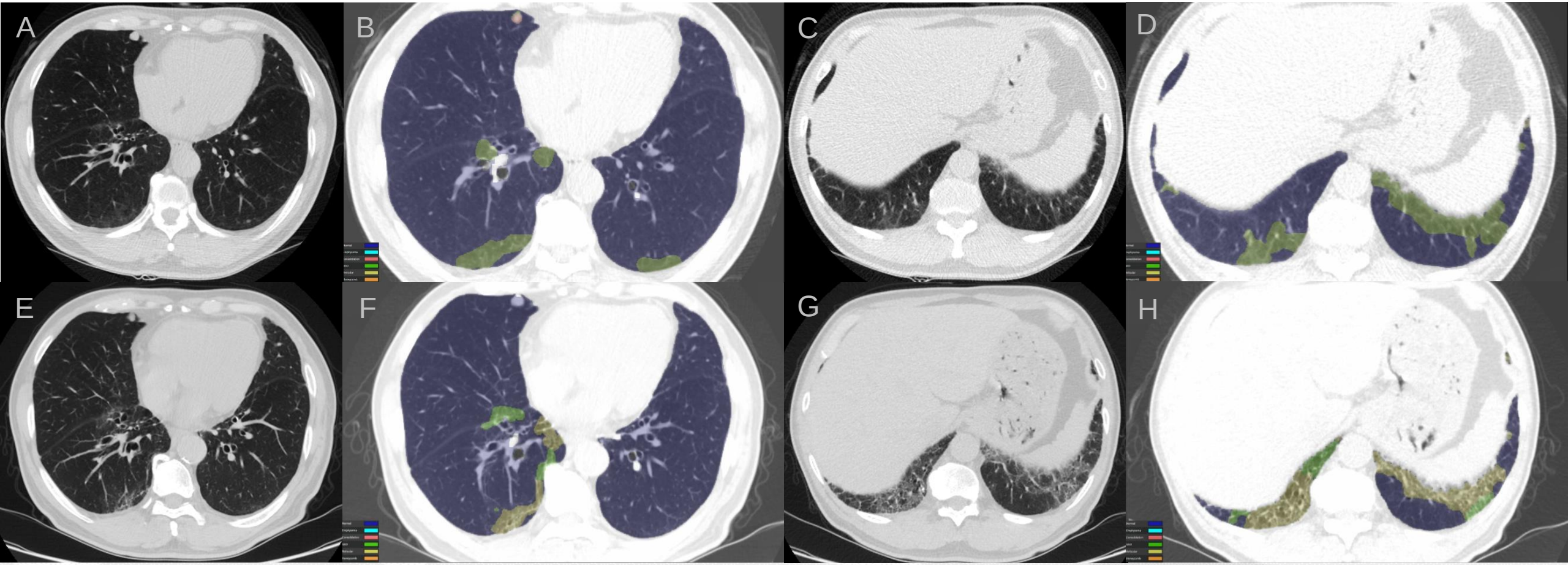
D-F) Expiratory CT

Franquet T et al. *Eur Radiol* 2022;32:4427–4436

Quantification of ILD

68M; RA and lesion quantification with color coding over the follow-up period of five years

Upper Row; ILA composed of mild GGO (green color) in subpleural peripheral lungs; GGO 3.14% reticulation 0.29%



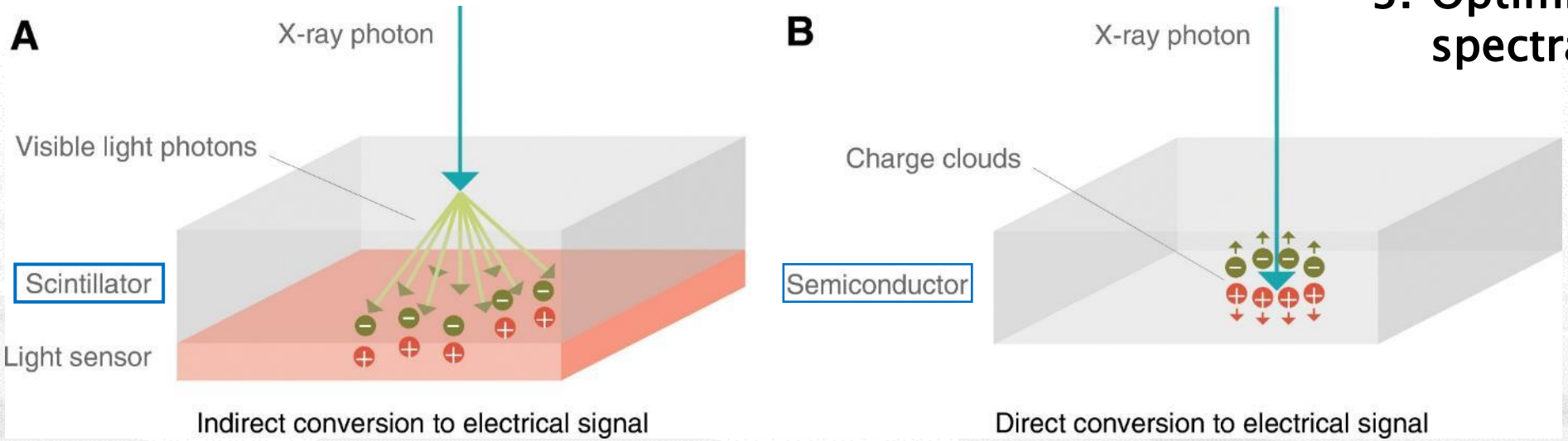
Lower Row; ILA progression with reticulation (yellow color); GGO 0.29%, reticulation 2.33%

High Spatial-Resolution CT (HSR-CT)

- Energy Integrated Detector-CT (EID-CT)
  - 150 μm in-plane and 250 μm through-plane resolution
- Photon Counting Detector-CT (PCD-CT)*
  - 125 μm in-plane and 200μm through-plane resolution

Cf.) HRCT
1.0-mm section thickness, 200 μm; 1.5-mm section thickness, 300 μm

*Use of semiconductor for CT detector rather than scintillator

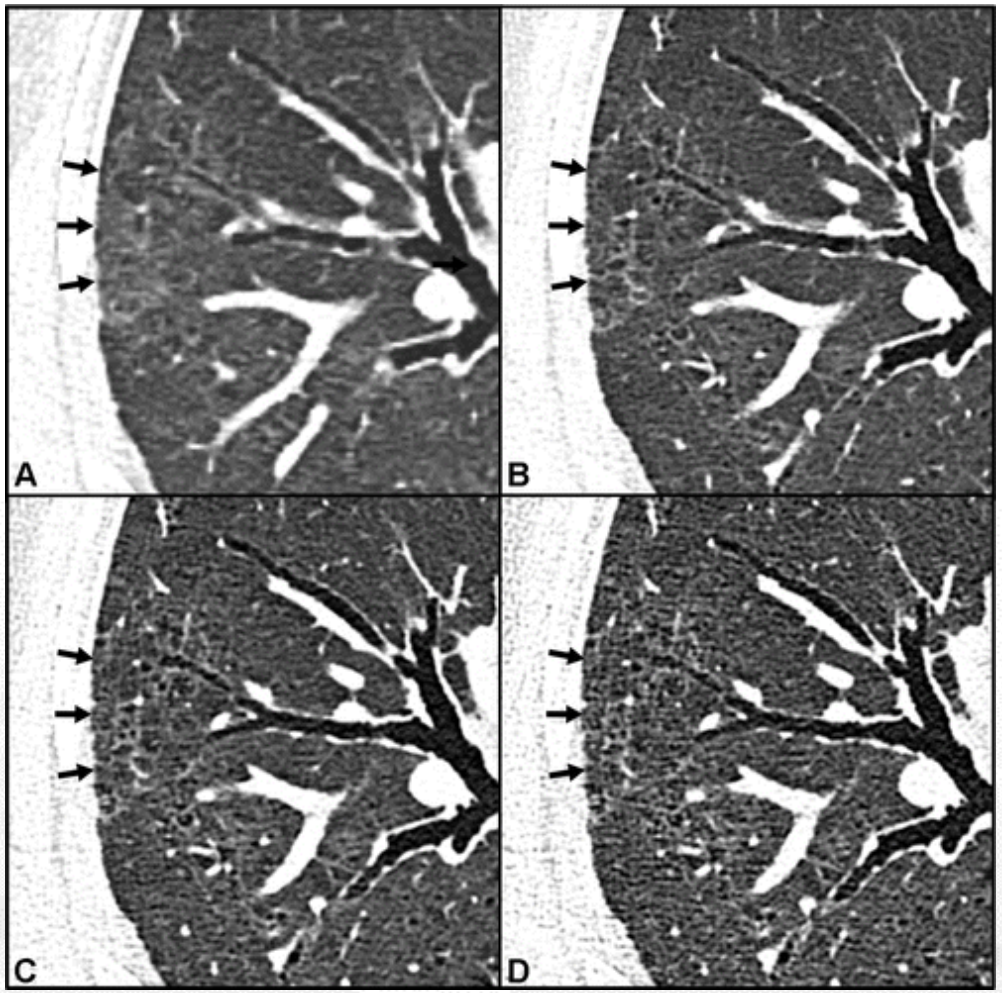


1. Higher contrast-to-noise ratio
2. Improved spatial resolution
3. Optimized spectral imaging

Willemink MJ et al. *Radiology* 2018; 289:293-312

High Spatial Resolution CT (HSR-CT)

55M; dyspnea and chronic fatigue, 399 days after COVID-19 (Long COVID or PCC)



A; 1.0-mm image with EID-CT, B; 1.0-mm PCD CT

C; 0.4-mm image with PCD-CT, D; 0.2-mm image with PCD CT

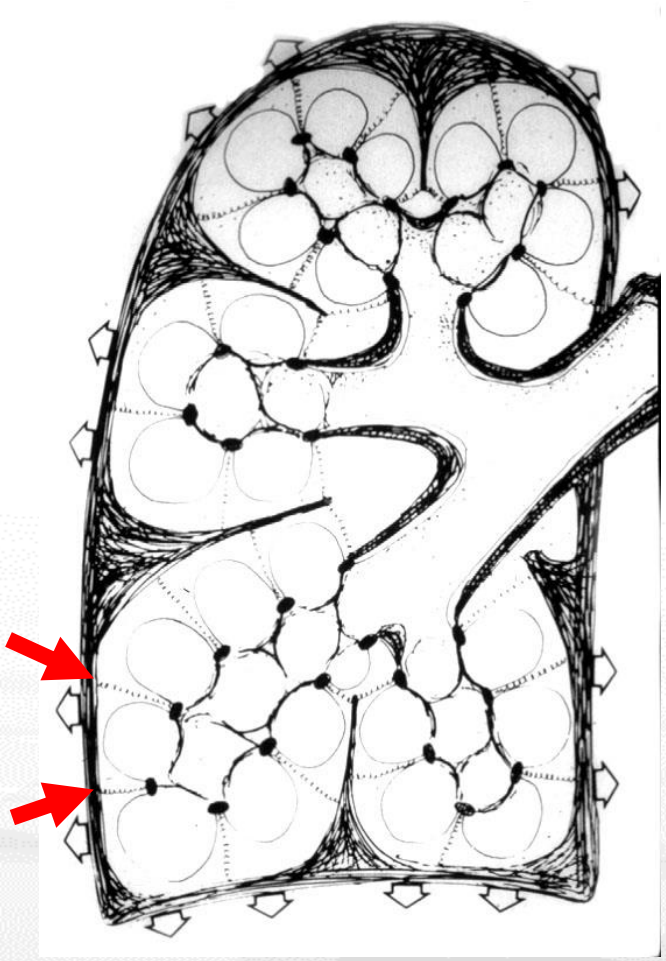
Ground-glass opacities detected with EID CT (arrows in A) are found to contain reticulations at PCD CT (arrows in B-D).

Prayer F et al. *Radiology* 2023 Apr;307(1):e222087

02

CT Anatomy of the Lung

Axial and Peripheral Interstitium and Lung Surface

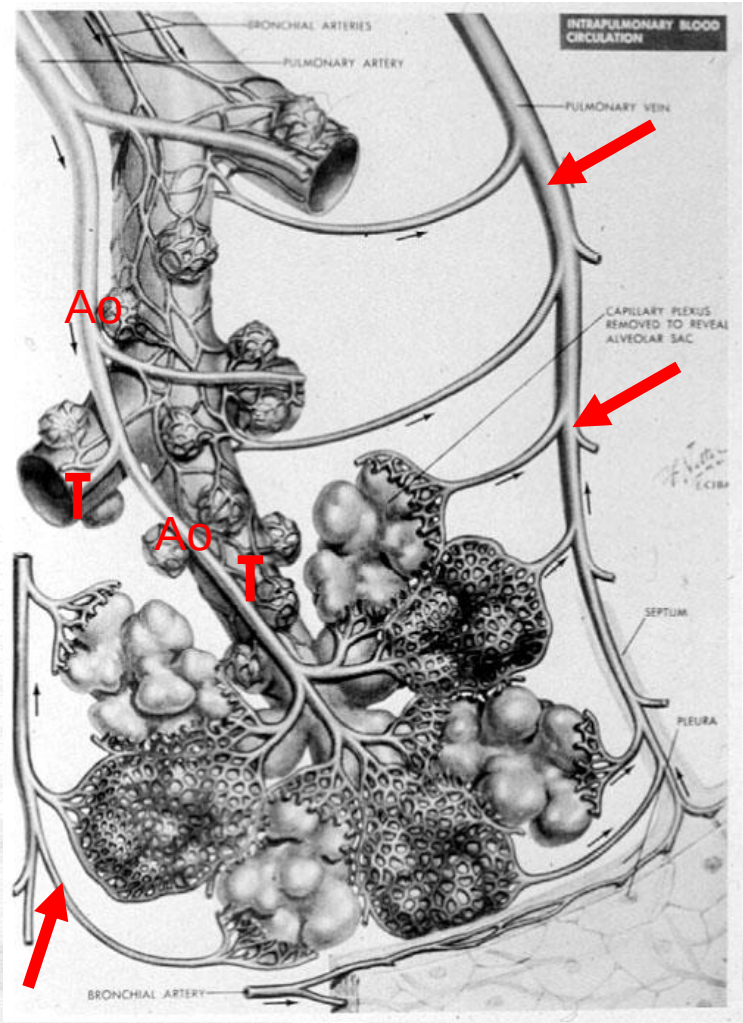


Coronal view of axial and peripheral interstitium

Outward lung surface and secondary pulmonary lobule

2ndary Pulmonary Lobule and Its CT Anatomy in Interstitial Pulmonary Edema

Ao = arteriole, T = terminal bronchiole, Arrows = 2ndary pulmonary lobule

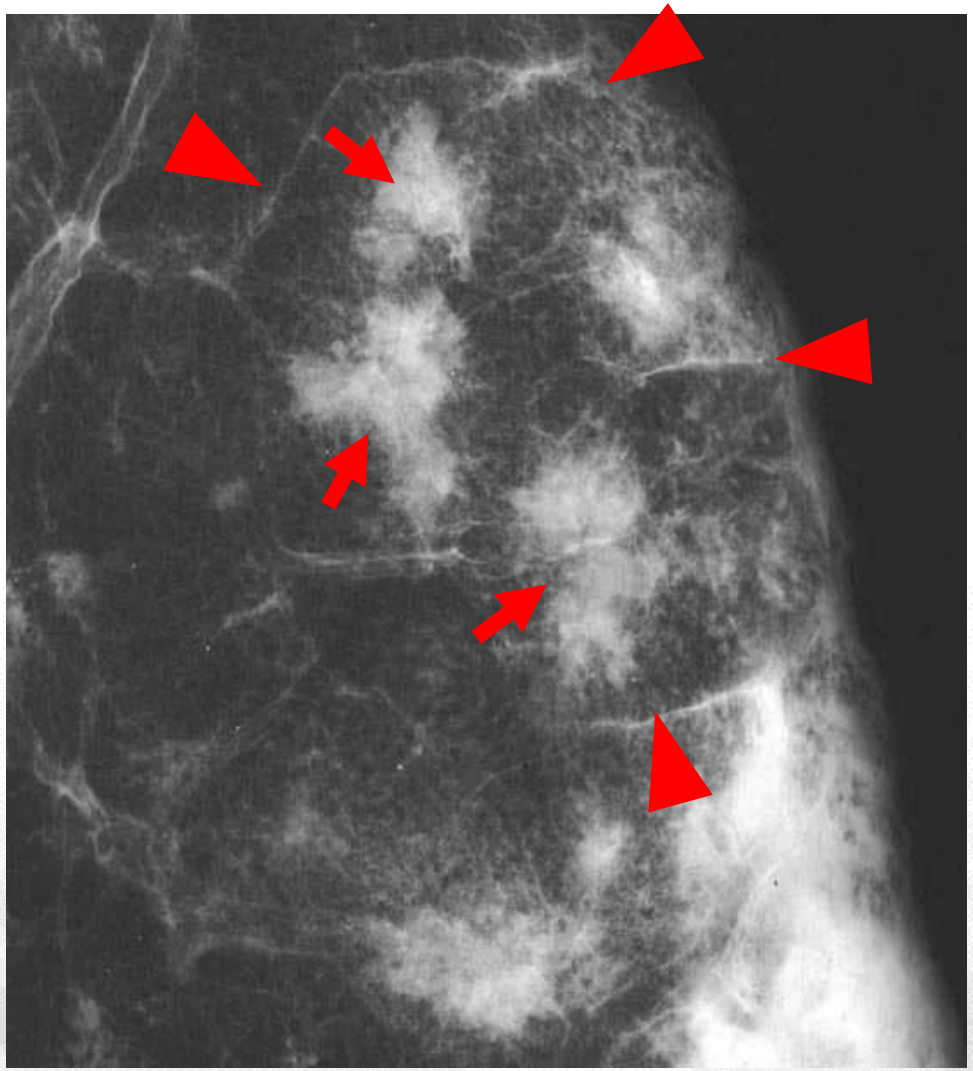


Arrows = 2ndary pulmonary lobule and interlobular septum in interstitial pulmonary edema
Small arrows = arterioles

Lung Anatomy and Centrilobular Nodules

Contact Radiograph of Act TB

Arrows = centrilobular small nodules, Arrowheads = boundary of 2ndary pulmonary lobule



