

Diagnostic Imaging in Sepsis of Pulmonary Origin

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Definition

- **Sepsis:** life-threatening organ dysfunction due to a dysregulated host response to infection.
 - ★ *Organ dysfunction is a clinical concept*
 - ★ *Is based on an increase of two or more points in the SOFA score.*
- **Septic shock:** subset of sepsis in which particularly profound circulatory, cellular, and metabolic abnormalities are associated with a greater risk of mortality than with sepsis alone.

- Singer M, Deutschman CS, Seymour CW, et al. The third international consensus definitions for sepsis and septic shock (sepsis-3). JAMA. 2016;315(8):801–10.

Introduction

- Lung infections (community- or hospital-acquired) represent the most common cause for sepsis,
 - ★ *In a variable percentage, is associated to acute lung injury and acute respiratory distress syndrome (ARDS).*
- Diagnostic imaging plays a crucial role in the initial evaluation of patients with criteria for sepsis and suspected pulmonary infection.

Introduction

- The diagnosis of pneumonia is based on the presence of :

1. Clinical manifestations of an infection (fever, chills, leukocytosis),
2. Signs, or symptoms located in the respiratory system (cough, increased sputum production, shortness of breath, chest pain, or abnormal lung exam),
3. New or changing opacities in the chest X-rays.

- ✓ *In young patients without cardiopulmonary disease, the diagnosis of pneumonia is relatively simple with the features mentioned above.*
- ✓ *However, in elderly patients or in those with underlying diseases (CHF, COPD, neoplasm, pulmonary fibrosis), the clinical picture may be variable, and pneumonia diagnosis could be complex.*

Introduction

- Specific groups of patients with pulmonary-associated sepsis, with different infectious etiology exist, and radiographic manifestations can have characteristic features:
 1. *immunocompromised (HIV-infected and non-HIV-infected),*
 2. *pneumonia associated to health care,*
 3. *pneumonia associated to mechanical ventilation.*

Chest X-ray

- In patients with clinical signs and symptoms of respiratory infection, the chest X-ray allows:

1. confirming the diagnosis of pneumonia,
2. useful to assess response to treatment (in some patients),
3. define a pattern suggesting specific germs (particularly TB),
4. identify complications (empyema and ARDS),
5. propose a differential diagnosis.

HRCT

- HRCT is used in patients with:

1. torpid clinical evolution,
2. comorbidities,
3. suspected complications such as empyema, ARDS, & lung abscess.

★ Recent studies suggest that HRCT can play a major role in patients with suspected pneumonia.

- Nie Y, Li C, Zhang J, et al. Clinical application of high resolution computed tomographic imaging features of community-acquired pneumonia. Med Sci Monit. 2016;22:1053–61.
- Karhu JM, Ala-Kokko TI, Ahvenjärvi LK, et al. Early chest computed tomography in adult acute severe community acquired pneumonia patients treated

Three classic radiographic patterns in pneumonia

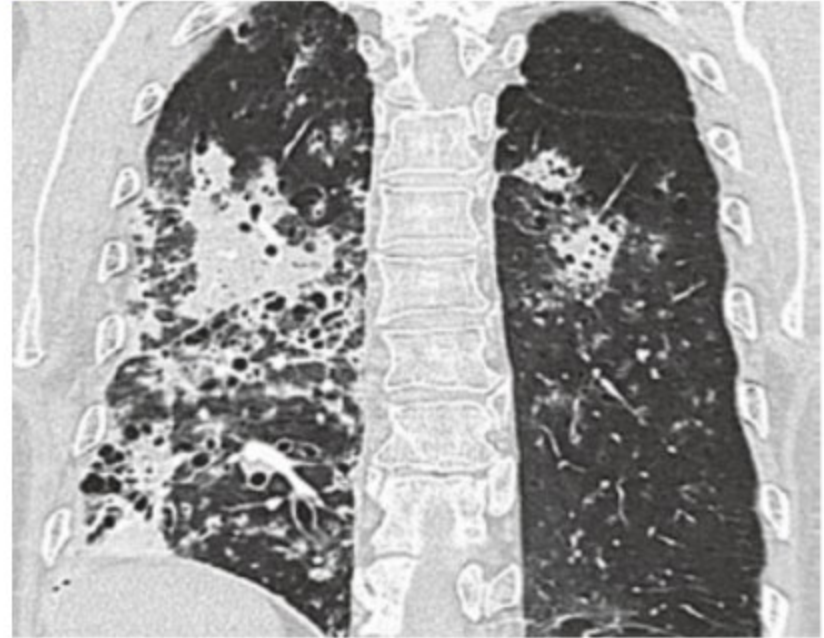
Three classic radiographic patterns in pneumonia:

(a) Focal or lobar pneumonia: *Resulting from a rapid production of fluid edema with scarce cellular reaction.*



Three classic radiographic patterns in pneumonia:

(b) Bronchopneumonia pattern: *Related to inflammation located in the airways and patchy alteration of adjacent lung parenchyma. With disease progression, parenchymal alterations may coalesce and form a lobar pattern.*

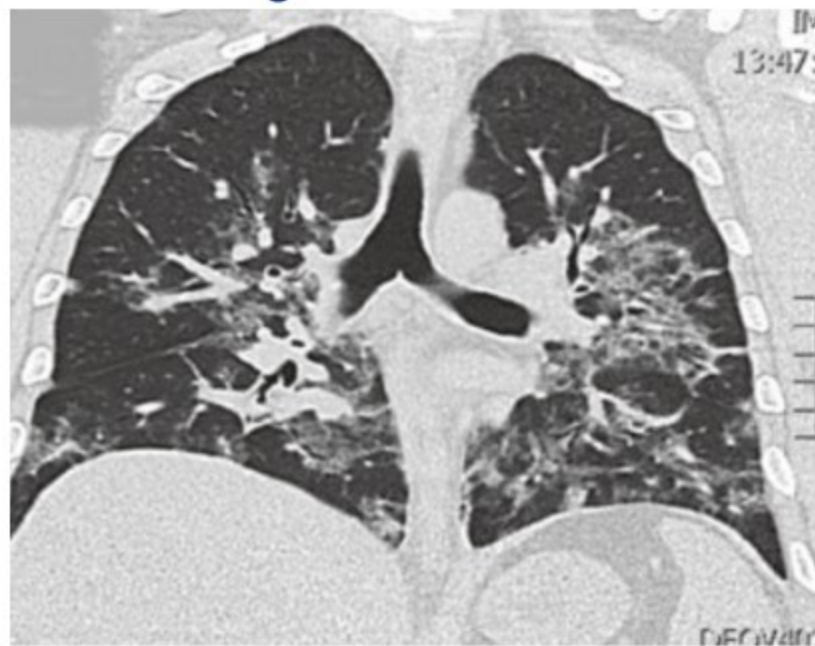


Bronchopneumonia *Mycoplasma pneumoniae*



Three classic radiographic patterns in pneumonia:

(c) Interstitial pattern: *Associated to an inflammatory cellular infiltrate and edema predominantly in the lung interstitium.*



