



March 11, 2020

Imaging of COVID-19

Benjamin W. Strong, MD

Juan Carlos Batlle, MD, MBA



Disclosures -

Katie Lozano, MD

- I have no relevant financial relationships to disclose or conflicts of interest to resolve.
- I will not be discussing any unapproved or off-label, experimental or investigational use of a drug or device.

Greg Klisch, MD

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Guido Santacana Lafitte, MD

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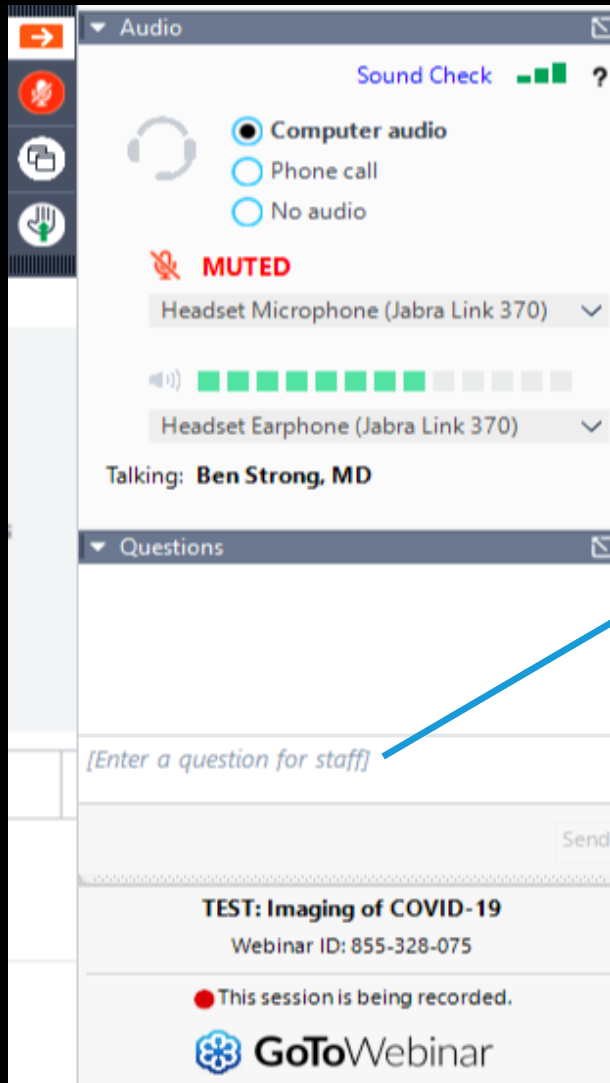
Benjamin W. Strong, MD

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Brian Schmidt

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Imaging COVID-19
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Thanks to:

Katie Lozano, MD (vRad Radiologist)

Greg Klisch, MD (vRad Radiologist)

Guido Santacana Lafitte, MD (vRad Radiologist)



“Chest CT is a vital component in the diagnostic algorithm for patients with suspected COVID-19.” (2)

“Chest CT has a high sensitivity for diagnosis of COVID-19. Chest CT may be considered as a primary tool for the current COVID-19 detection in epidemic areas.” (3)

“In a series of 51 patients with chest CT and RT-PCR assay performed within 3 days, the sensitivity of CT for COVID-19 infection was 98% compared to RT-PCR sensitivity of 71% ($p < .001$).” (4)

“With analysis of serial RT-PCR assays and CT scans, 60% to 93% of patients had initial positive chest CT consistent with COVID-19 before the initial positive RT-PCR results.” (3)

“The National Health Commission of the People’s Republic of China has encouraged diagnosis based on clinical and chest CT findings alone.” (2)

“In China, the disease epicenter, imaging has been at the forefront of investigation for patients with suspected or confirmed COVID-19 infection. As a result, computed tomography (CT) of the chest has been utilized on an unprecedented scale.” (5)

CT findings and stages:

Stage 1 (early, 0-4 days after onset of initial symptom): Ground glass opacity (GGO), usually peripheral, can be unilateral or bilateral). Lower lobe predominance (6). Often bilateral with rounded morphology (2).

Stage 2 (progressive, 5-8 days after onset of initial symptom): Crazy paving. Increased ground glass opacities, more diffuse, with some consolidation. Lower lobe predominance (6).