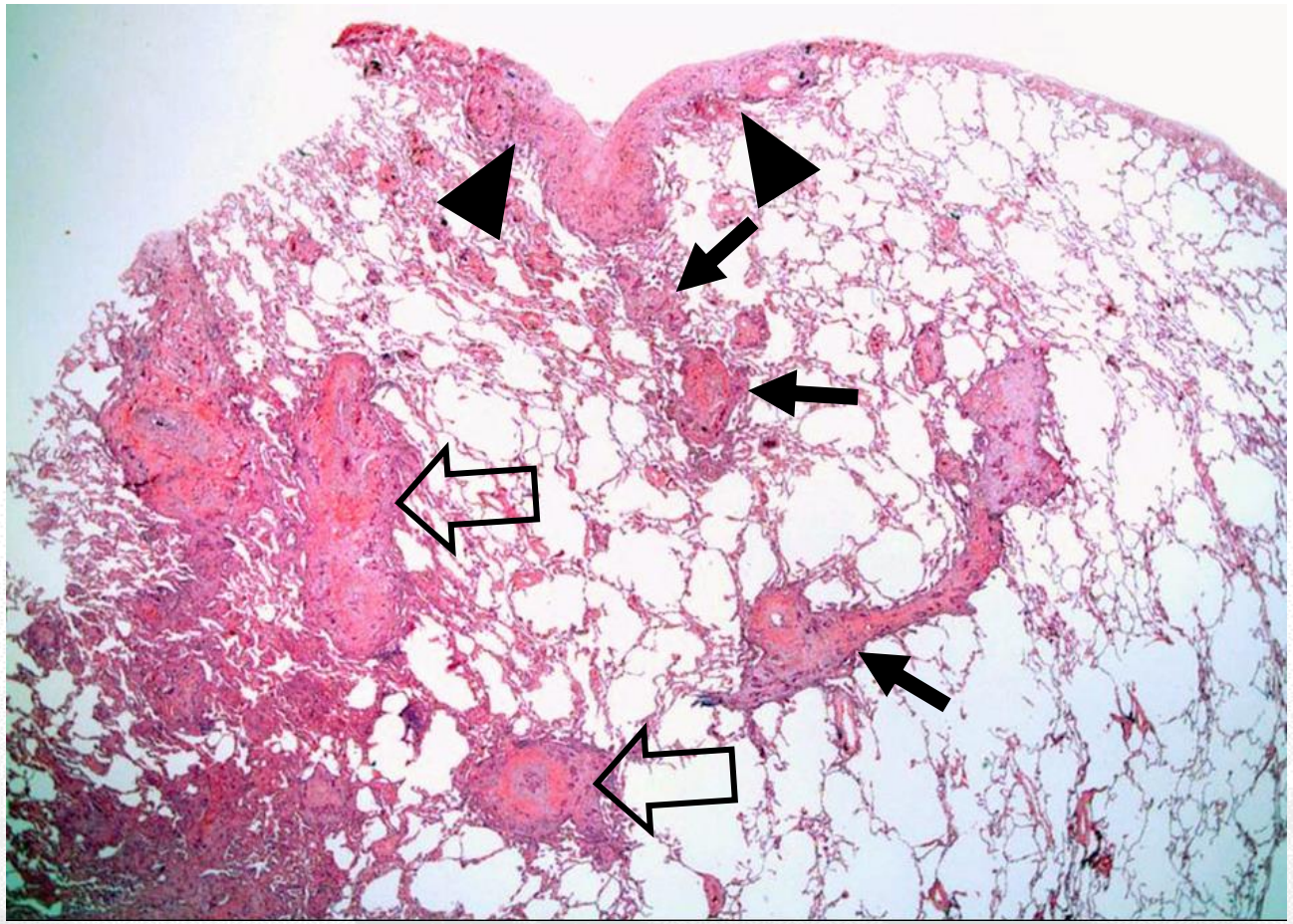
Courtesy of DRs. JG Im and H Itoh

03

Radiologic Signs for Interpretation of ILD

Beaded Septum Sign

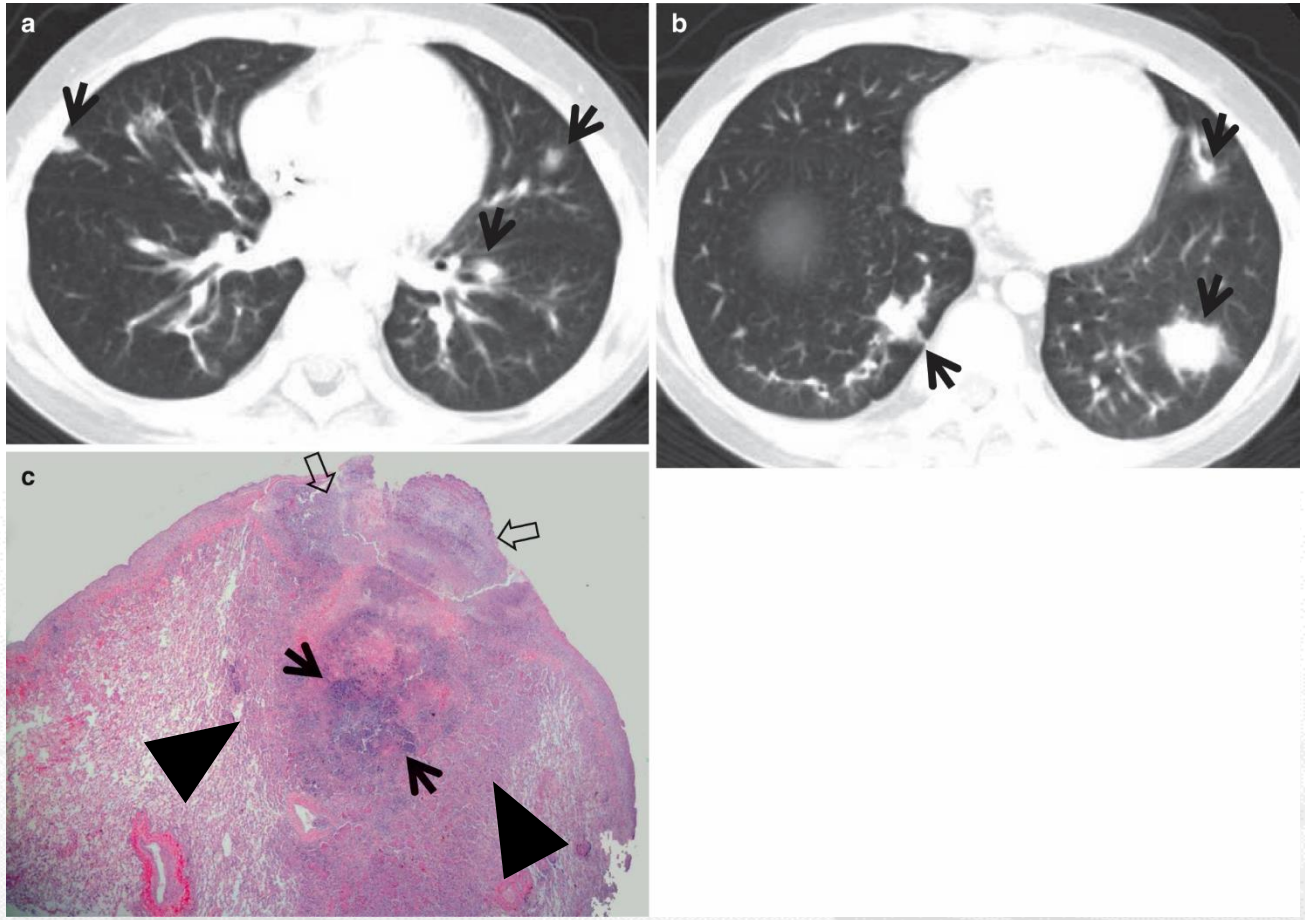
54F, PLC + hematogenous metastases with left breast cancer



Arrows = nodular thickening of interlobuar septae, Small arrows = hematogenous metastases, Open arrows = septal vein containing cancer cells in and around interstitial lymphatics, arrowhead = pleural thickening with intra-lymphatic cancer cells

CT Halo Sign

11M, Invasive pulmonary aspergillosis (APL) in ALL and neutropenia patient



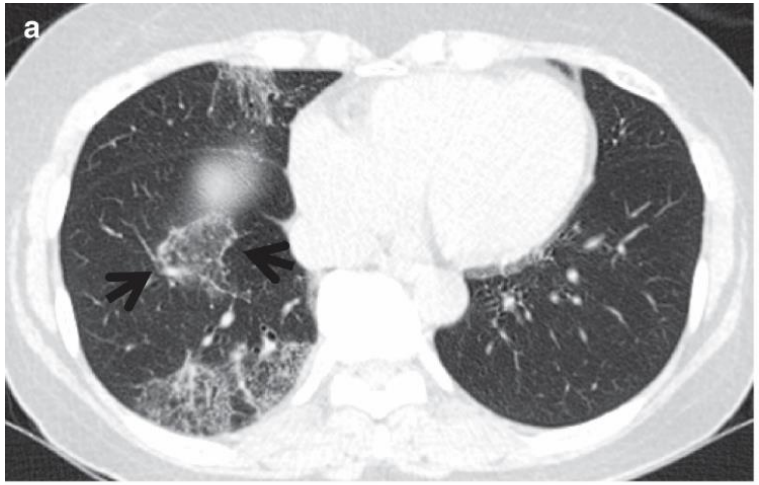
Arrows = Nodules with halo

Arrows = necrotic abscess containing fungal colonization, Open arrow = extension of fungal organism to pleura, Arrowhead = surrounding inflammation and hemorrhage

Lee KS et al. Radiology Illustrated: Chest Radiology 2nd ed. Springer 2023

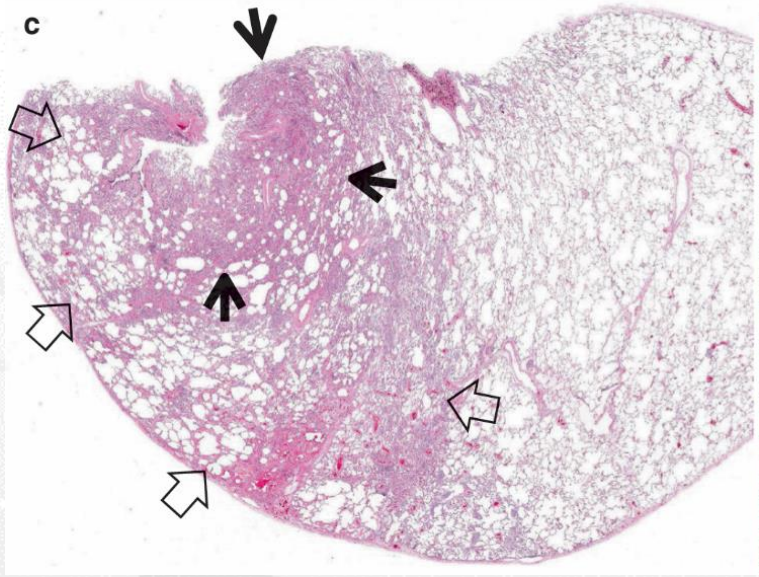
Reversed Halo Sign (Atoll Sign)

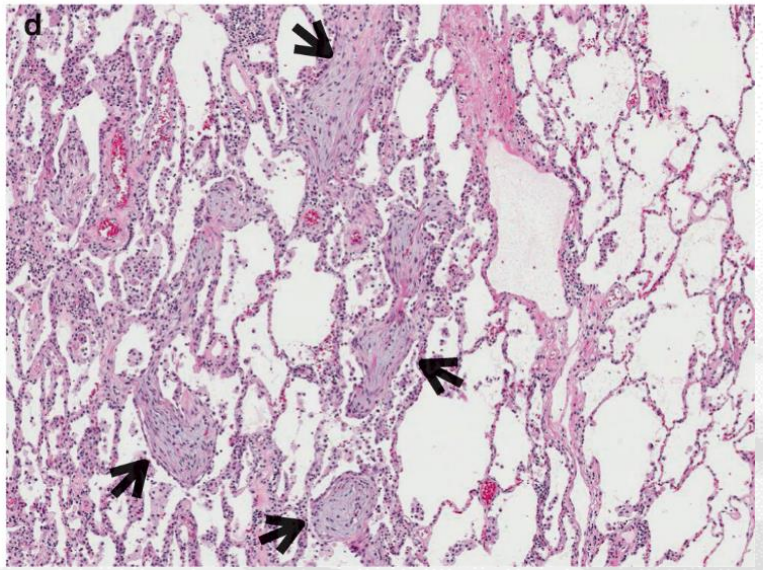
58F, Cryptogenic organizing pneumonia



Arrows = Reversed halo sign

Arrows = denser consolidation, Open arrows = interstitial inflammatory cell infiltration

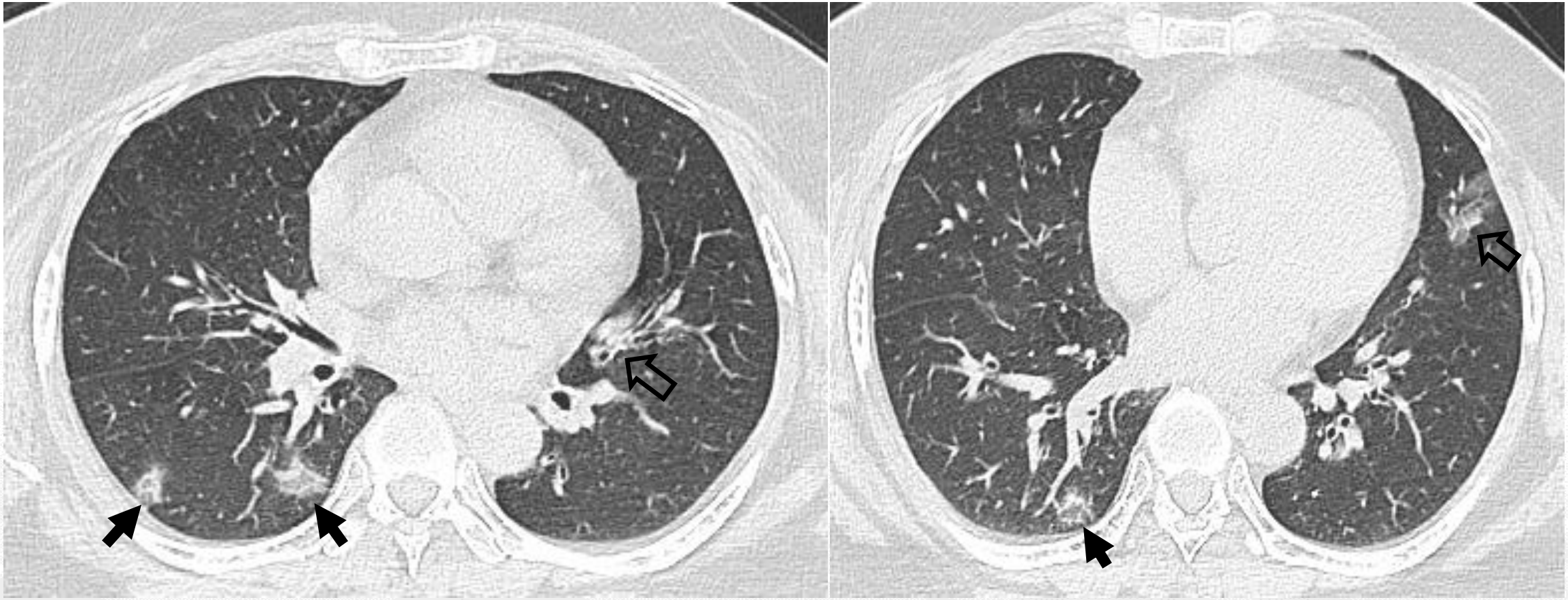




Arrows = fibroblastic polyps within lumens of respiratory bronchiole, alveolar ducts and alveoli; interstitial thickening with mononuclear inflammatory cells

Reversed Halo Sign (Atoll Sign)

60F, Organizing pneumonia pattern of COVID-19 pneumonia at Delta variant dominant period



Lee KS et al. Radiology Illustrated: Chest Radiology 2nd ed. Springer 2023

CT Galaxy Sign

Original Report

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Large Coalescent Parenchymal Nodules in Pulmonary Sarcoidosis: "Sarcoid Galaxy" Sign

OBJECTIVE. The purpose of this study was to evaluate the large parenchymal nodules in pulmonary sarcoidosis and to describe a new CT sign termed the "sarcoid galaxy."

CONCLUSION. The CT appearance of pulmonary sarcoidosis suggests that the large nodules arise from a coalescence of small nodules. The large nodules are surrounded by many tiny satellite nodules. These findings were considered to simulate the appearance of a galaxy. This observation was supported by radiologic–pathologic correlation. The sarcoid galaxy sign may be a useful adjunct in the diagnosis of pulmonary sarcoidosis.

Sarcoidosis is a systemic disorder of unknown cause characterized by the presence of noncaseating granulomas [1, 2]. The prevalence of sarcoidosis in Japan involves two to three per 100,000 individuals, which is less frequent than in the United States where 40–60 per 100,000 individuals are affected. Although small parenchymal nodules along the bronchoarterial bundles, interlobular septa, and major fissures and in the subpleural regions are frequently observed in pulmonary sarcoidosis on CT [3–10], large nodules (≥1 cm in diameter) are less common [3]. To our knowledge, a detailed description of large nodules in pulmonary sarcoidosis has not been reported in previous research. The purpose of this study was to evaluate the large parenchymal nodules in pulmonary sarcoidosis on CT and to describe a new CT sign the "sarcoid galaxy" sign.

Materials and Methods

Patients

Fifty-nine patients (37 men and 22 women) ranging in age from 21 to 73 years (mean age, 42.7 years) with histologically confirmed pulmonary sarcoidosis were included in this retrospective study. All CT scans showed parenchymal abnormalities. Histologic proof was obtained by means of bronchial biopsy (n = 28), mediastinal or peripheral nodal biopsy (n = 12), transbronchial lung biopsy (n = 11), open lung biopsy (n = 5), and biopsy of other organs (n = 3).

CT Examination

CT studies were performed with a helical scanner (X-Vigor; Toshiba Medical, Tokyo, Japan). After routine helical CT scans were obtained with a 10-mm collimation, CT scans with a 3-mm collimation at 10-mm intersection spacing (120 kVp, 200 mA, and 1.0-sec scanning time) were acquired. A high-spatial-frequency algorithm (bone-detail algorithm) with a field of view of 20 cm and a matrix of 512 · 512 was used. All scans were obtained from the lung apices to the bases during suspended end-inspiration, and all patients were in the supine position when examined. All images were observed and photographed at window settings appropriate for pulmonary parenchyma (level, –700 H; width, 900 H) and mediastinum (level, 30–50 H; width, 350–500 H).