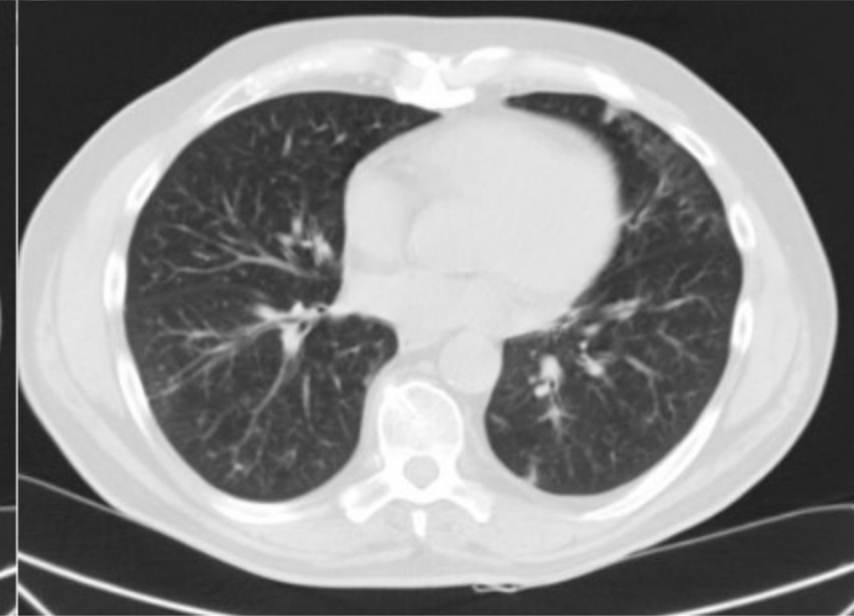
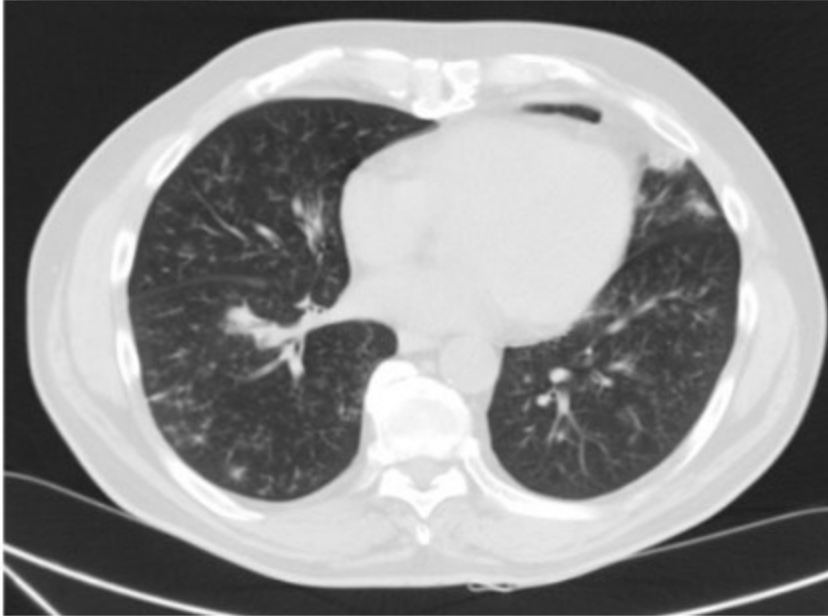
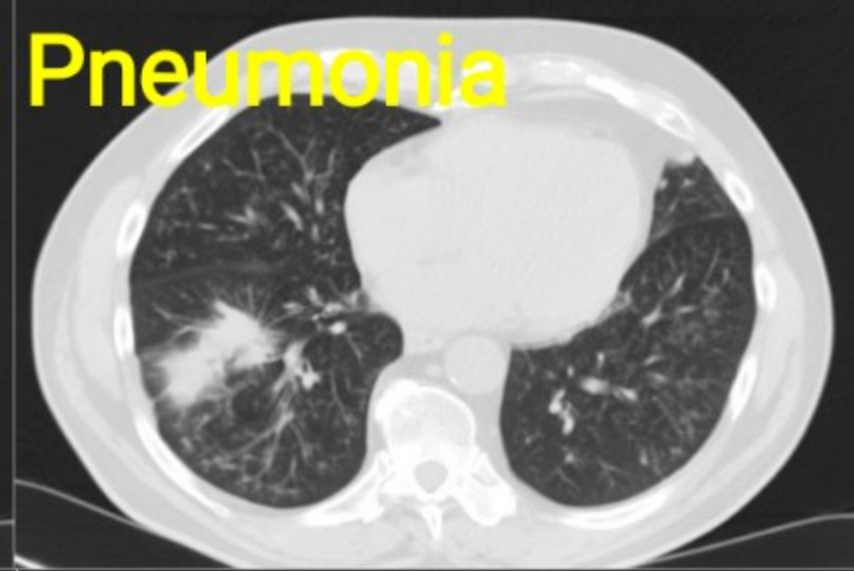
Particular alterations or patterns

suggesting specific germs on certain clinical contexts

Ground-glass pattern: Increased attenuation of lung parenchyma that allows visualization of lung vessels and bronchial walls.
*In immunocompromised patients, can suggest *P. jiroveci* or CMV pneumonia.
*Pneumonia due to *M. pneumoniae* can also be accompanied by predominant GGO.



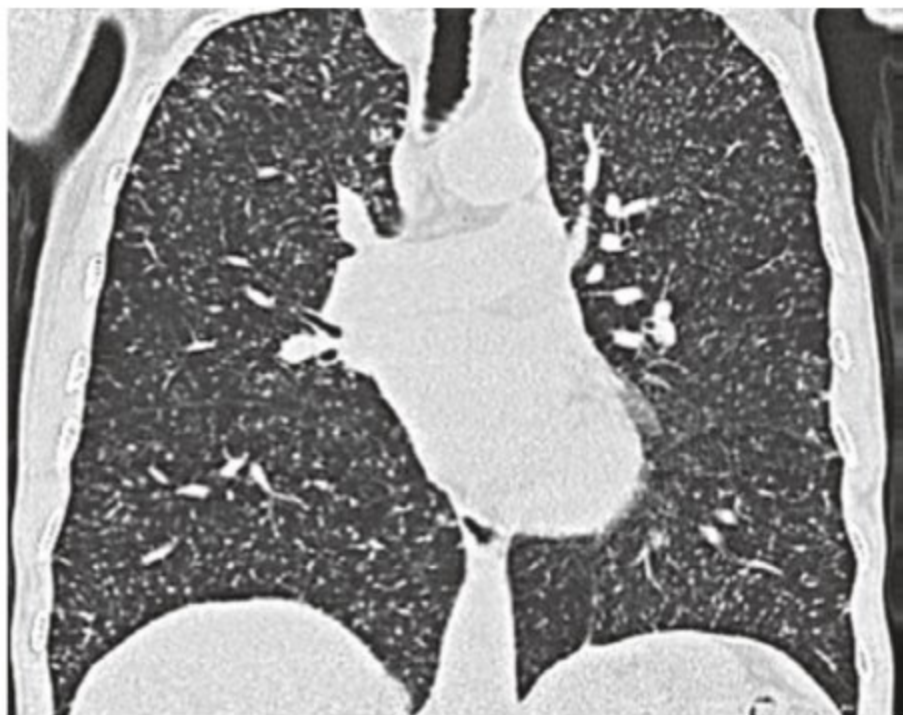
Aspiration Pneumonia



Nodules

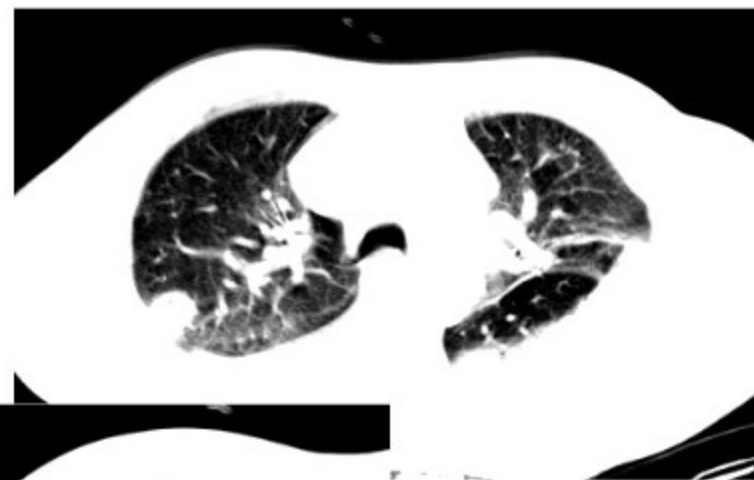
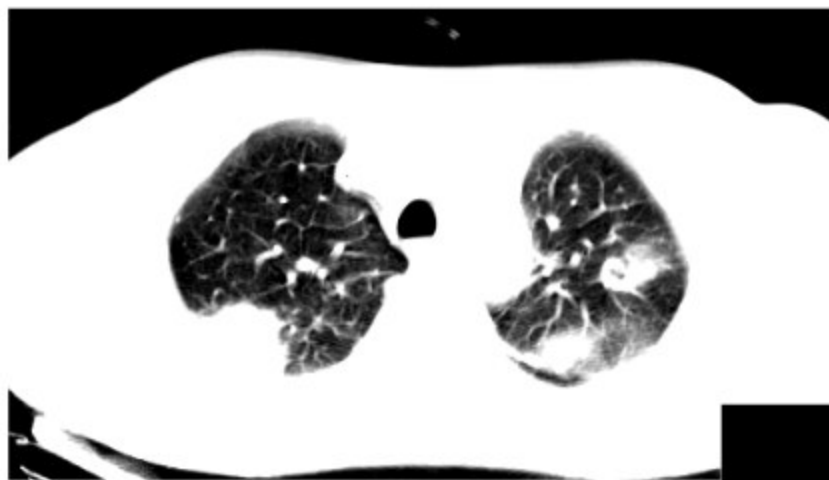
- The presence of small, randomly distributed nodules (<10 mm in diameter) or micronodules (<3 mm):
 - ★ *suggest hematogenous dissemination of TB or mycosis (histoplasmosis).*
- Nodules >10 mm in diameter: are not a frequent finding in patients with CAP, and their presence may suggest:
 - ★ *specific germs such as N. asteroides, mycosis (histoplasmosis), TB,*
 - ★ *or an alternative diagnosis (metastatic disease).*

