COVID-19
Imaging findings

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- Infection by SARS-CoV-2 virus ranges from asymptomatic to severe and sometimes fatal disease, most frequently the result of acute lung injury.
- The role of imaging has evolved during the pandemic, initially with CT as alternative and possibly superior test compared to RT-PCR, to a more limited role based on specific indications.
- Furthermore, some studies looking at the extent of lung involvement on chest radiography and CT showed correlations with critical illness and need for mechanical ventilation.
- In addition to pulmonary manifestations, cardiovascular complications such as thromboembolism and myocarditis have been ascribed to COVID-19, sometimes contributing to neurologic and abdominal manifestations

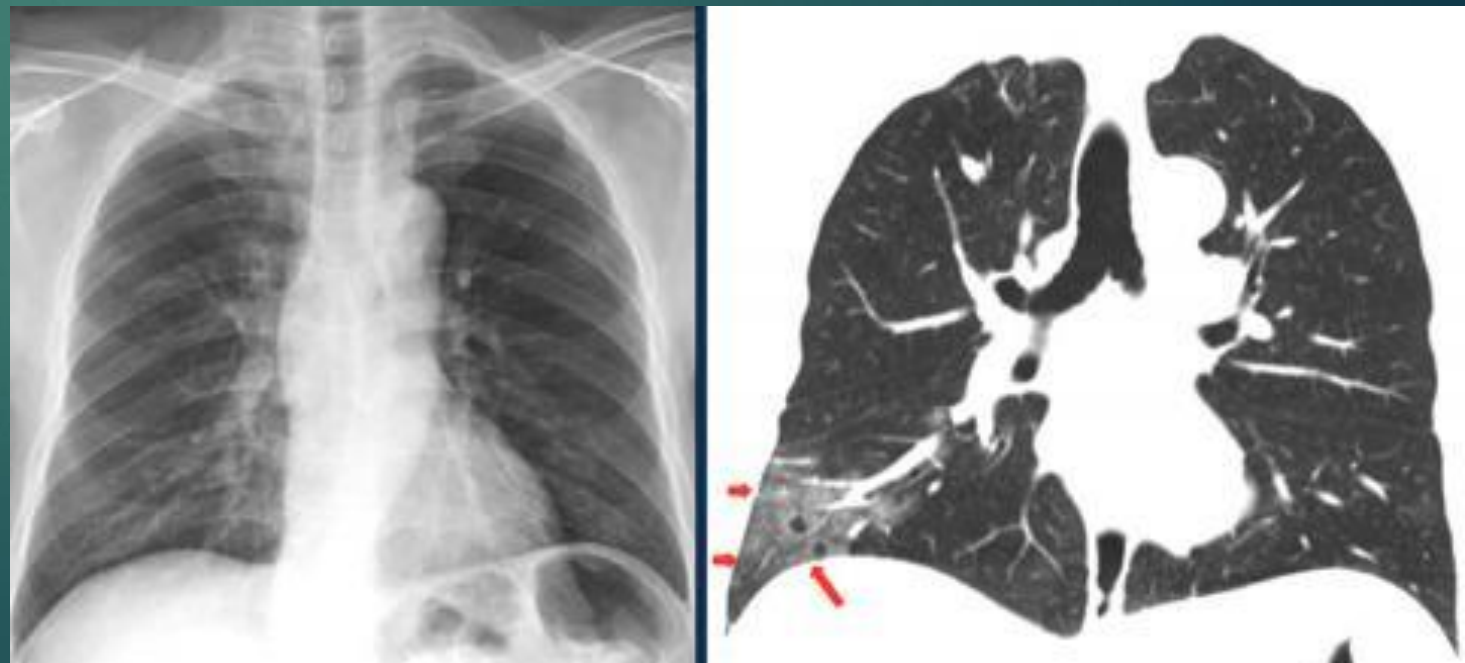
Indications for Imaging in COVID-19

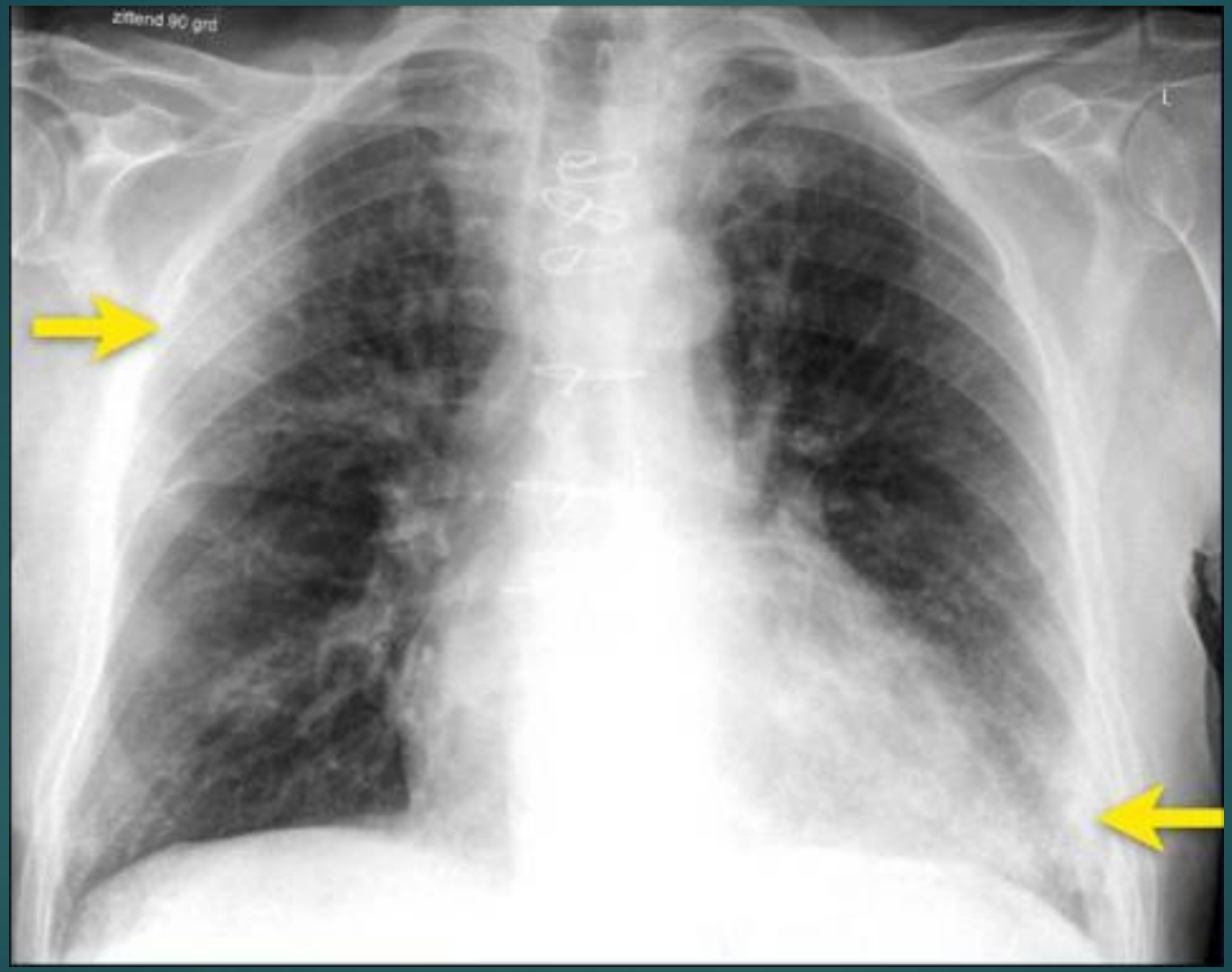
- While some early proponents particularly in China advocated for routine imaging in diagnosis of suspected COVID-19 pneumonia, others particularly in the United States and Europe proposed a much more conservative approach

- Based on expert opinions of panel members, recommendations were issued including: **no indication for routine imaging as a screening test for COVID-19 in asymptomatic individuals, no indication for daily CXR in stable intubated patients with COVID-19, and CT is indicated in patients with functional impairment, hypoxemia, or both after recovery from infection**.

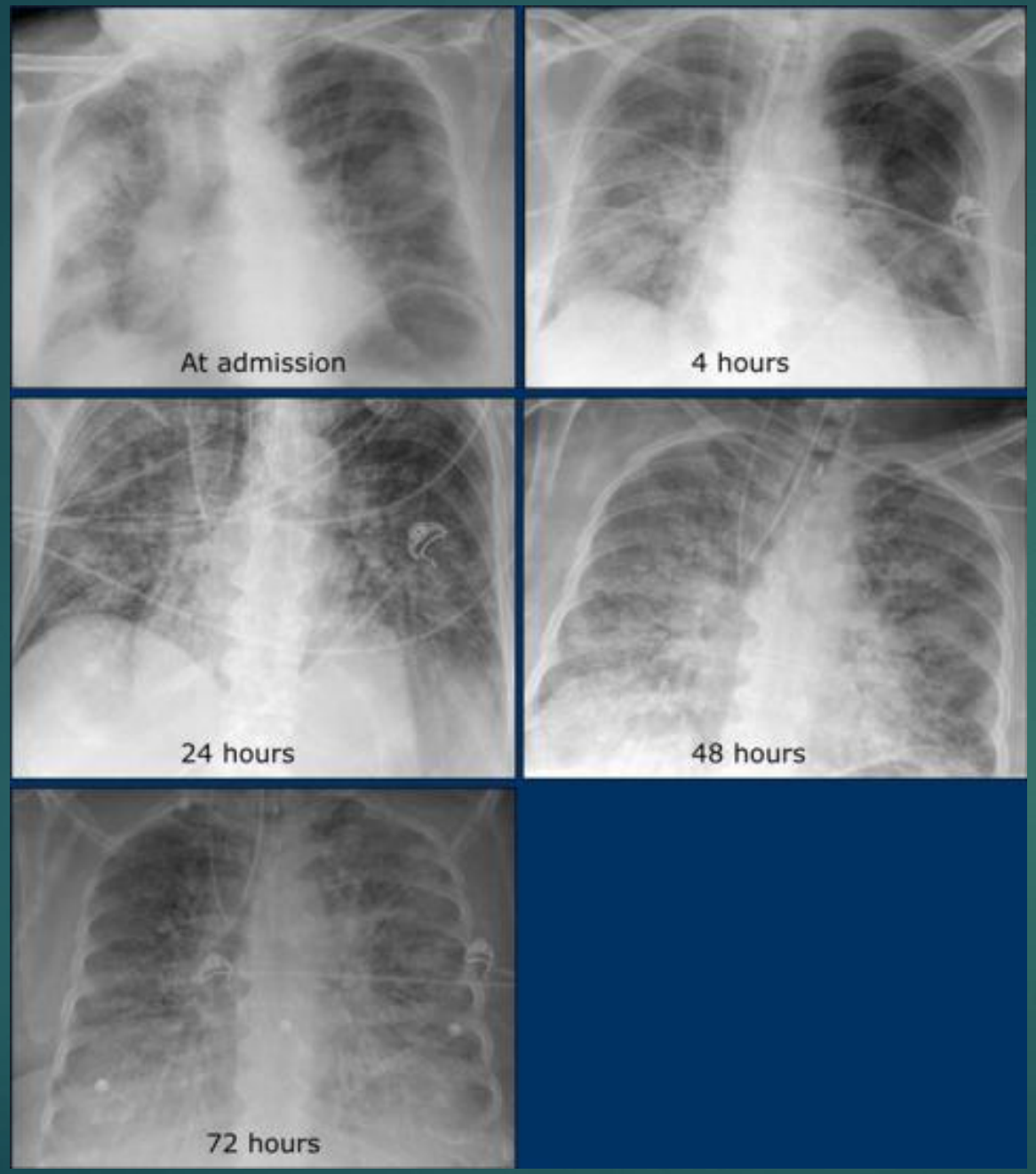
Chest radiograph

- Findings of COVID-19 on CXR vary, ranging from normal in the early stages of disease to unilateral or bilateral lung opacities, sometimes with a basilar and strikingly peripheral distribution
- underlying comorbidities such as chronic lung disease or congestive heart failure may confound CXR interpretation




zittend 90 grd

- Chest-films can be useful in the follow-up of the disease


At admission
4 hours
24 hours
48 hours
72 hours

Possible role of CT

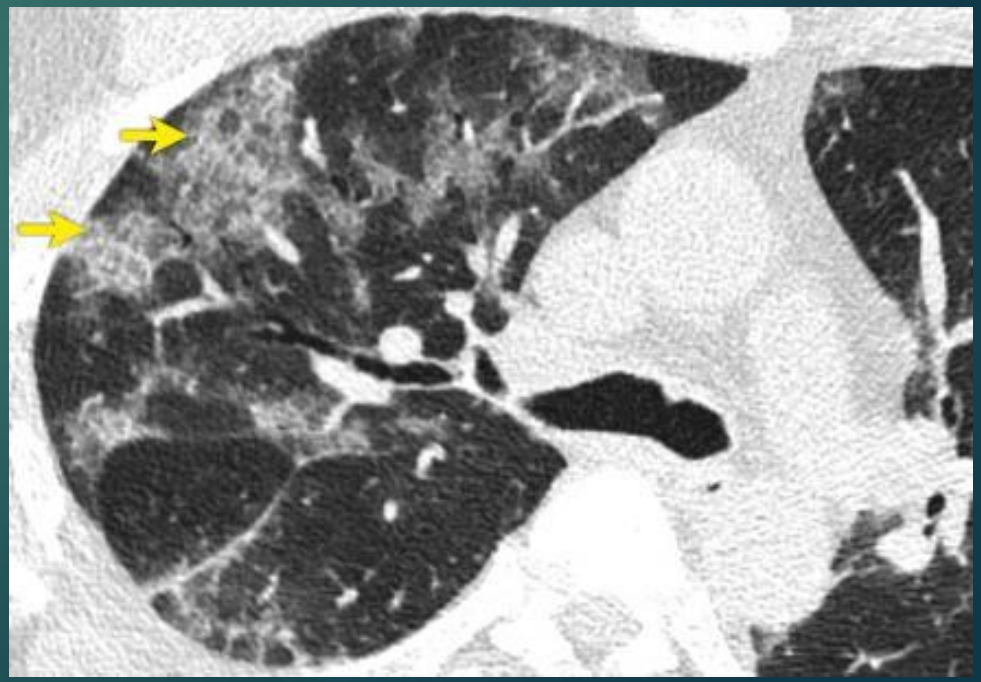
- CT can play a role in:
- Triage of patients:
  - no COVID-19
  - possible or most likely COVID-19
  - severity of the disease
- Prediction of worsening
- Prediction of improvement
- Problem solver

CHEST CT

- **Ground glass**
- Ground glass (GGO) pattern is the most common finding in COVID-19 infections.
  They are usually multifocal, bilateral and peripheral, but in the early phase of the disease the GGO may present as a unifocal lesion, most commonly located in the inferior lobe of the right lung

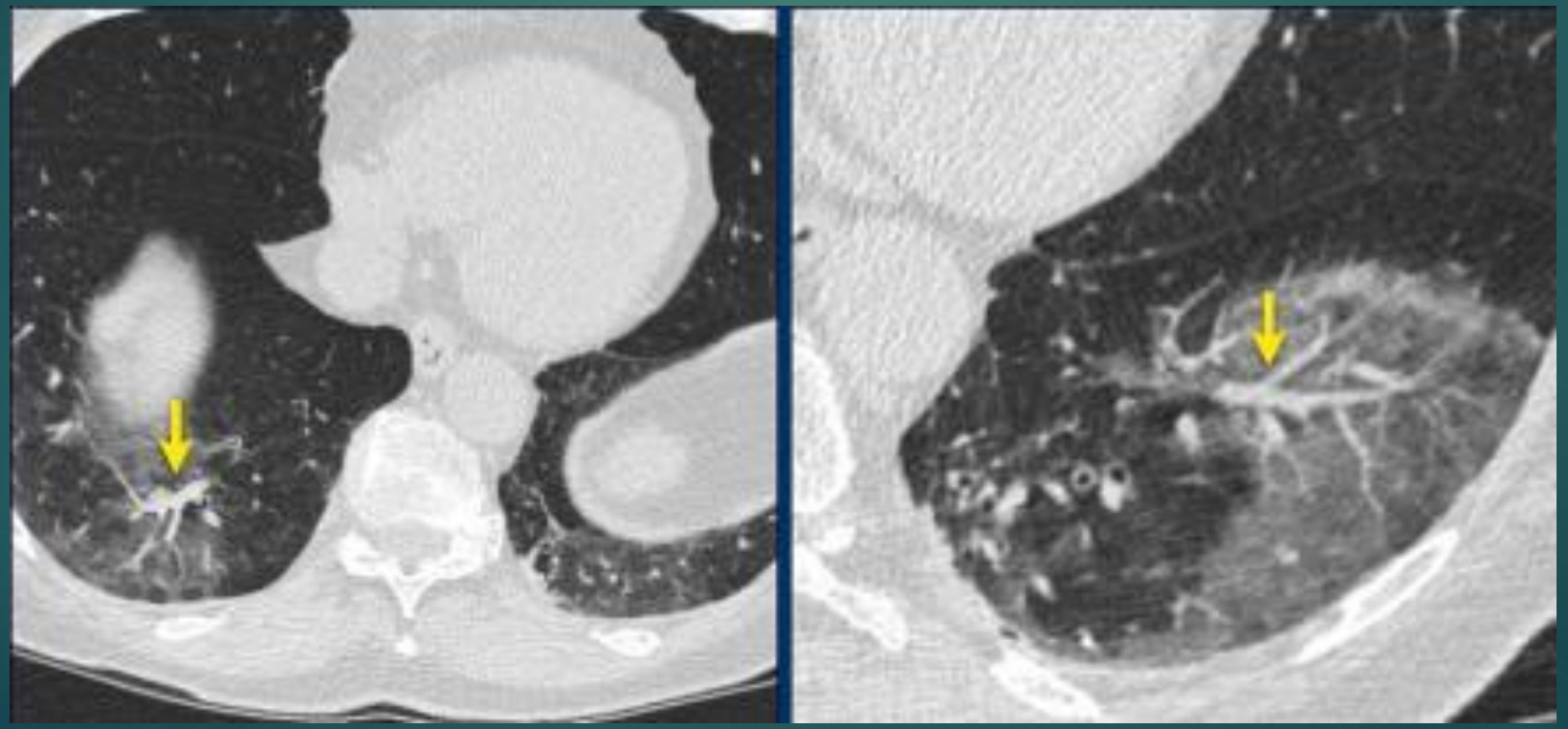
Crazy paving

- Sometimes there are thickened interlobular and intralobular lines in combination with a ground glass pattern.
  This is called crazy paving.
- It is believed that this pattern is seen in a somewhat later stage

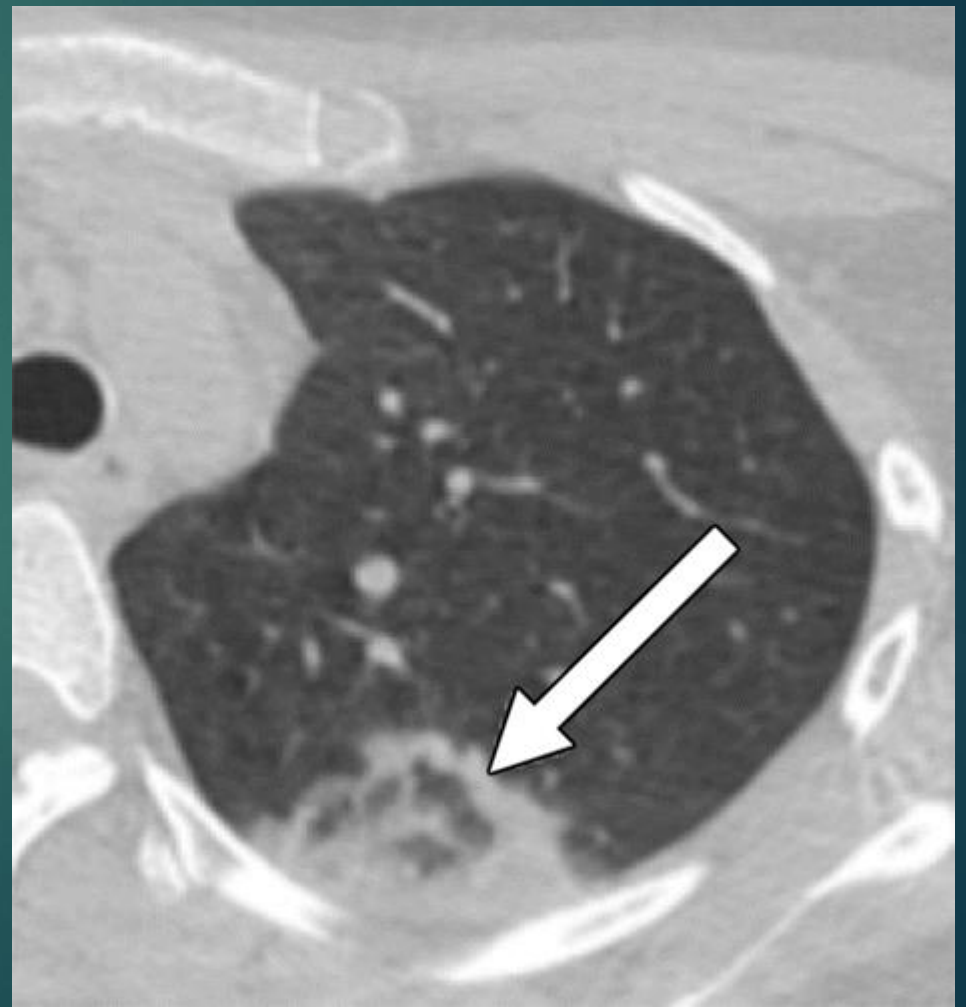


Vascular dilatation

- A typical finding in the area of ground glass is widening of the vessels (arrow).