Stage 3 (peak, 9-13 days after onset of initial symptom, most severe at 10 days): Bilateral consolidative opacities, can be peripheral, rounded (6). Reverse halo sign may be seen (2).

Stage 4 (absorption, 14 or more days after onset of the initial symptom): Gradual resolution of consolidation, resolution of crazy paving (6). Improvement begins centrally (2). Of note, Stage 4 is when things go well.

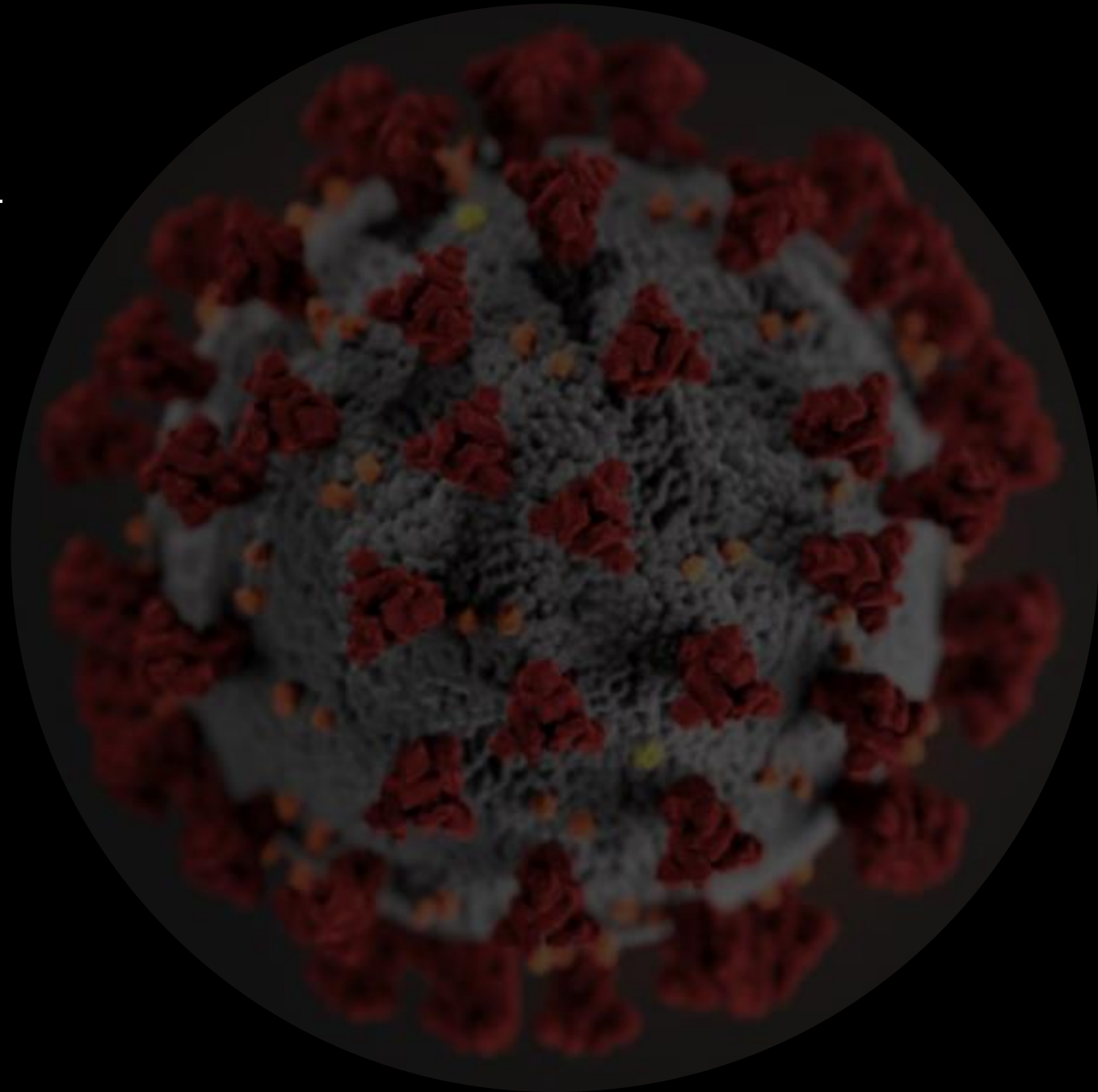
CT findings and stages:

Ground Glass

Crazy Paving

Consolidation

Resolution



Notably absent:

Pulmonary nodules

Cavitation

Lymphadenopathy (2)

Pleural effusions (5)

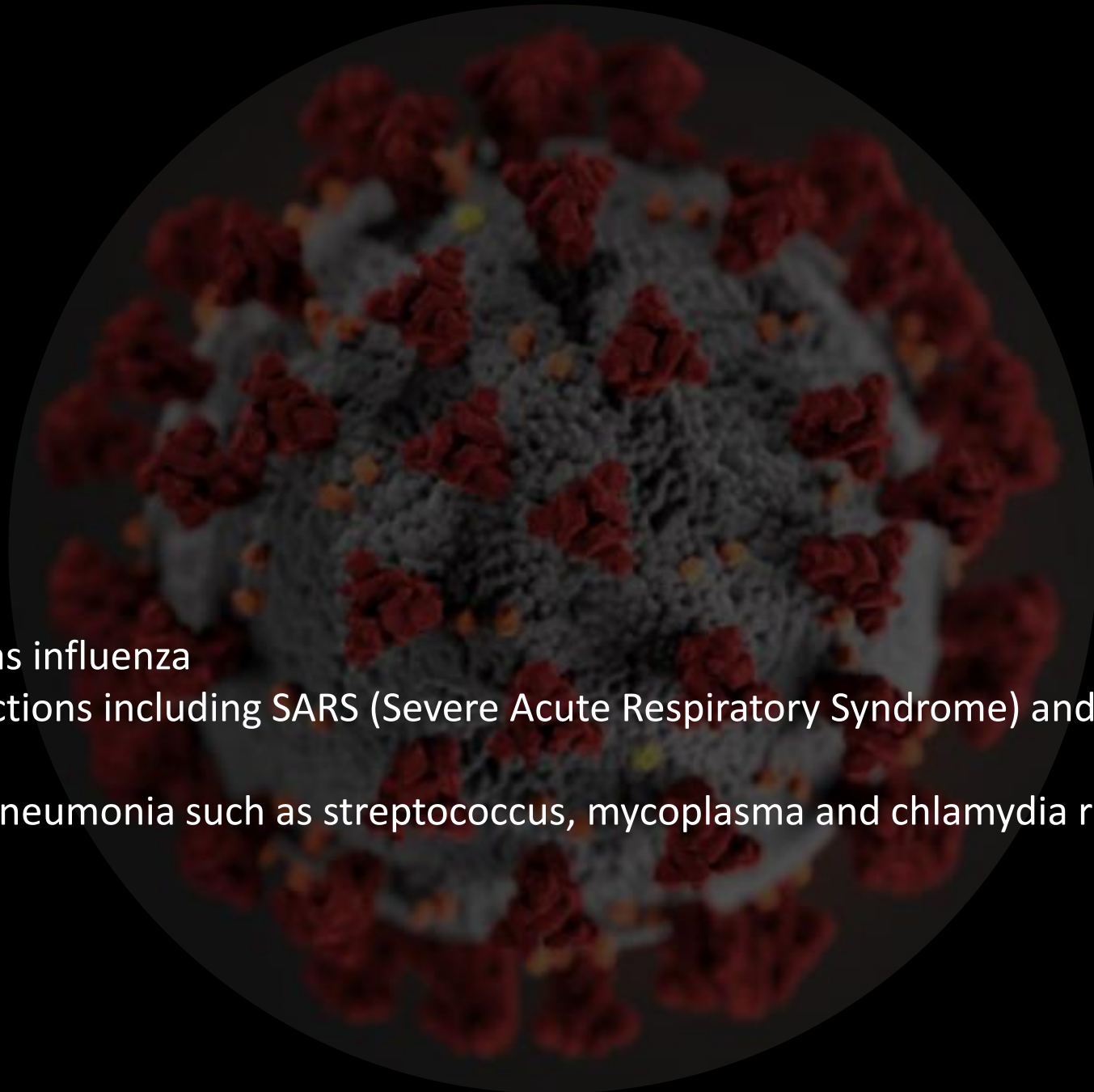
Calcification (7)