Nodules

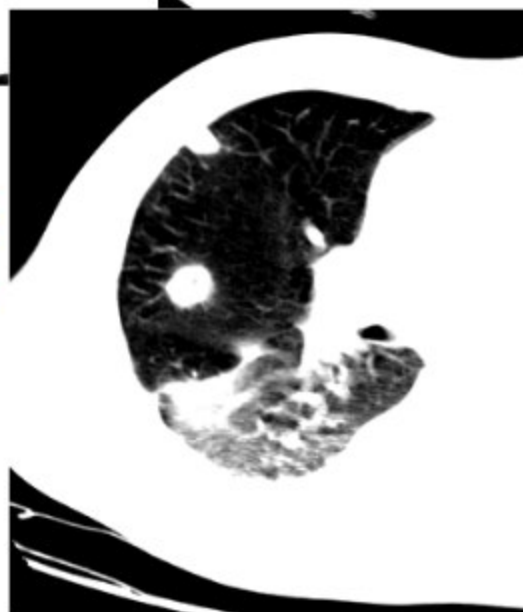


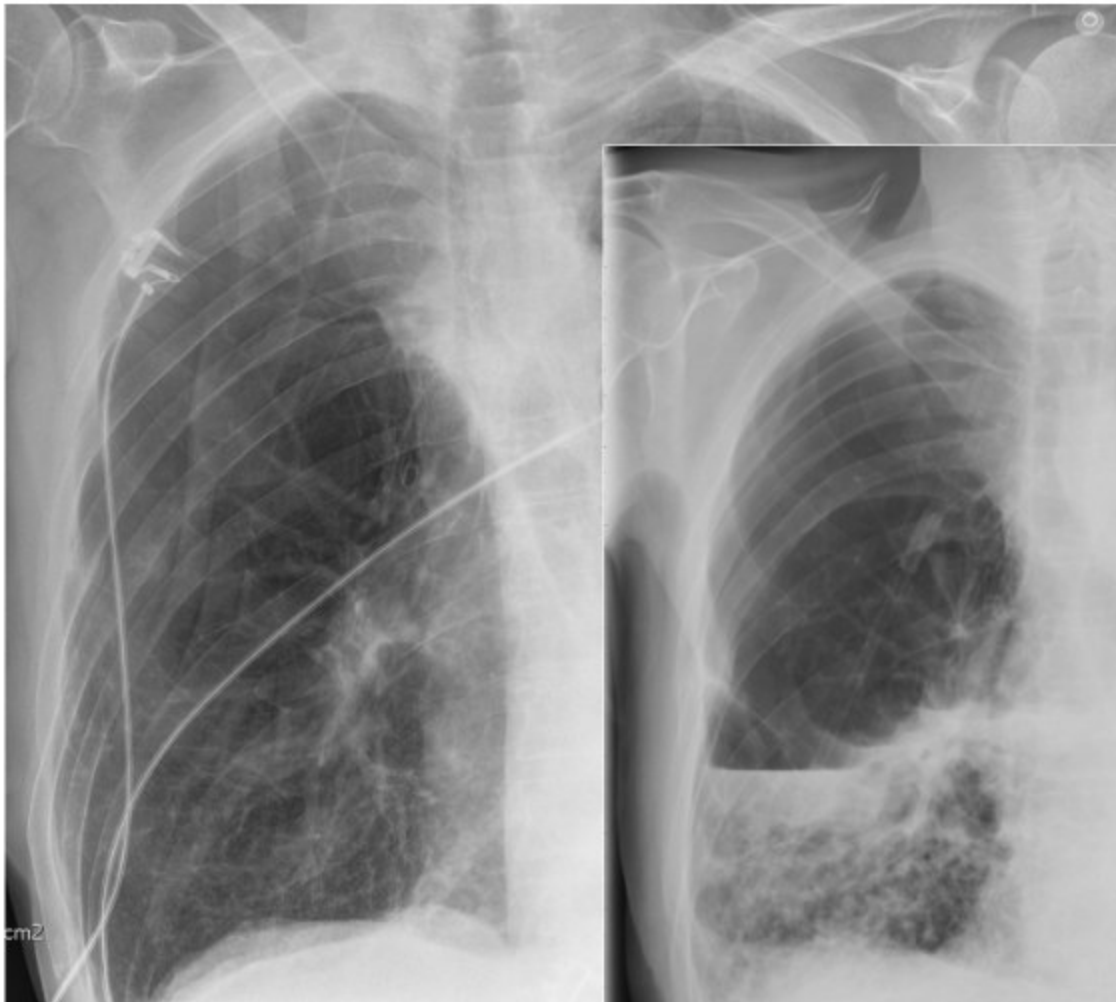
Tree-in-bud: The presence of centrilobular linear branching densities.
It may suggest TB in cases with associated apical cavitation (in immunocompromised patients)

Halo sign: The presence of a ground-glass halo around a nodule, mass, or consolidation.
In neutropenic immunocompromised patient, can be associated to invasive mycosis (aspergillosis, mucormycosis).