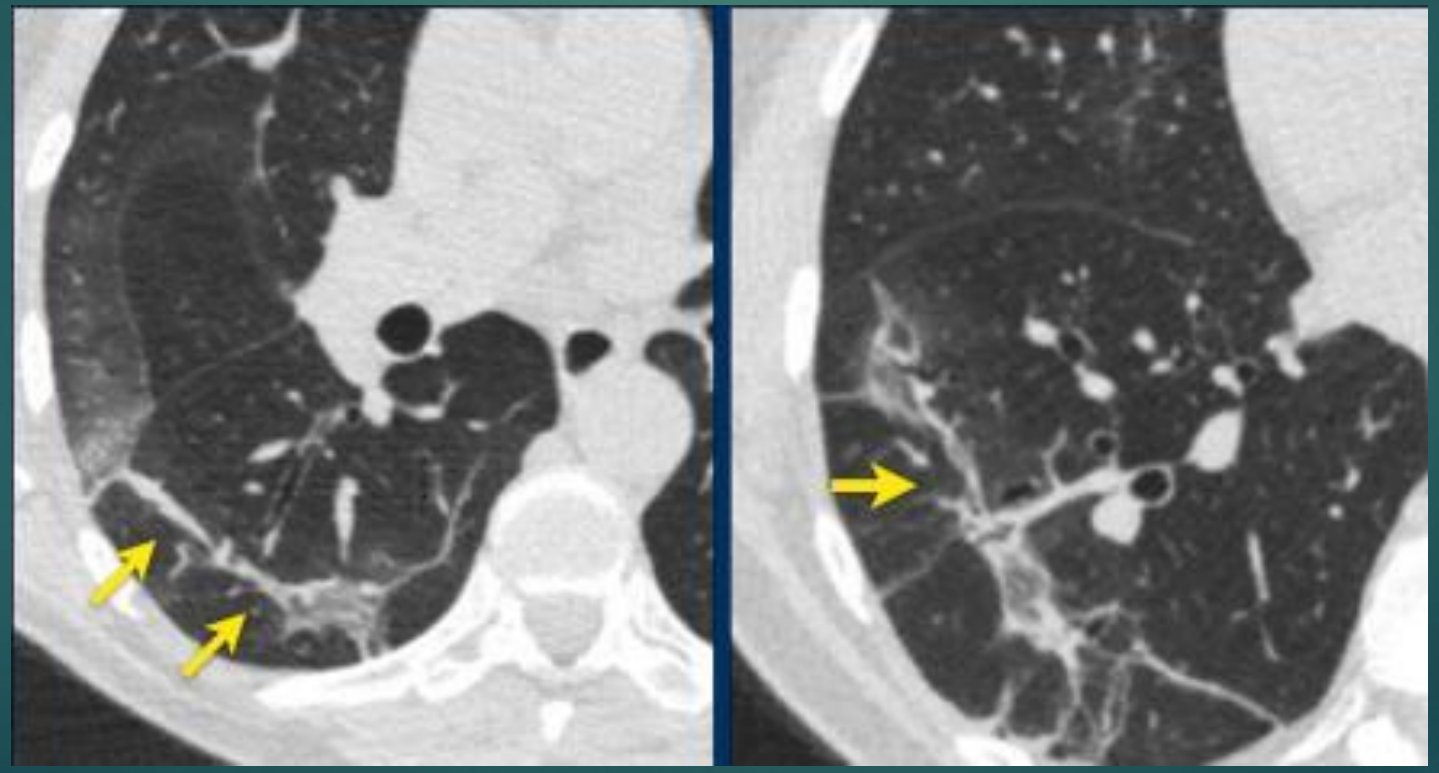


Reverse halo sign

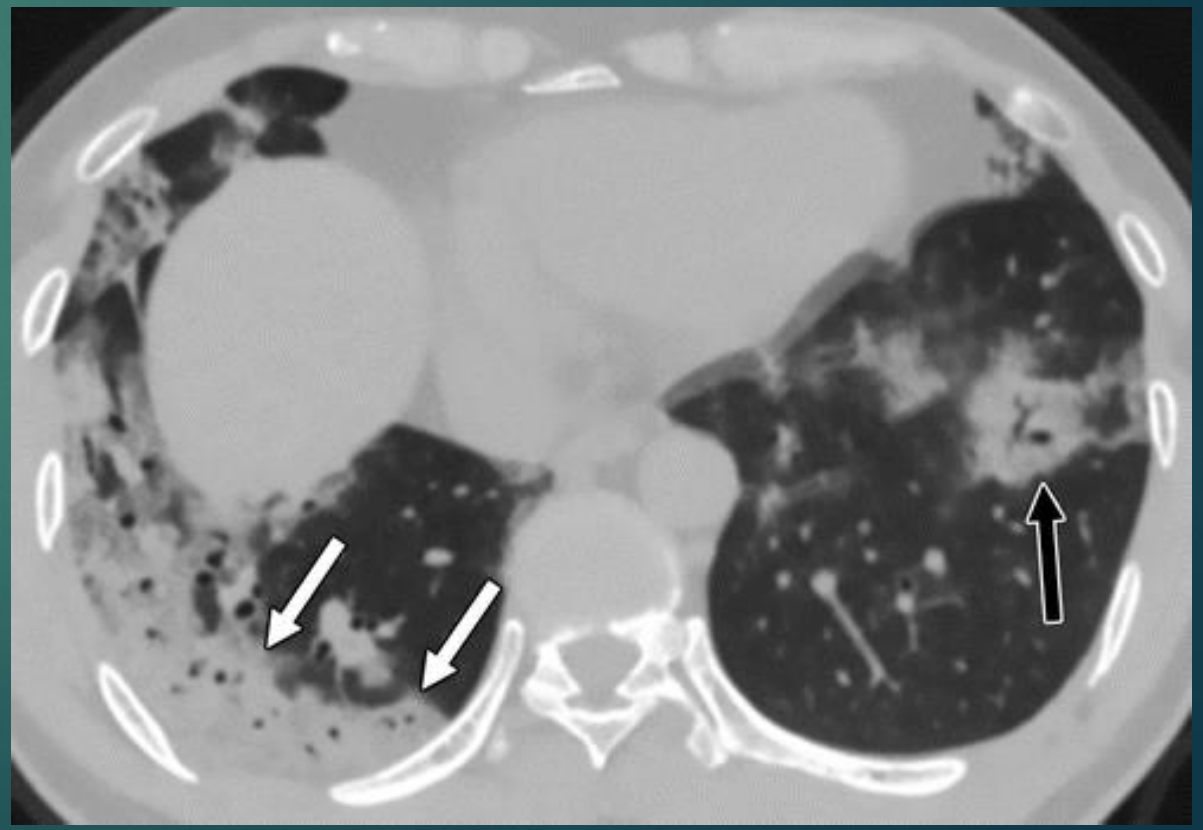


Subpleural bands and Architectural distortion

- In some case there is architectural distortion with the formation of subpleural bands.

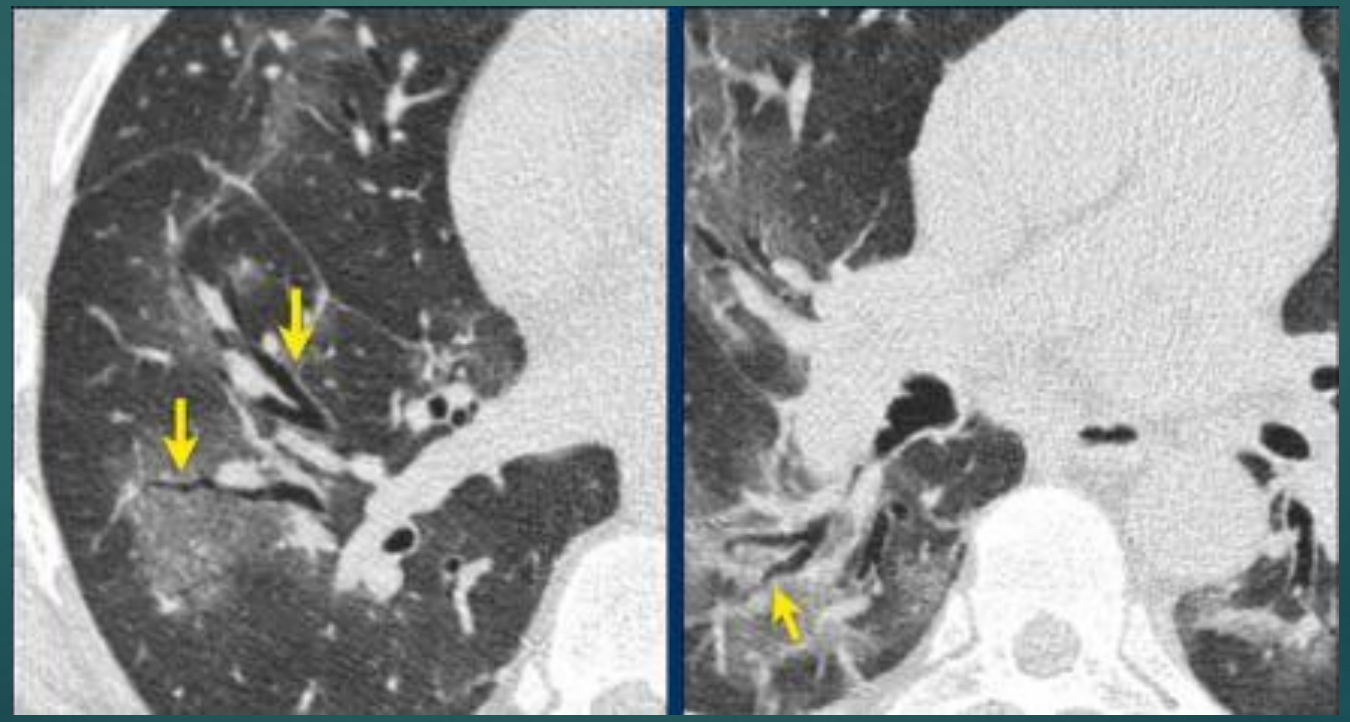


consolidation



Traction Bronchiectasis

- Another common finding in the areas of ground glass is traction bronchiectasis (arrows).



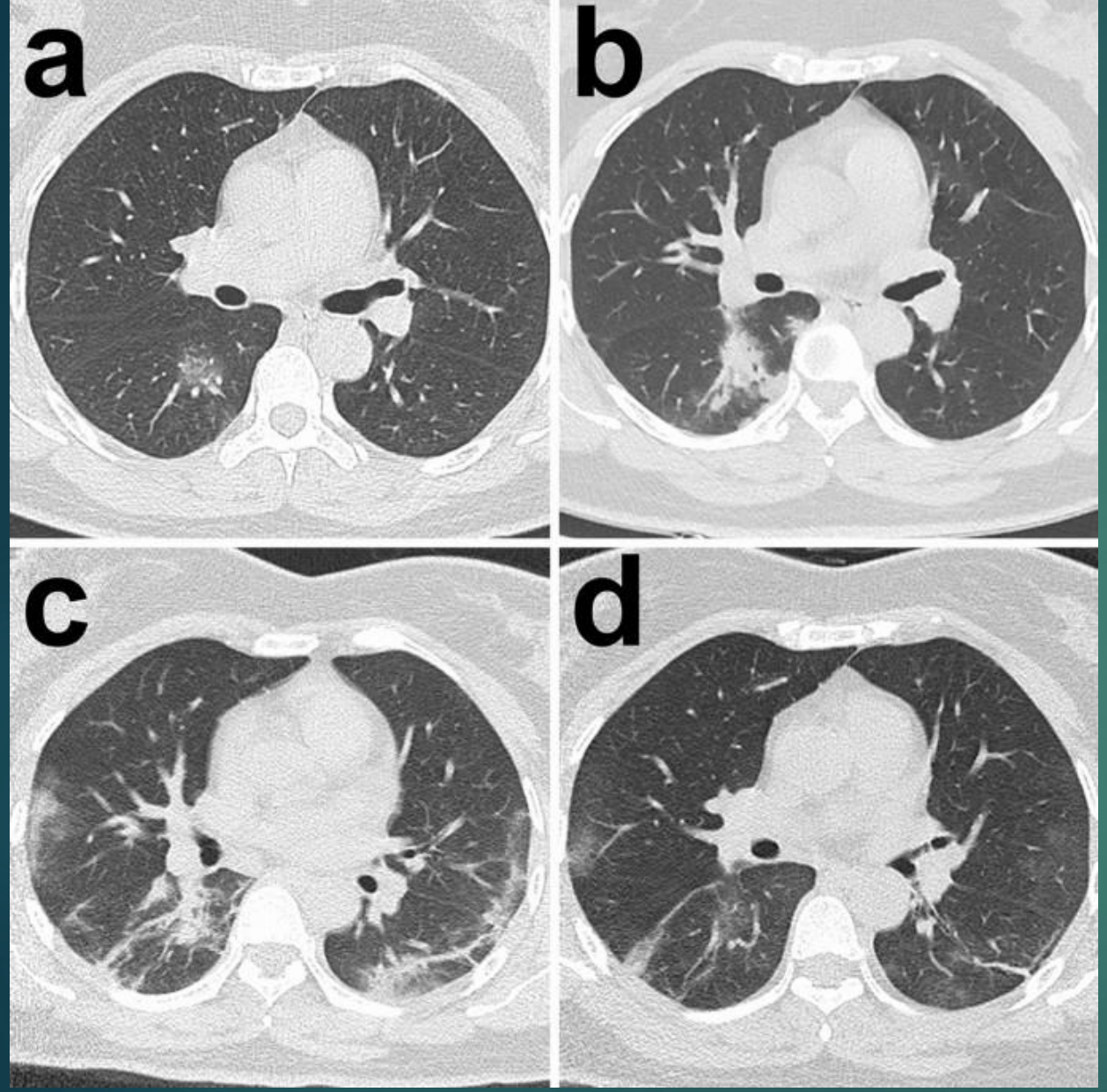
- Consolidation superimposed on GGO as the initial imaging presentation is found in a smaller number of cases, mainly in the elderly population.
- Septal thickening, bronchiectasis, pleural thickening, and subpleural involvement are some of the less common findings, mainly in the later stages of the disease.
- Pleural effusion, pericardial effusion, lymphadenopathy, cavitation, CT halo sign, and pneumothorax are some of the uncommon but possible findings seen with disease progression

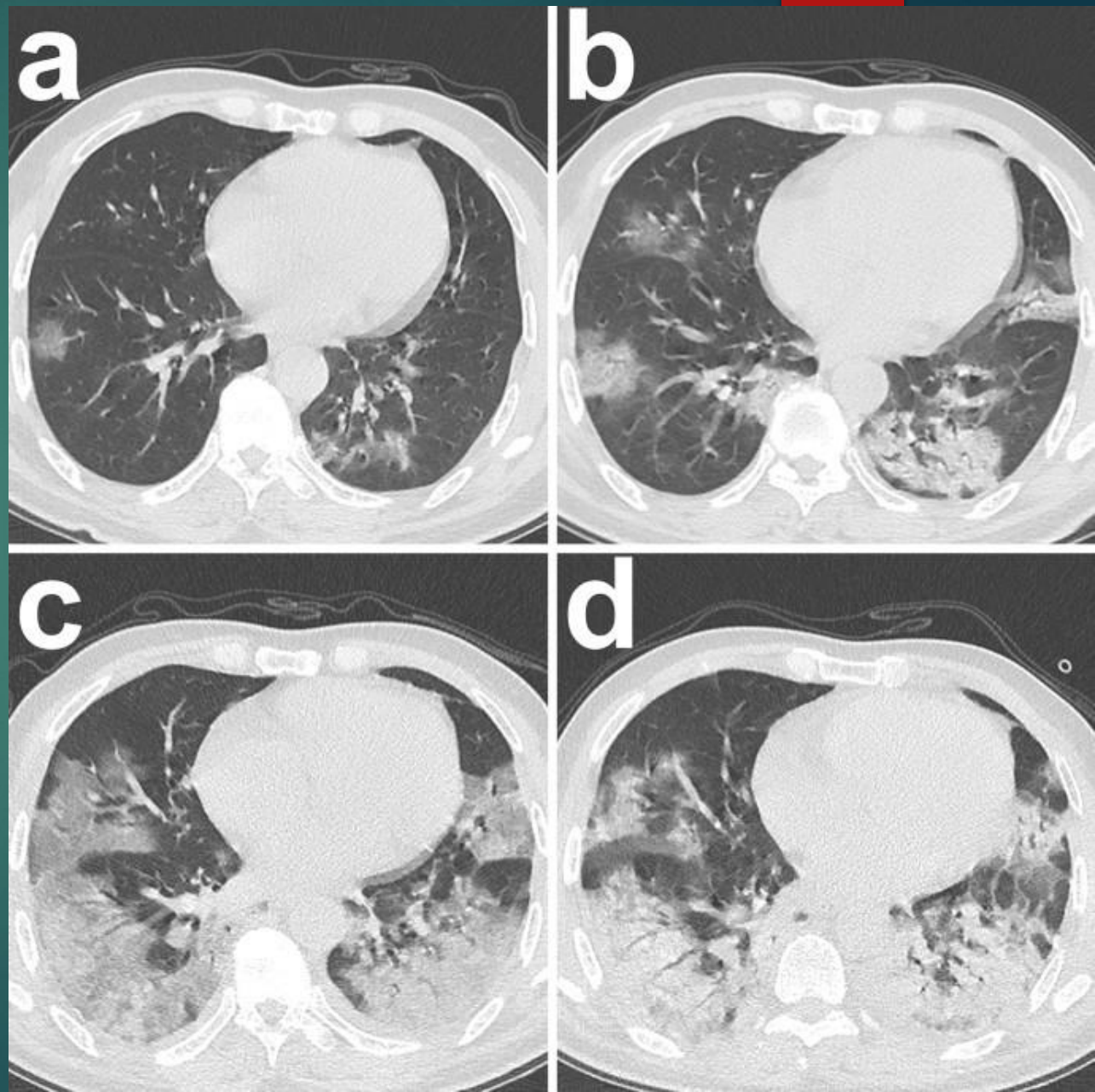
intitial CT-patterns in COVID-19

Ground-glass opacification	88%
Bilateral involvement	88%
Posterior distribution	80%
Multilobar involvement	79%
Peripheral distribution	76%
Consolidation	32%