Differential:

Viral pneumonia such as influenza

Other coronavirus infections including SARS (Severe Acute Respiratory Syndrome) and MERS (Middle East Respiratory Syndrome)

Community-acquired pneumonia such as streptococcus, mycoplasma and chlamydia related pneumonia (7)



Reporting recommendations (AZ):

- 1) If the requesting physician does not indicate a suspicion for coronavirus in the clinical history or in searching the electronic medical record, the radiologist should report the relevant findings on chest CT and provide a general differential diagnosis such as infection, organizing pneumonia or hemorrhage, but specifically avoid mentioning the possibility of coronavirus.
- 2) If coronavirus is specifically of concern as indicated in the history or medical record, the radiologist should provide an opinion as to the likelihood that the CT findings are consistent with coronavirus, while also including a statement that the CT findings are nonspecific overall. Even if the chest CT is negative, be aware that this does not rule out the possibility that the patient will subsequently develop pulmonary findings of coronavirus, and radiologists should not state that the virus has been excluded based on a negative chest CT scan.



Reporting recommendations (KY):

...asked by the Chief of Infectious Disease to instruct his onsite and remote radiologists to call the ordering clinician whenever they see CT findings that have been described with COVID-19 illness. The clinicians have been instructed to then contact the Chief of ID...



Reporting recommendations (IA):

“All Iowa health care providers and public, private, and hospital clinicians shall immediately report all positive laboratory tests for Coronavirus Disease 2019 (COVID-19) infection to the department prior to patient notification. Reports shall be made by phone (1-800-362-2736).”