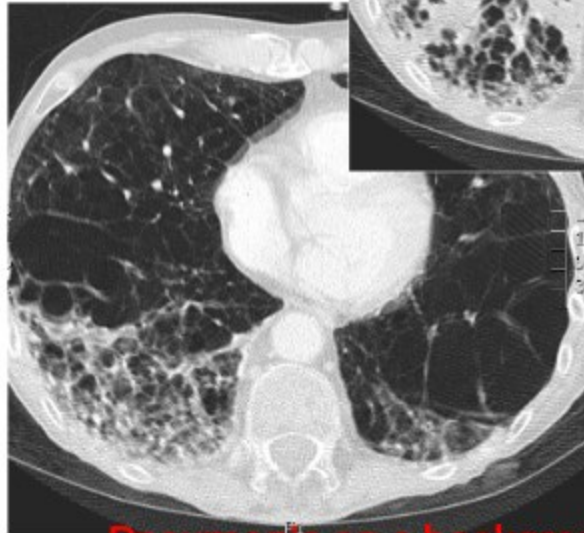
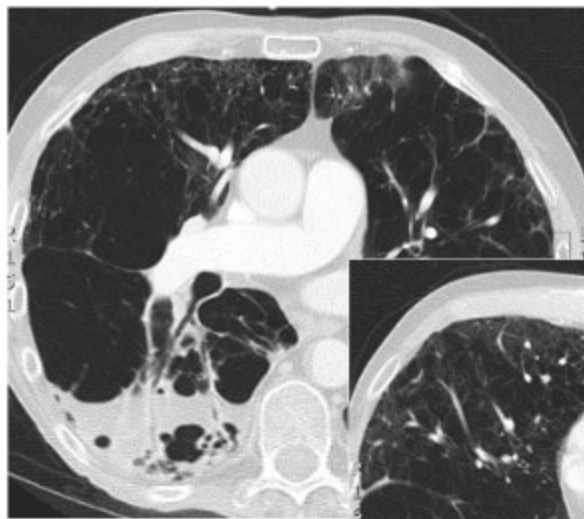
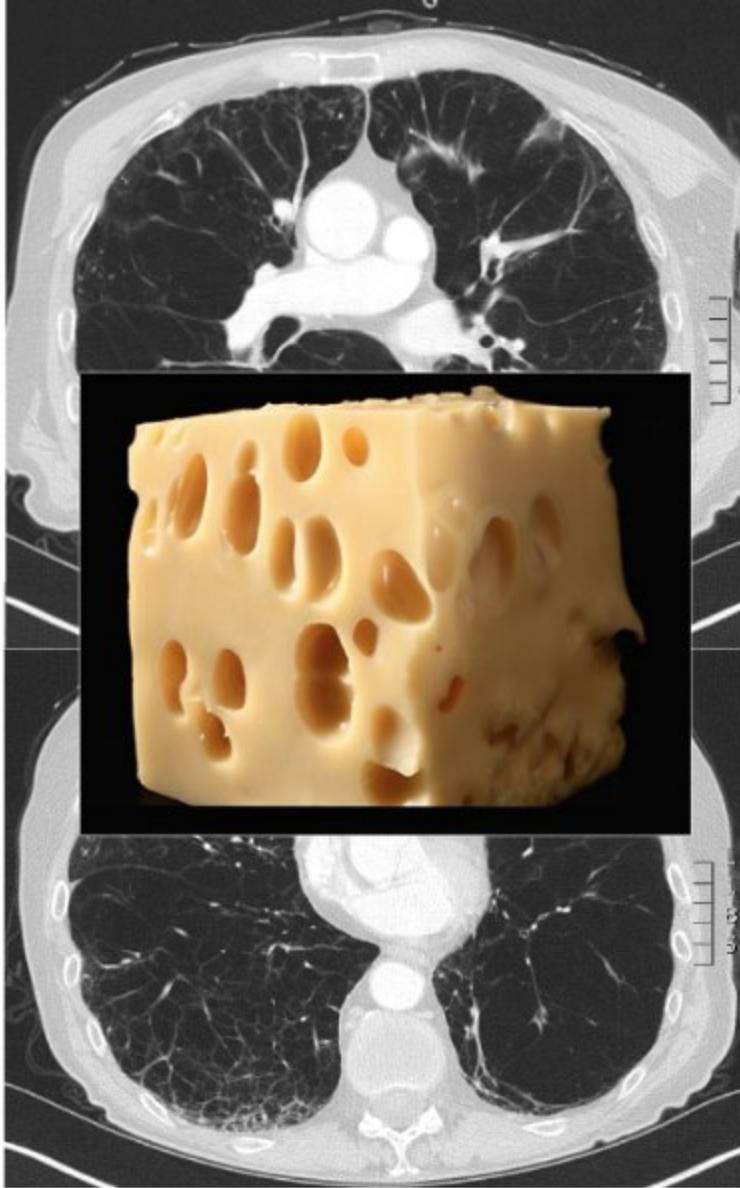


Septic Emboli





**Pneumonia on a background
of pulmonary emphysema**



Pneumonia on a background of pulmonary

Special Infectious Etiology

Virus

- The most frequent cause of respiratory infections in children and adults.
 - ★ *In immunocompetent patients, mostly self-limited.*
 - ★ *In a group of immunocompetent patients & in immunocompromised patients, could present with severe tracheobronchitis, bronchiolitis, or pneumonia.*
- The direct cytopathic effect of the virus causing damage to the respiratory epithelium can be associated to:
 1. *necrotizing bronchitis/bronchiolitis,*
 2. *diffuse alveolar damage,*
 3. *and/or alveolar hemorrhage.*

The manifestations of viral pneumonia on imaging

depend on:

1-the degree of airway and/or lung parenchymal alteration

2- the association of permeability pulmonary edema or alveolar hemorrhage.

● Chest X-ray findings:

- normal X-ray,
- bronchial wall thickening,
- ill-defined nodules,
- “patches” of peribronchovascular consolidation.

● HRCT may show:

- GGO,
- consolidation,
- thickening of peribronchovascular interstitium,
- thickening of interlobular septum,
- nodules,
- tree-in-bud pattern,
- areas of focal air entrapment with mosaic attenuation pattern.

- Franquet T. Imaging of pulmonary viral pneumonia. Radiology. 2011;260(1):18–39.

Influenza virus

- Type A: the most important respiratory virus in the general population.
 - Between 10%-20% of the world population is infected each year.
 - The mortality associated to the seasonal influenza type A virus occurs mainly in patients over 65 years.
 - In the recent influenza A virus (H1N1) pandemic originated in Mexico, severe cases of pneumonia occurred in younger patients, pregnant women and obese patients.
 - The most frequent HRCT findings:
 1. *centrilobular nodules (69.6%),*
 2. *tree-in-bud (50%),*
 3. *and bronchial wall thickening (30.3%).*
 - No differences in HRCT alterations between the different types & subtypes of influenza virus.
 - In the immunocompromised patients, lung parenchymal alterations prevailed,
 - In the immunocompetent patients, the most frequent alterations were found in the airways.
-
- Kloth C, Forler S, Gatidis S, et al. Comparison of chest-CT findings of

Influenza virus

Covid 19

Covid 19

Respiratory infections due to adenovirus

- Can present with severe pneumonia in immunocompetent patients.
 - ★ *Sixty percent require mechanical ventilation.*
- Radiographic manifestations; similar to bacterial pneumonia with:
 - ★ *focal consolidation that progresses to bilateral consolidation,*
 - ★ *associated to ground-glass opacities and pleural effusion.*

Other Viruses

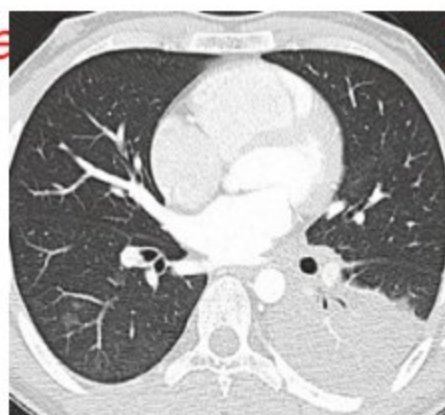
- In immunocompromised patients, cases of pneumonia due to HSV, VZV, CMV as well as RSV or ADV have been described.
- ★ In a series including 51 immunocompromised patients with clinical pneumonia and positive RSV tests, the most frequent findings:
 - ✓ *in the early stages of the disease: nodules and tree-in-bud pattern.*
 - ✓ *with disease progression: GGO(64%), consolidation (56%), & small nodules (55%).*
- The association of sinusitis, risk factors, and the radiographic manifestations described may suggest the diagnosis RSV pneumonia

S. pneumoniae

- The most frequent cause of bacterial CAP in most of the series.
- The clinical course is variable, with adequate response to antibiotics (in most patients) or with complications that include ARDS and death.
- The characteristic radiographic pattern is:

✓ *focal or lobar compromise,*

✓ *with consolidation predominantly affecting the lower lobes.*



S. aureus

In recent years, respiratory infections due to MRSA & MSSA are considered as an important cause of severe CAP.