CT-changes over time

Early stage	0-4 days	GGO, partial crazy paving, lower number of involved lobes
Progressive stage	5-8 days	Progressive (5-8 days): Extension of GGO, increased crazy paving pattern
Peak stage	10-13 days	Consolidation
Absorption stage	≥14 days	Gradual resolution


a
b
c
d


a
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Advanced-phase disease is associated with a significantly increased frequency of:

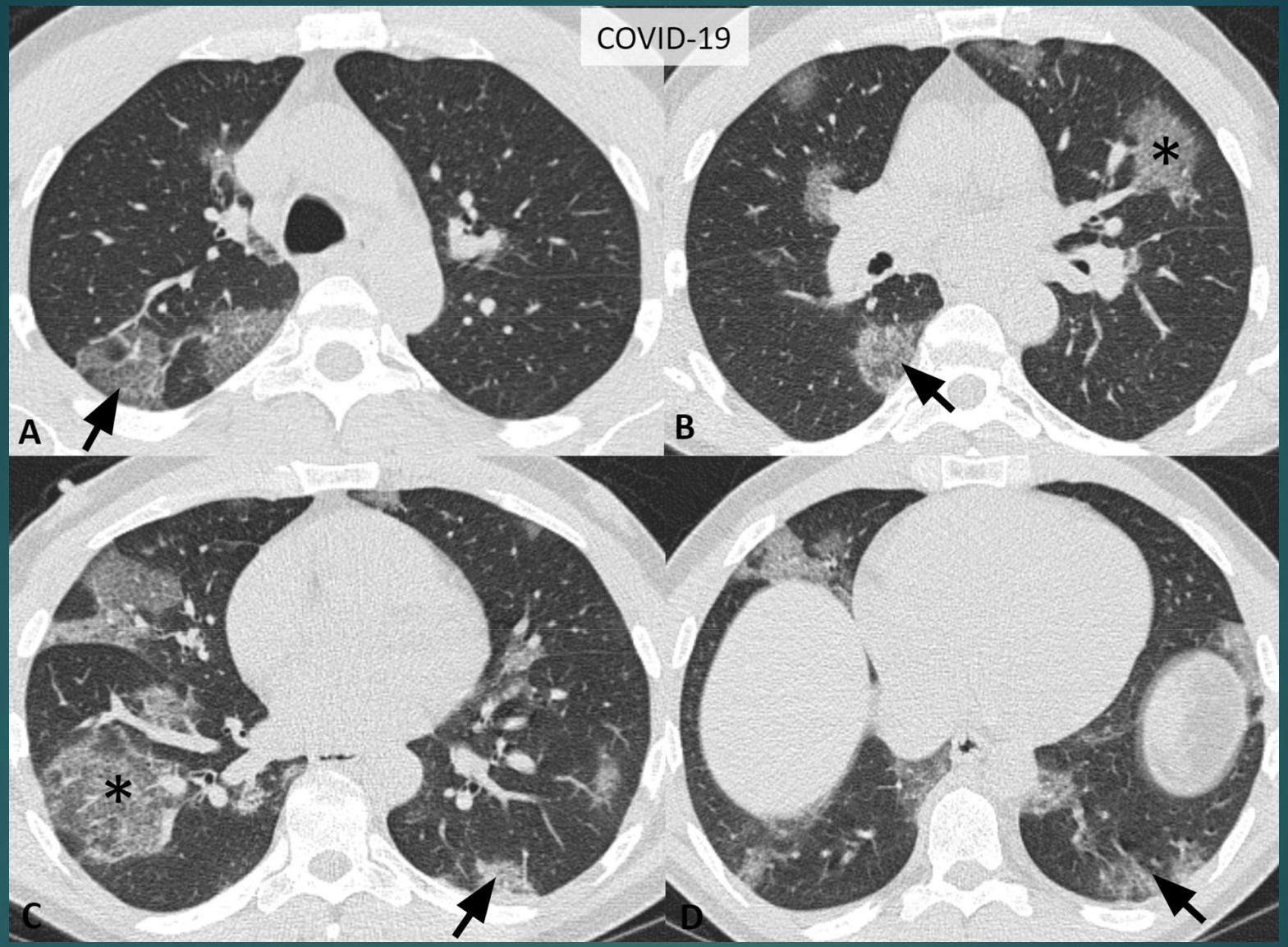
- GGO plus a reticular pattern (crazy pavin)
- Vacuolar sign
- Fibrotic streaks
- Air bronchogram
- Bronchus distortion
- Subpleural line or a subpleural transparent line
- Pleural effusion

Radiological Society of North America Expert Consensus Statement on Reporting Chest CT Findings Related to COVID-19.

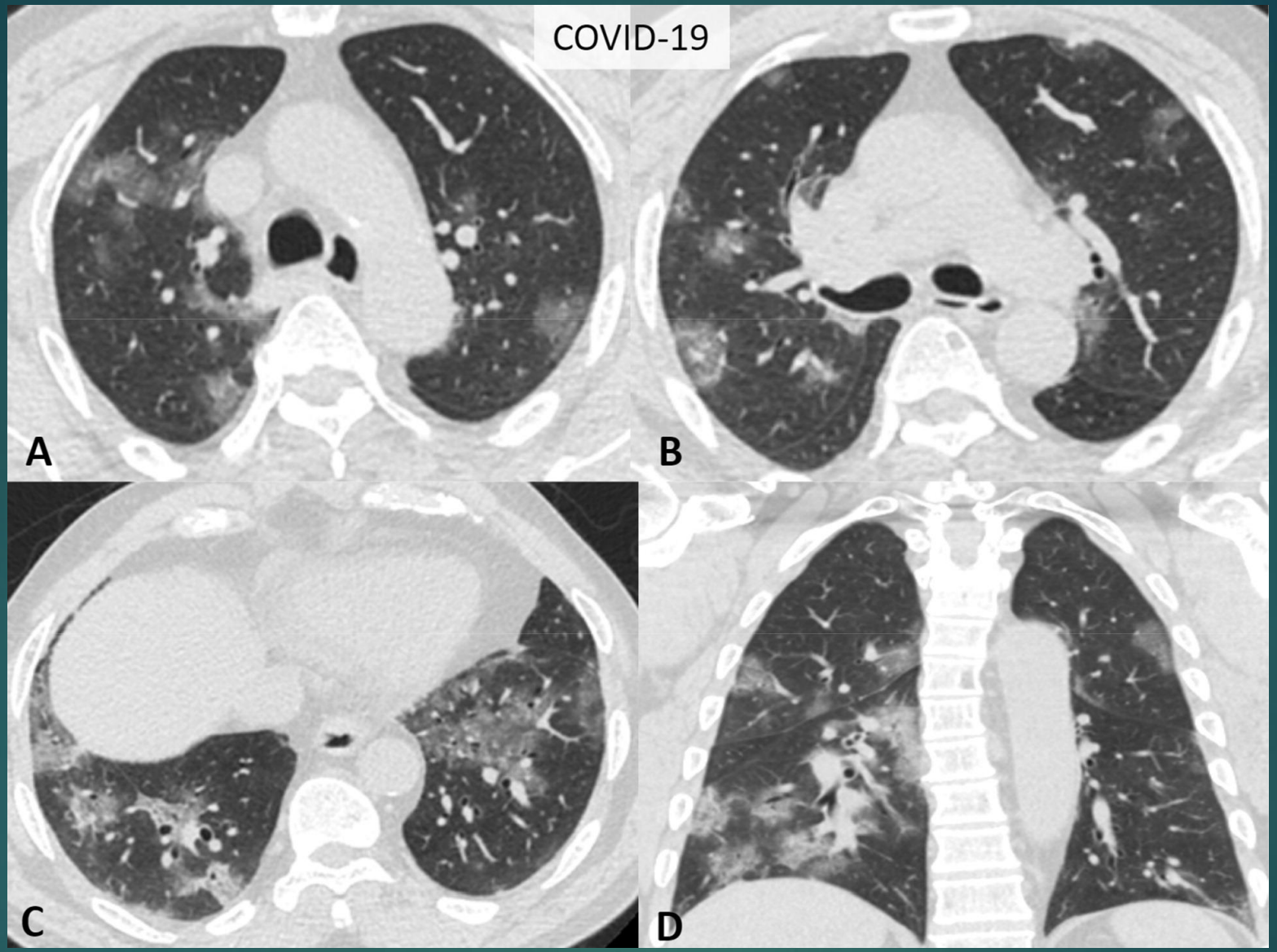
Proposed Reporting Language for CT Findings Related to COVID-19

Routine screening CT for diagnosis or exclusion of COVID-19 is currently not recommended by most professional organizations or the US Centers for Disease Control and Prevention

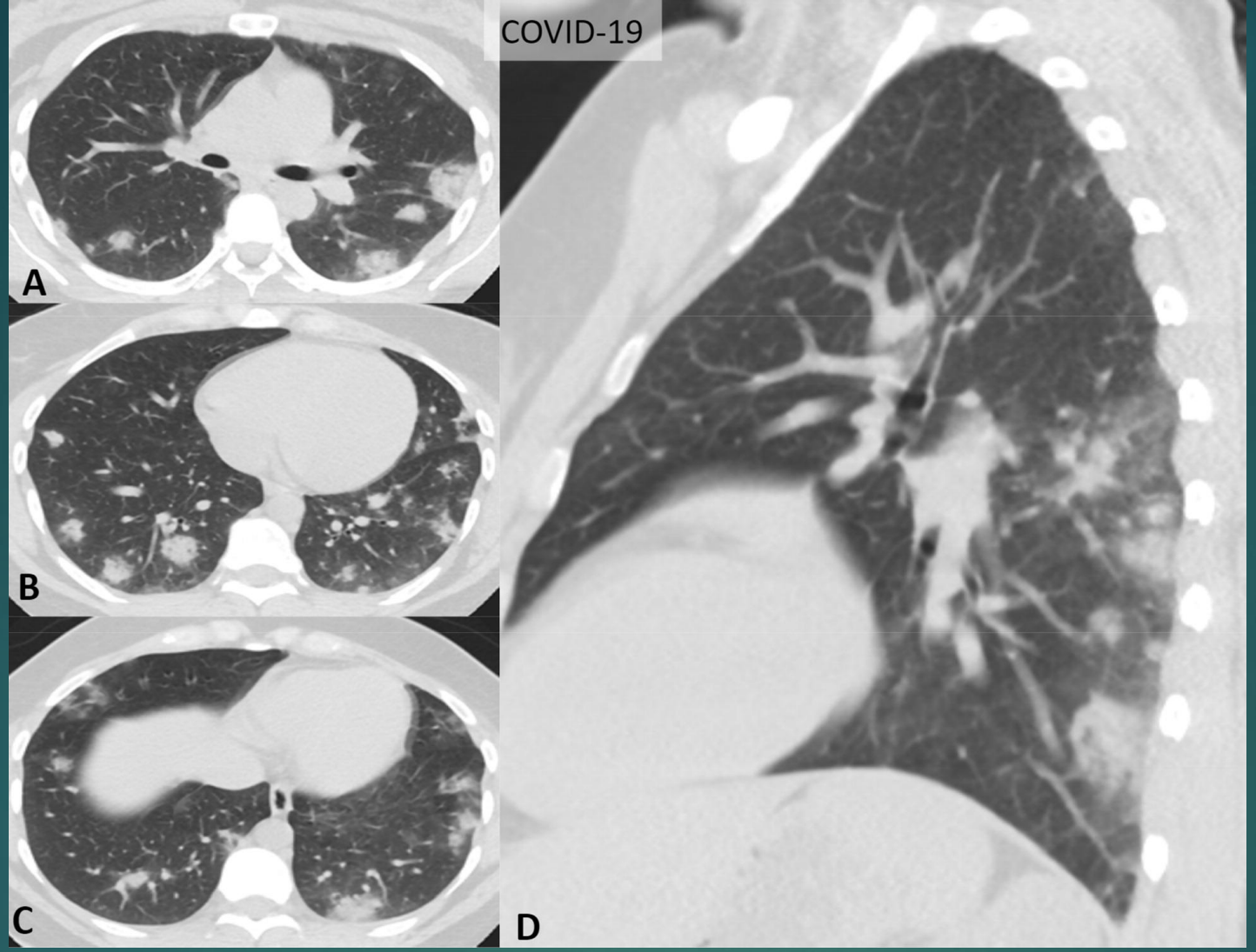
COVID-19 pneumonia imaging classification	Rationale (6-11)	CT Findings+	Suggested Reporting Language
Typical appearance	Commonly reported imaging features of greater specificity for COVID-19 pneumonia.	Peripheral, bilateral , GGO* with or without consolidation or visible intralobular lines (“crazy-paving”) Multifocal GGO of rounded morphology with or without consolidation or visible intralobular lines (“crazy-paving”) Reverse halo sign or other findings of organizing pneumonia (seen later in the disease)	“Commonly reported imaging features of (COVID-19) pneumonia are present. Other processes such as influenza pneumonia and organizing pneumonia, as can be seen with drug toxicity and connective tissue disease, can cause a similar imaging pattern.” [Cov19Typ]^



Typical CT imaging features for COVID-19. Unenhanced, thin-section axial images of the lungs in a 52-year-old man with a positive RT-PCR (A-D) show bilateral, multifocal rounded (asterisks) and peripheral GGO (arrows) with superimposed interlobular septal thickening and visible intralobular lines (“crazy-paving”)

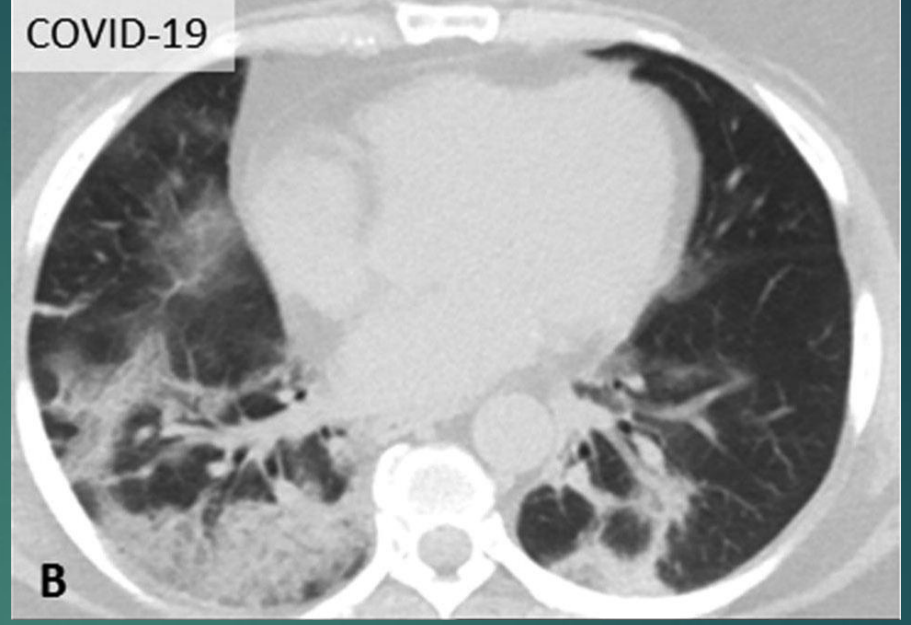


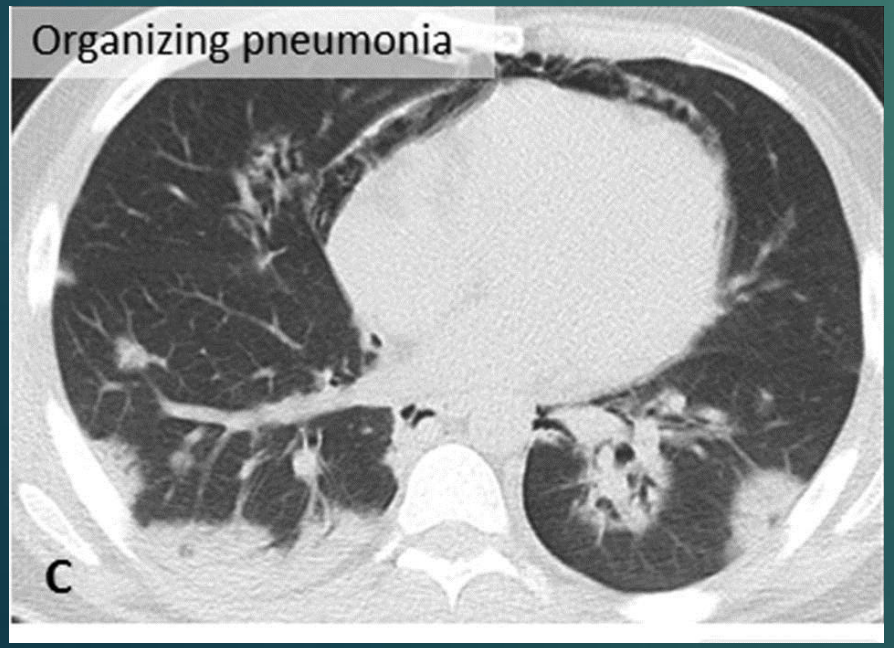
Typical CT imaging features for COVID-19. Unenhanced, thin-section axial (A-C) and coronal multiplanar reformatted (MPR) images (D) of the lungs in a 77-year-old man with a positive RT-PCR show bilateral, multifocal rounded and peripheral GGO.



- Typical CT imaging features for COVID-19. Unenhanced axial (A-C) and sagittal MPR (D) images of the lungs in a 29-year-old man with a positive RT-PCR show multiple bilateral, rounded consolidations with surrounding GGO.