Data Analysis

Large nodules in pulmonary sarcoidosis were defined as round areas of soft-tissue attenuation greater than or equal to 1 cm in diameter [3, 4]. The presence of large nodules was assessed by three radiologists who were experienced in chest radiography and CT and who were informed that all patients had pulmonary sarcoidosis; however, the radiologists were unaware of other clinical information. A conclusion was reached by consensus if there was disagreement. The number, character, size, and extension of the large nodules and their relation to other findings, including mediastinal

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AJR 2002;178:1389–1393

0361–803X/02/1786–1389

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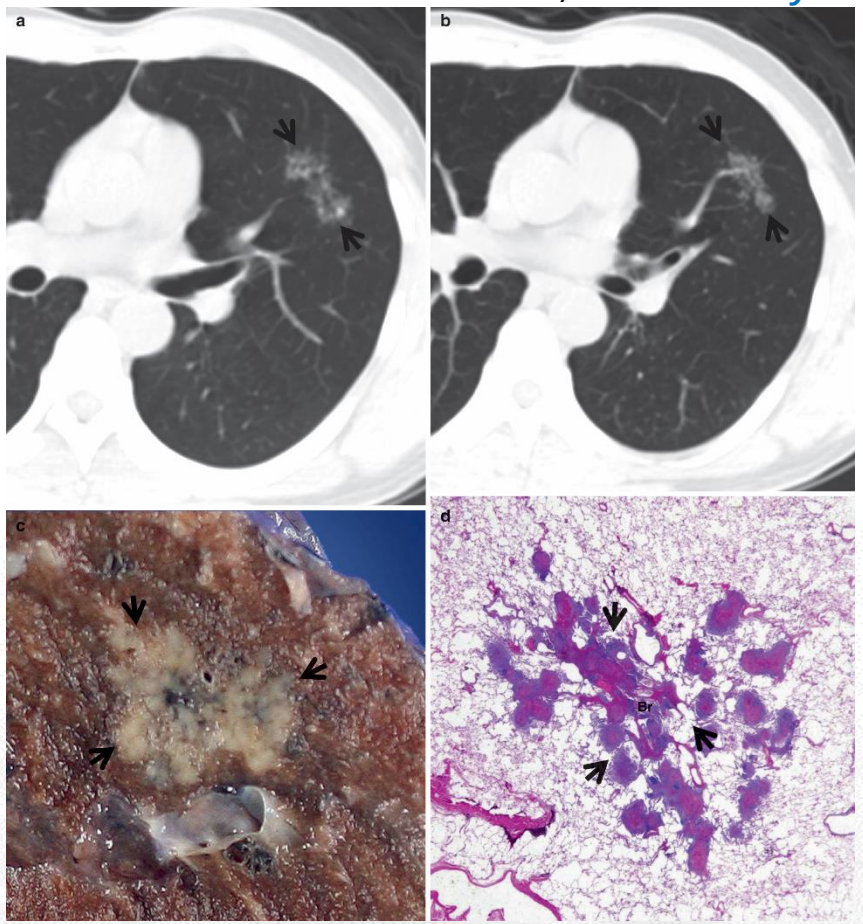
Nakatsu M et al. *AJR Am J Roentgenol* 2002;178:1389–1393

44M, Pulmonary tuberculosis



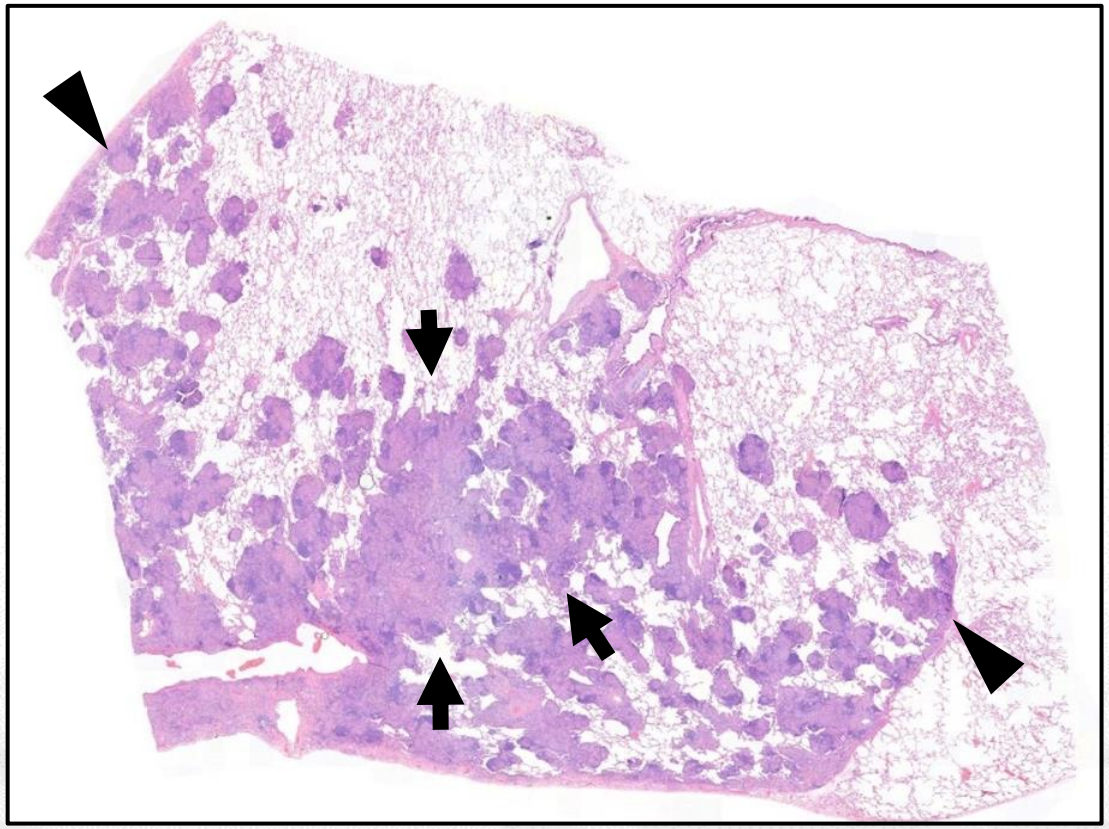
Arrows = granuloma aggregation having central necrosis in peribronchiolar interstitium; Bo = bronchiole

Nodular aggregation in peribronchiolar interstitium

Hoe JN et al. *AJR Am J Roentgenol* 2005;184:639–642

CT Galaxy Sign

45M, Pulmonary sarcoidosis

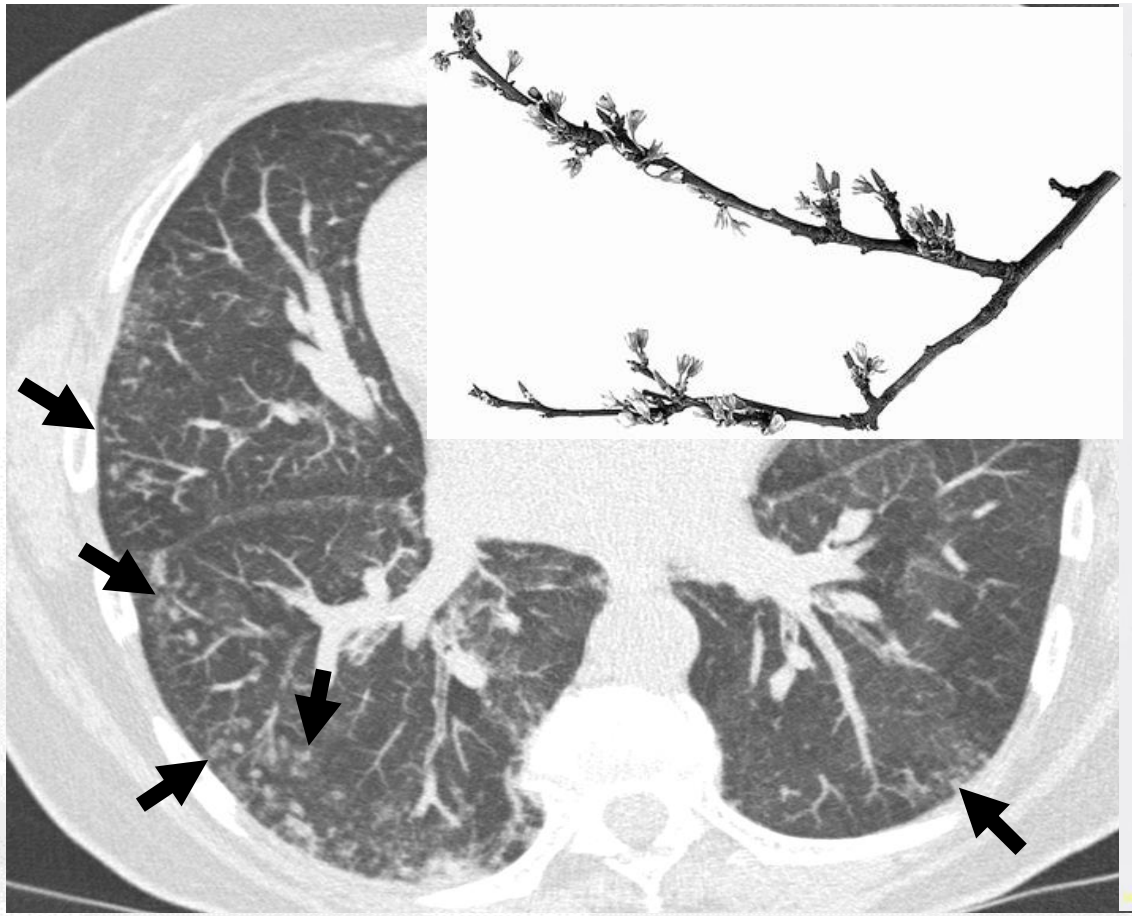


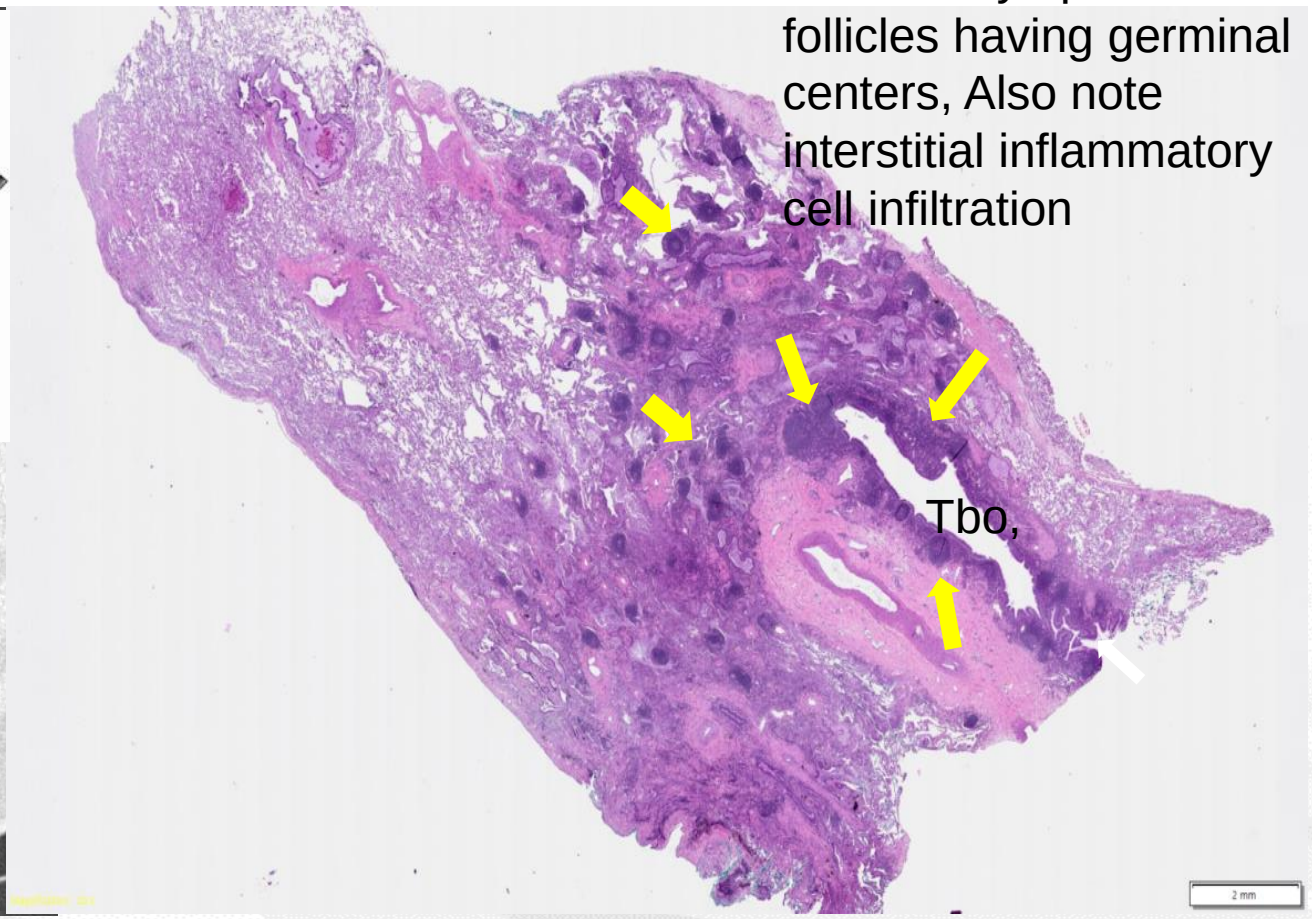
Arrows; large pulmonary nodule composed of multiple small non-caseating granulomatous nodules, Arrowheads; many very smaller satellite nodules (arrowheads)

Lee KS et al. Radiology Illustrated: Chest Radiology 2nd ed. Springer 2023

Tree-in-Bud Sign

76F, Follicular bronchiolitis and Sjogren's syndrome

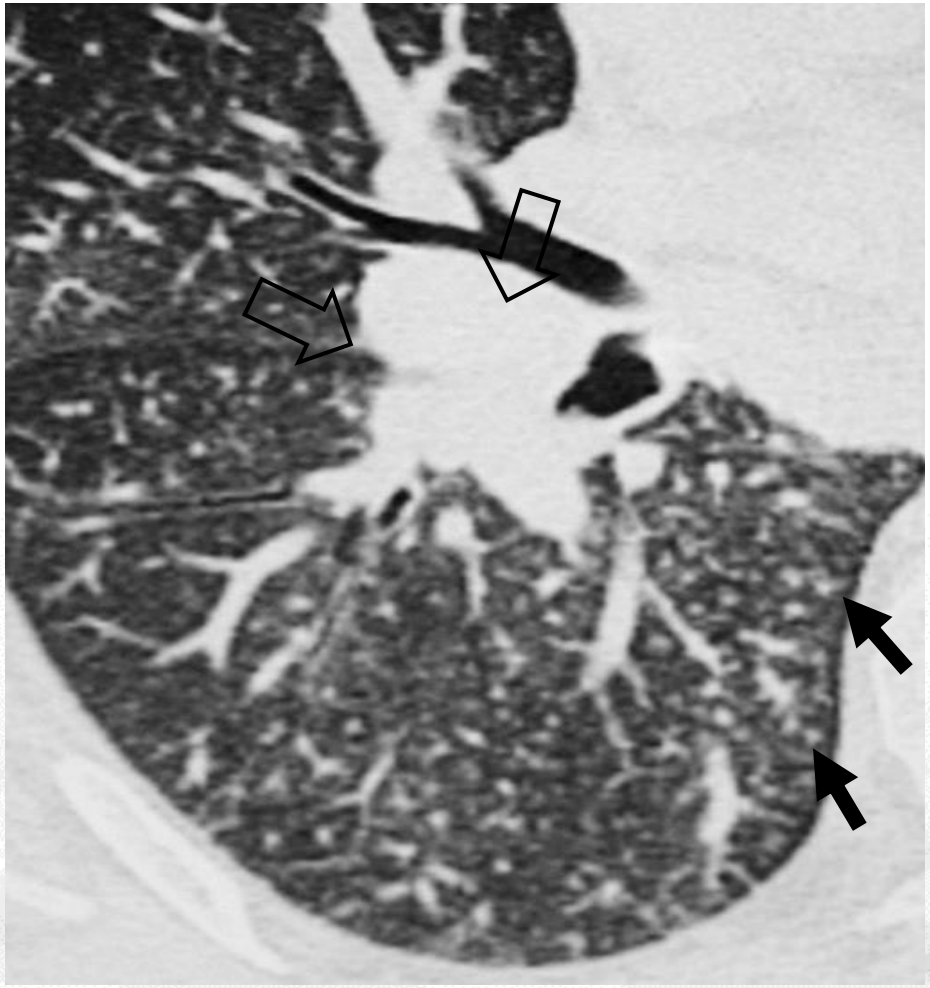




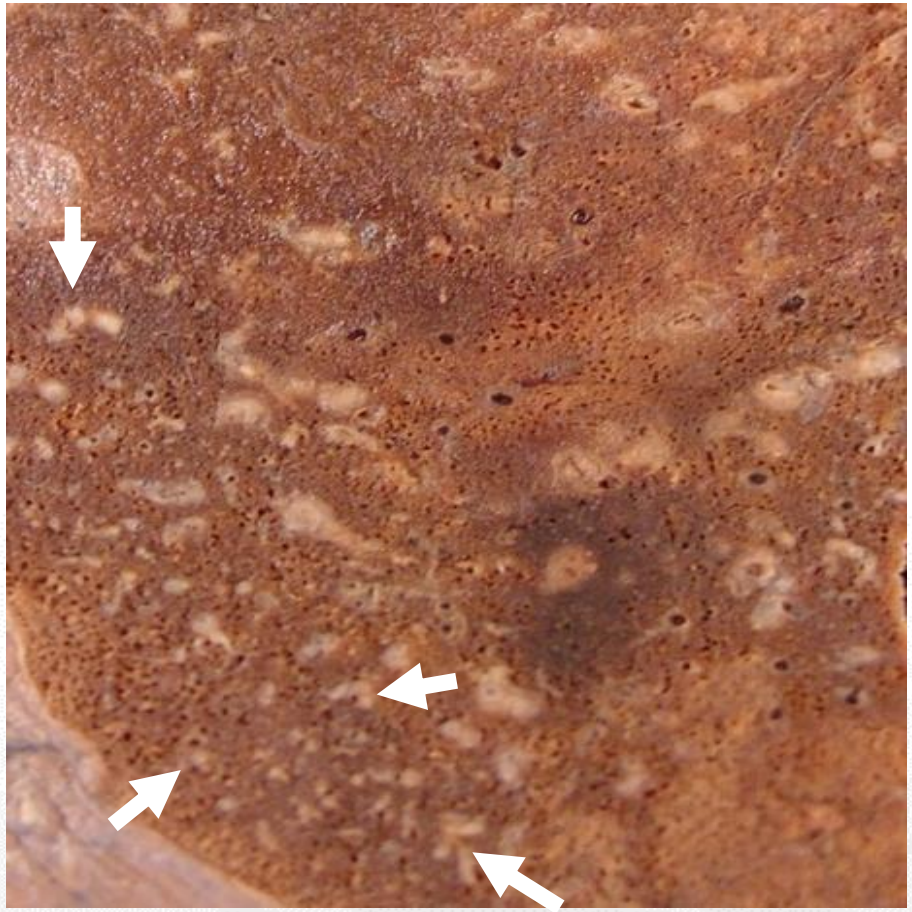
TBo = terminal bronchiole,
Arrows = lymphoid follicles having germinal centers, Also note interstitial inflammatory cell infiltration

Tree-in-Bud Sign

48M, AGC and Pulmonary Tumor Thrombotic Microangiopathy (PTTM)



Arrows = TIB signs, Open arrows = enlarged PA

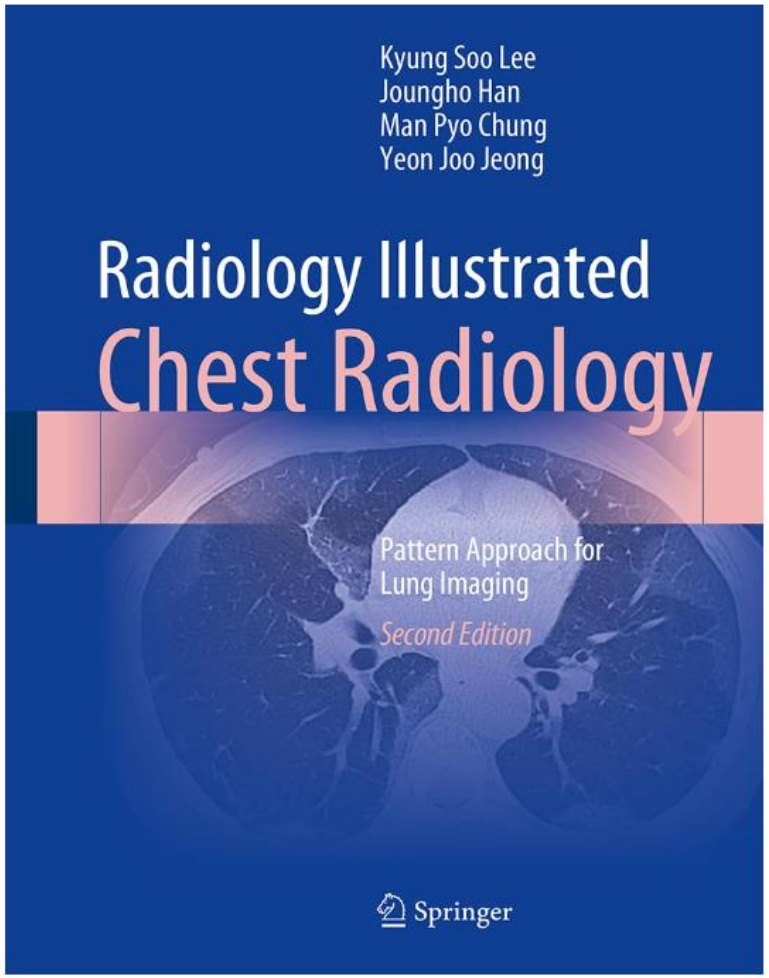


Arrows = centrilobular branching nodular lesions representing arteriolar occlusions with fibrocellular intimal proliferation