- ✓ *In a multicenter study of 2259 adults hospitalized due to CAP, S. aureus was identified in 1.6% of the patients (0.7% MRSA and 1.0% MSSA).*
- ✓ *the incidence of MRSA was higher in patients undergoing chronic hemodialysis*

The most frequent radiographic pattern in these patients is of bronchopneumonia, with:

1. *bronchial wall thickening,*
2. *ill-defined nodules,*
3. *areas of peribronchovascular consolidation (multilobar and bilateral),*
4. *cavitation.*

M. pneumoniae

- An important cause of pneumonia in adolescents and young adults.
 - ★ Causes an interstitial inflammatory response by mononuclear cells,
 - ★ An extracellular pathogen, whose survival depends on the adherence to the bronchial epithelium. So, the frequent findings in M. pneumoniae pneumonia are:
 - ★ *bronchial wall thickening,*
 - ★ *and the presence of centrilobular nodules.*
- Appearing on the X-rays as perihilar and basal reticular opacities.
- Other HRCT findings include ground-glass opacities and consolidation.
 - ✓ *The study by Miyashita et al. comparing rapid diagnostic tests for M. pneumoniae concluded that the ImmunoCard Mycoplasma kit was not useful to diagnose this entity*



M. tuberculosis

- An important cause of morbimortality associated to respiratory disease.
- Generally has a subacute or chronic course, but may manifest with acute respiratory clinical features, and differentiating it from respiratory infections of another etiology (bacterial) may prove difficult in the clinic.
- The frequency of respiratory failure in patients with active TB ranges between 1.5 and 5%, with variable presentations (miliary TB-disseminated TB-ARDS).
 - ★ *In a series, 350 patients with CAP admitted to the ICU, 3.1% of the patients developed ARDS associated to TB. In more than half of the patients, the suspicion of TB was based on radiographic manifestations.*
 - ★ *The work by Yeh et al. to predict active pulmonary TB by means of the development of an HRCT score showed good performance with sensitivity (100%), specificity (96.9%), positive predictive value (76.5%), and negative predictive value (100%).*

Aspergillus

- Invasive Aspergillus infection is an important cause of pulmonary sepsis in immunocompromised patients.
 - ★ *It has been traditionally described in neutropenic patients.*
 - ★ *Invasive aspergillosis has also been found in non-neutropenic patients (with COPD, in solid organ transplant recipients and in ICU patients).*
- Radiographic manifestations of invasive aspergillosis are variable:
 - ✓ *In the angioinvasive form, radiographic manifestations include large nodules (with halo sign), consolidation, and cavitation.*
 - ✓ *In aspergillosis with airway invasion (usually associated to parenchymal disease), the findings described include tree-in-bud, centrilobular nodules and consolidation.*

P. jiroveci

PCJ pneumonia is described in immunocompromised patients due to HIV infection or in those immunocompromised without HIV infection (immunosuppression due to drug therapy, postTx, etc.).

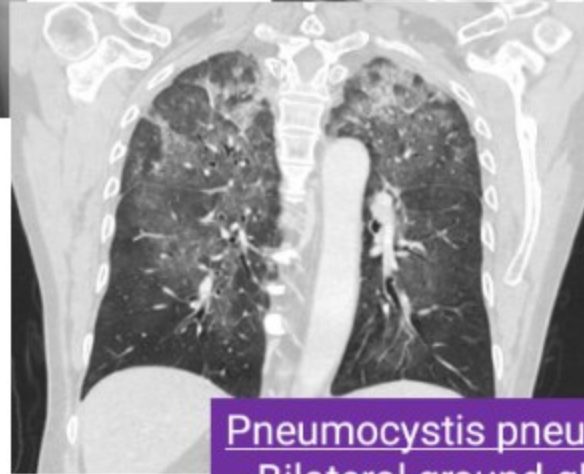
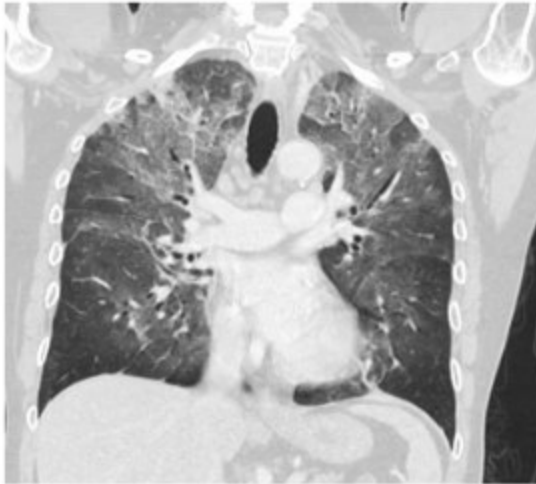
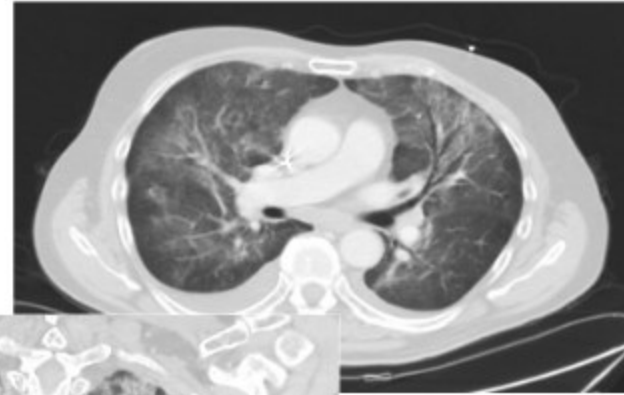
- *The clinical course is variable in the two groups (subacute in the first and acute in the second)*

P. jiroveci

In both groups, the main radiographic manifestation is the:

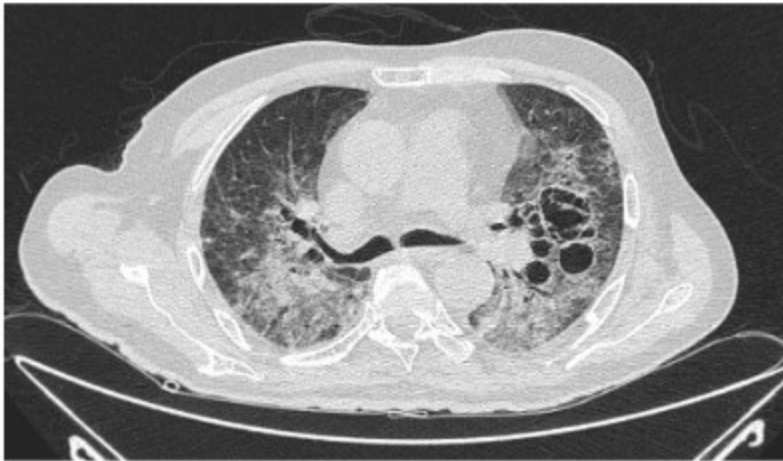
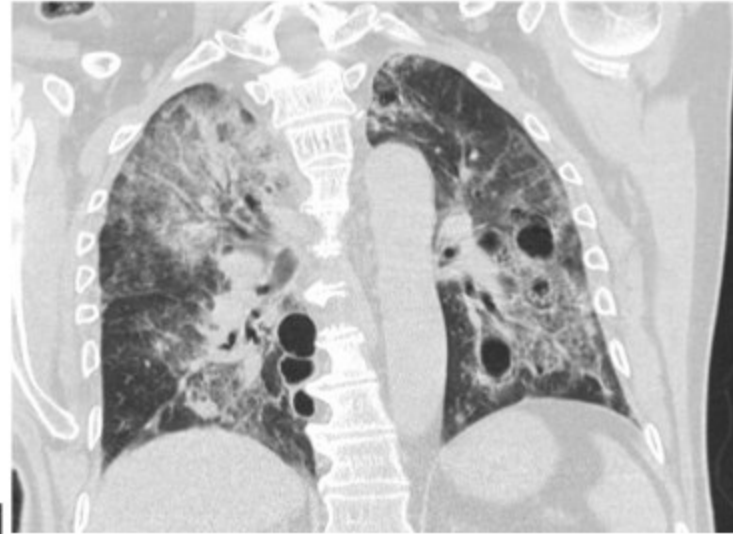
- ✓ *GGO with a geographic or diffuse pattern.*
- ✓ *Other less frequent manifestations include: consolidation, crazy-paving pattern, cysts, intralobular lines, and nodules.*

The most frequent complications associated to pneumonia, and that may be evaluated with imaging studies, correspond to secondary pleural infection, lung parenchymal necrosis (abscess), and ARDS.



Pneumocystis pneumonia

- Bilateral ground-glass opacities
- Patchy or diffuse
- Perihilar, upper or lower
- Sometimes crazy-paving pattern



Pneumocystis pneumonia

- Bilateral ground-glass opacities
- Patchy or diffuse
- Perihilar, upper or lower
- Sometimes crazy-paving pattern
- Cystic lesions 30 % of cases

Complications of Pulmonary Infections

Pleural Infection

The microbiology of pleural disease is different to that described in CAP.