COVID-19
A

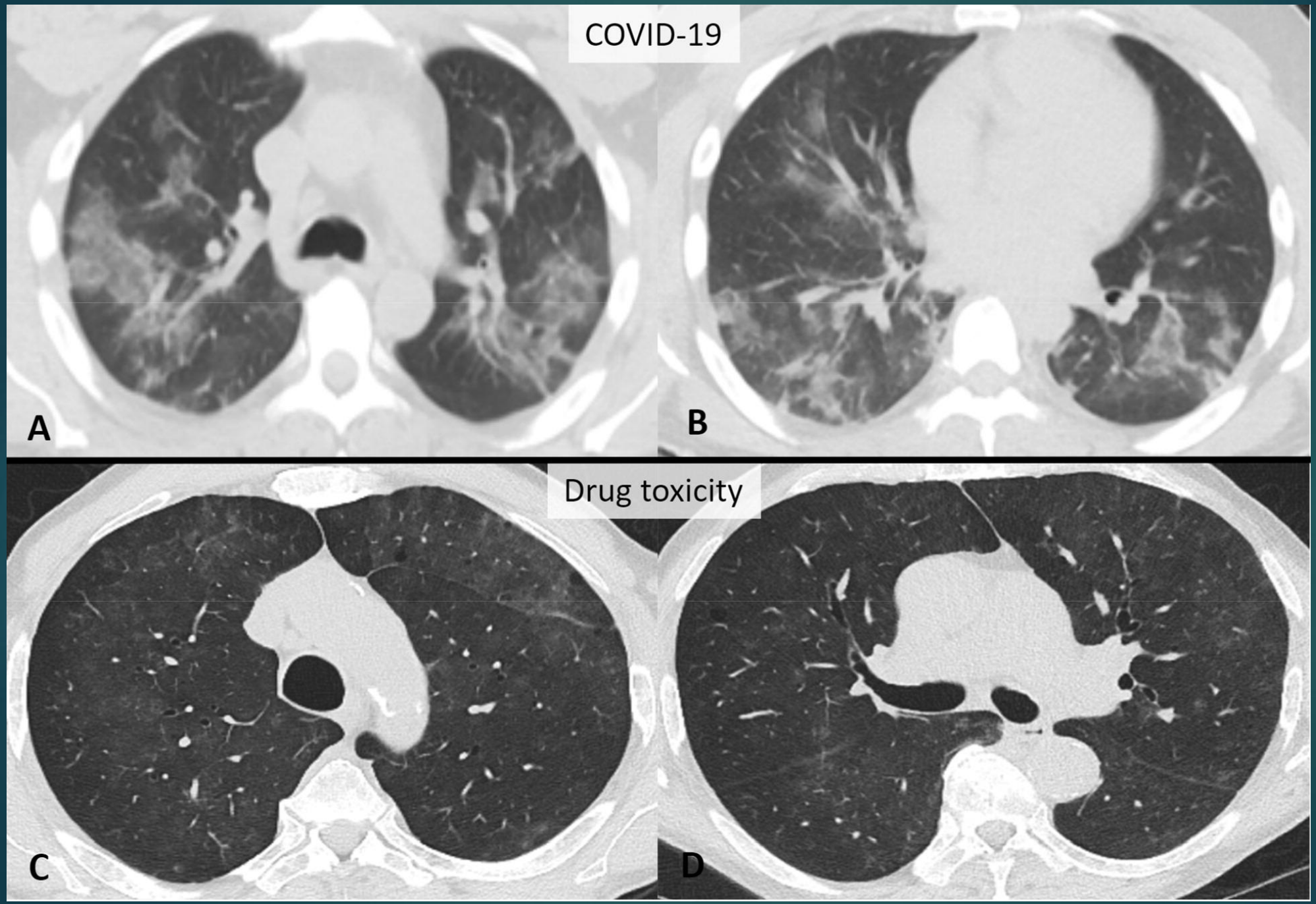

COVID-19
B

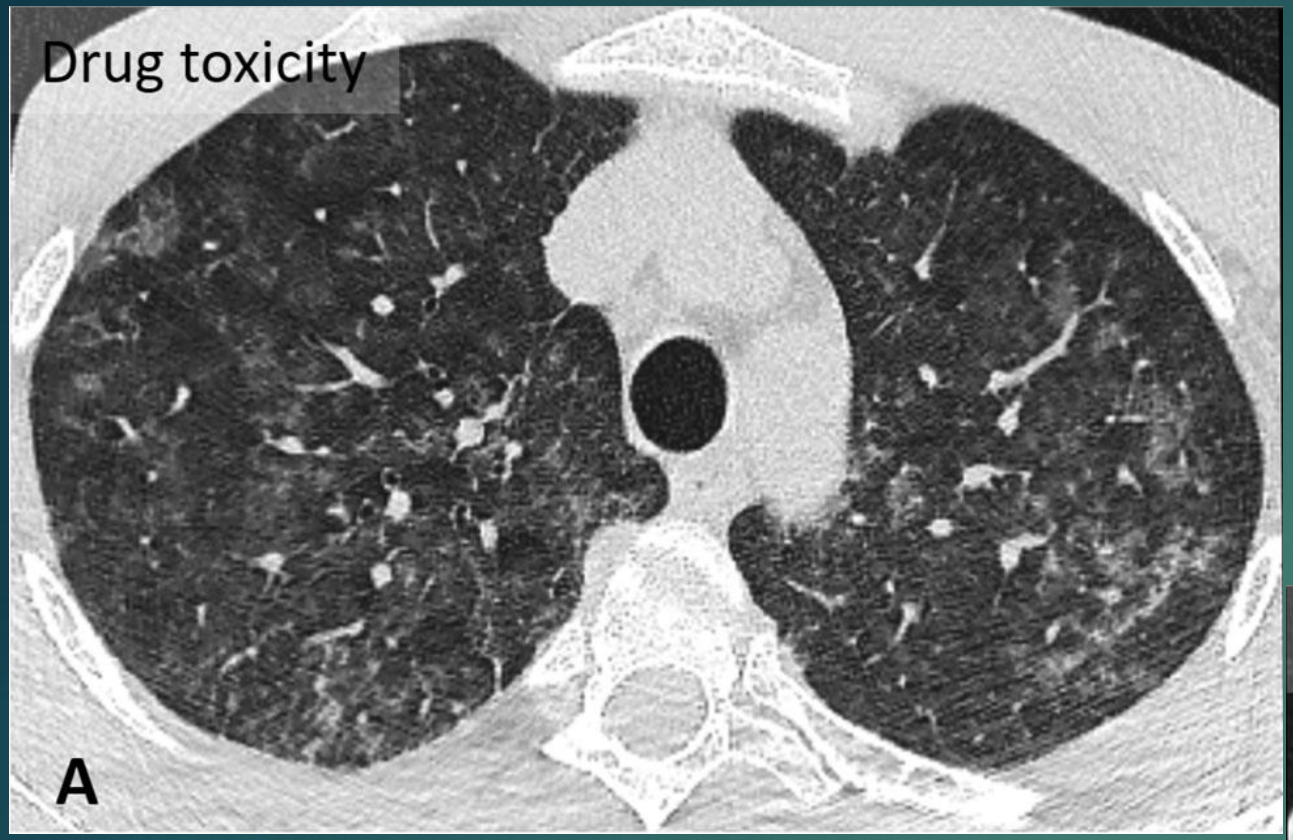

Organizing pneumonia
C

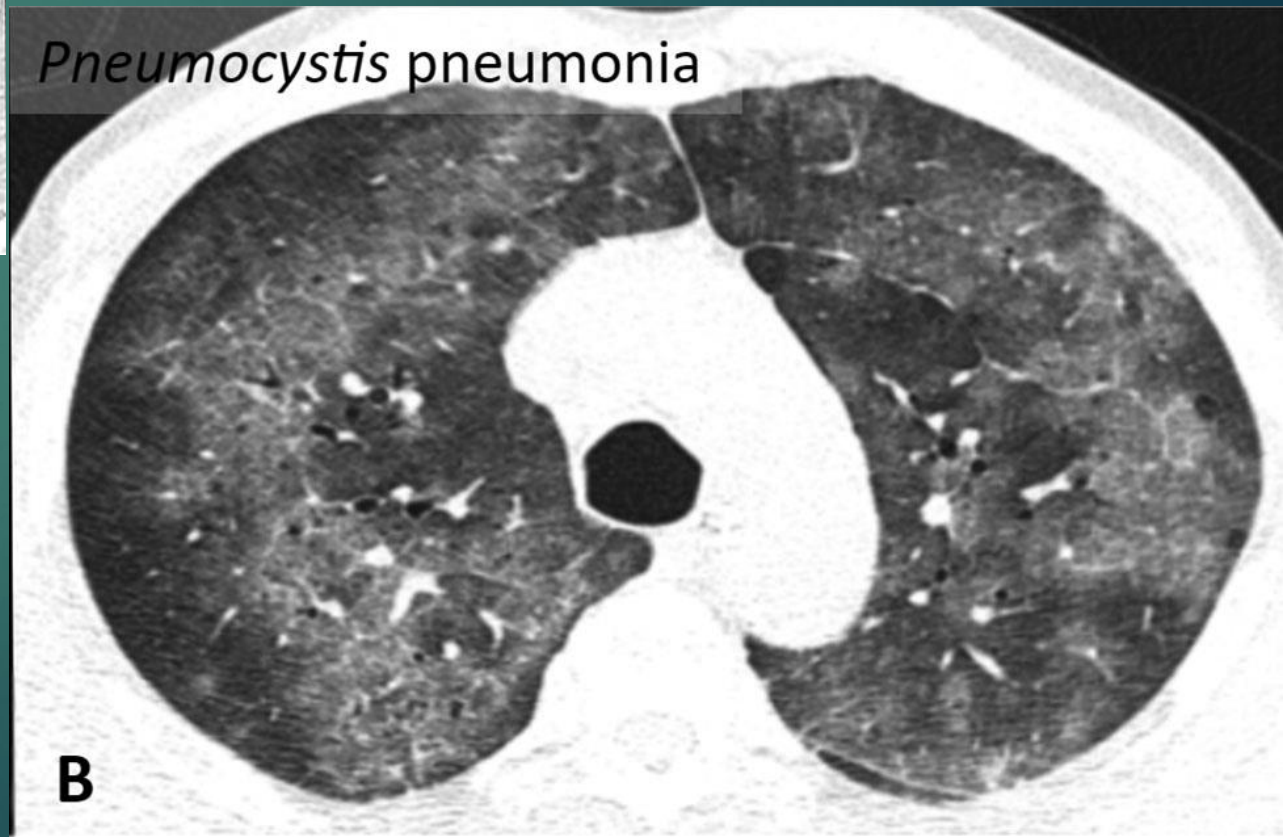
Influenza A pneumonia
D

Indeterminate appearance	Nonspecific imaging features of COVID-19 pneumonia.	**Absence of typical features AND** **Presence of:** Multifocal, diffuse, perihilar, or unilateral GGO with or without consolidation lacking a specific distribution and are non-rounded or non-peripheral. Few very small GGO with a non-rounded and non-peripheral distribution	"Imaging features can be seen with (COVID-19) pneumonia, though are nonspecific and can occur with a variety of infectious and noninfectious processes." [Cov19Ind]^

This finding is common in COVID-19 pneumonia but occurs in a wide variety of diseases such as acute hypersensitivity pneumonitis, Pneumocystis infection, and diffuse alveolar hemorrhage, which are difficult to distinguish by imaging alone.

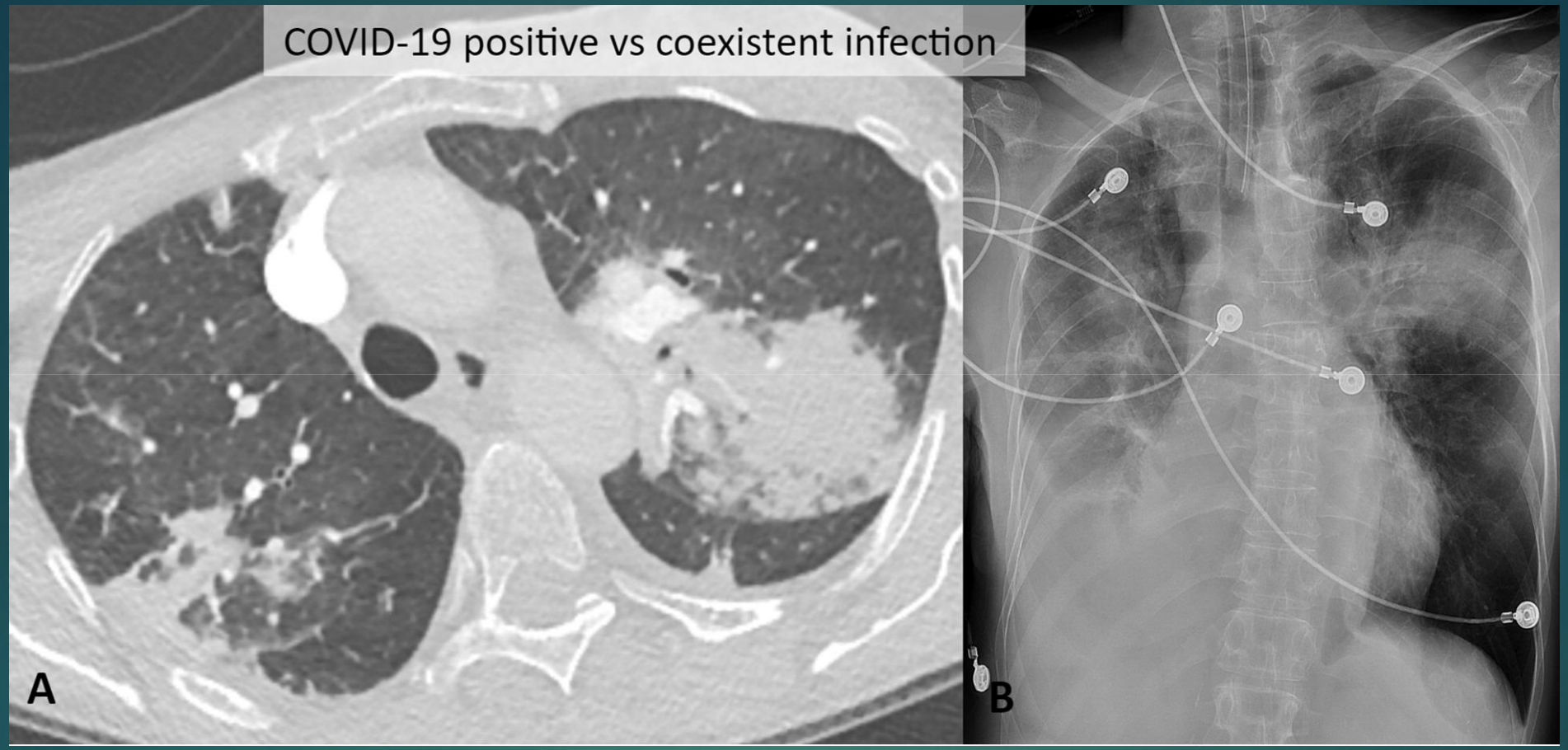

COVID-19
A
B
Drug toxicity
C
D


Drug toxicity
A

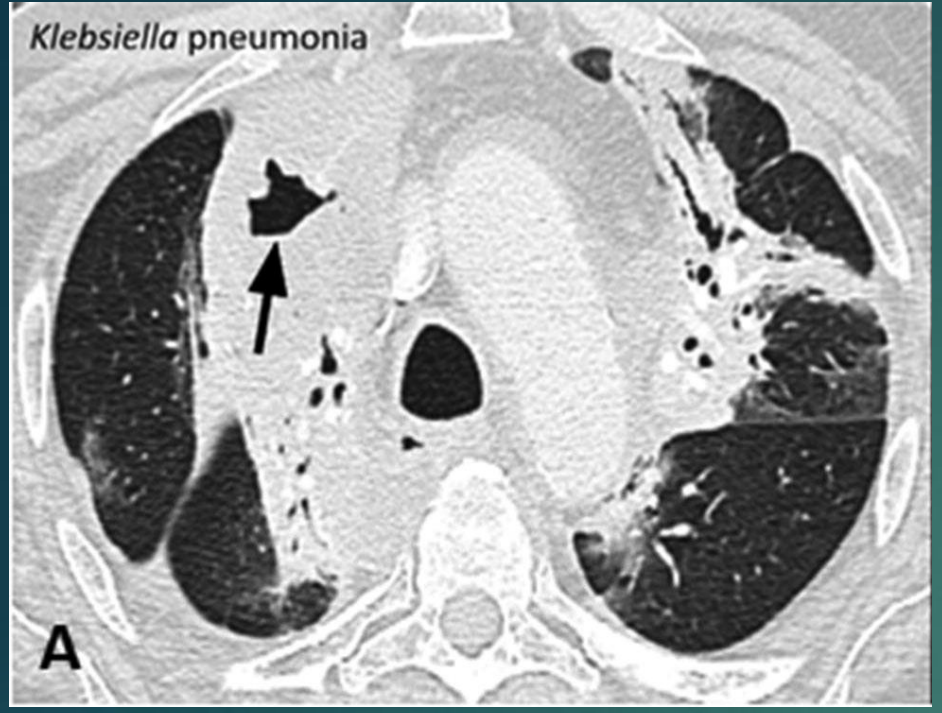

Pneumocystis pneumonia
B

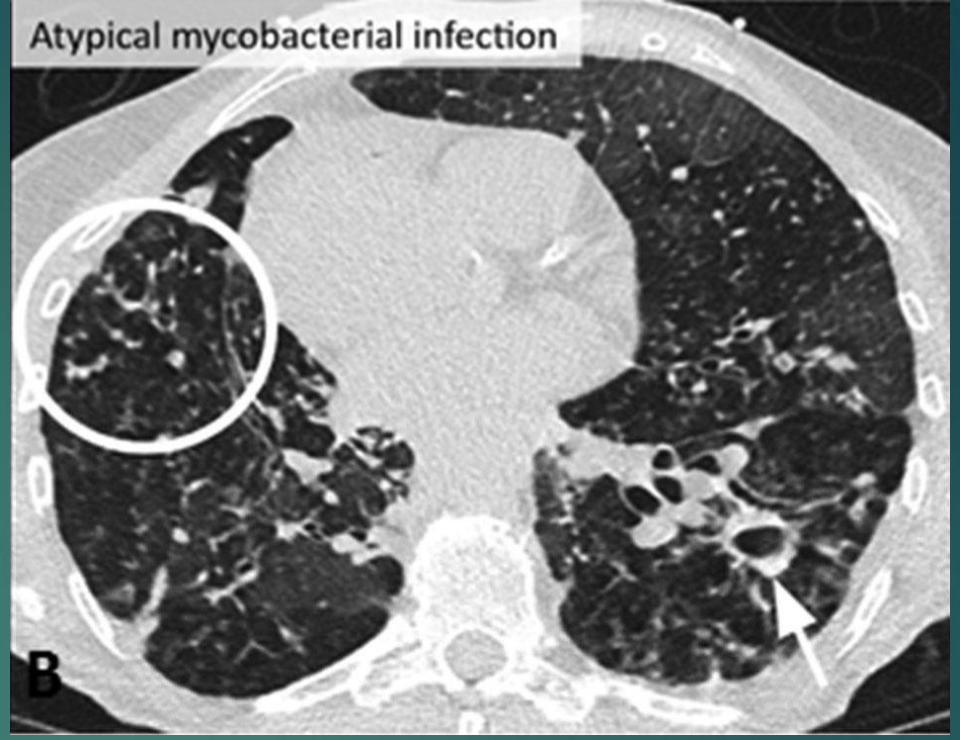
Atypical appearance	Uncommonly *or* not reported features of COVID-19 pneumonia.	**Absence of typical or indeterminate features AND** **Presence of:** Isolated lobar or segmental consolidation without GGO Discrete small nodules (centrilobular, "tree-in-bud") Lung cavitation Smooth interlobular septal thickening with pleural effusion	"Imaging features are atypical or uncommonly reported for (COVID-19) pneumonia. Alternative diagnoses should be considered." [Cov19Aty]^

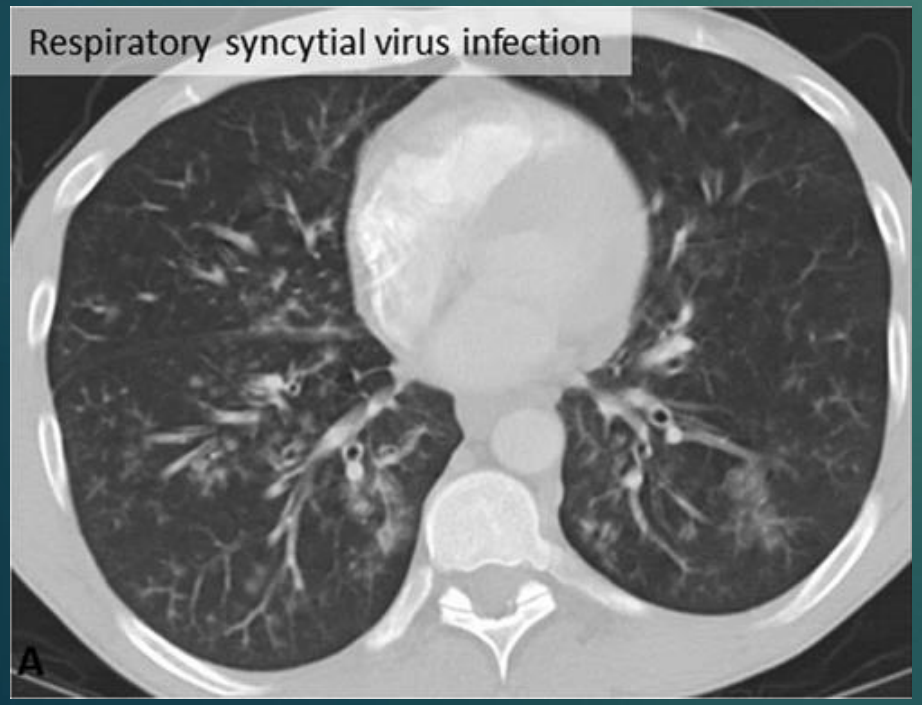
Atypical features are those that are reported to ***be uncommon or not occurring in COVID-19*** *pneumonia and are more typical of other diseases such as lobar or segmental consolidation in the setting* of a ***bacterial pneumonia***, cavitation from necrotizing pneumonia, and tree-in-bud opacities with centrilobular nodules, as can occur with a variety of community acquired infections and aspiration