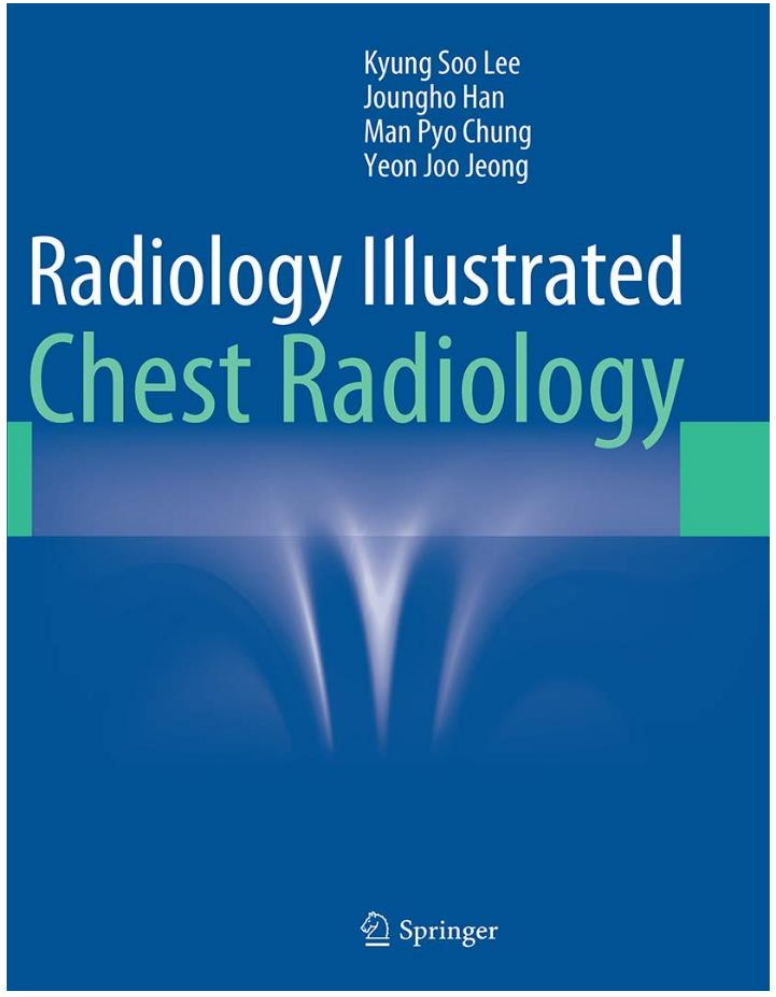
04

Pattern Approach

Pattern Approach for Lung Imaging



2023



2013

Patterns and Distribution on TSCT

- Patterns
  - Nodular
  - Reticular
  - Ground-glass opacity (GGO)
  - Consolidation
  - Cystic
  - Mosaic attenuation (decreased attenuation)
- Distribution
  - Focal
  - Bronchovascular
  - Diffuse
  - Zonal (upper, middle and lower)*

*Landmarks; Aortic arch, Right Inferior pulmonary vein

Nodules

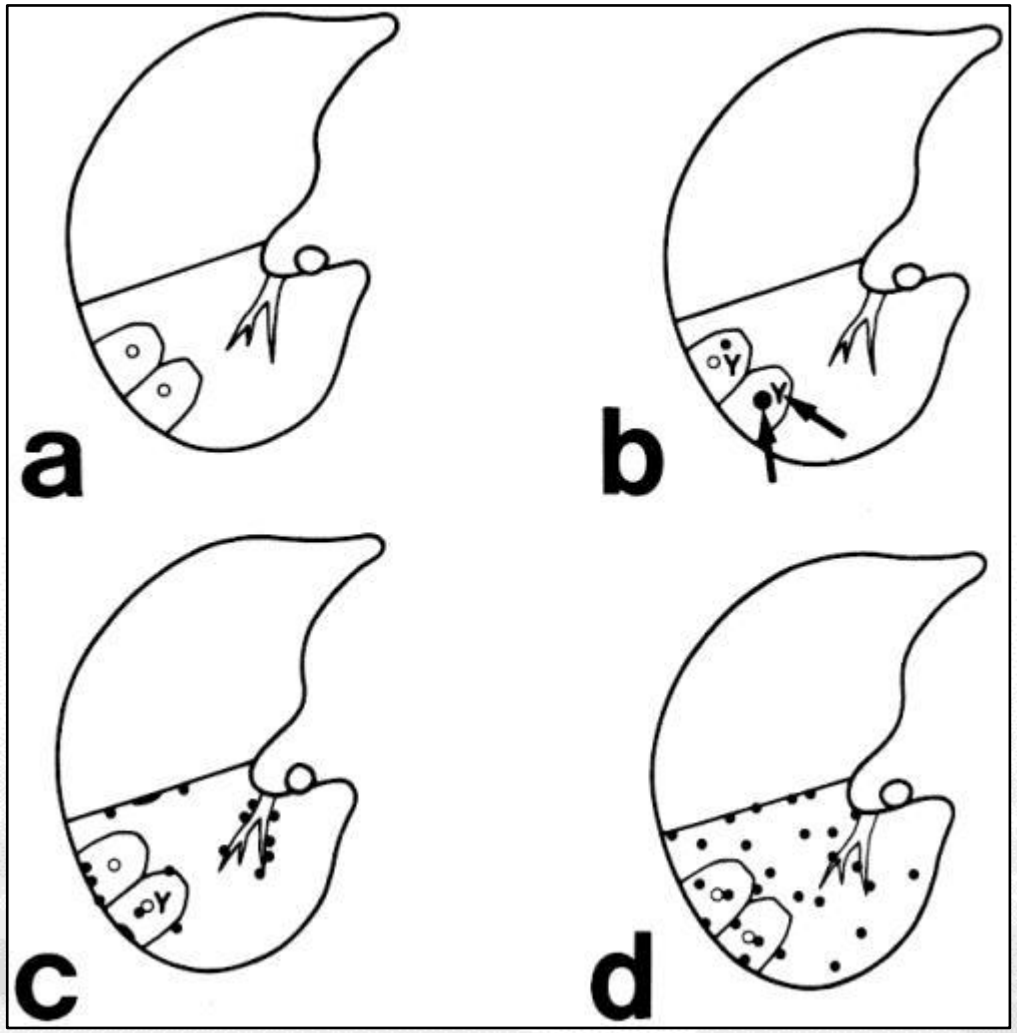
- Definition of Nodule(s)

Well-defined round or oval structure

- Size of Nodules
  - 30 mm or less in diameter
  - small nodules ≤ 10 mm in diameter
  - micronodules ≤ 5 mm in diameter
- Distribution of Nodules
  - centrilobular; inflammatory or cellular bronchiolitis
  - perilymphatic; pneumoconiosis, sarcoidosis, amyloidosis
  - random; miliary lung disease including miliary infection and miliary metastasis

Diffuse Micro-nodular Lung Diseases: Classification

Normal



Centrilobular

Perilymphatic

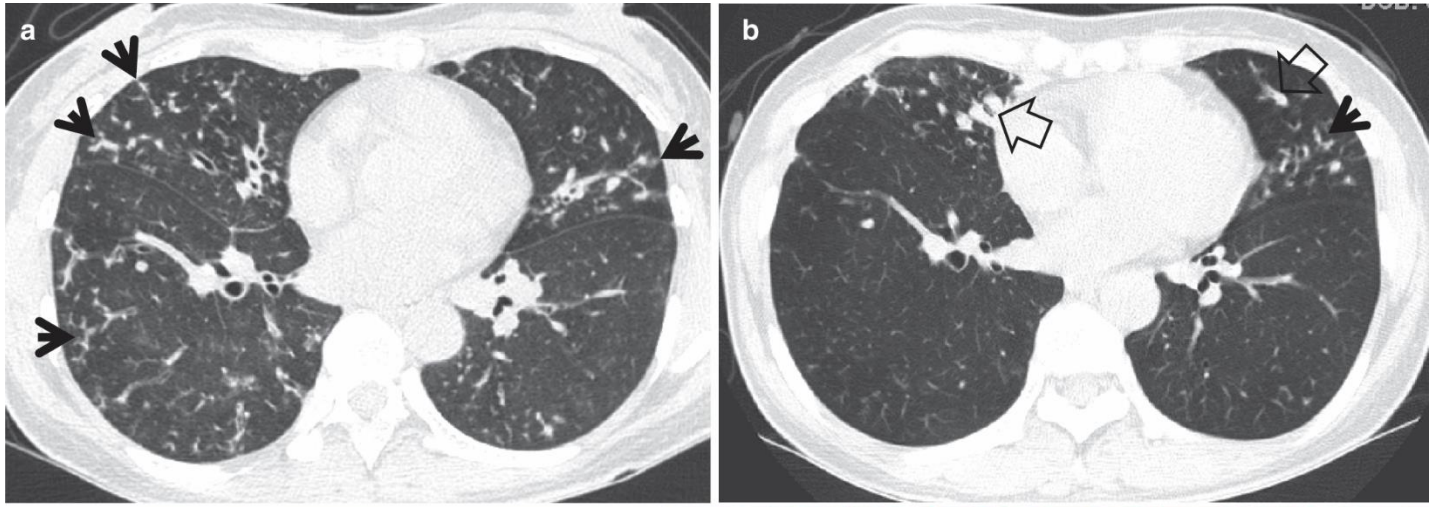
Random, > 30% of lung volume

Lee KS et al *J Comput Assist Tomogr* 1999;23:99-106

Centrilobular Nodules

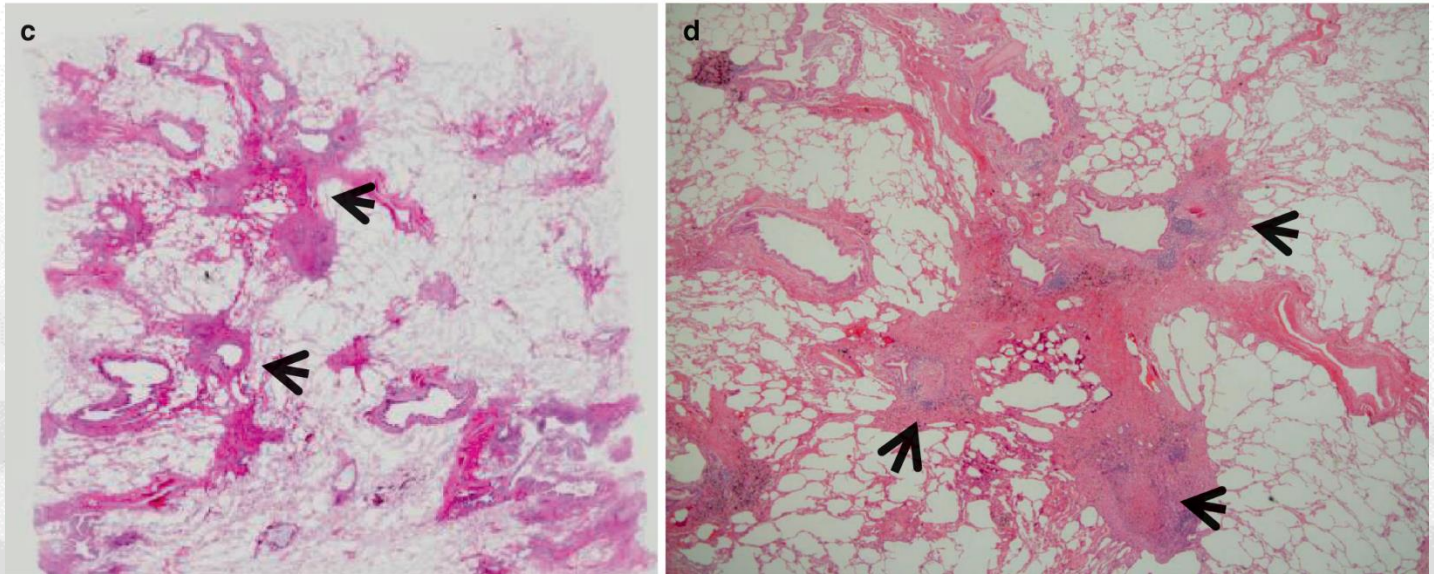
53F, NTM-PD

Arrows = centrilobular nodules,
Open arrows = bronchiectasis with mucus plugging



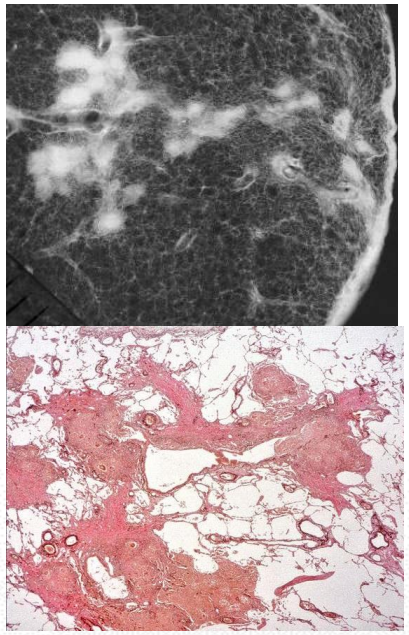
Arrows in **c** = <u>bronchiolocentric</u> chronic inflammation, fibrosis and granuloma formation

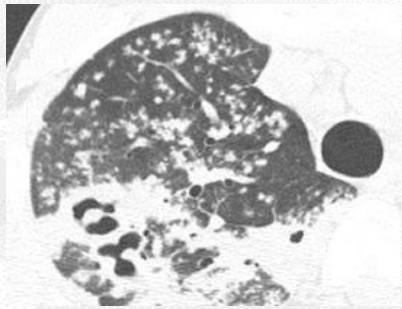
Arrows in **d** = granulomas with surrounding chronic inflammation and fibrosis



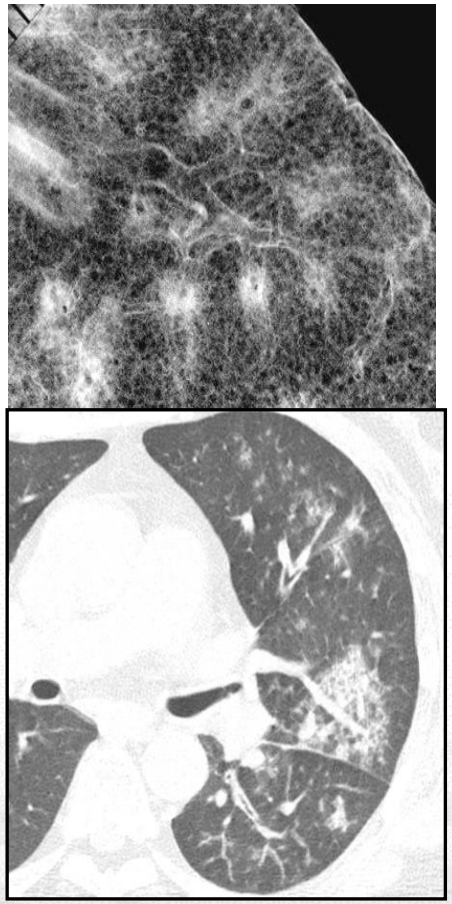
Centrilobular Nodules

Tuberculosis (chronic granulomatous infection) vs. Community-acquired pneumonia (acute pneumonia)





TB;
Granulomatous infection in walls and lumens of RB and alveolar ducts; few inflammatory cells in surrounding alveoli



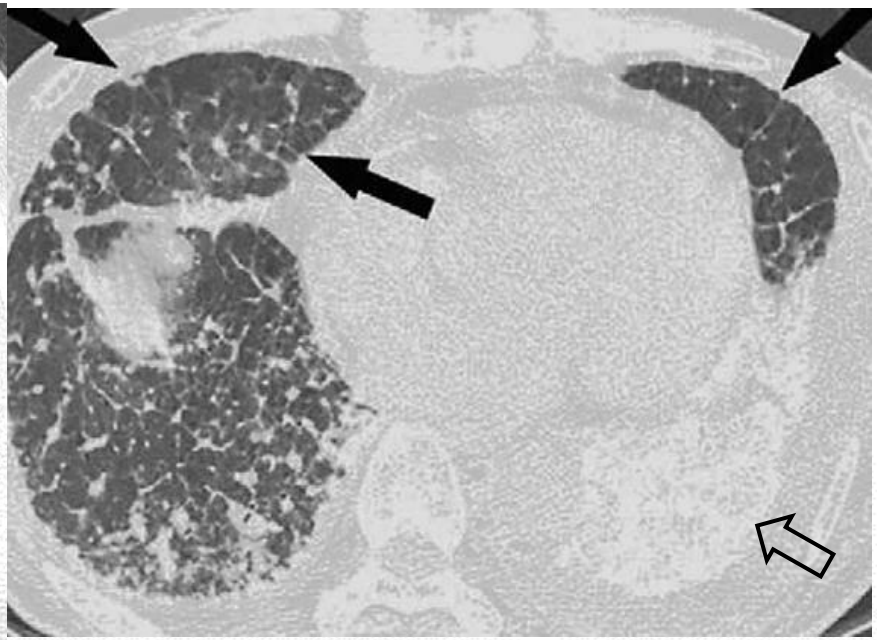
CAP;
Spread of inflammation into alveoli via channel of Lambert (RB)and Cohn's pores,
Fluffy nodule formation

Lee KS et al. Radiology Illustrated: Chest Radiology 2nd ed. Springer 2023

Three Main Diseases of Perilymphatic Nodular Pattern

66M, Pneumoconiosis

46M, Sarcoidosis



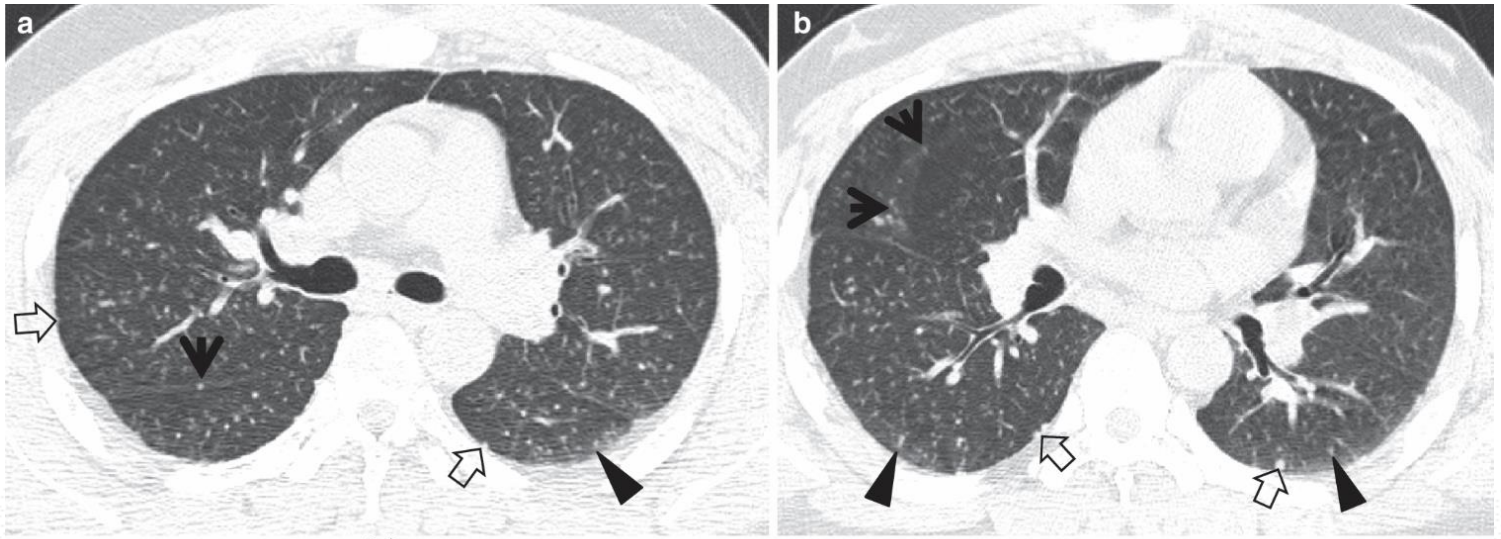
54F, Alveolo-septal amyloidosis

Arrows = septal thickening,
Open arrow = parenchymal calcifications

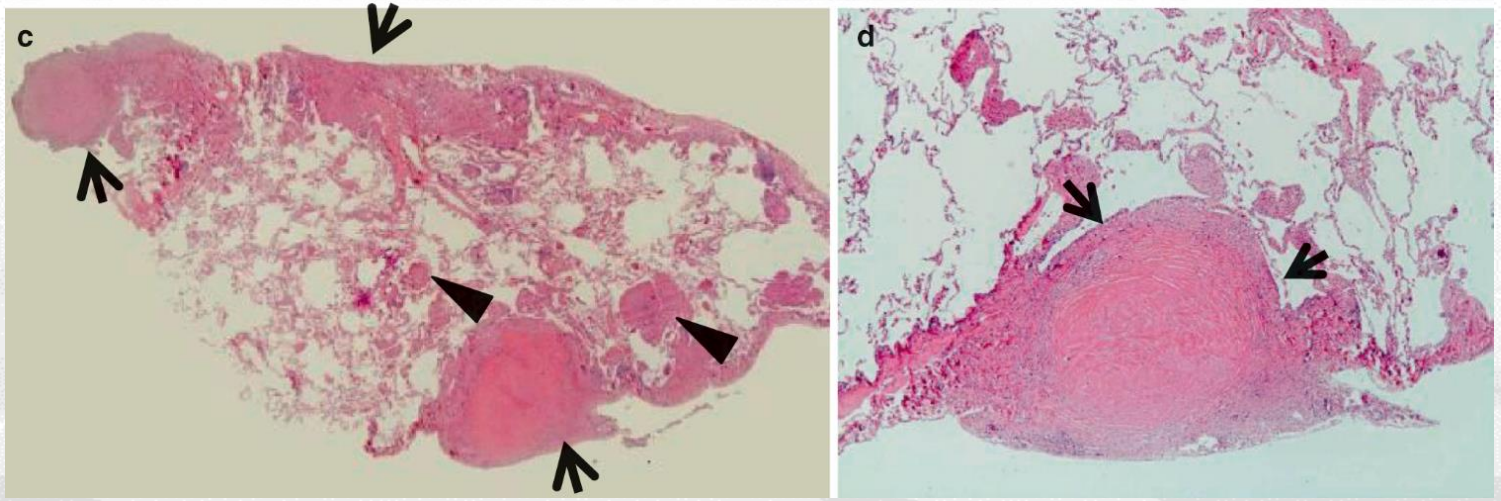
Perilymphatic Nodules

32M, Pneumoconiosis in a building demolition worker

Arrows = small nodules along fissures, Arrowheads = nodules in centrilobular regions, Open arrows = nodules in subpleural lung