✓ *In a multicenter study of intrapleural sepsis, the most common germs associated to pleural infection were Streptococcus intermedius (24%), Streptococcus pneumoniae (21%), and other Streptococci (7%), followed by anaerobic bacteria (20%) and staphylococci (10%).*

✓ *The most common pathogens in hospital-acquired infections were staphylococci (35%) and gram-negative bacteria (23%).*

Pleural Infection

Ultrasound studies allow characterization of the pleural liquid and defining the presence of particles or septa and associated pleural thickening.

CT allows defining the precise distribution of pleural collections, the presence of pleural thickening (with or without lung entrapment), and characterizing associated parenchymal alterations.

Pleural & Chest Wall TB

Lung Abscess

Defined as a circumscribed area of necrotic tissue or pus within the lung parenchyma that can cavitate and show an air-fluid level due to the occurrence of BPF.

1. *Primary (generally related to aspiration)*
2. *Secondary (due to bronchial obstruction).*

In imaging studies, appears:

- ✓ *as a mass with well-defined margins,*
- ✓ *cavitation (liquid or air densities within the lesion),*
- ✓ *walls of variable thickness (according to time of evolution).*

ARDS

- Diffuse lung edema characterized by increased permeability of capillary endothelial cells and alveolar epithelial cells leading to refractory hypoxemia and diffuse bilateral lung opacity in CXR.
- ARDS may be either:
 1. *primary or pulmonary (related to pneumonia /aspiration) ,*
 2. *secondary or extrapulmonary (trauma, nonpulmonary sepsis, pancreatitis, etc.).*

ARDS

Radiographic manifestations depend on the evolution of the ARDS and the degree of the lung's fibroproliferative response:

★ *Early phases: GGO and/or consolidation of variable distribution (patchy, AP attenuation gradient, or diffuse distribution).*

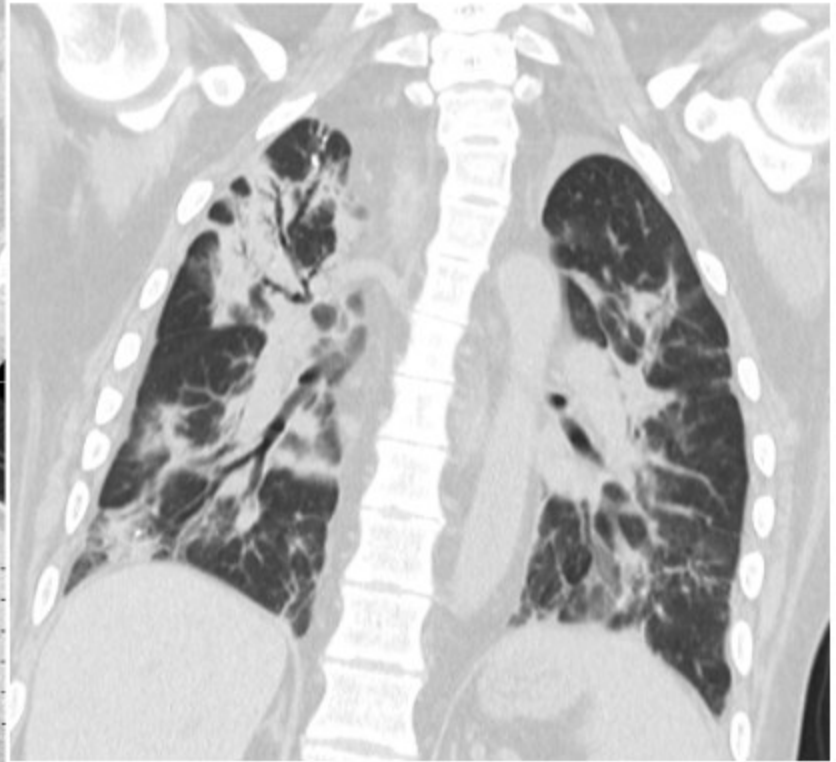
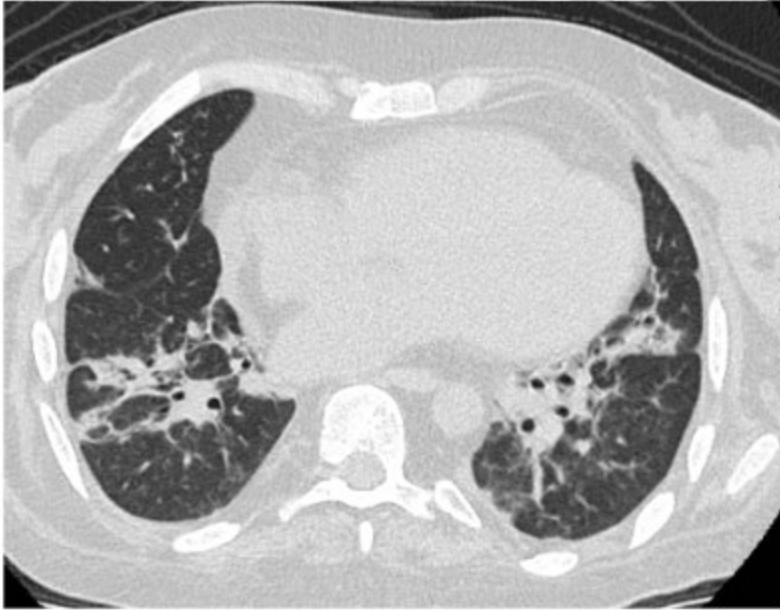
★ *With significant fibroproliferative changes, HRCT findings include: GGO, intralobular densities, distorted lung architecture, traction bronchiectasis, and honeycombing pattern.*

Differential Diagnosis

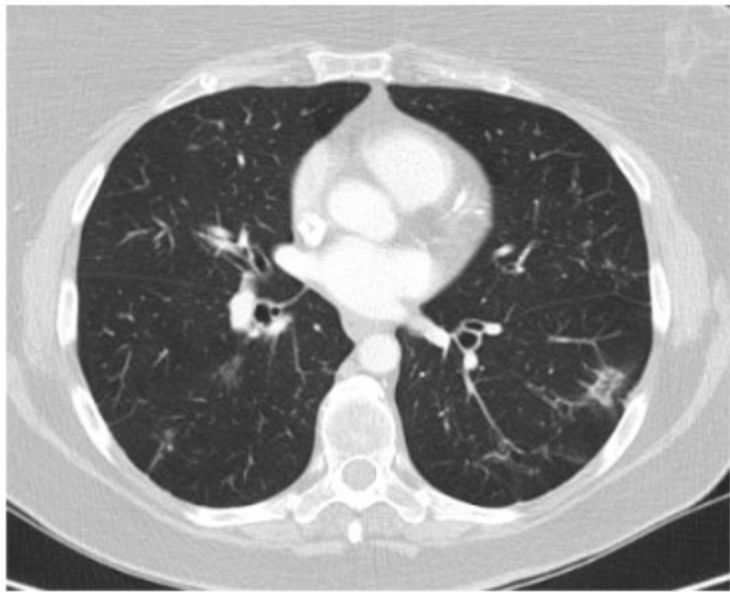
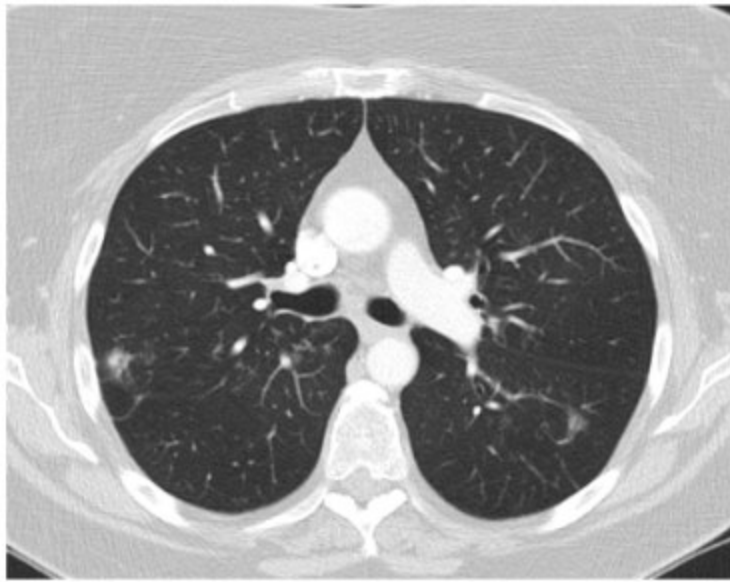
- The list of imaging DDX for patients with pulmonary infection is long and includes disorders coursing with GGOs, consolidation, or nodules (most frequent findings in infections):
 - *small vessel pulmonary vasculitis,*
 - *cryptogenic organizing pneumonia,*
 - *chronic eosinophilic pneumonia,*
 - *lipoid pneumonia,*
 - *lymphoma,*
 - *aspiration,*
 - *primary lung adenocarcinoma.*
- In cases of severe pulmonary infection with extensive parenchymal alterations or in those coursing with ARDS, among the differential diagnostic possibilities:
 - *Pulmonary edema (of different etiologies),*
 - *Acute interstitial pneumonia,*
 - *Acute eosinophilic pneumonia,*
 - *Diffuse alveolar hemorrhage.*
 - *Acute HP,*
 - *Acute eosinophilic pneumonia*
 - *Acute OP.*