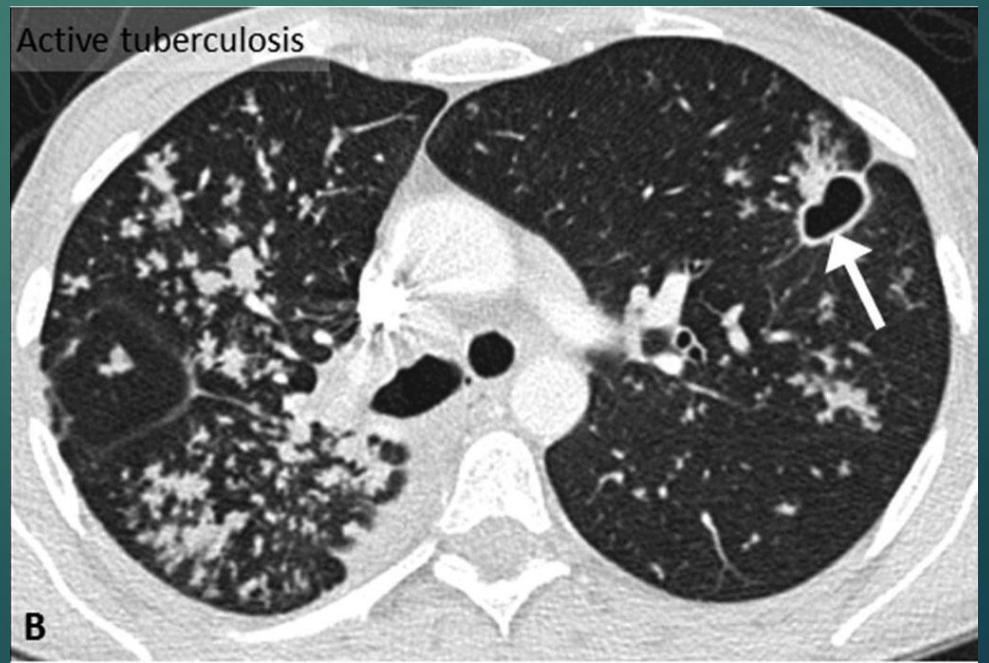


Atypical CT imaging features for COVID-19. Contrast-enhanced axial CT image (A) and frontal chest radiograph (B) showing segmental consolidation without significant GGO. Although this patient tested positive for COVID-19, the imaging features are not typical and could represent pneumonia related to COVID-19 or a secondary infectious process.


Klebsiella pneumonia
A


Atypical mycobacterial infection
B


Respiratory syncytial virus infection
A


Active tuberculosis
B

Negative for pneumonia	No features of pneumonia	No CT features to suggest pneumonia.	“No CT findings present to indicate pneumonia. (Note: CT may be negative in the early stages of COVID-19.) [Cov19Neg]^

Pros and Cons of Standardized Reporting for Chest CT Findings Related to COVID-19

Routine screening CT for diagnosis or exclusion of COVID-19 is currently not recommended by most professional organizations or the US Centers for Disease Control and Prevention

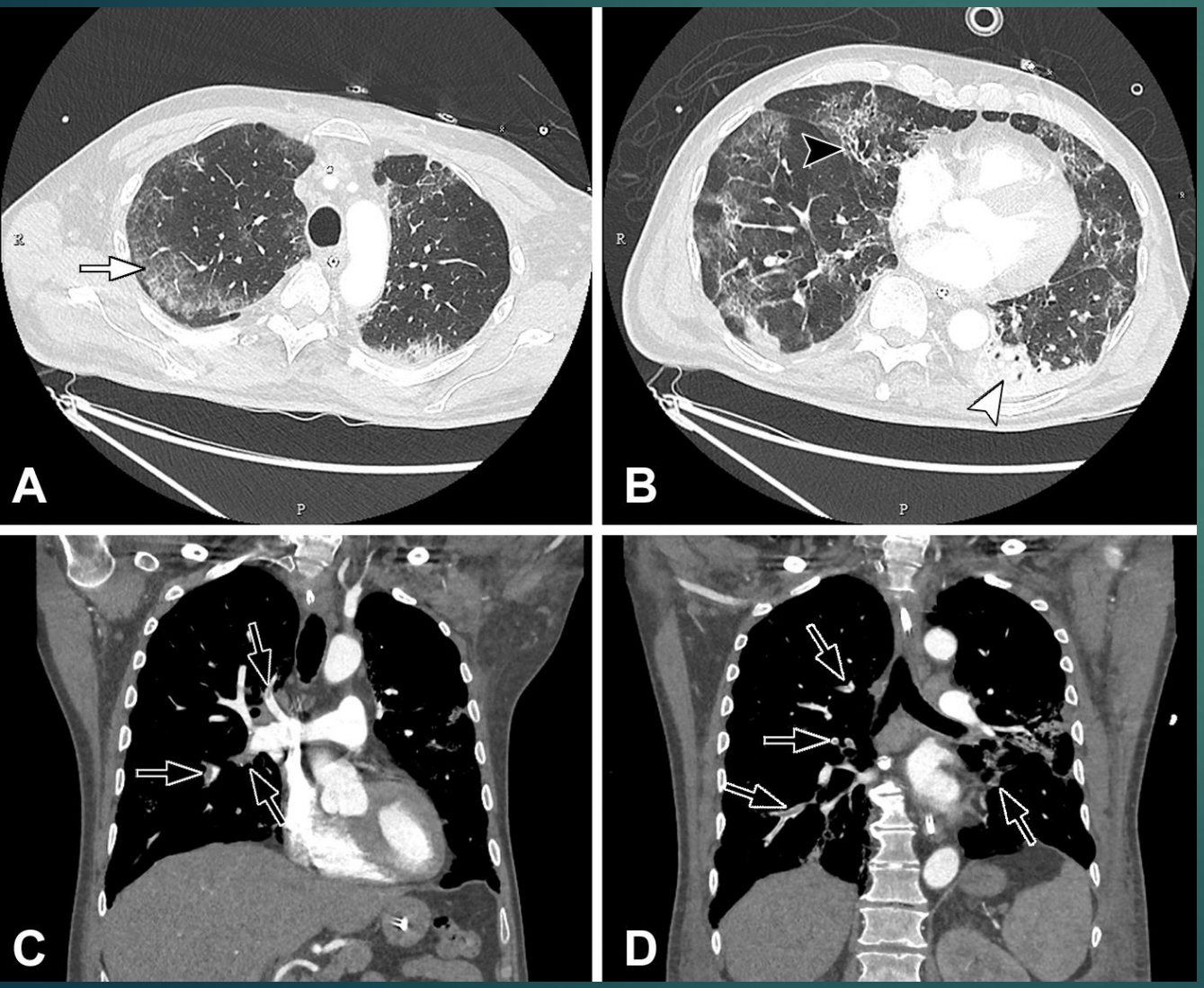
Pros	Cons
• Clinicians may be unsuspecting of COVID-19 in atypical presentations • Initial RT-PCR may be negative, and typical features may encourage repeat confirmatory testing • Standardized reporting language can improve report quality and clarity by ensuring consistent terminology • Reporting data can be used for future teaching, research, clinical quality improvement, and future management pathways	• The true sensitivity and specificity of chest CT are unknown. Even patients with a normal chest CT or only atypical features may have COVID-19 • Clinicians may feel that having “COVID-19” in a report boxes them in and limits their options for patient management • Patients may be apprehensive about having terminology like "COVID-19" or "coronavirus" in their reports and medical records

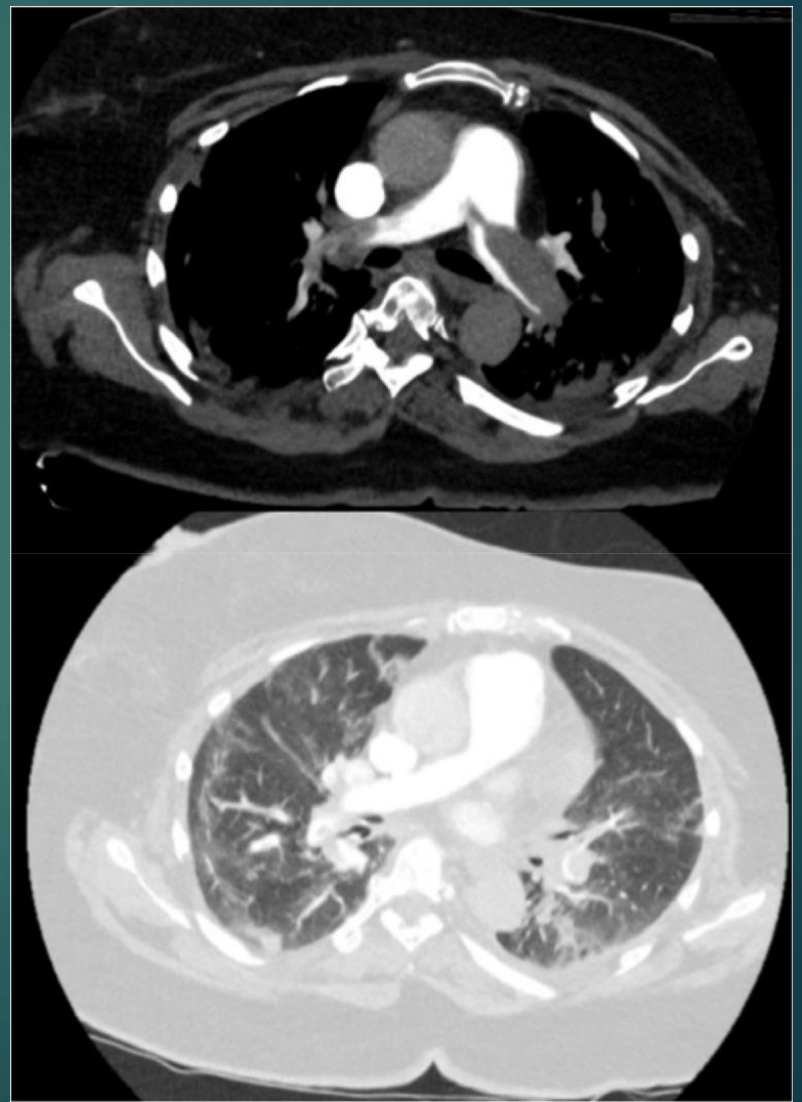
CT involvement score

The severity of the lung involvement on the CT correlates with the severity of the disease.

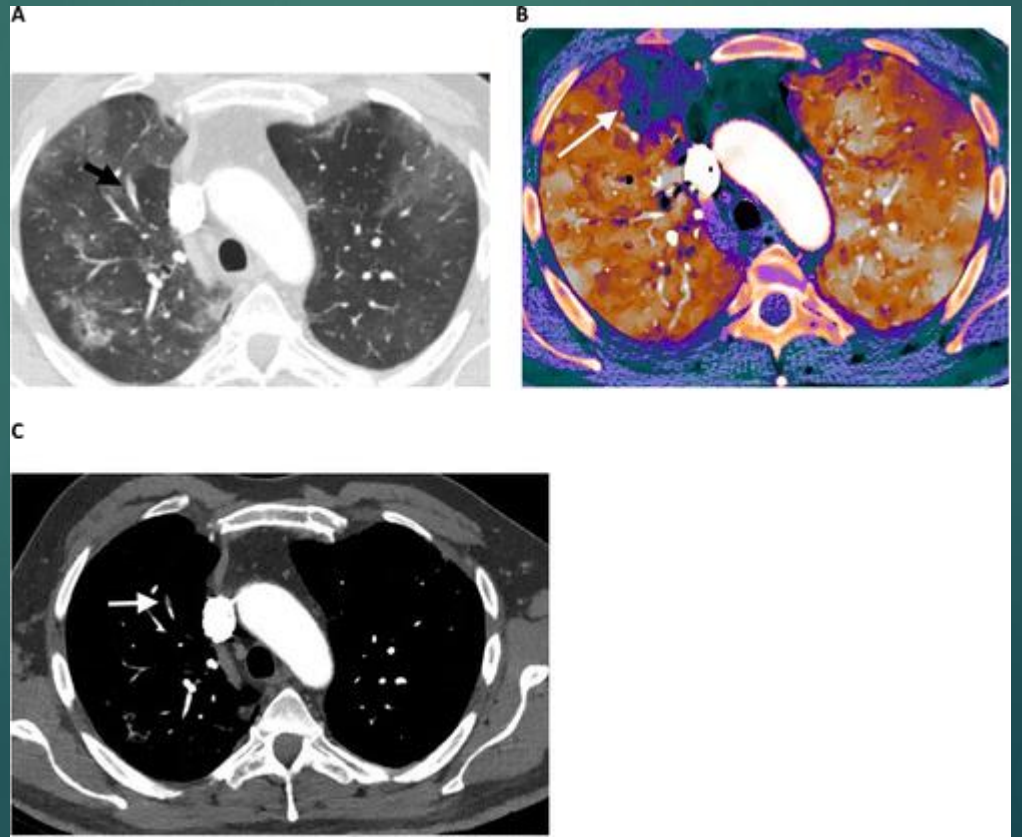
- **Visual assessment**
  The severity on CT can be estimated by visual assessment.
  This is the easiest way to score the severity.
- **Severity score**
  Another method is by scoring the percentages of each of the five lobes that is involved:
- 1.< 5% involvement
- 2.5%-25% involvement
- 3.26%-49% involvement
- 4.50%-75% involvement
- 5.> 75% involvement.
- The total CT score is the sum of the individual lobar scores and can range from 0 (no involvement) to 25 (maximum involvement), when all the five lobes show more than 75% involvement.

CTA





- Thrombotic lesions affected COVID-19-involved lung in all cases with a lower thrombus burden and lower rate of proximal pulmonary artery involvement compared to controls
- Pulmonary emboli or thrombi were present in the segmental and more distal vessels in greater than 90% of patients

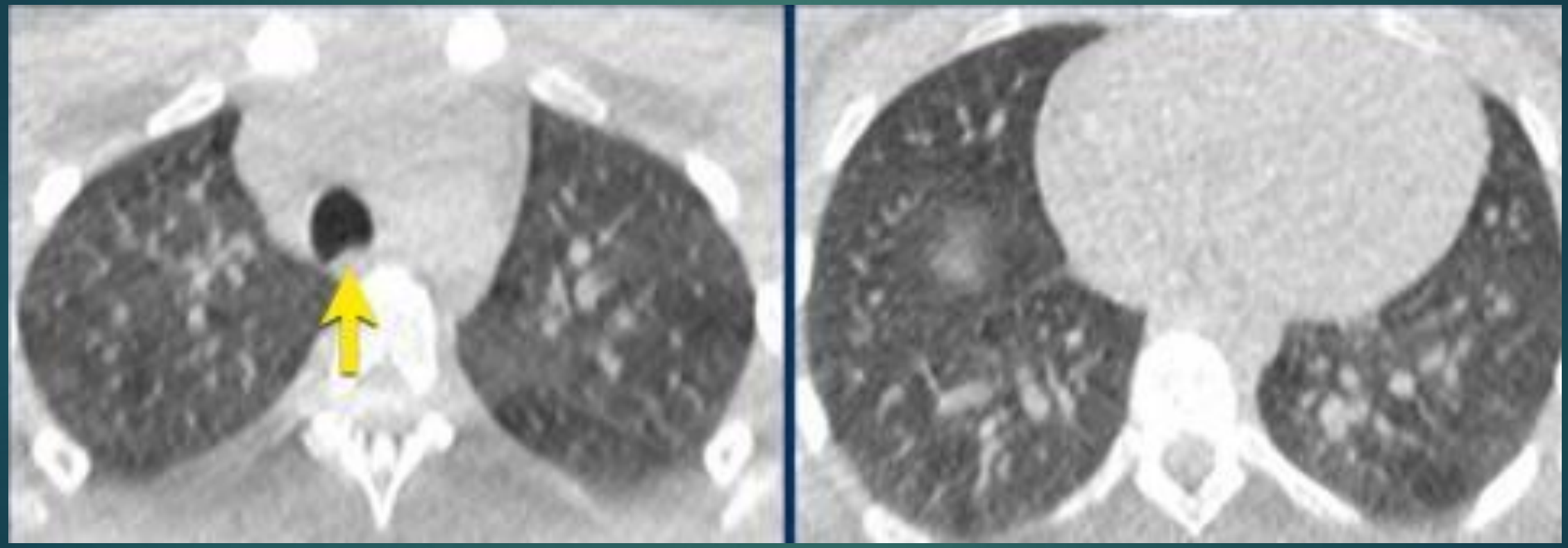


COVID-19 Differential Diagnosis

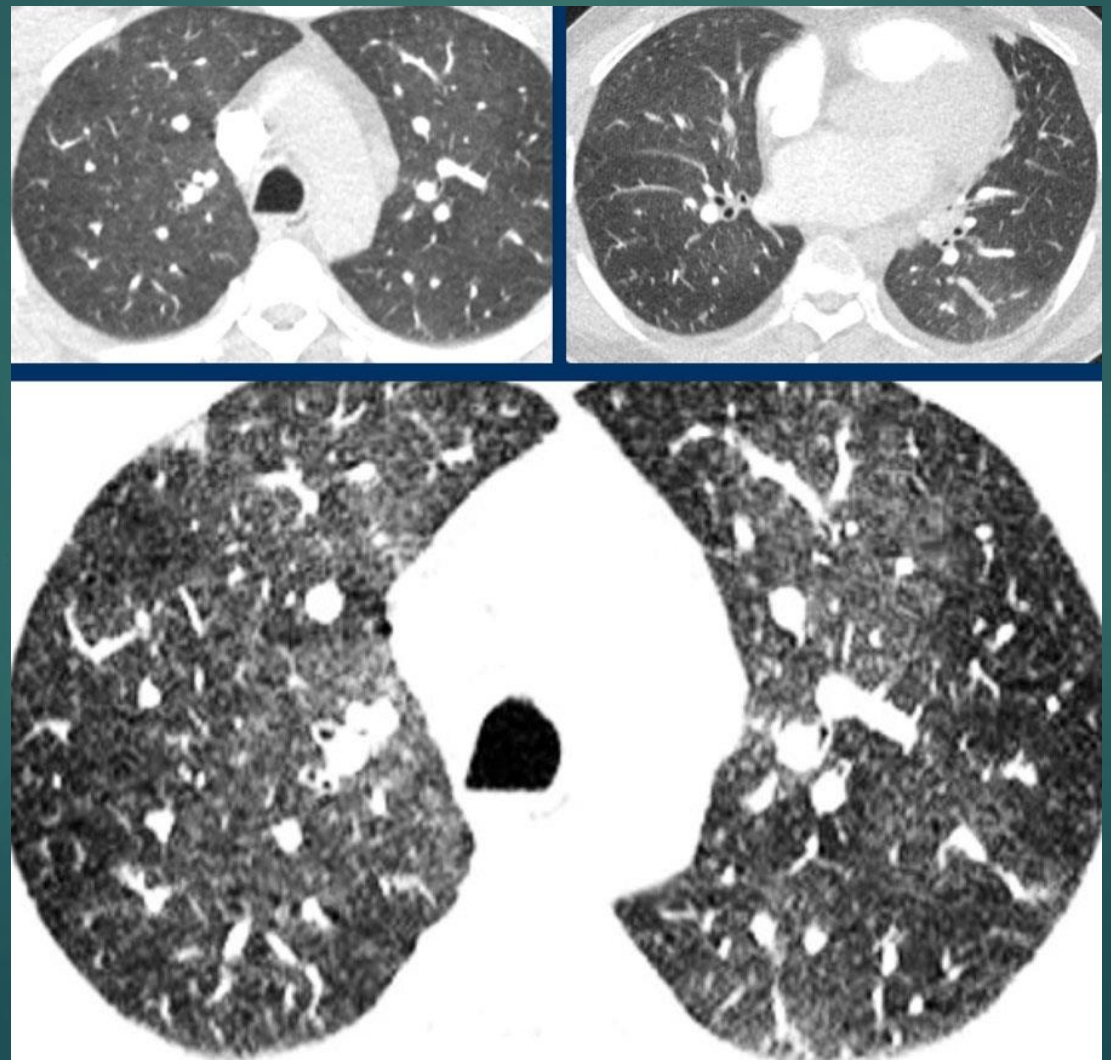
COVID-19 Ground glass mimickers

- **Inadequate inspiration**
- **Mosaic attenuation**
  - hypoperfusion in pulmonary emboli
  - bronchopathy with secondary vasoconstriction in:
    - asthma
    - bronchiolitis obliterans
    - hypersensitivity pneumonitis