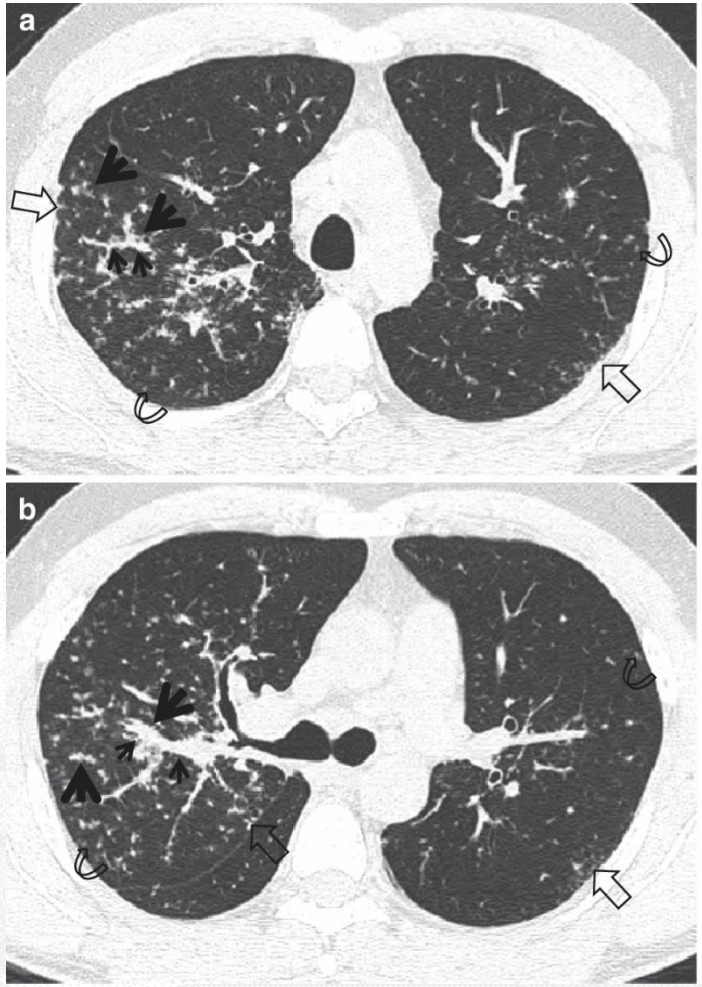
Small noncaseating and fibrotic nodules along pleura (arrows in **c**) and in alveolar wall (arrowheads in **c**); well circumscribed subpleural pneumoconiotic nodule (arrows in **d**) composed of mature collagen (center) and particle-laden macrophages (periphery)

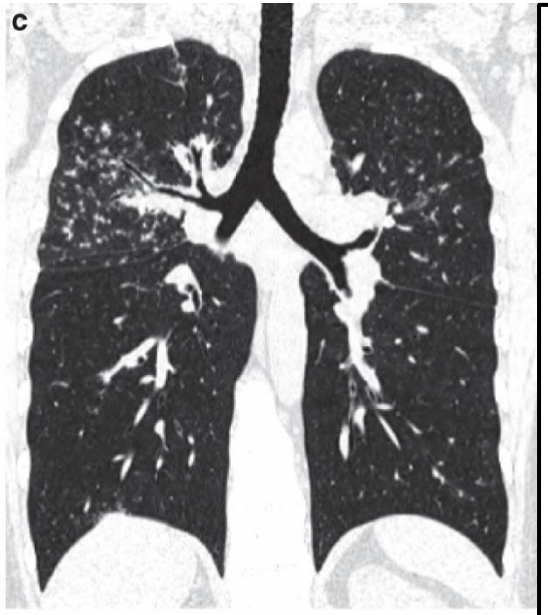


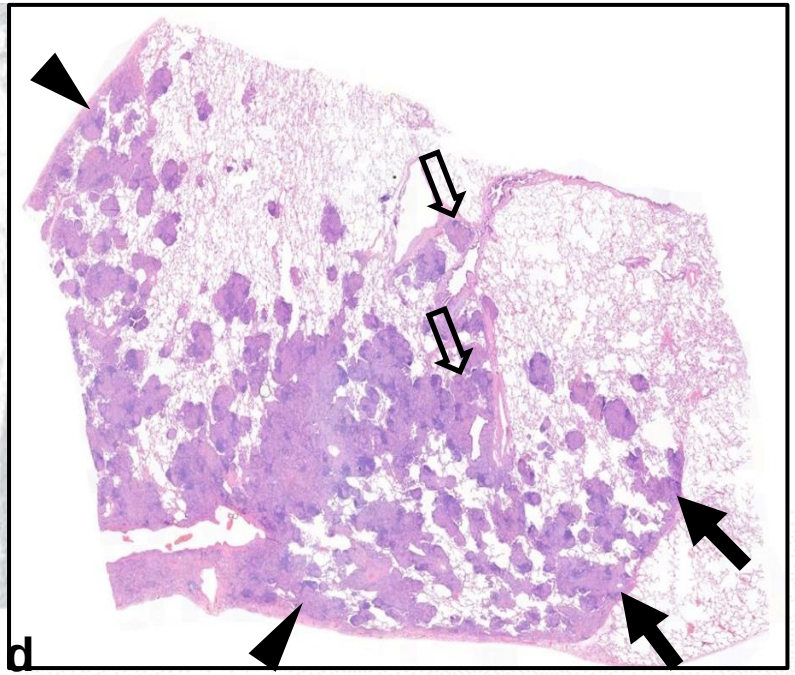
Perilymphatic Nodules

31M, Pulmonary sarcoidosis

A & b) Arrows = small nodules along bronchovascular bundles, Open arrows = along subpleural lungs (open arrows), Curved arrows = in centrilobular areas (curved arrows), and Small arrows = bronchovascular bundle thickening





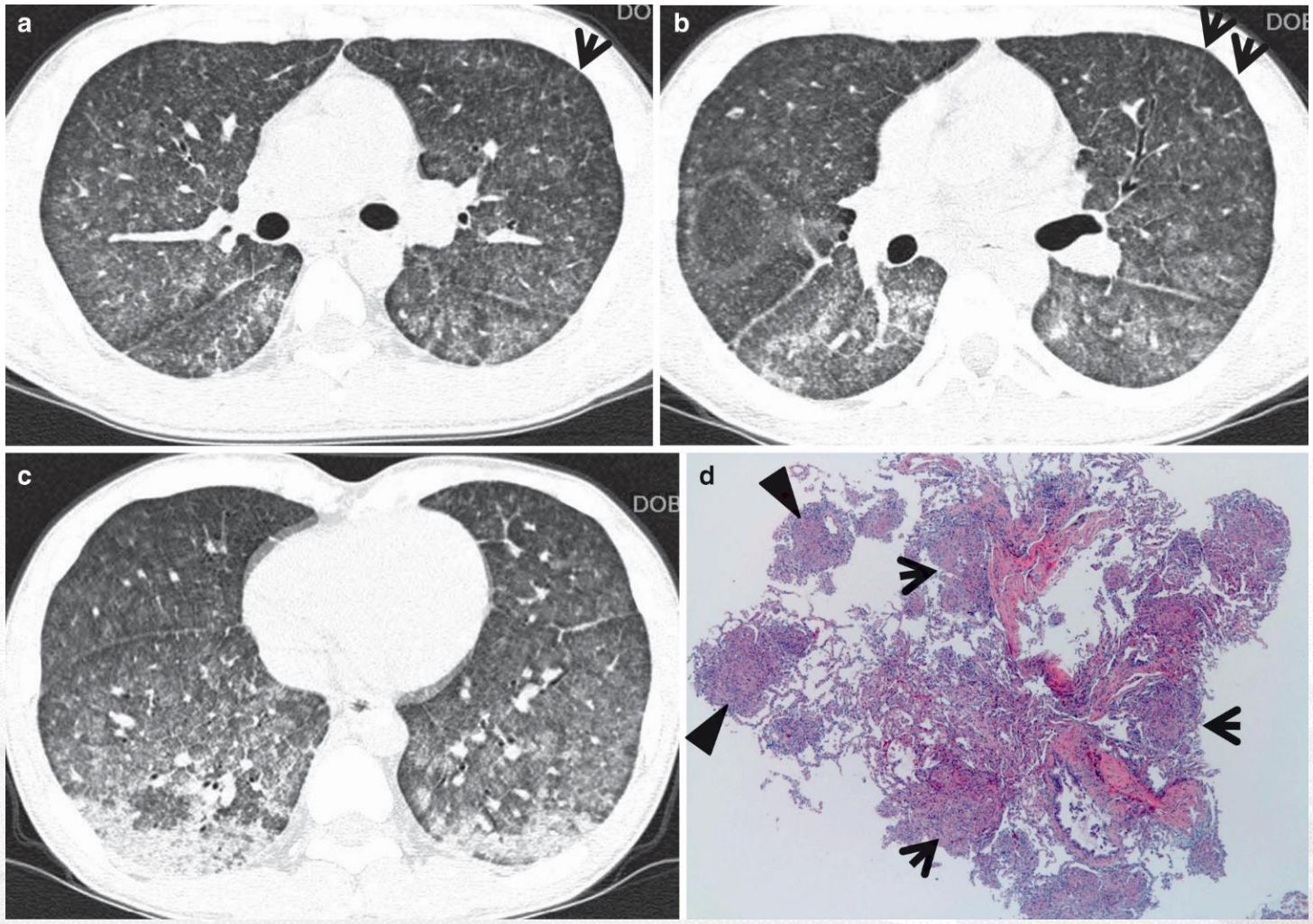


d) Numerous noncaseating small granulomas in subpleural (arrowheads), para-interlobular septal (arrows), and peribronchiolar (open arrows) interstitium

Lee KS et al. Radiology Illustrated: Chest Radiology 2nd ed. Springer 2023

Random (Miliary) Nodules

27M, Miliary TB



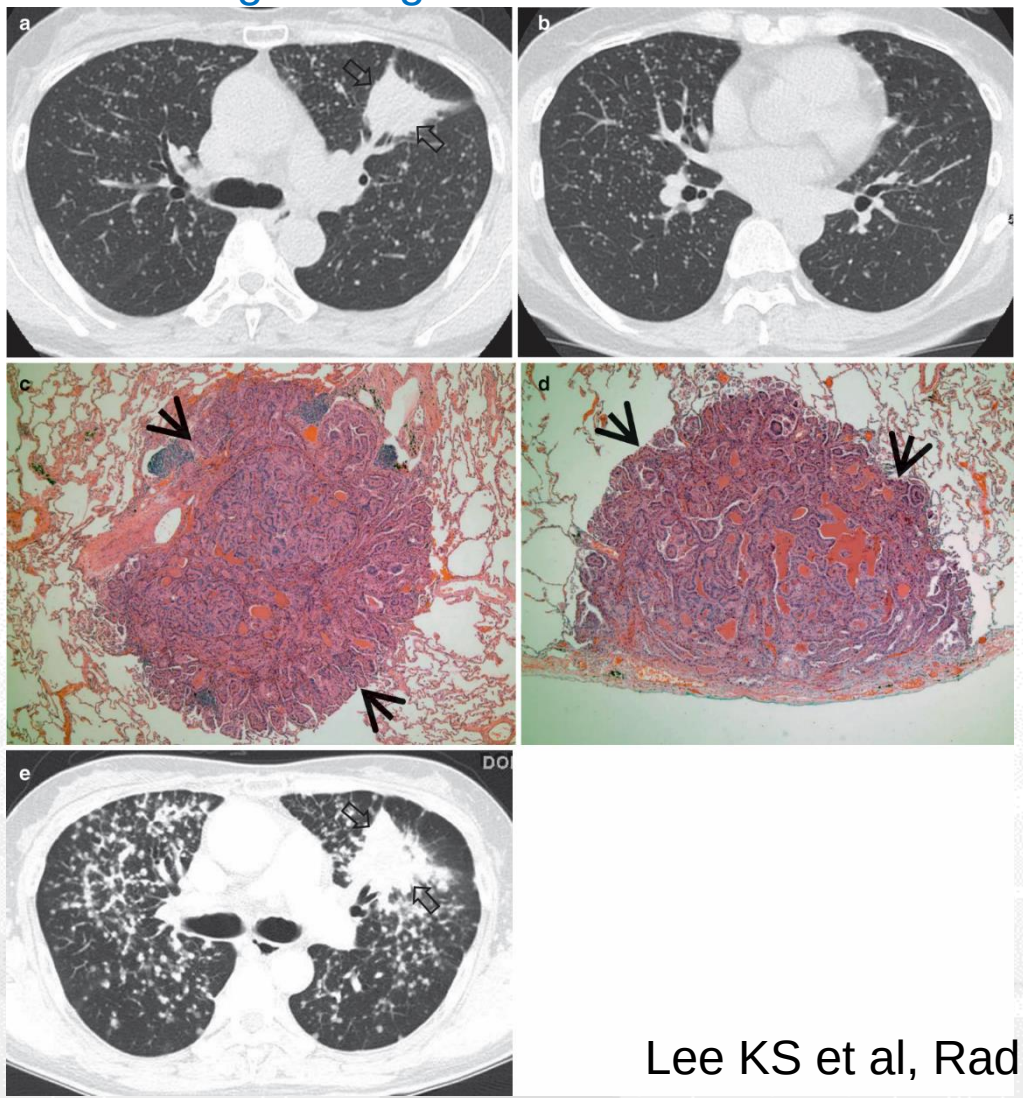
Arrows = interlobular septal thickening

Arrows = multiple granulomas along bronchiolar walls, Arrowheads = along alveolar walls

Lee KS et al. Radiology Illustrated: Chest Radiology 2nd ed. Springer 2023

Miliary (Random) Nodules

60F, Lung ADC and lung-to-lung metastases



Open arrows: primary lung cancer in left upper lobe

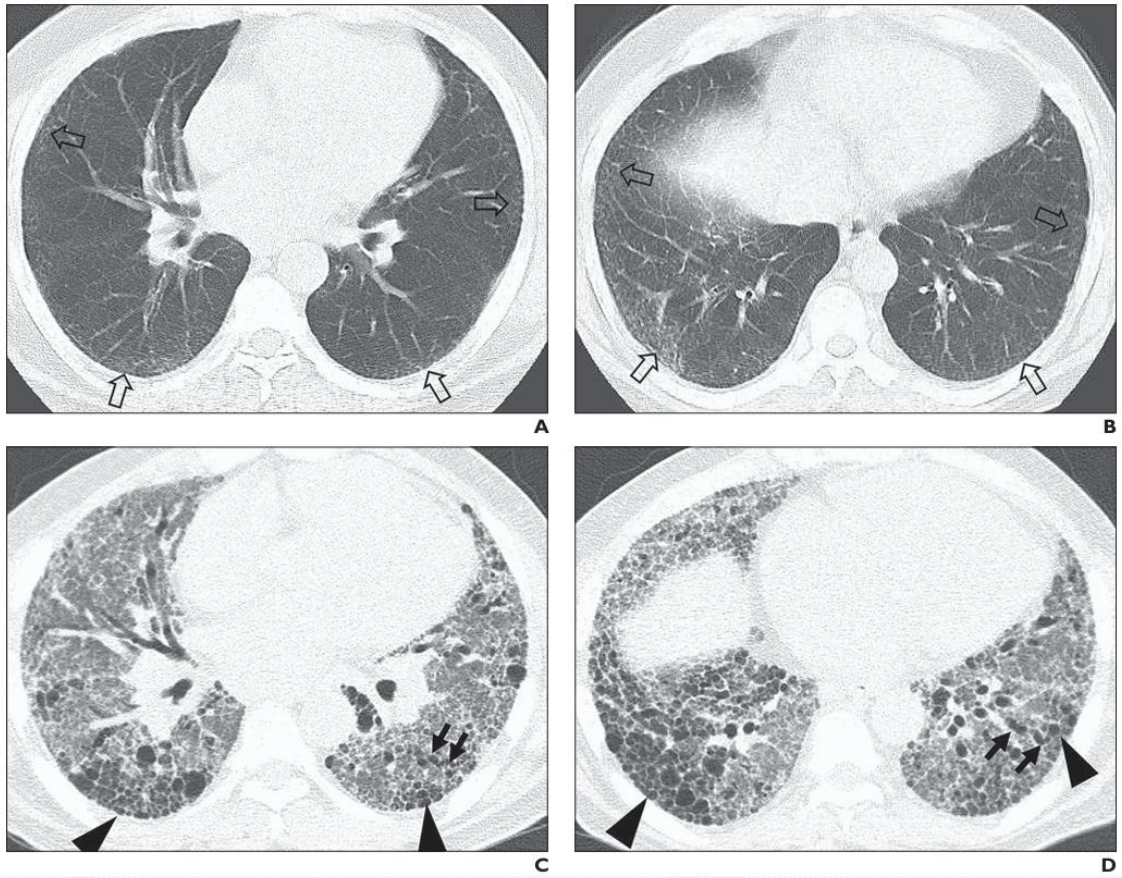
Arrows in **c** = cancer nodule along bronchovascular bundle, Arrows in **d** = cancer nodule along pleural surface