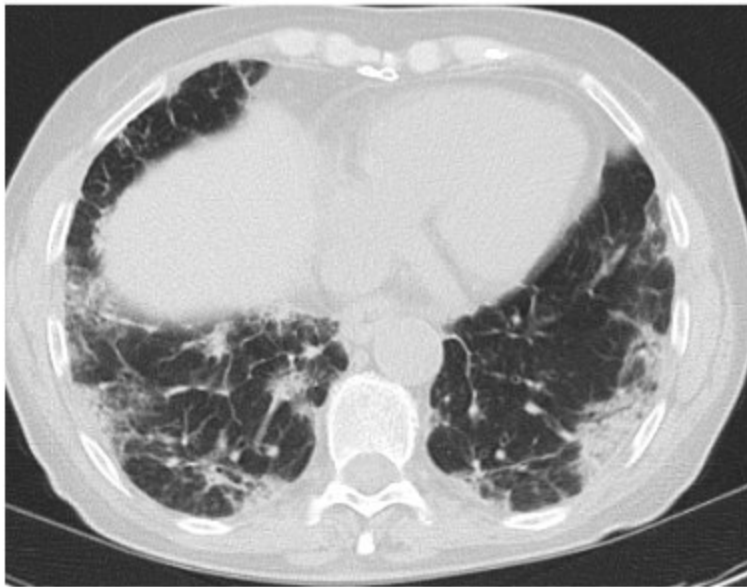
a 52-year-old woman with diffuse alveolar hemorrhage secondary to microscopic polyangiitis shows multilobar crazy-paving opacities and consolidation

OP



OP





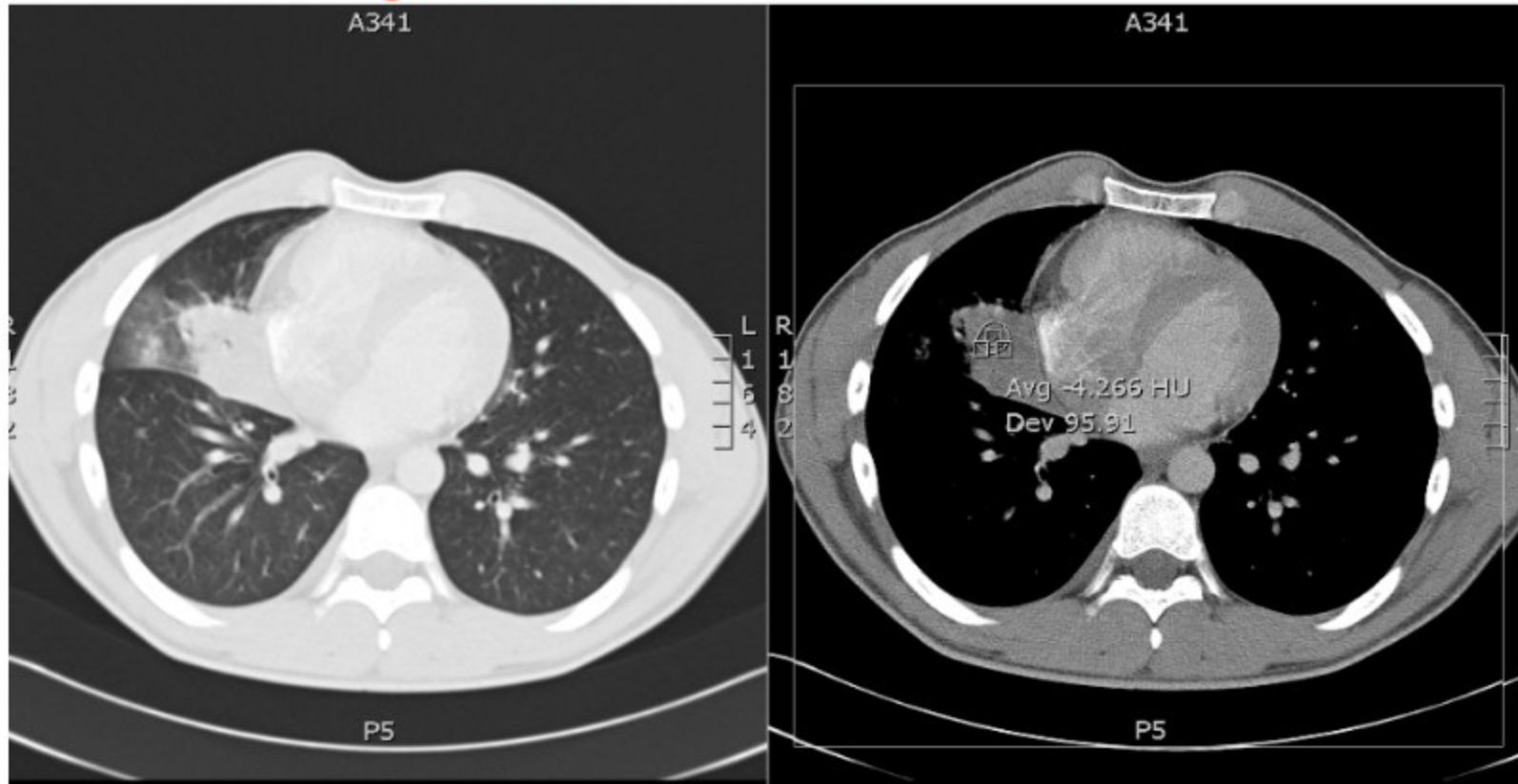
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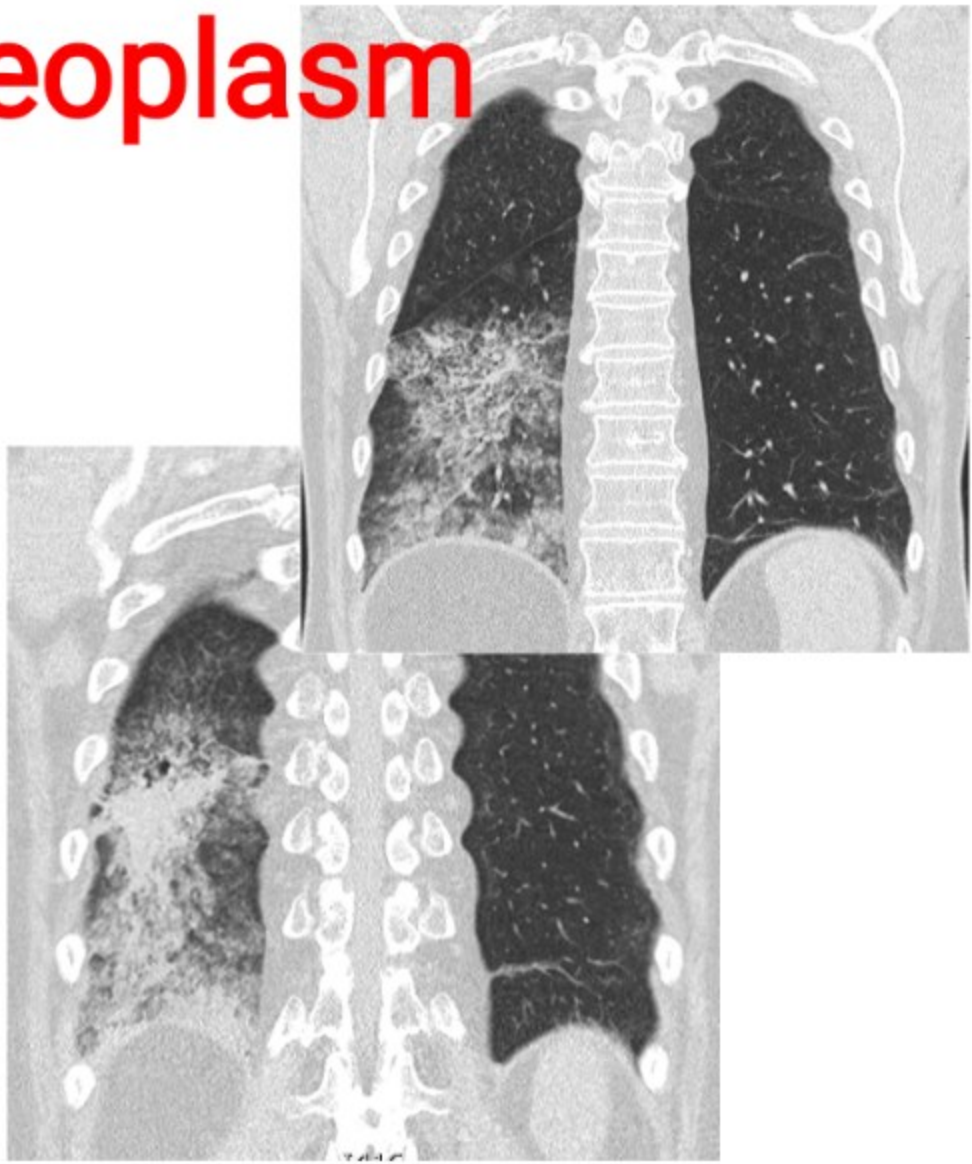
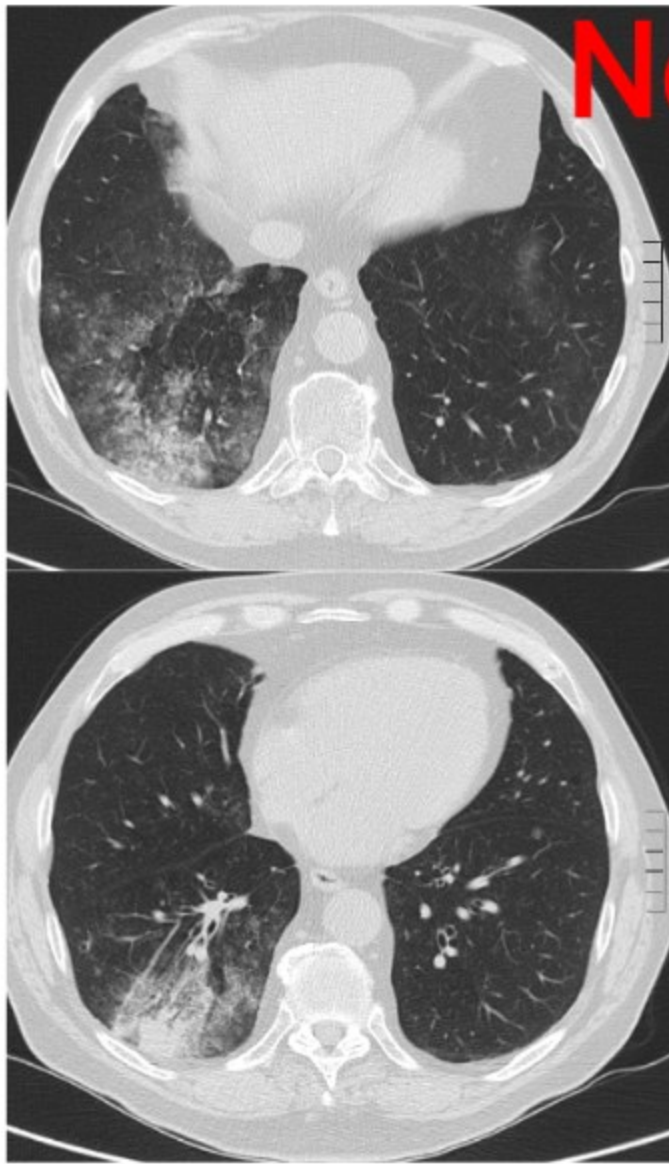
Lipoid Pneumonia