Inadequate inspiration



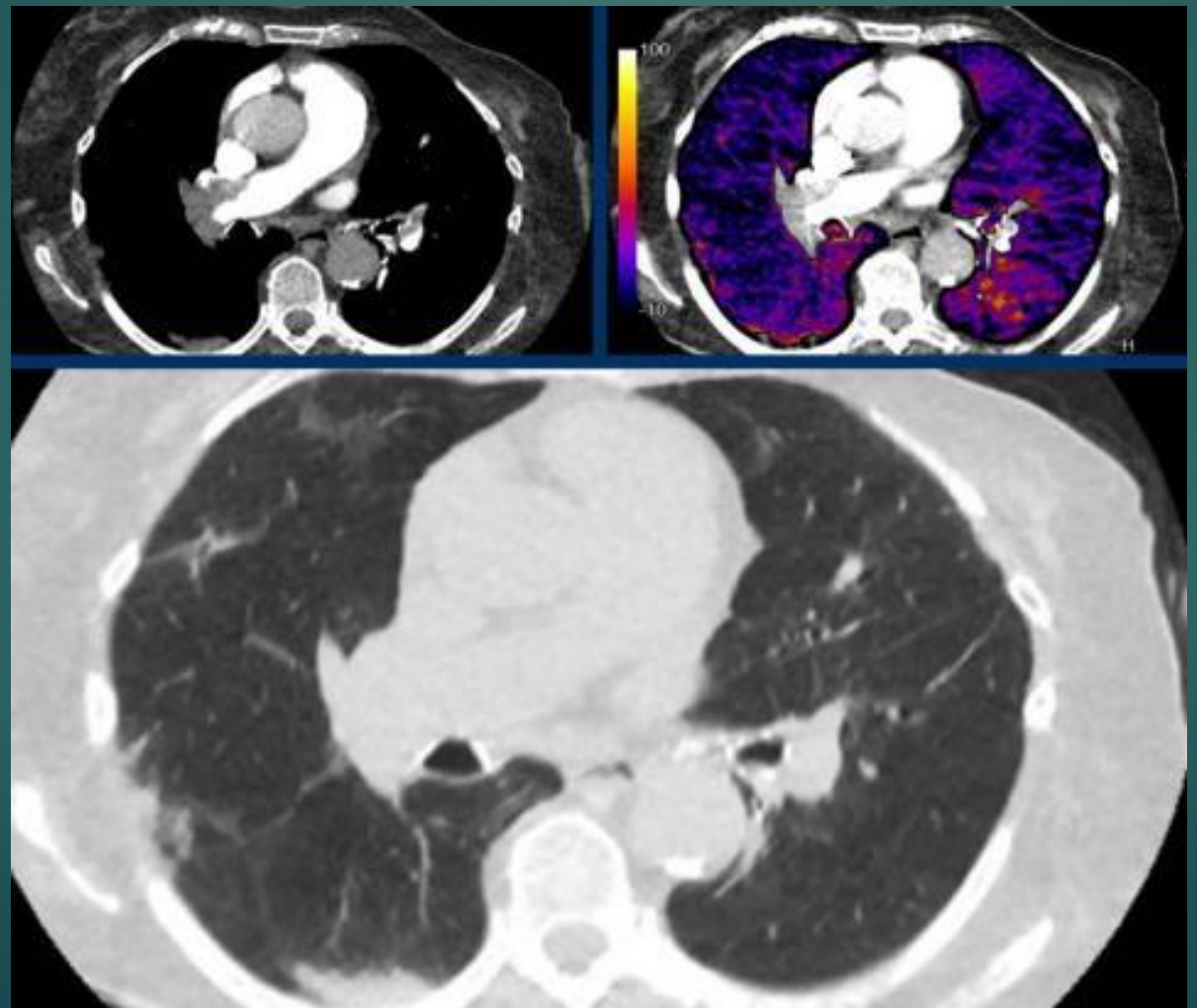
Mosaic attenuation



Pulmonary cardiogenic edema

- ground-glass opacities are typically more centrally distributed with sparing of the peripheral parenchyma
- Accompanying signs suggestive of cardiogenic edema:
- Interlobular septal thickening
- Diiffuse vascular enlargement
- Lymph node enlargement
- Structural cardiac pathology
- Pleural fluid
- Clinical presentation of the patient

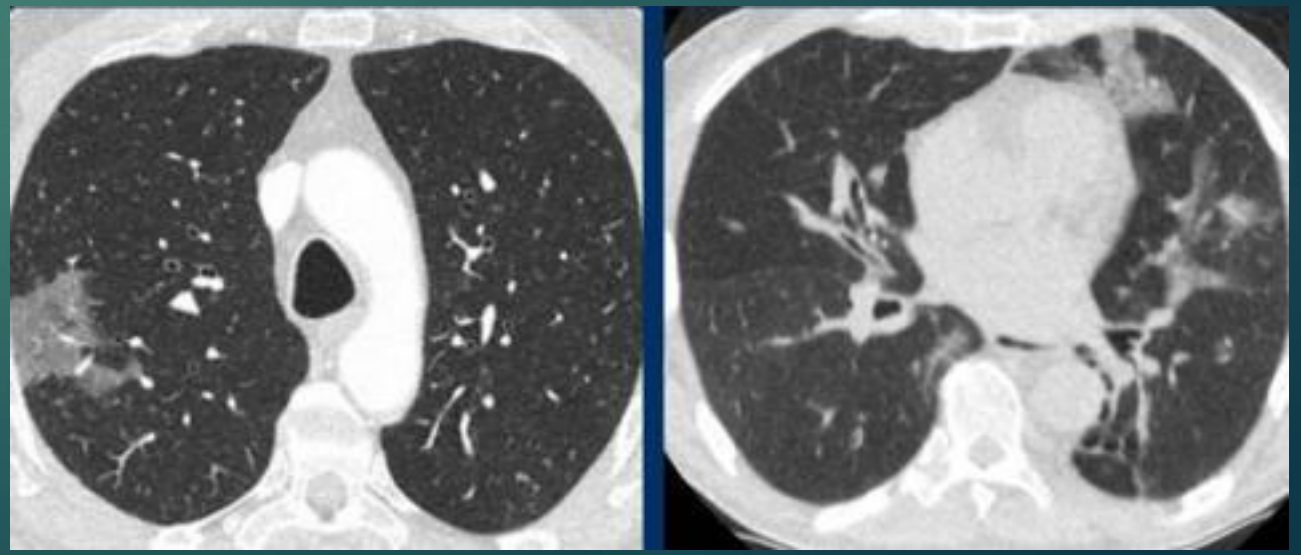
Pulmonary infarctions



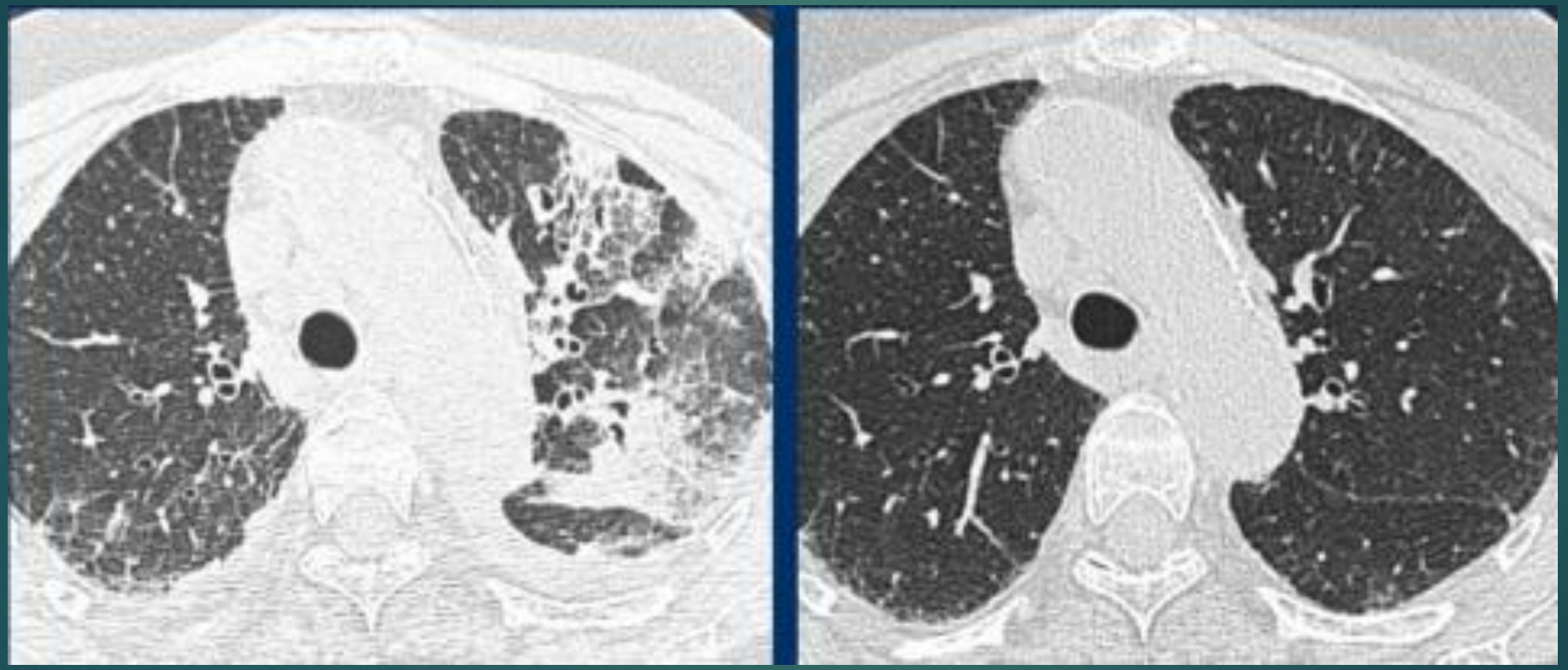
Alveolar hemorrhage

Eosinophilic pneumonia

- Clinical presentation with slow onset of symptoms
- Association with asthma
- Eosinophilia in bronchioalveolar lavage and blood samples
- Mainly upper lung zone distribution

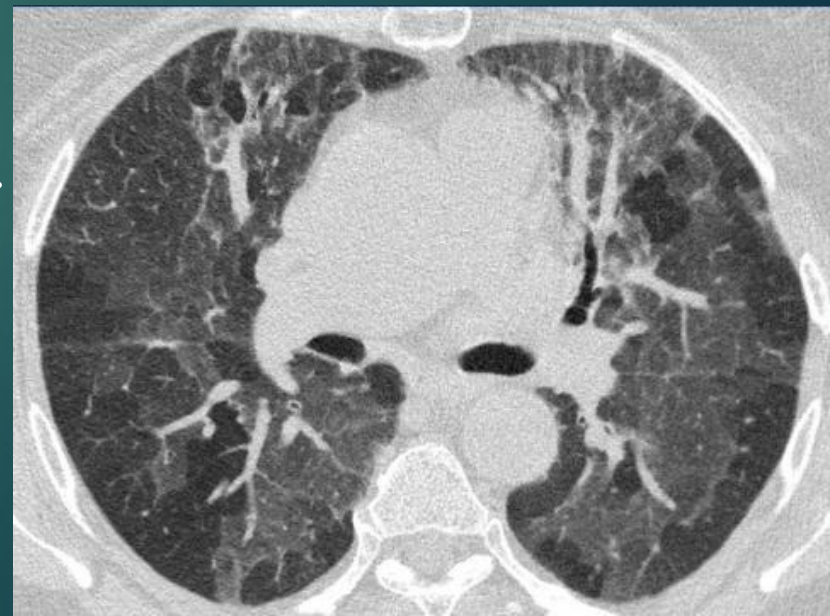


Drug-induced pneumonitis



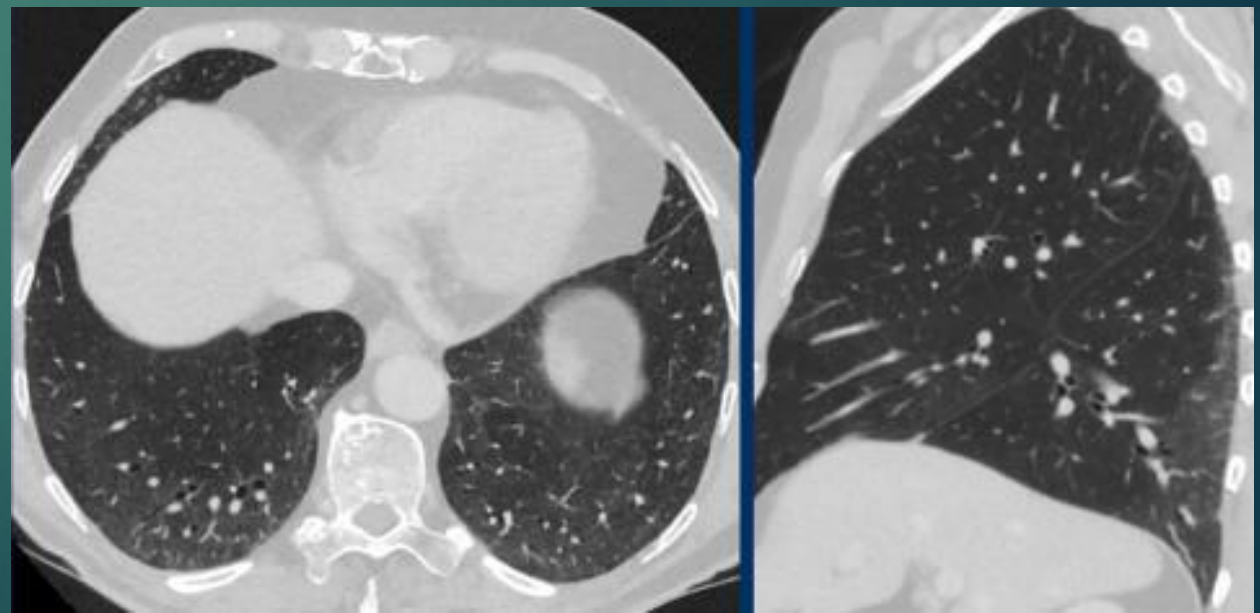
Hypersensitivity pneumonitis

- Centrilobular nodules
- Headcheese sign" with a mixture of lobules with ground glass, normal density parenchyma, and air trapping
- Clinical presentation with a history of exposure to sometimes unknown antigens
- HP patients can develop fibrotic changes in a later stage.



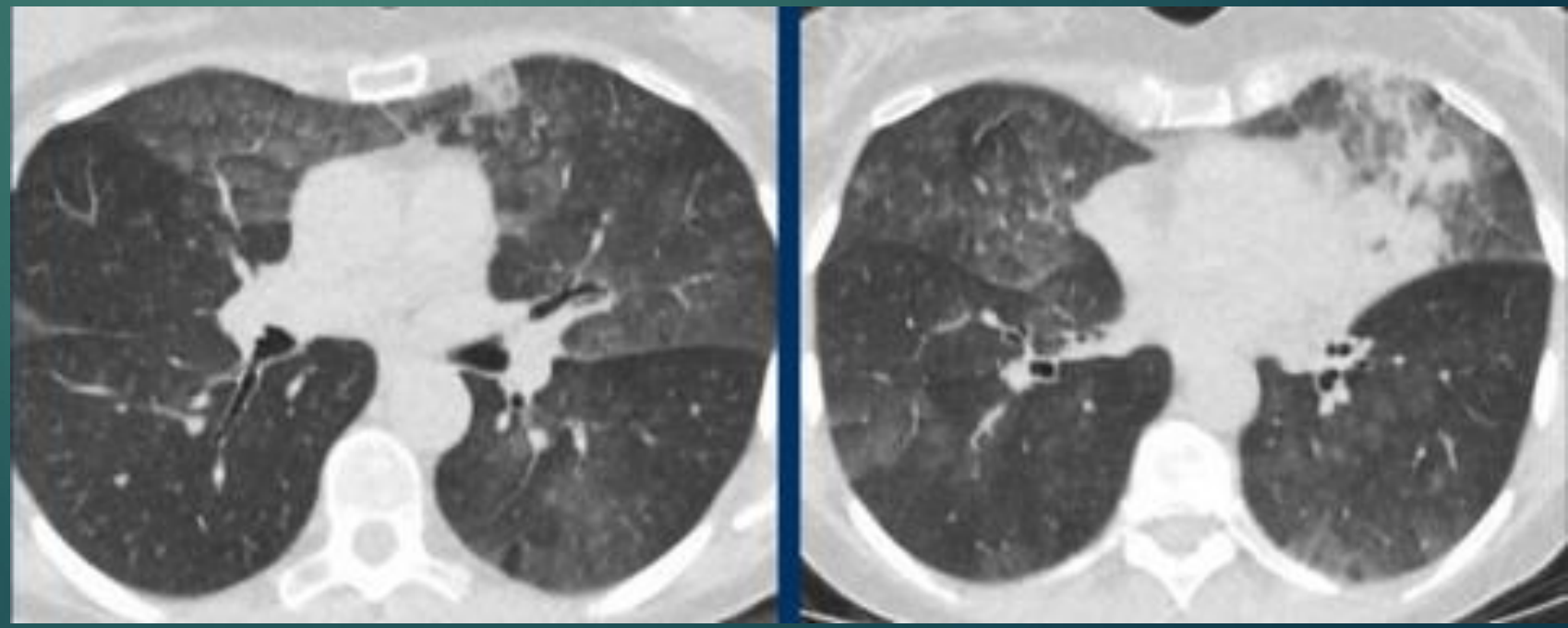
Nonspecific interstitial pneumonia

- The opacities are not demarcated
- No confirmatory patterns of COVID-19
- Mostly stable over time
- Clinical presentation is distinct from infection.