Six-month FU CT: Open arrow = enlarged primary cancer

Lee KS et al, Radiology Illustrated: Chest Radiology 2nd ed. Springer 2023

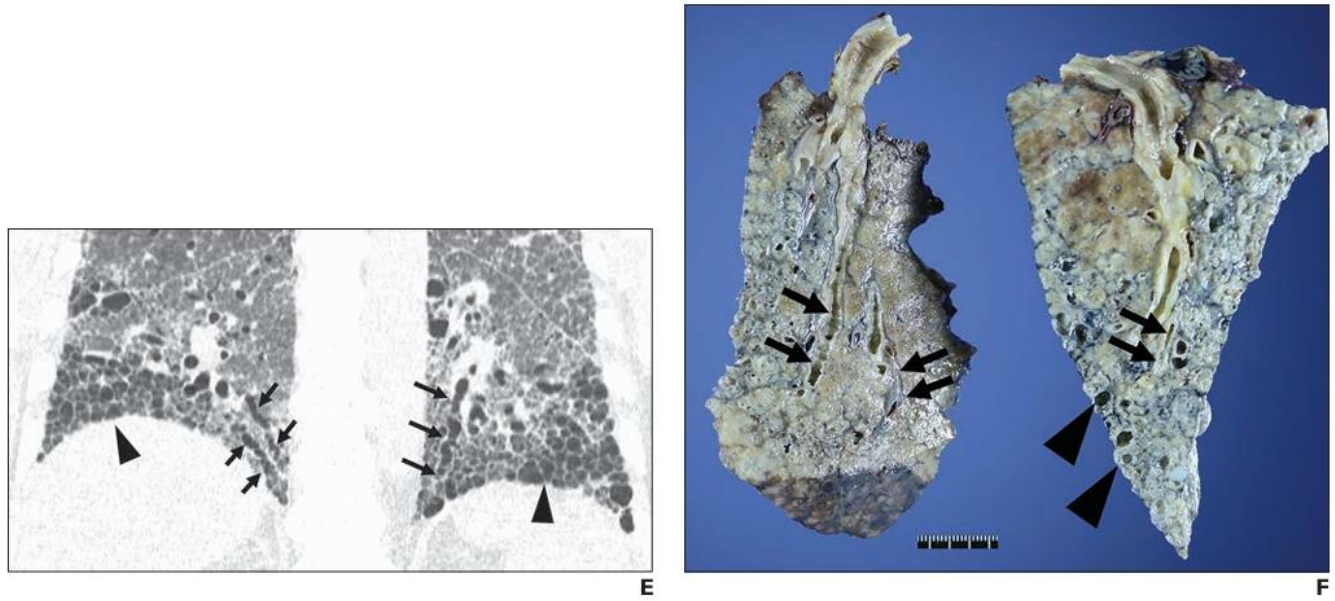
Reticulation

62M, IPF (usual interstitial pneumonia) and its progression over follow-up period of 61 months



C & D: 61-month follow-up CT scans show reticular lesions involving entire lung bilaterally with areas of HC (arrowheads) and traction bronchiectasis (arrows)

A & B: Subpleural reticular lesions in bilateral lower lung zones

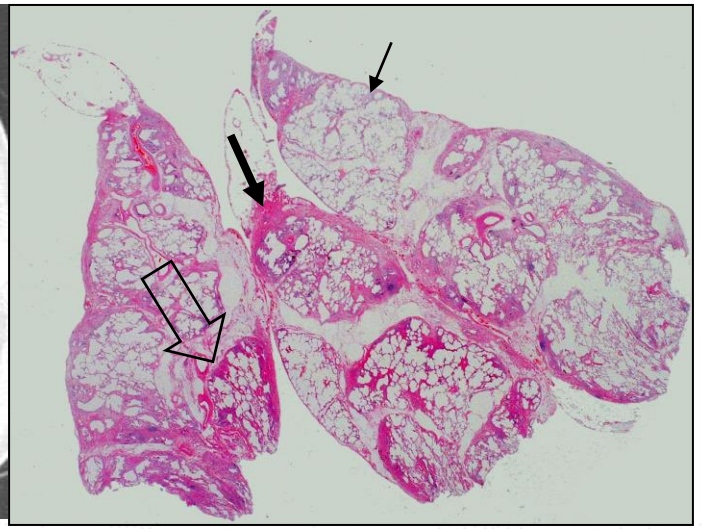


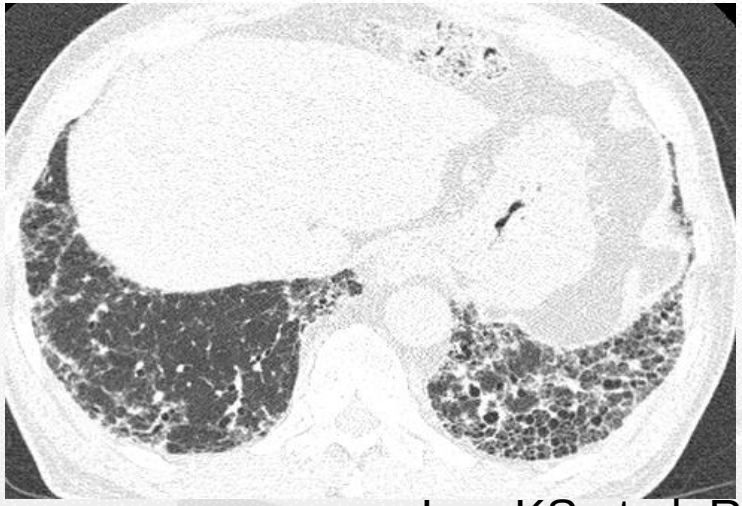
E: coronal image shows traction bronchiectasis and/or bronchiolectasis (arrows) in both lower lobes. Dilated bronchioles extend to centrilobular regions, thus presenting as HC when viewed on axial images. **F:** Traction bronchiectasis (arrows) and HC (arrowheads)

Lee KS et al. *AJR Am J Roentgenol* 2024 Feb;222(2):e2329119.

Reticular Lesions

62M, UIP and evolution for seven years



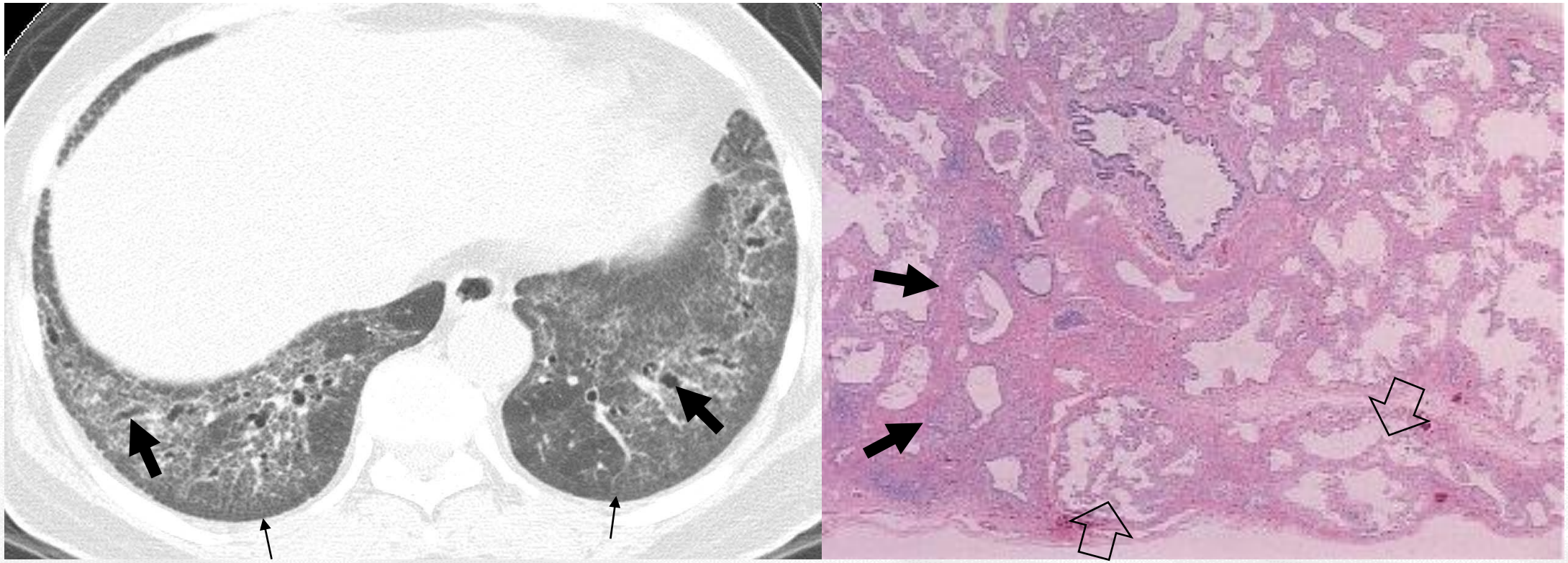


Interstitial fibrosis with temporal homogeneity;
Arrow = honeycombing, Small arrow = normal lung, Open arrow = interstitial fibrosis

Lee KS et al, Radiology Illustrated: Chest Radiology 2nd ed. Springer 2023

Reticular Lesions

54F, Idiopathic NSIP



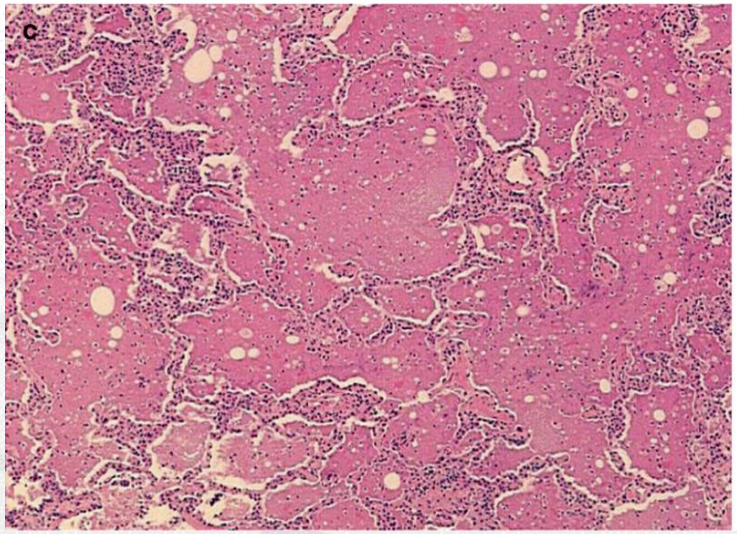
Interstitial fibrosis with temporal homogeneity

Lee KS et al, Radiology Illustrated: Chest Radiology 2nd ed. Springer 2023

Reticular Lesions plus Ground-Glass Opacity but without Traction BE (Reversible Components)

52M, Pulmonary Alveolar Proteinosis

Arrows: diffuse GGO containing internal reticulation (crazy-paving appearance)

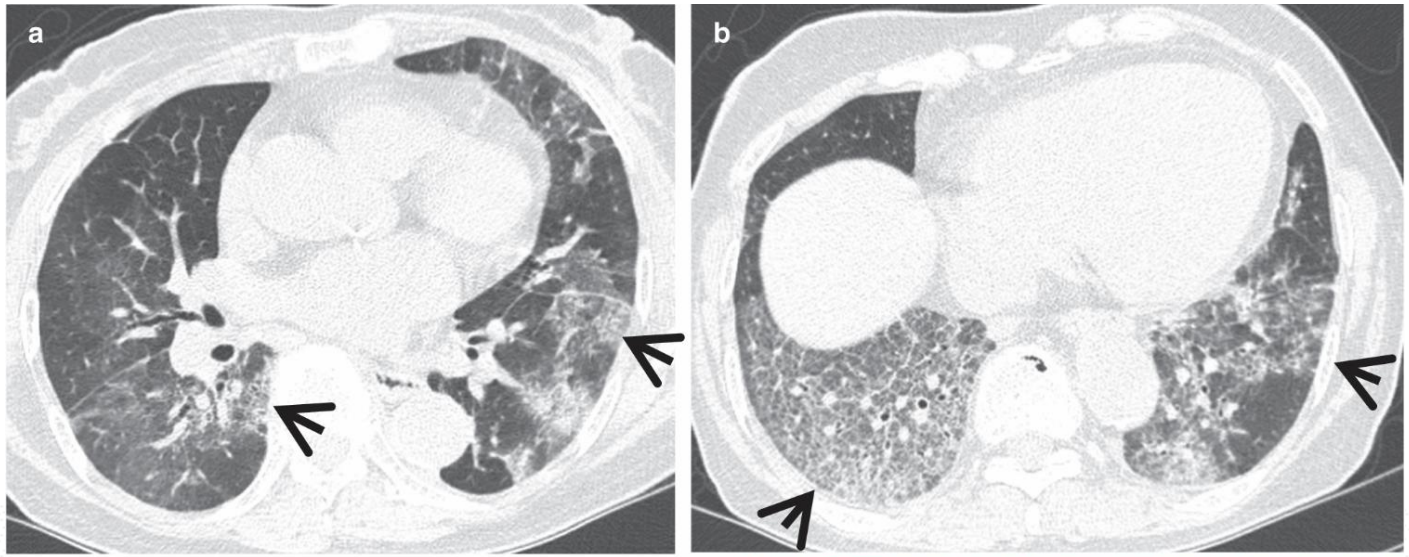


Filling of alveolar spaces with finely granular eosinophilic materials like surfactant. Also note near normal alveolar walls.

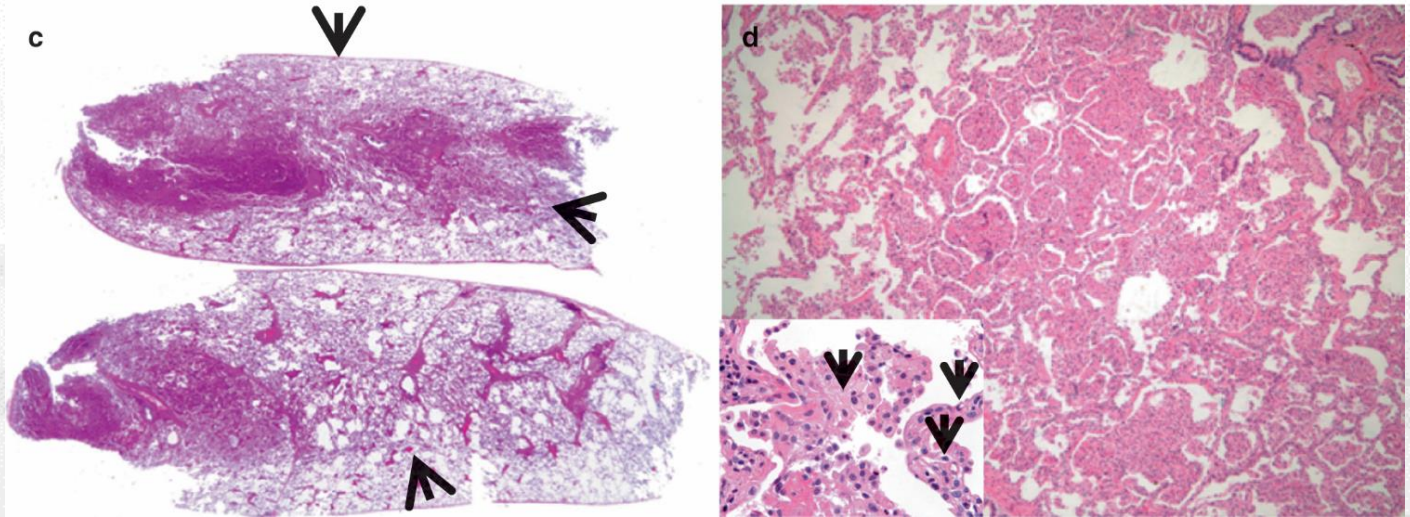
Lee KS et al, Radiology Illustrated: Chest Radiology 2nd ed. Springer 2023

Reticular Lesions plus Ground-Glass Opacity but without Traction BE (Reversible Components)

73M, Lipoid pneumonia (squalene lung)



Arrows in **a & b**: patchy and extensive areas of GGO harboring internal reticulation (crazy paving) indicated by arrows

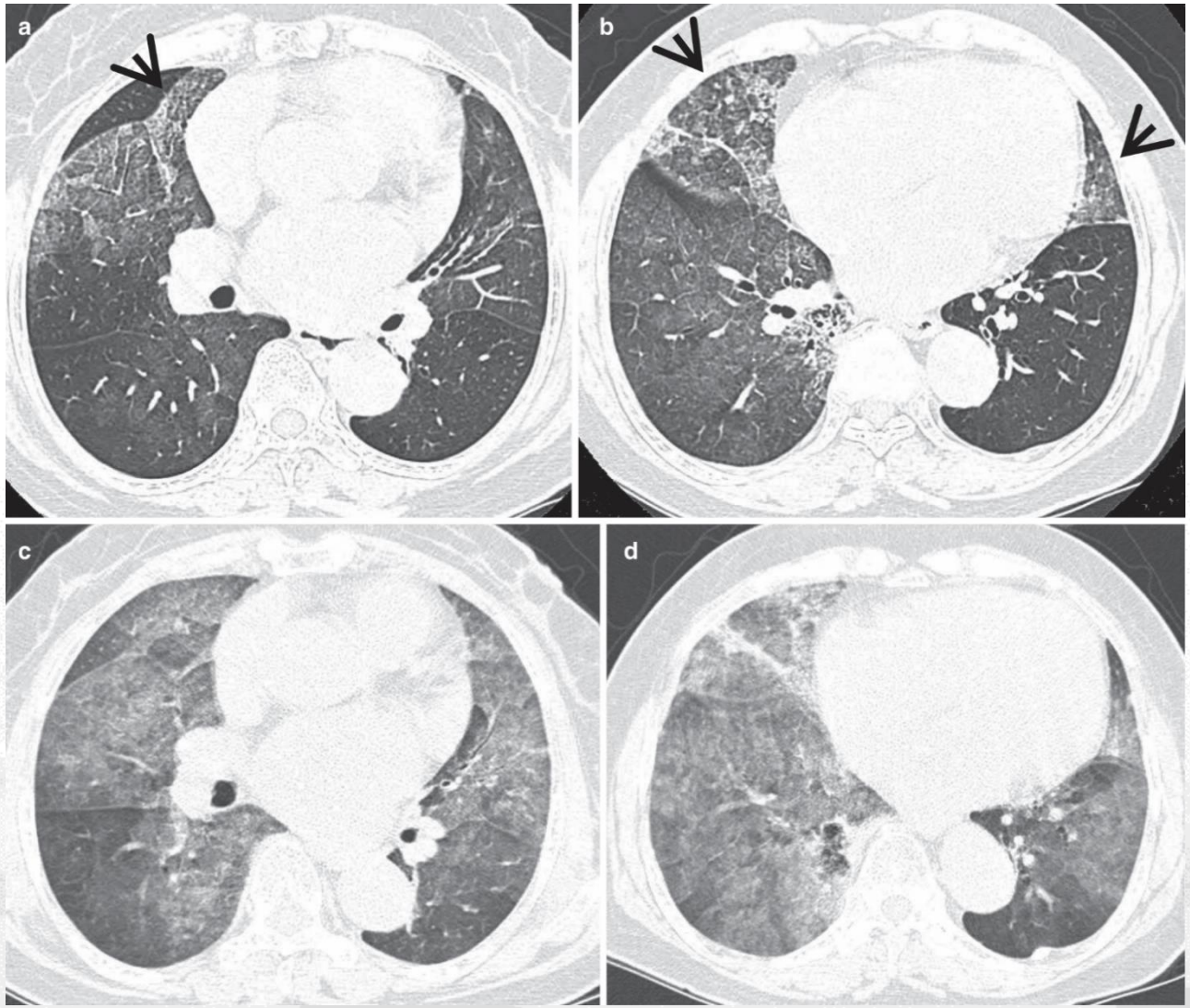


Arrows in **c**: consolidative lesions filled with inflammatory cells and interstitial thickening with loose fibrosis and inflammation

d: Arrows = alveolar filling with lipid-laden macrophages, other inflammatory cells, and fibrin **Inset**: lipid-laden macrophages

Reticular Lesions plus Ground-Glass Opacity without Traction BE (Malignancy)