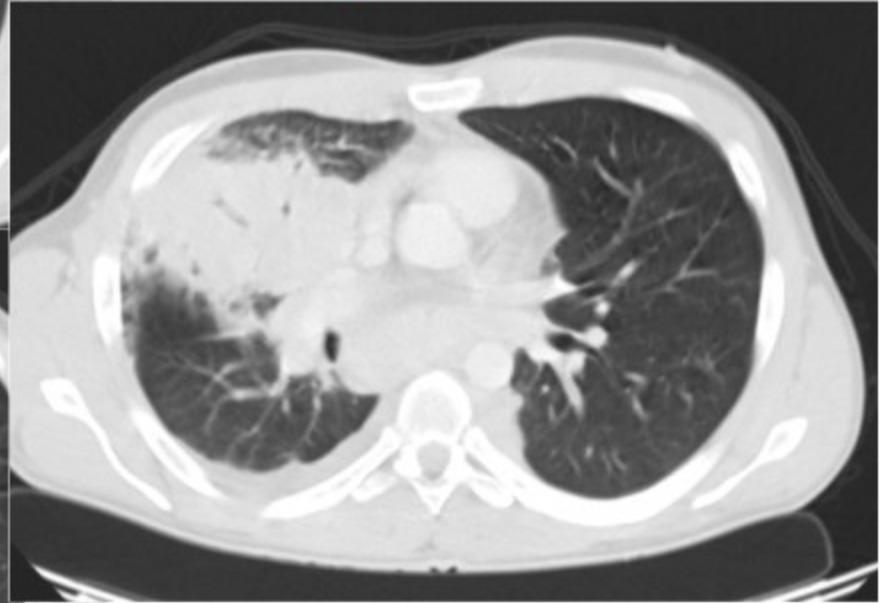
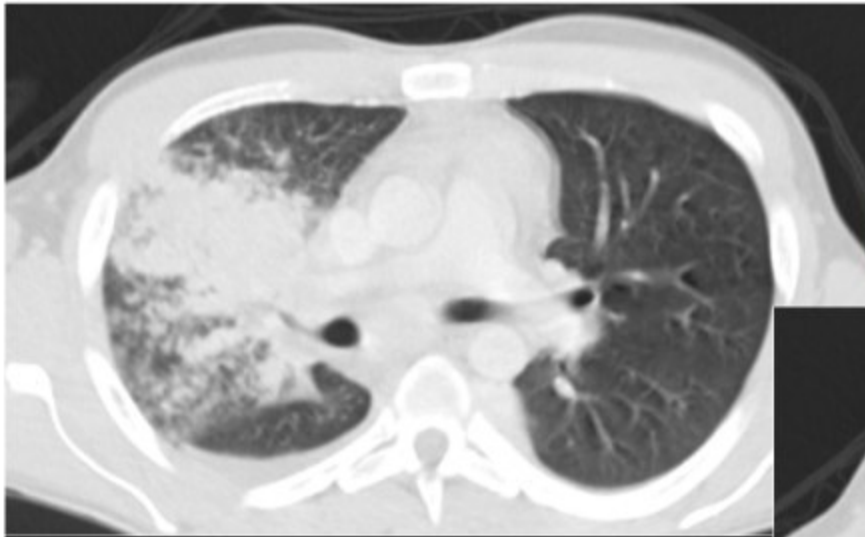
Lipoid Pneumonia



Neoplasm



Neoplasm



A photograph of a field with green grass, yellow dandelions, and two prominent red poppies. One poppy is in the upper left, and another is in the center. The text "THANK YOU FOR YOUR ATTENTION" is overlaid in red at the top.

THANK YOU FOR YOUR ATTENTION

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Disease