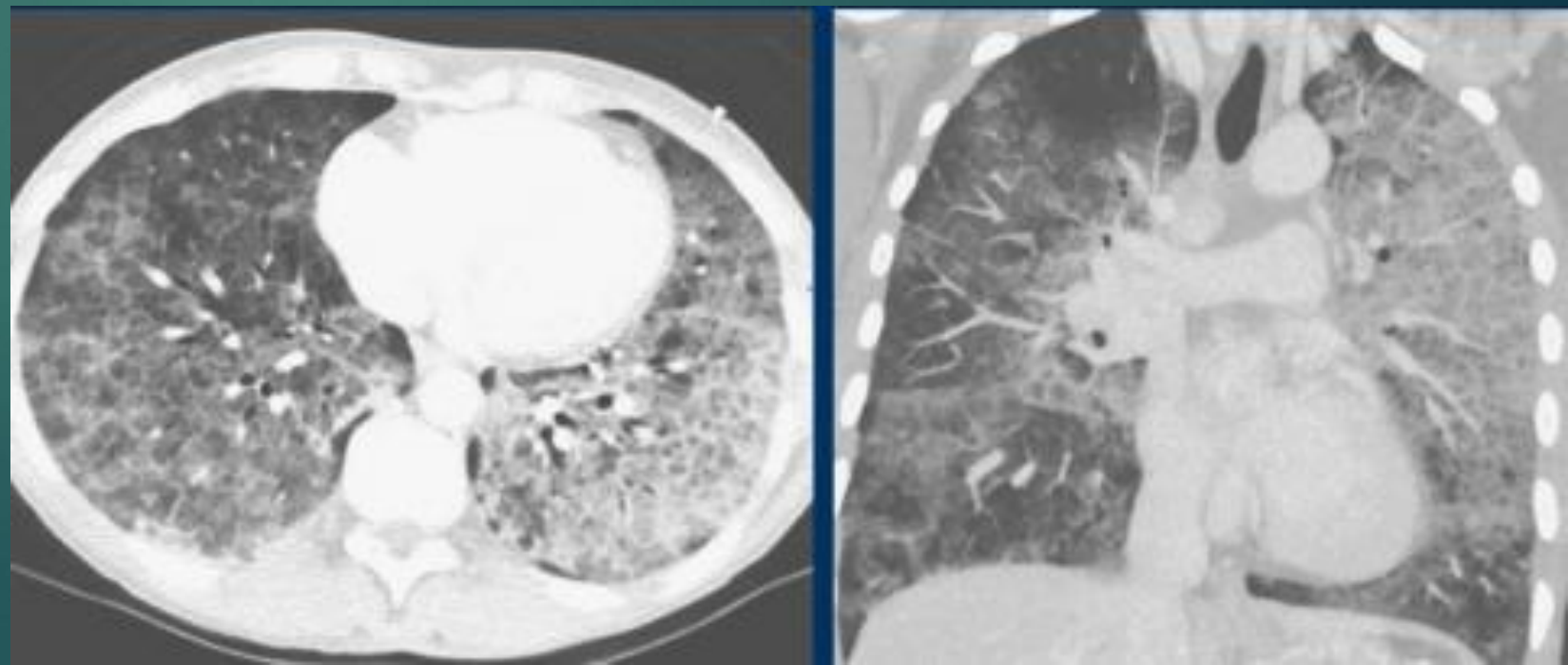
Adenocarcinoma

- Multifocal adenocarcinoma can present as bilateral ground glass opacities,
- a more geographical and diffuse distribution.



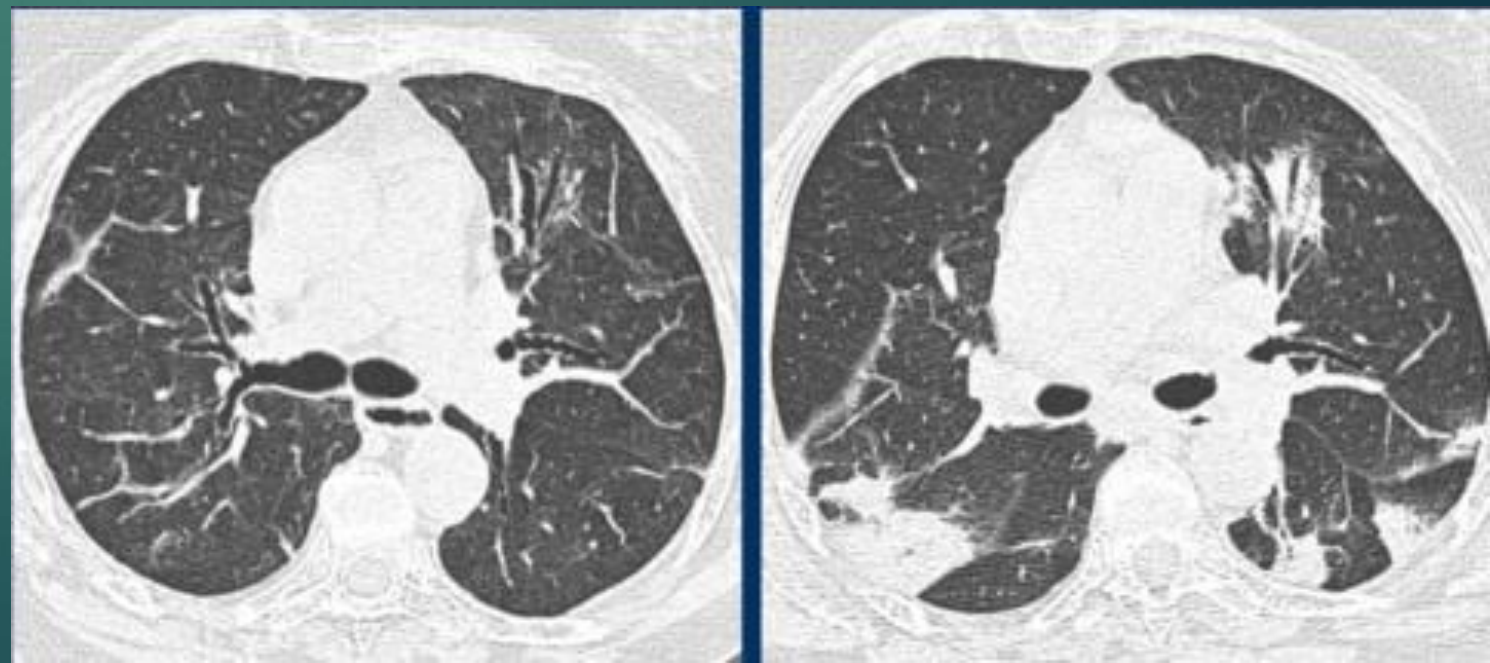
Alveolar proteinosis

- Crazy paving in alveolar proteinosis is much more diffuse than in COVID-19, with incidental lobular or geographic sparing, and is frequently disproportional with severity of complaints.



Organizing pneumonia

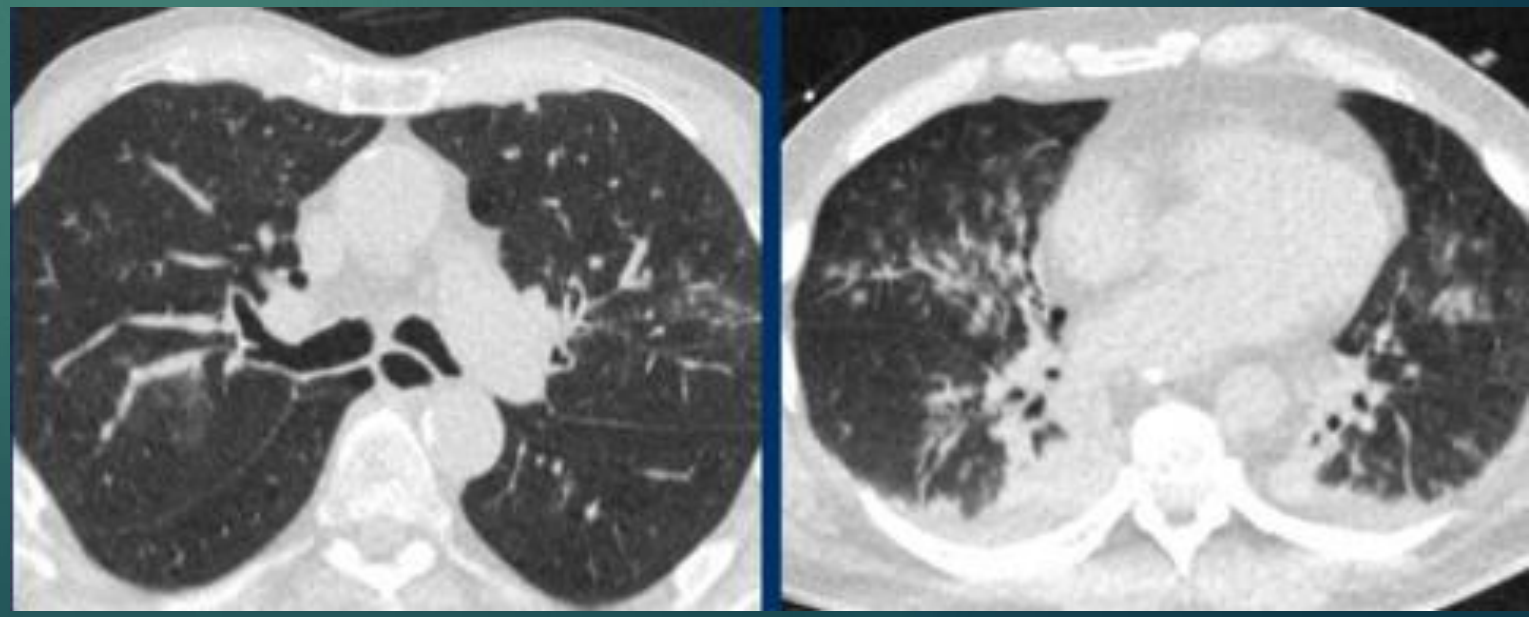
- Patterns compatible with organizing pneumonia commonly occur in COVID-19.
- It is regarded as a confirmatory pattern, reflecting a later stage in the temporal evolution of the parenchymal abnormalities.



Influenza pneumonia

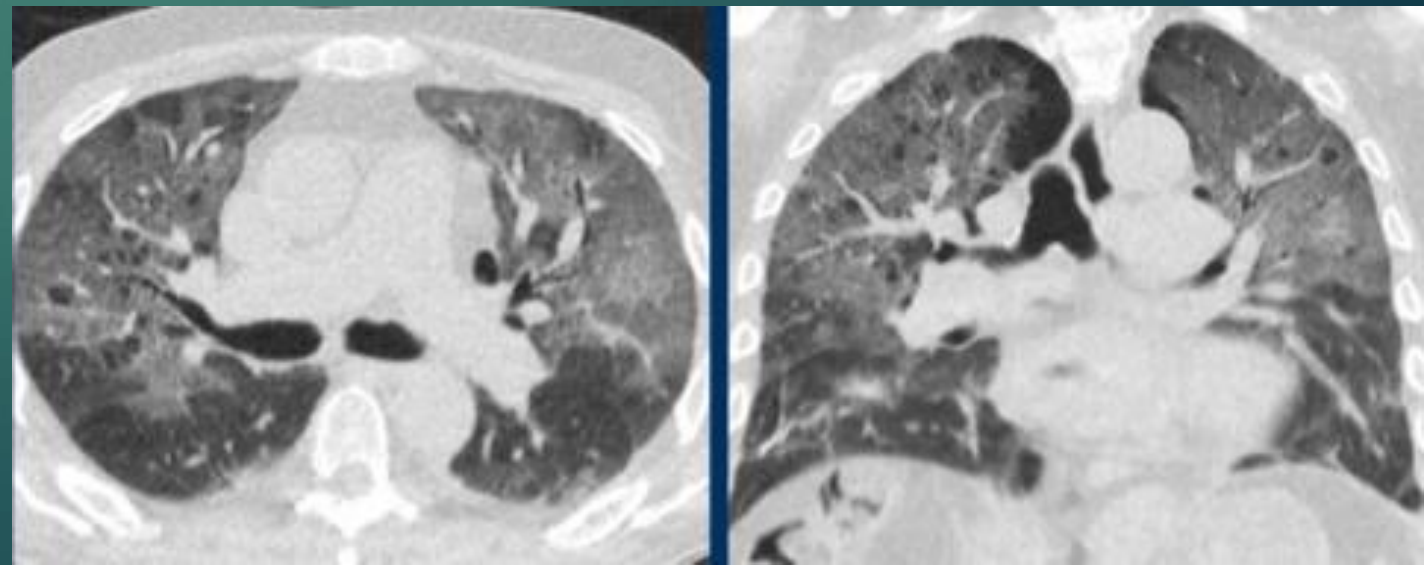
- Influenza virus infection can result in bilateral ground-glass opacities, consolidations and crazy paving that appear similar to COVID-19.
- Typical features of influenza are:

- Mucoid airway impaction
- Linear opacities
- Central distribution



Pneumocystis pneumonia

- Pneumocystis pneumonia also causes bilateral ground-glass and in later stages consolidations with or without crazy paving.
- However, this frequently occurs in a more central distribution than in COVID-19, and only in immunocompromised patients.
- PCP is furthermore associated with pulmonary cysts and spontaneous pneumothoraces, although pneumothoraces and bullae also present in a small minority of hospitalized COVID-19 patients.



Adult respiratory distress syndrome

- Diffuse alveolar damage can also show peripheral ground-glass, consolidations and crazy paving, which can be similar to the alveolar damage in patients with COVID-19 (left), but also more gravity dependent reflecting permeability edema (right).
- ARDS can only occur in the appropriate setting, such as in a postoperative situation or in case of prolonged mechanical ventilation.

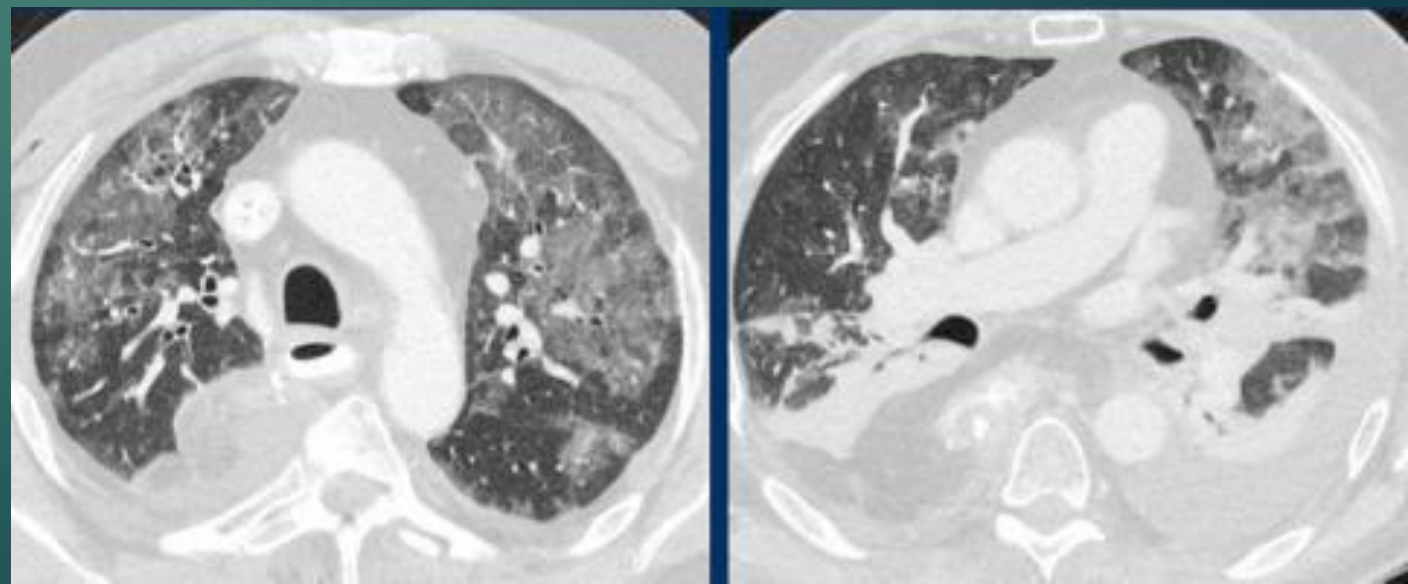


Table 3: Differential diagnosis of CT ground glass opacities in the COVID-19 era

Diagnosis	Association	Location of Parenchymal abnormality	Small nodules	Cavitation	Subpleural sparing	Lymphadeno -pathy	Pleural effusion	Other findings
COVID-19	Signs and symptoms of infection, loss of sense of taste or smell, leukopenia, lymphopenia	Bilateral, basal and subpleural predominant	-	-	-	-	-	
Pulmonary edema	History of heart disease	Perihilar	-	-	-	++	+	Imaging findings of heart disease - cardiomegaly, Coronary calcifications
Bacterial pneumonias	Signs and symptoms of infection	No specific	-	+	-	++	+	
Viral pneumonias	Signs and symptoms of infection; some patients may be immunosuppressed	No specific	-	-	-	+	+/-	No specific differentiating features
Aspiration	Dilated Esophagus Neuromuscular disorders Anatomical abnormality, e.g., tracheo-esophageal fistula, head and neck malignancy etc.	Dependent	Dependent centrilobular and Tree-in-bud ++	+/-	-	+/-	+/-	Air-way opacification
Pneumocystis carinii pneumonia	Immunosuppression CD4 <200	Upper	-	-	-	-	-	Cysts +/- Spontaneous pneumothorax possible
Nonspecific Interstitial pneumonitis	Connective tissue disorder or other predisposing condition	Subpleural Lower lung zone predominant Subpleural sparing	-	-	++	+/-	-	Features of fibrosis-traction bronchiectasis, architectural distortion Honeycombing +/-
Cryptogenic organizing pneumonia	Predisposing conditions +/-	Subpleural, peri-bronchovascular	-	-	-	-	-	Perilobular thickening Migratory opacities Prior episodes
Hypersensitivity pneumonitis	Exposure history in 70%	Upper lung zone predominant	Upper lung zone predominant centrilobular ground glass nodules	-	-	-	-	Air trapping on expiratory CT images Mosaic attenuation Upper and/or mid lung predominant fibrosis +/-
Drug induced toxicity	History of recent drug exposure	No zonal distribution	-	-	-	-	-	No specific differentiating imaging features
Desquamative interstitial pneumonia	Smoking history (in 90%)	Lower lung zone	-	-	-	-	-	Small cystic spaces +/-.
Diffuse alveolar hemorrhage	History of hemoptysis Renal disease Other systemic illness	No specific	-	-	-	-	-	H/o prior episodes may be present Migratory opacities
Pulmonary alveolar proteinosis	Tobacco use Subacute symptom onset H/o prior episodes	No specific	-	-	-	-	-	Pronounced crazy-paving pattern often with lobular or geographic sparing.
e-cigarette or vaping product use associated lung injury	History of vaping (New or increased use history may be helpful)	No specific	Centrilobular and upper lung zone predominant nodularity	-	++	-	-	Subpleural sparing
Chronic Eosinophilic Pneumonia	Asthma Subacute presentation	Upper lung zone	-	-	-	-	-	Crazy paving +/-