70F, Diffuse mucinous adenocarcinoma

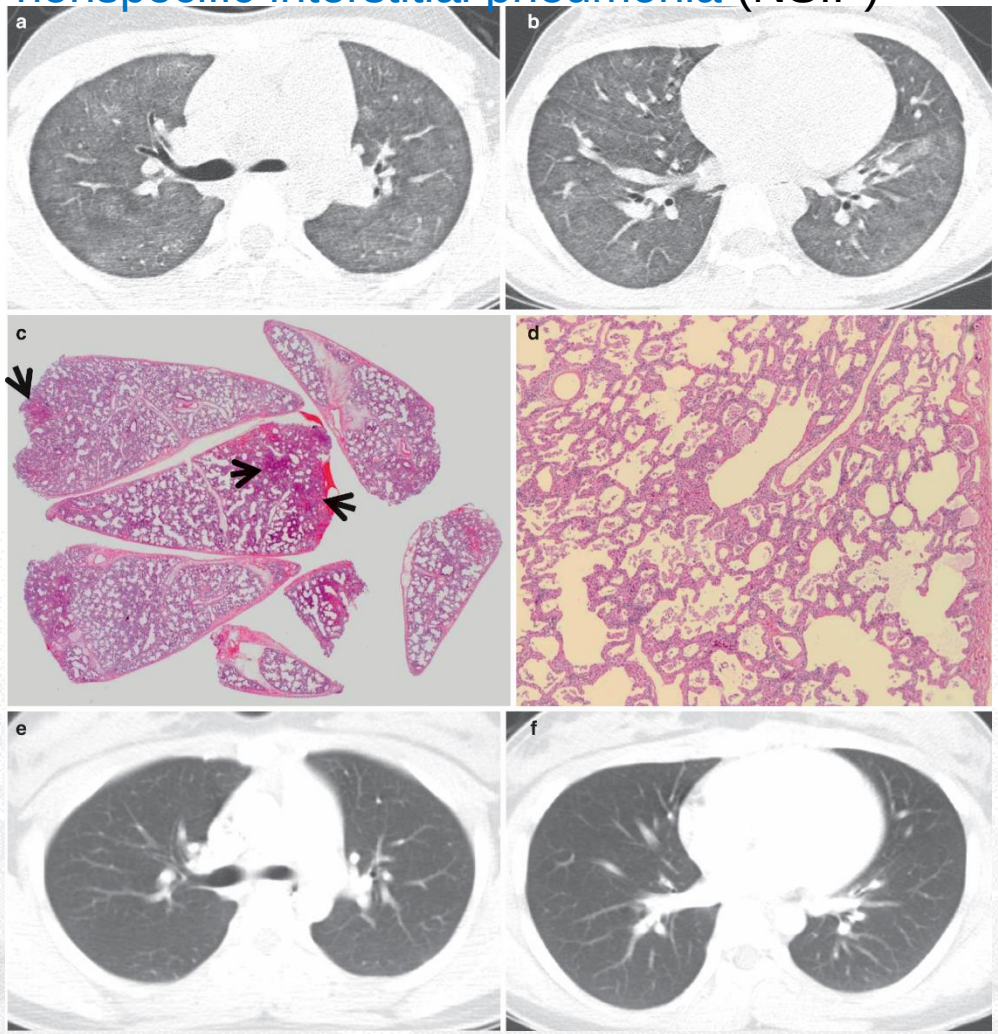


Arrows in **a & b**: patchy and extensive areas of GGO having internal reticulation

Ten-month follow-up CT scans demonstrate progressive disease with diffuse GGO in both lungs.

Ground-Glass Opacity

10F, Cellular nonspecific interstitial pneumonia (NSIP)



Diffuse GGO in both lugs

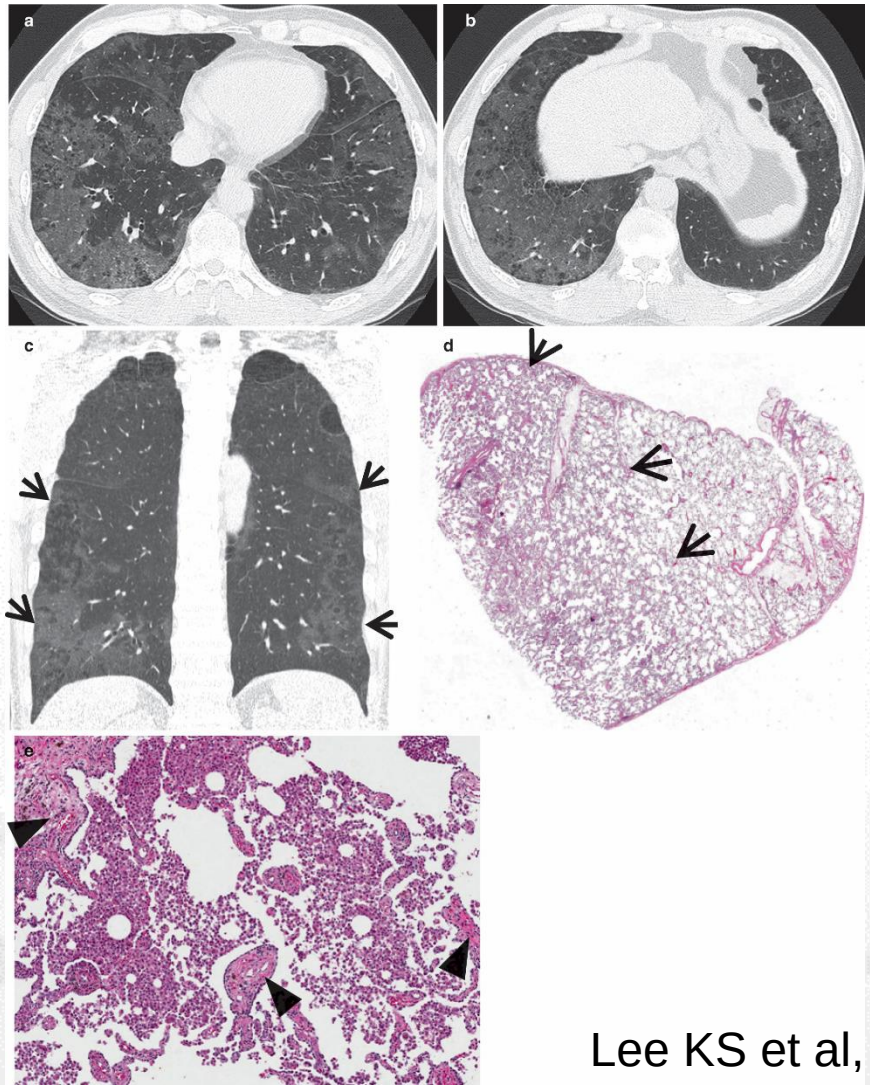
c: Diffuse alveolar wall thickening with inflammatory cell infiltration; note temporal homogeneity and uniform alveolar wall thickening; Arrows = focal organizing pneumonia
d: Alveolar wall thickening with chronic inflammatory cell infiltration and mild alveolar wall pneumocyte hyperplasia and many intra-alveolar macrophage aggregates

Two-year FU CT exhibit complete disappearance of GGO in both lungs with corticosteroid therapy

Lee KS et al, Radiology Illustrated: Chest Radiology 2nd ed. Springer 2023

Ground-Glass Opacity

51M, Desquamative interstitial pneumonia (DIP)



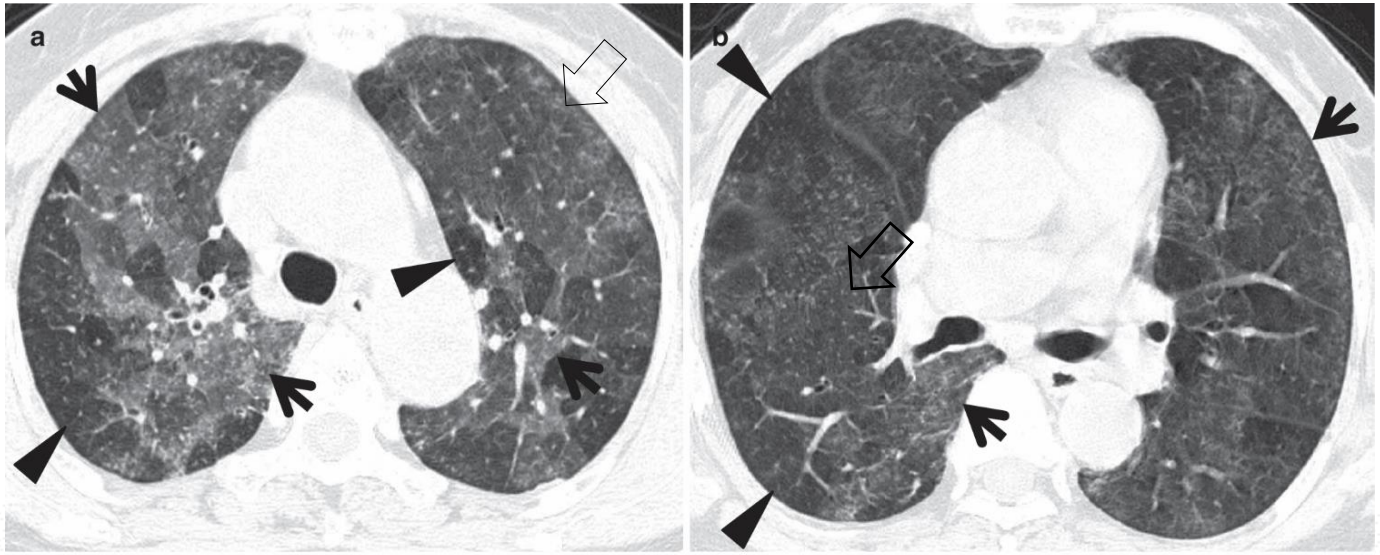
Patchy and extensive but subpleural areas of GGO in both lungs; bullae in upper lung zones in **c**

d: Uniform accumulation of inflammatory cells in intra-alveolar spaces and mildly in interstitium (alveolar walls) (Arrows)
e: Intra-alveolar macrophage accumulation and mild interstitial fibrosis (Arrowheads)

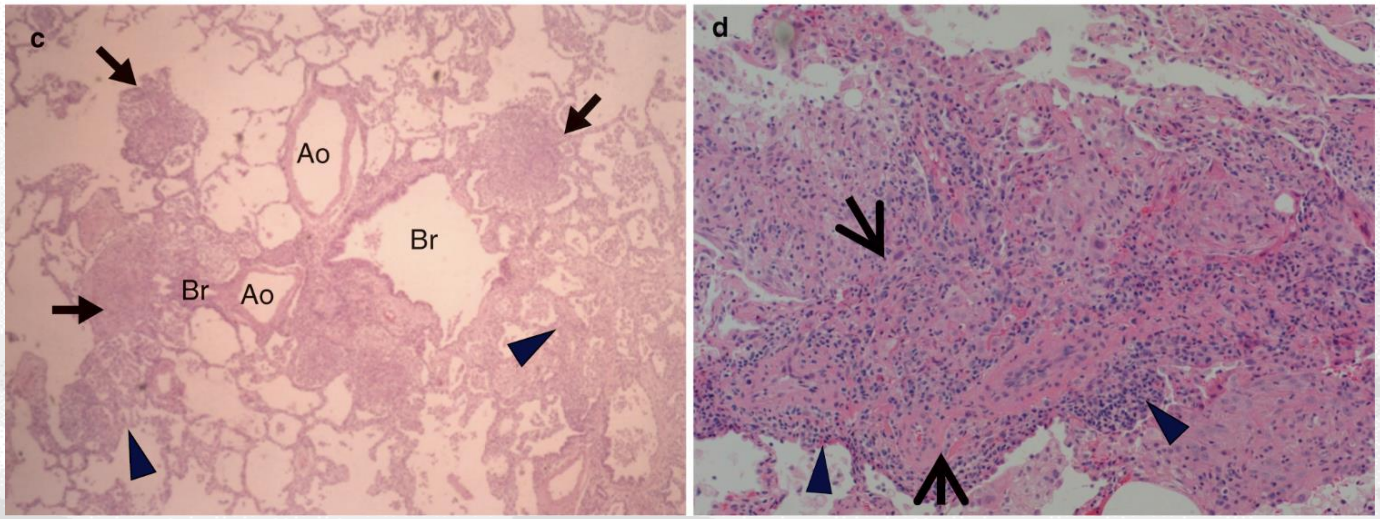
Lee KS et al, Radiology Illustrated: Chest Radiology 2nd ed. Springer 2023

Ground-Glass Opacity

66F, Nonfibrotic hypersensitivity pneumonitis



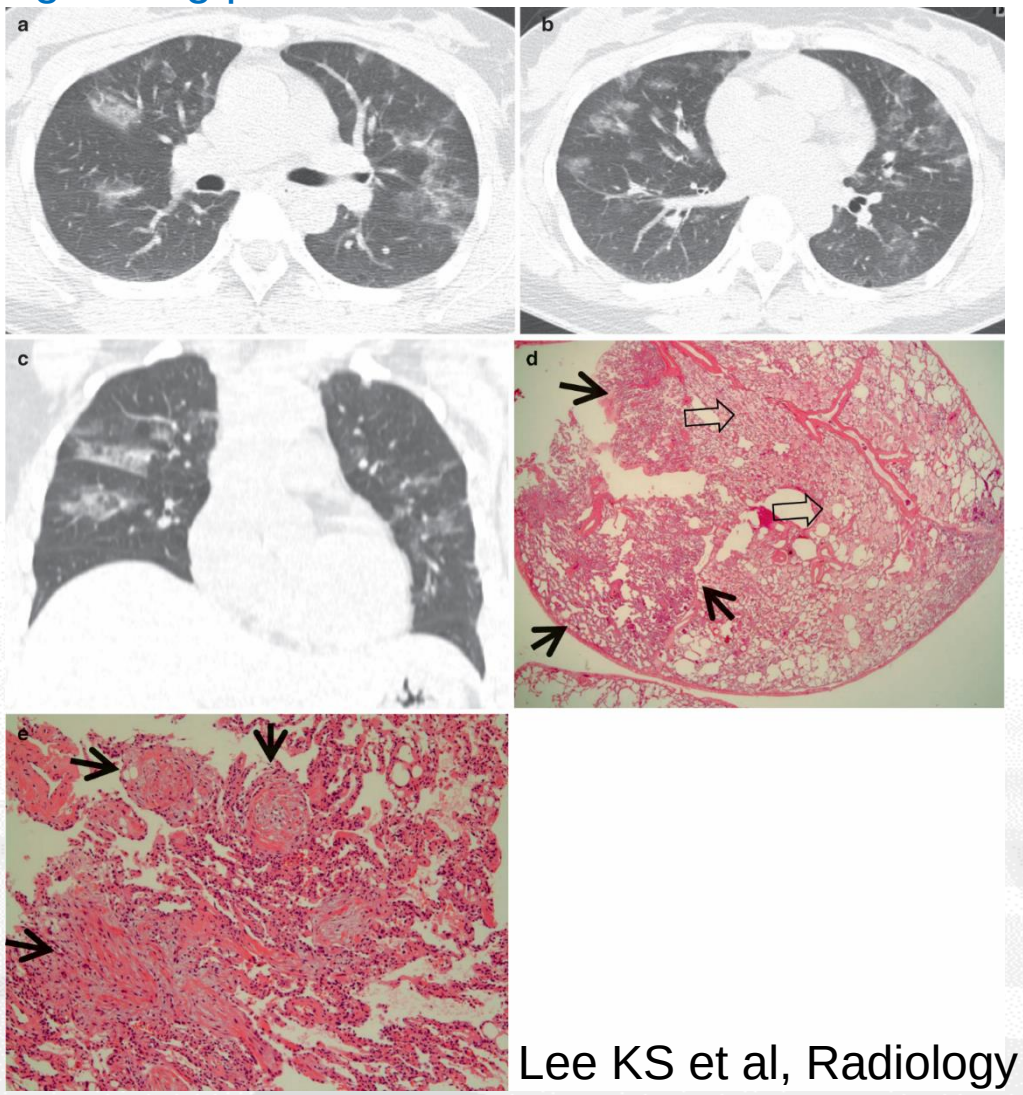
Three-density sign: Arrows = GGO, Open arrows = normal lungs, Arrowheads = mosaic attenuation



c: Arrows = bronchiolocentric granulomas, Arrowheads = chronic inflammatory cells in peribronchiolar interstitium (alveolar walls)
d: Arrows = loosely formed peribronchiolar granuloma (Arrows) composed of epitheliod histiocytes and giant cells and surrounding lymphocyte cuff (Arrowheads)

Consolidation

44F, Cryptogenic organizing pneumonia



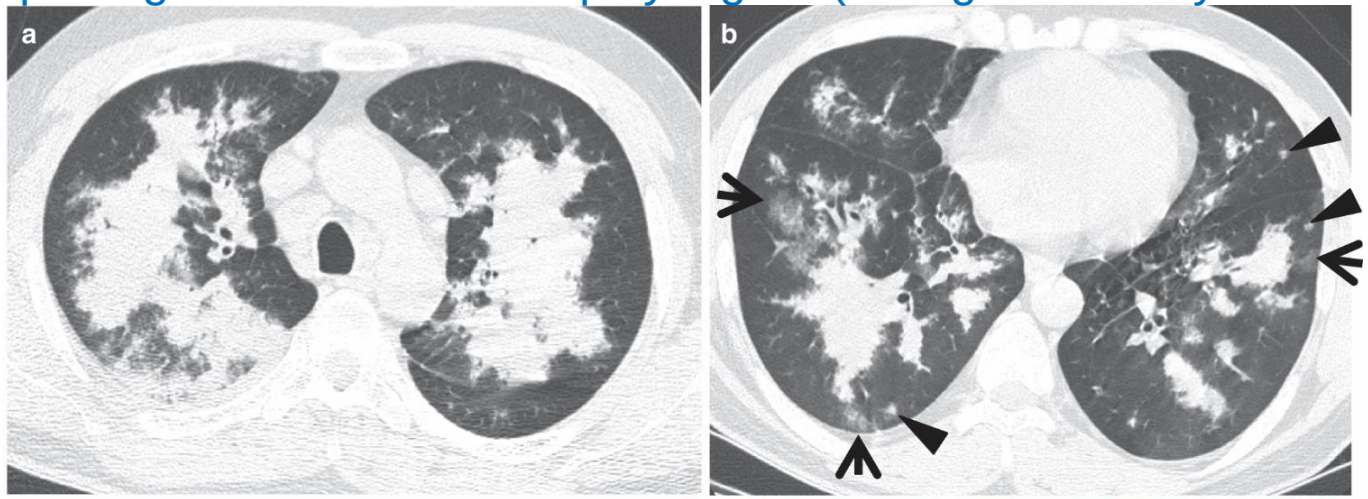
Patchy consolidation, GGO or GGO nodules showing typically bronchovascular bundle or subpleural distribution

d: alveolar filling process with inflammation (Arrows) and fibrinous exudates (Open arrows)
e: granulation plugs (Arrows) filling alveolar spaces and alveolar ducts