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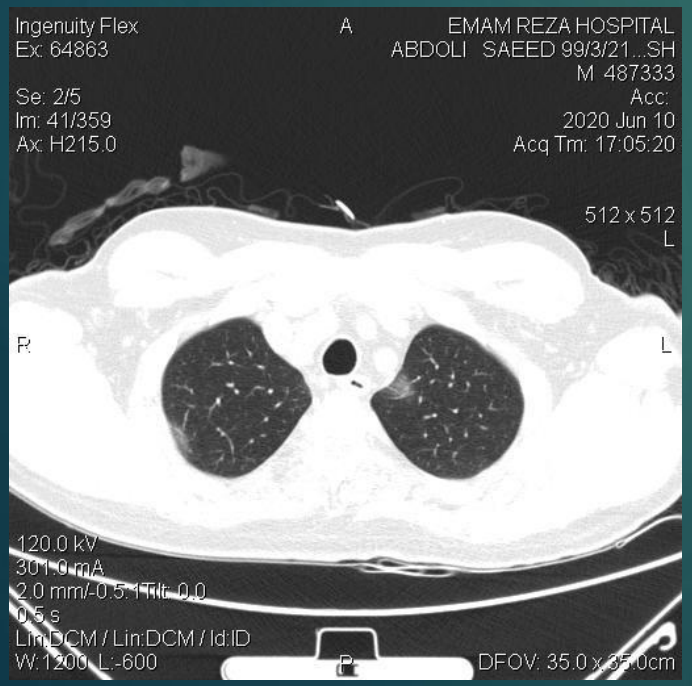
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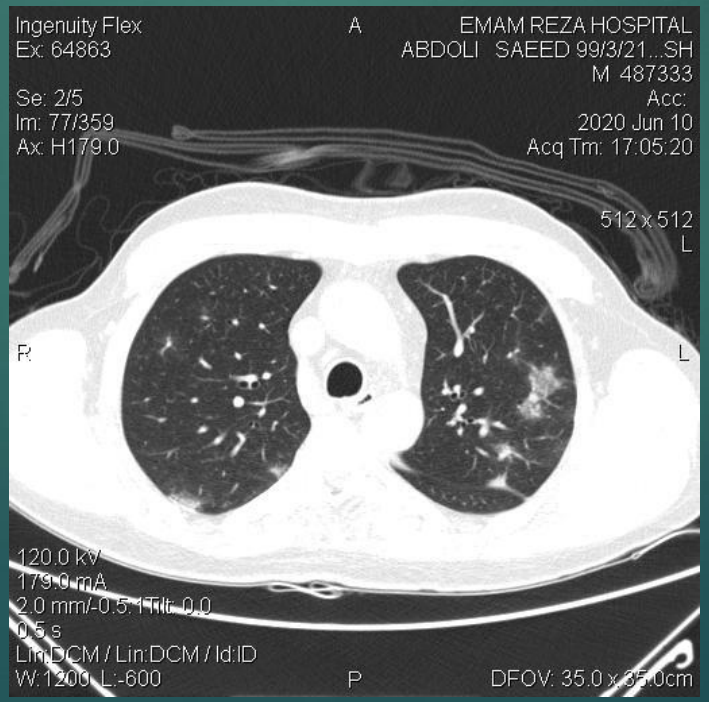
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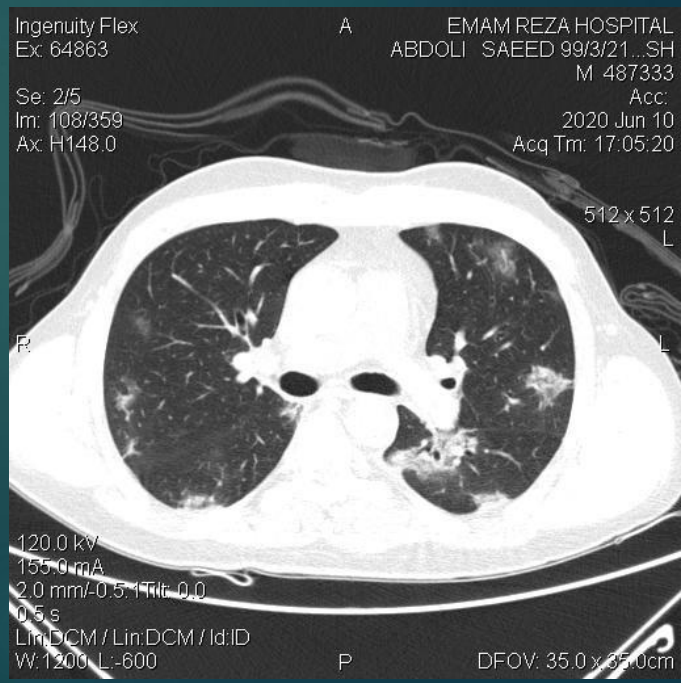
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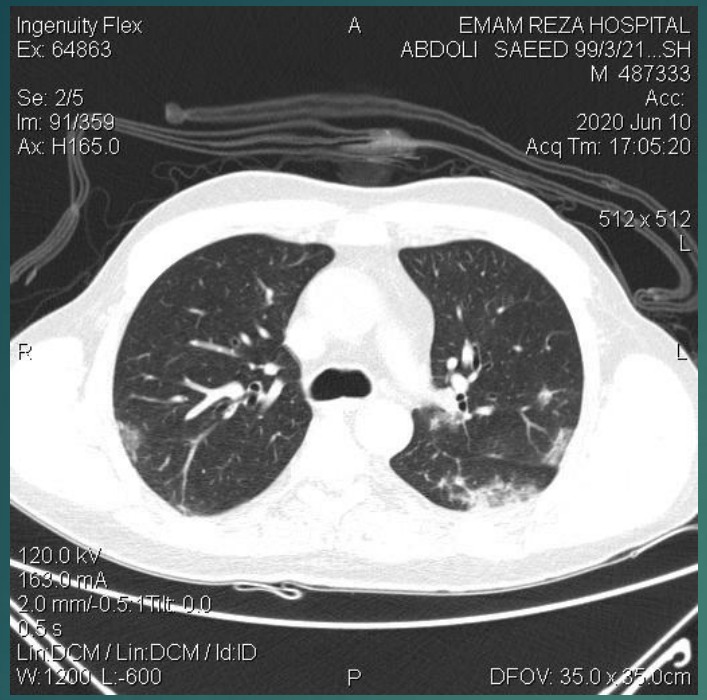
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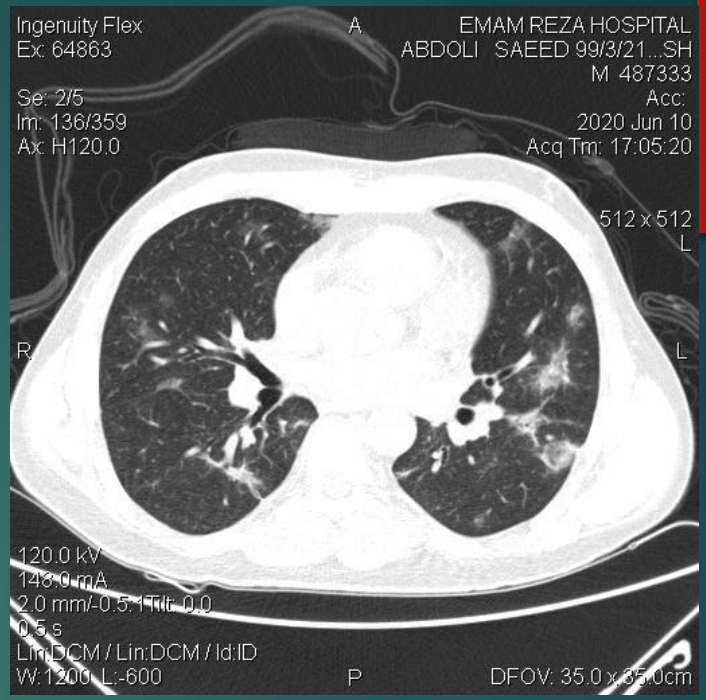
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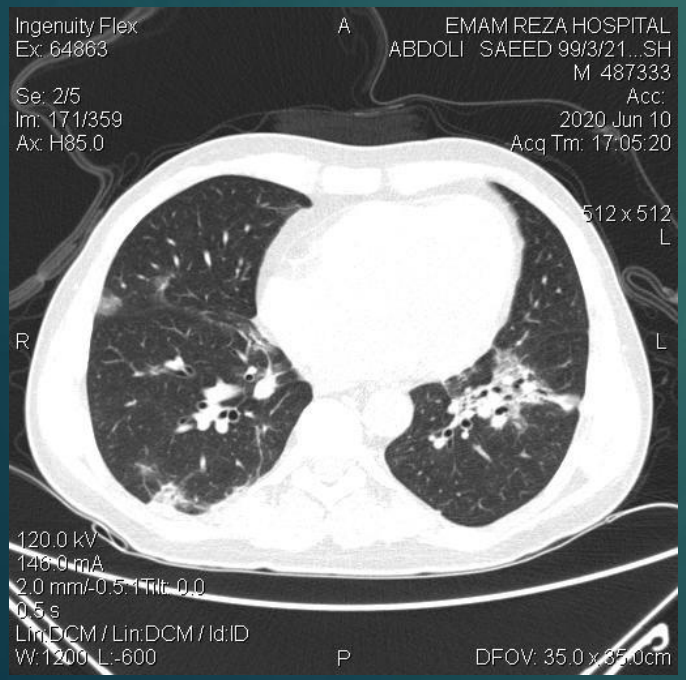
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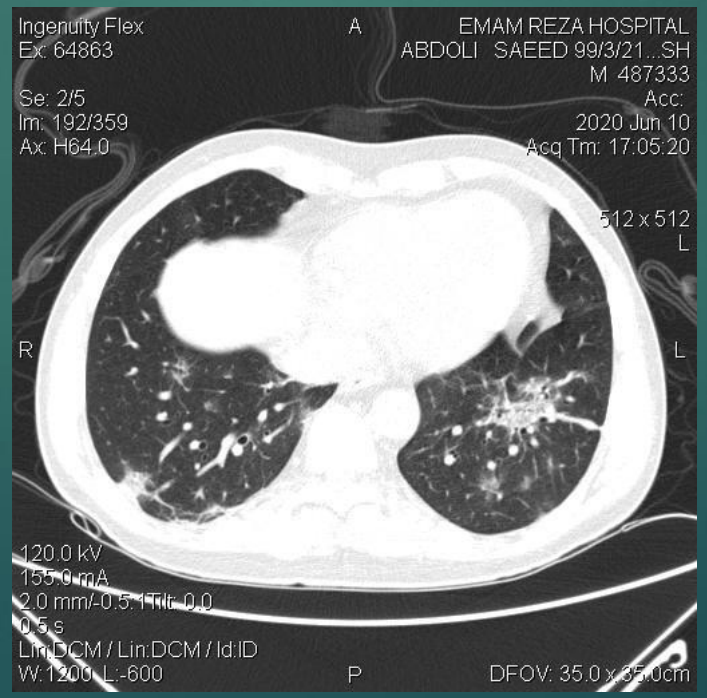
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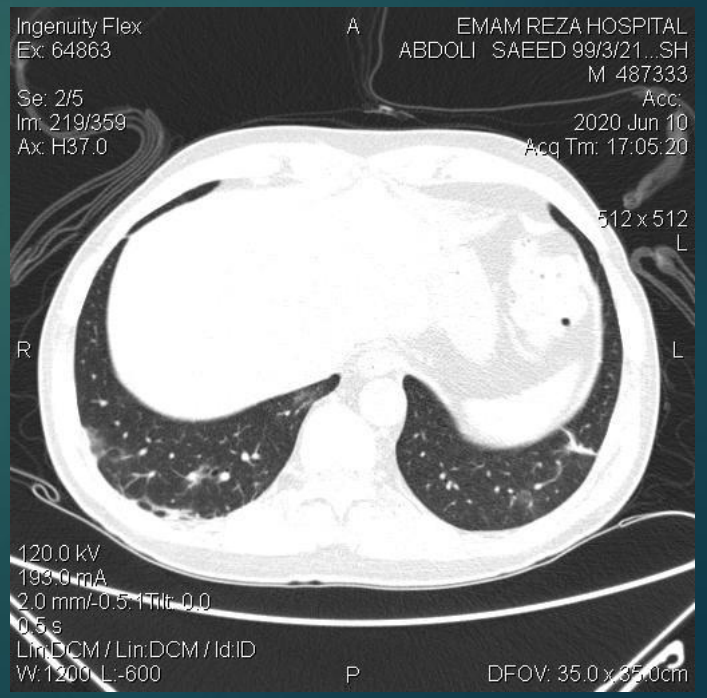
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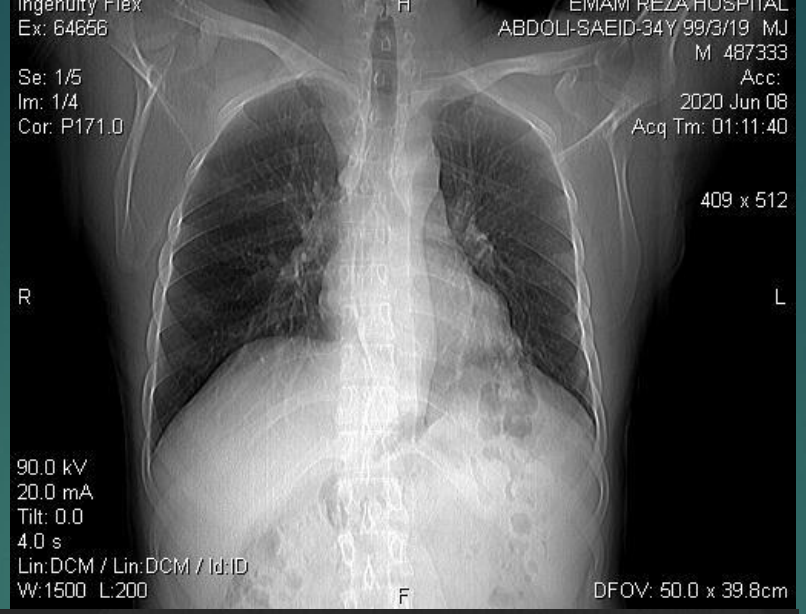
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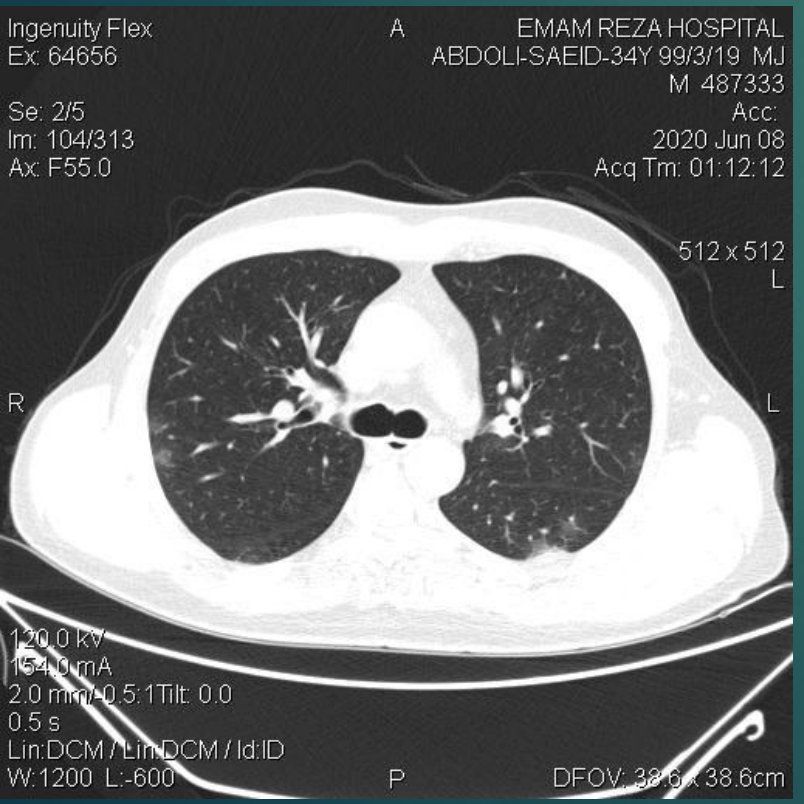
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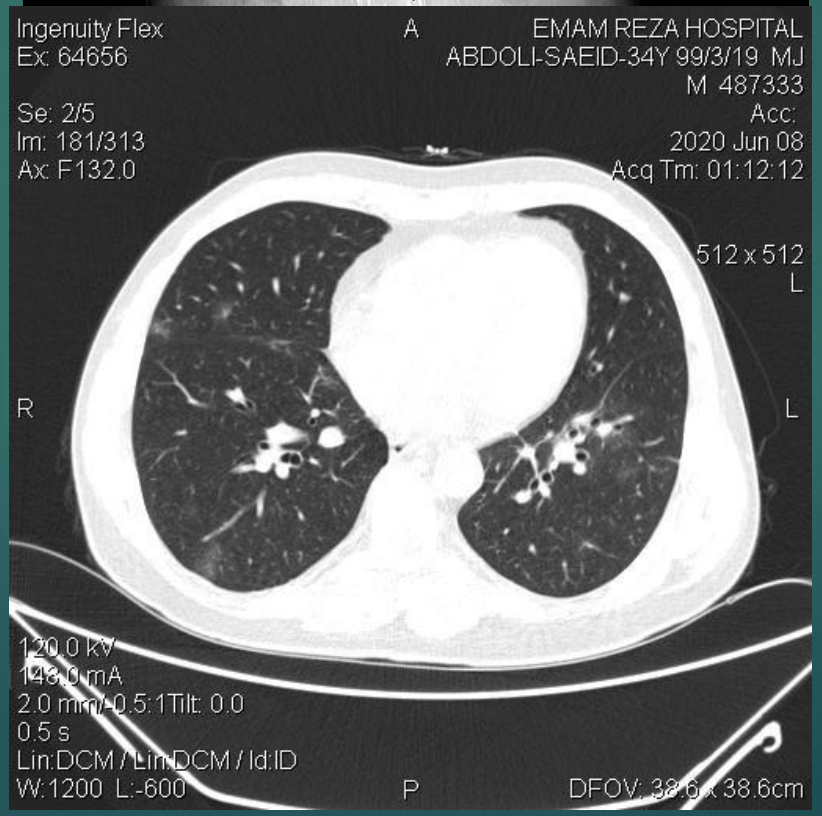
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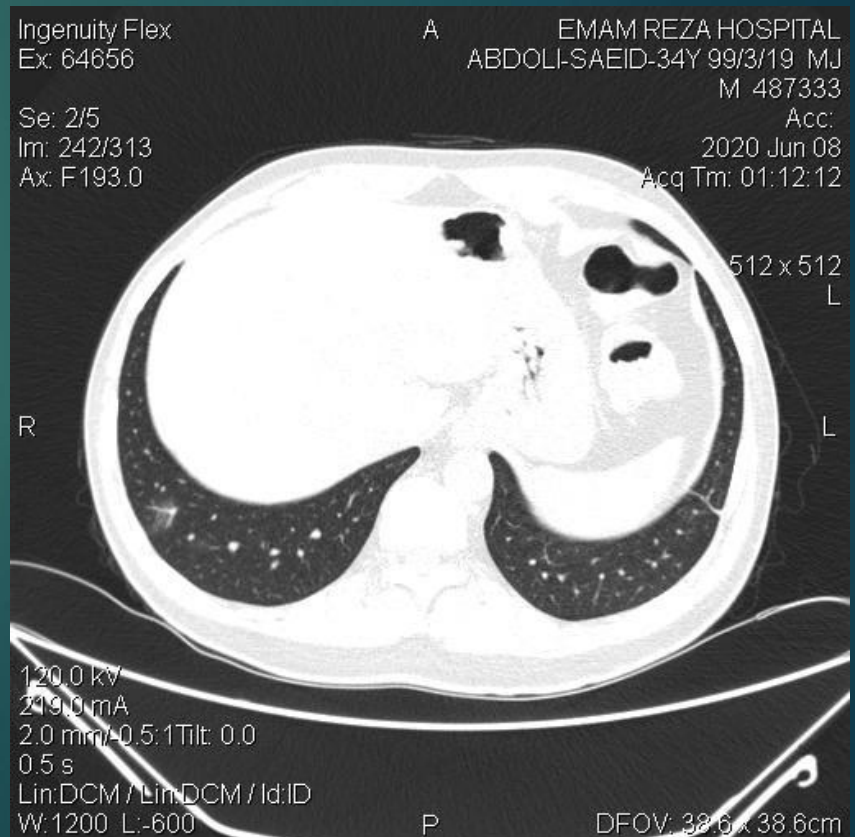
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