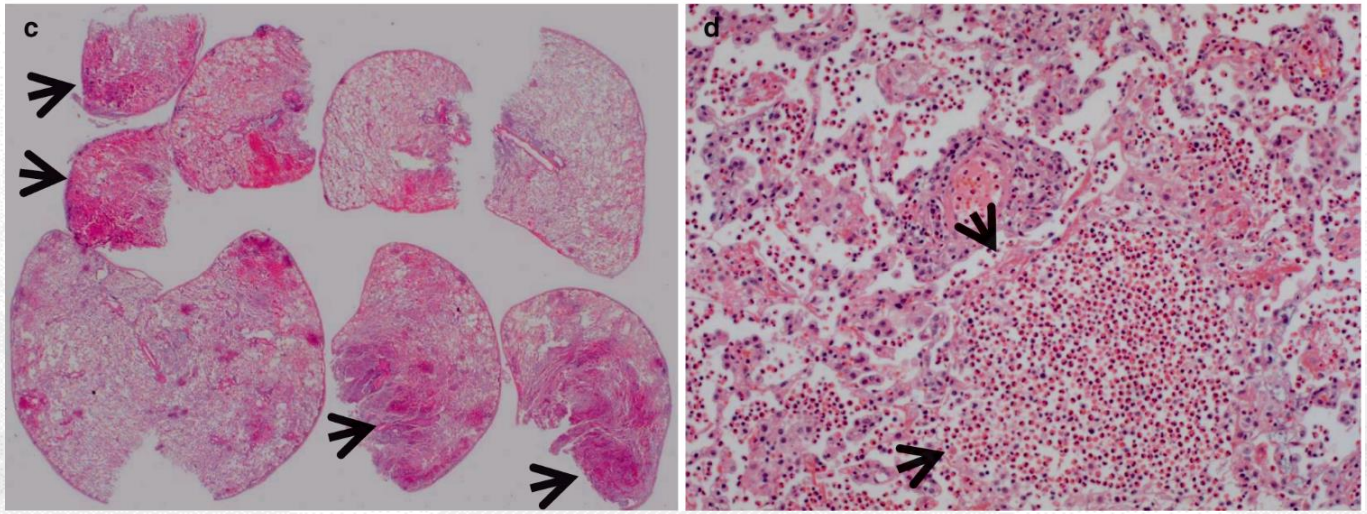
Lee KS et al, Radiology Illustrated: Chest Radiology 2nd ed. Springer 2023

Consolidation

39M, Eosinophilic granulomatosis with polyangiitis (Churg-Strauss syndrome) with asthma



Patchy and extensive consolidation in both lungs with some areas of GGO (Arrows) and poorly-defined nodules (Arrowheads)



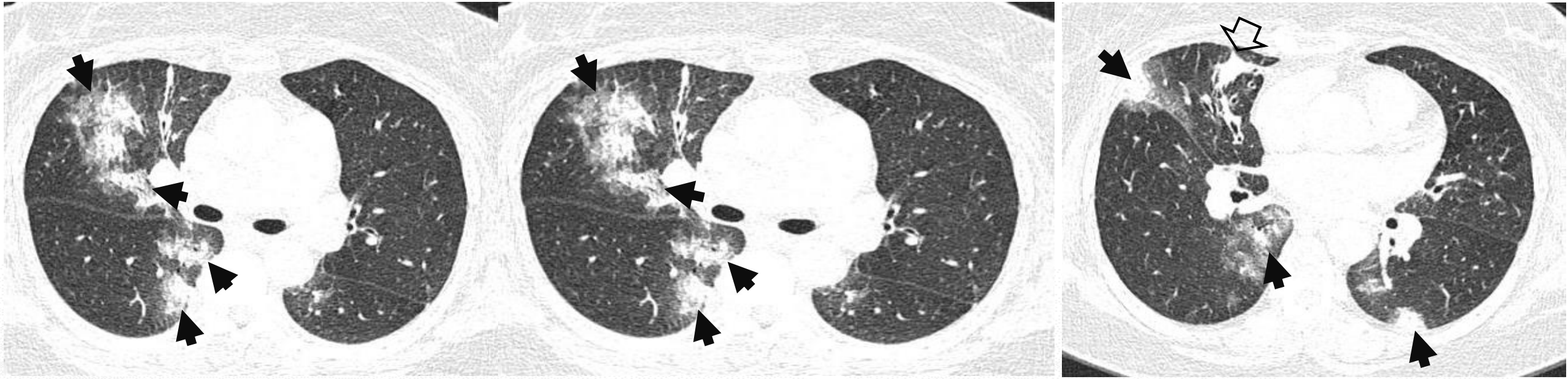
c: alveolar filling process with eosinophils
d: alveolar spaces filled with eosinophils (eosinophilic pneumonia)

Of note; in other areas, small extravascular granulomas and few areas of capillaritis were seen (not shown here)

Lee KS et al, Radiology Illustrated: Chest Radiology 2nd ed. Springer 2023

Consolidation

51F with lung ADC in right middle lobe, Radiation pneumonitis with OP pattern

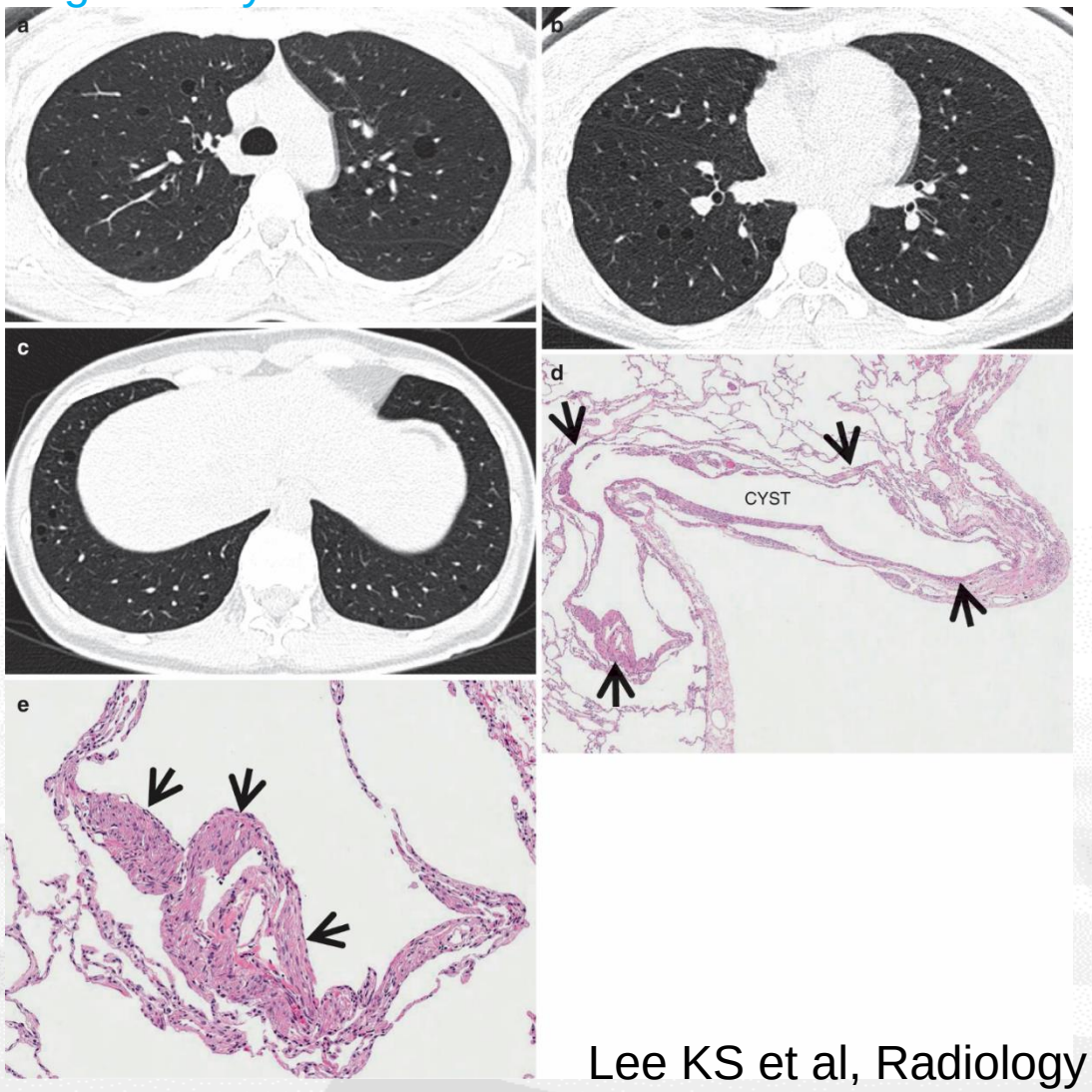


Patchy consolidation (Arrows in **a**, **b** and **c**) showing bronchovascular or subpleural distribution mainly in right lung; also note OP in left lower lobe. Remaining primary cancer in right middle lobe (Open arrow)

Lee KS et al, Radiology Illustrated: Chest Radiology 2nd ed. Springer 2023

Cystic Lung Lesions

37F with lymphangioleiomyomatosis



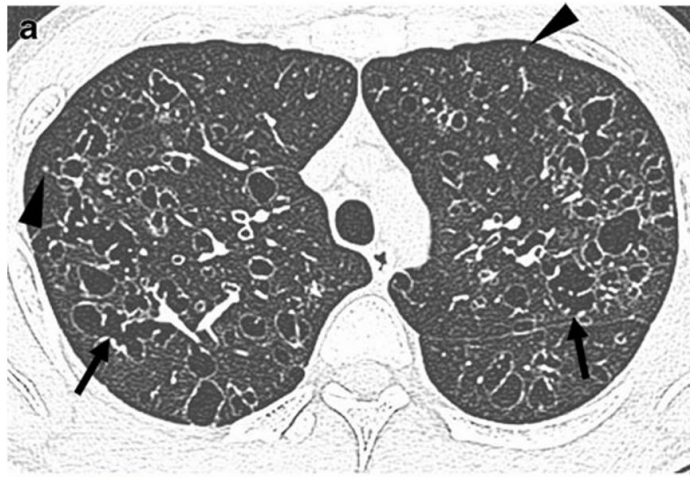
Multiple variable-sized air-filled cysts in both lungs; please note involvement of lung bases differently from PLCH

d: cystic lesion (CYST) and its wall composed of spindle or ovoid smooth muscle cells (Arrows); **e**: discloses clearly that cystic wall composed of spindle or ovoid smooth muscle cells (Arrows).

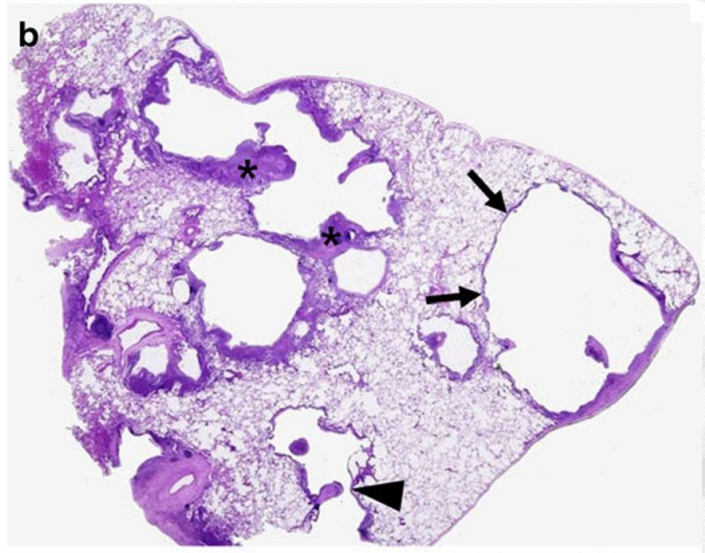
Lee KS et al, Radiology Illustrated: Chest Radiology 2nd ed. Springer 2023

Cystic Lung Lesions

23M with pulmonary Langerhans cell histiocytosis (indeterminate phase)



a & c: bizarre cysts (Arrows) in **a** have changed into larger confluent cysts (**b**) and several discrete small nodules (Arrowheads) have disappeared on 23-month FU CT with corticosteroid therapy

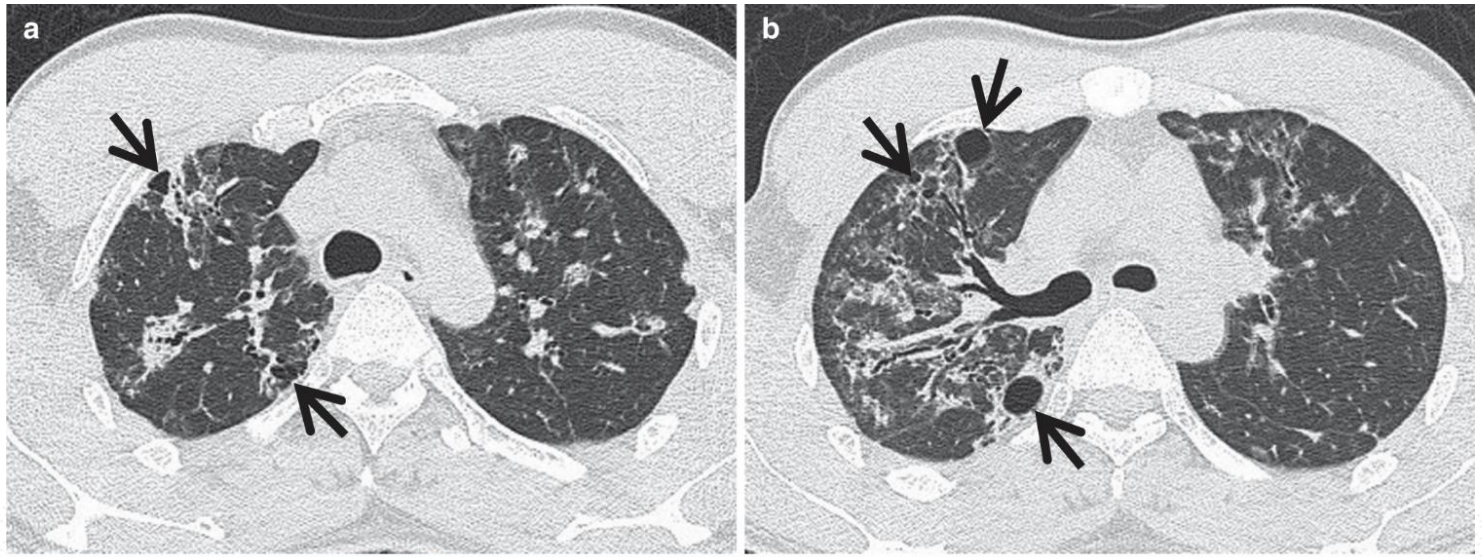


b: Relatively thick-walled cystic lesions of variable shapes. Wall of cystic lesions is composed of numerous Langerhans and other inflammatory cells (Asterisks).Some walls show thin fibrotic changes (Arrows). Focal destruction of cystic walls might have caused coalescence with adjacent cystic spaces (Arrowheads).

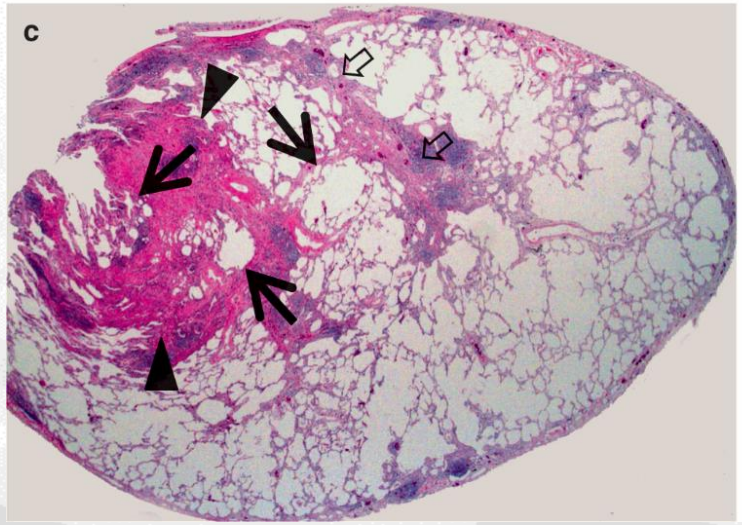
Kim HJ et al *Eur Radiol* 2011; 21:1406–1415

Cystic Lung Lesions

37M with lymphoid interstitial pneumonia and Sjogren's syndrome



GGO nodules or GGO along bronchovascular bundles or subpleural lungs; also note cystic lung lesions (Arrows)

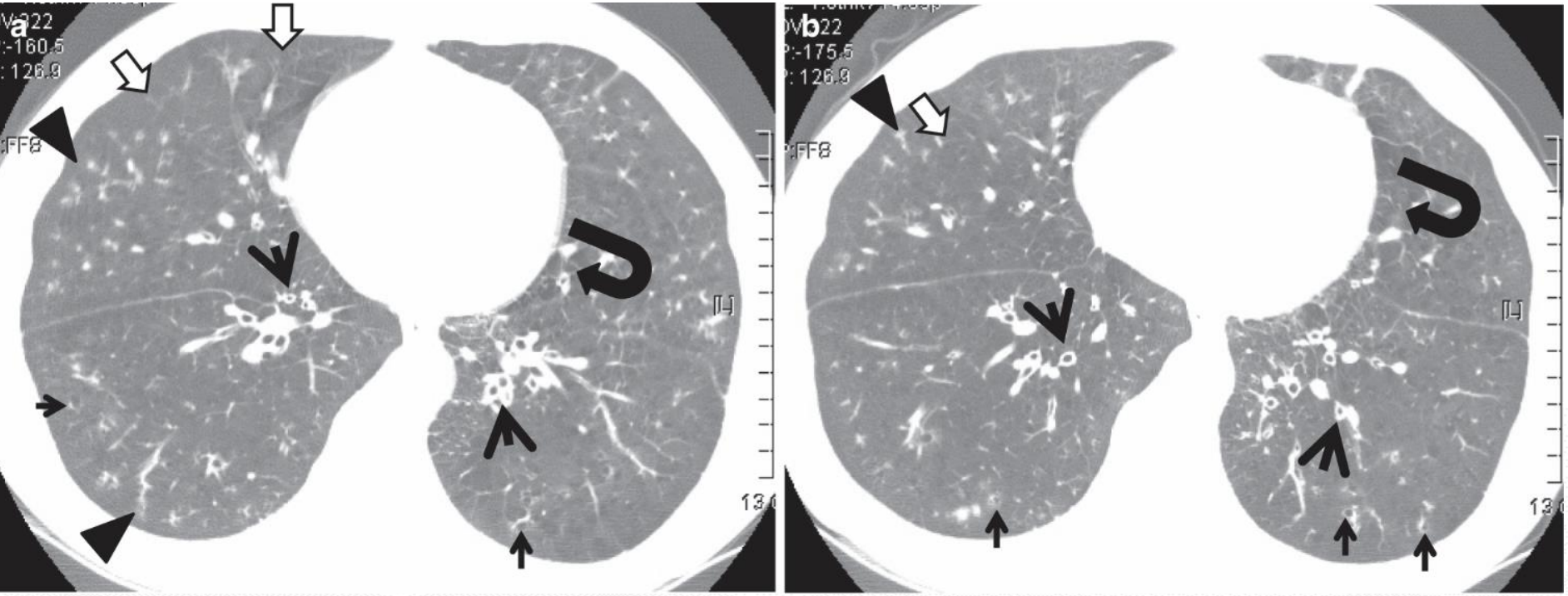


c: peribronchiolar dense fibrosis and scanty lymphocyte aggregations (Arrowheads); similar changes are also seen in interlobular septa (Open arrows) and subpleural regions; cystic changes (Arrows) of alveoli are associated with bronchiolar fibrosis and inflammation.

Lee KS et al, Radiology Illustrated: Chest Radiology 2nd ed. Springer 2023

Mosaic Attenuation

45M with status asthmaticus



Open arrows = mosaic attenuation, Curved arrows = emphysema, Arrowheads = tree-in-bud signs, Arrows = bronchial wall thickening, Small arrows = bronchial dilatation

Lee KS et al, Radiology Illustrated: Chest Radiology 2nd ed. Springer 2023

05

Conclusion

Conclusion

1. Correct MeSH (Medical Subject Heading) words promptly bring you several diseases for correct diagnosis; likewise when we encounter similar patterns or distribution of lung abnormality at CT, we can enumerate many diseases as potential differential diagnoses.
   Radiology Illustrated: Chest Radiology **Preface** of Edition One, 2013
1. Significant advancement in understanding and expansion of concepts regarding drug-related pneumonitis (DRP), connective tissue disease-associated interstitial lung disease (CTD-ILD), and COVID-19 and long COVID has been made; in these diseases you can also apply pattern approach for differential diagnosis and prognostication.
2. Pattern approach to lung abnormalities serves as the foundation for image-based training in computer science (artificial intelligence [AI] and deep learning [DL]).
   Radiology Illustrated: Chest Radiology **Preface** of Edition Two, 2023

SAMSUNG MEDICAL CENTER

Thank You

For your attention