COVID-19

Ground Glass

Crazy Paving

COVID-19

Ground Glass

Crazy Paving

Consolidation

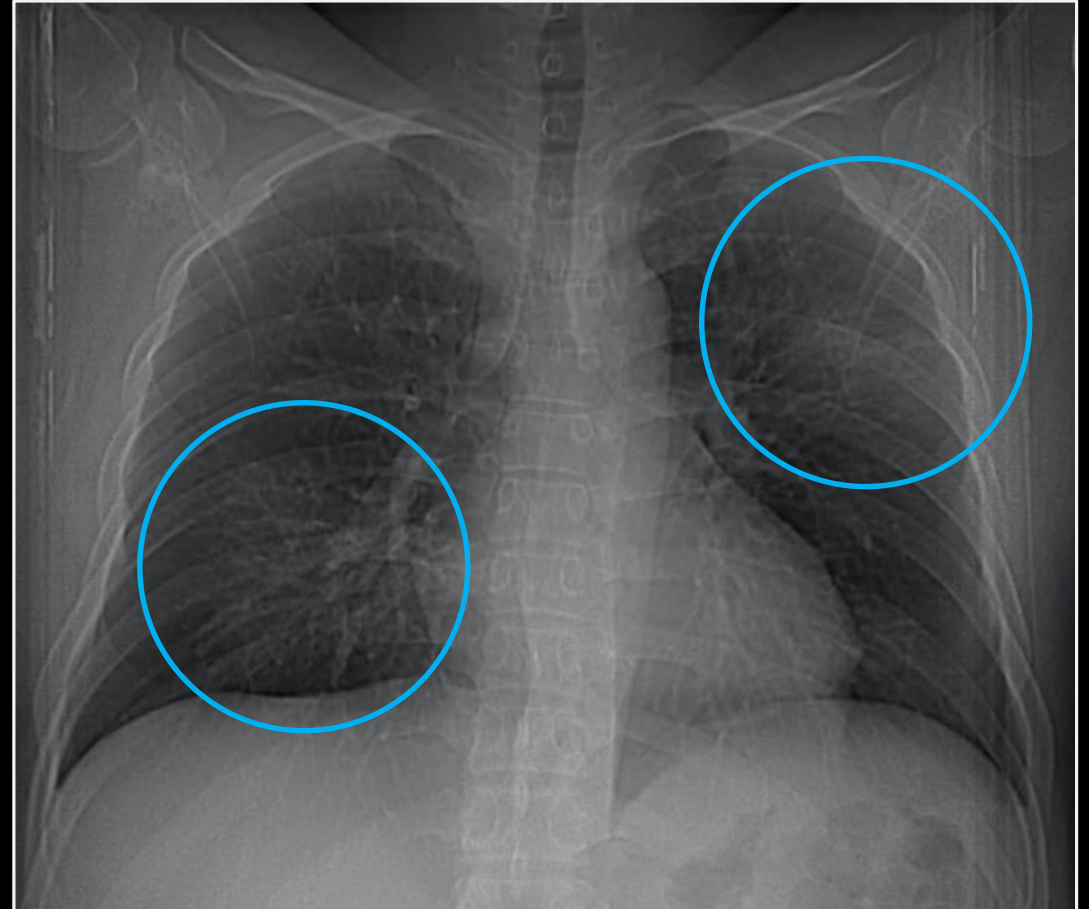
Influenza

Crazy Paving

Consolidation

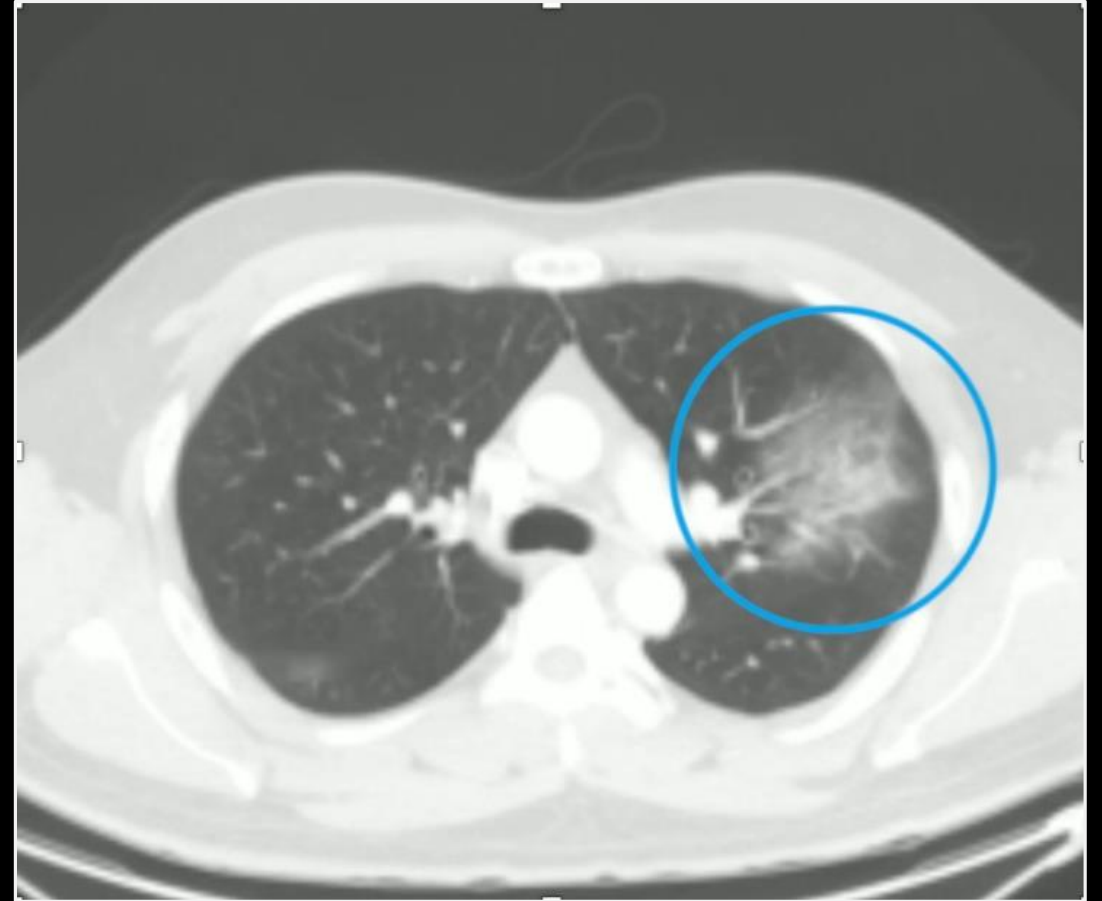
Ground glass opacity
Crazy paving

COVID-19 pneumonia



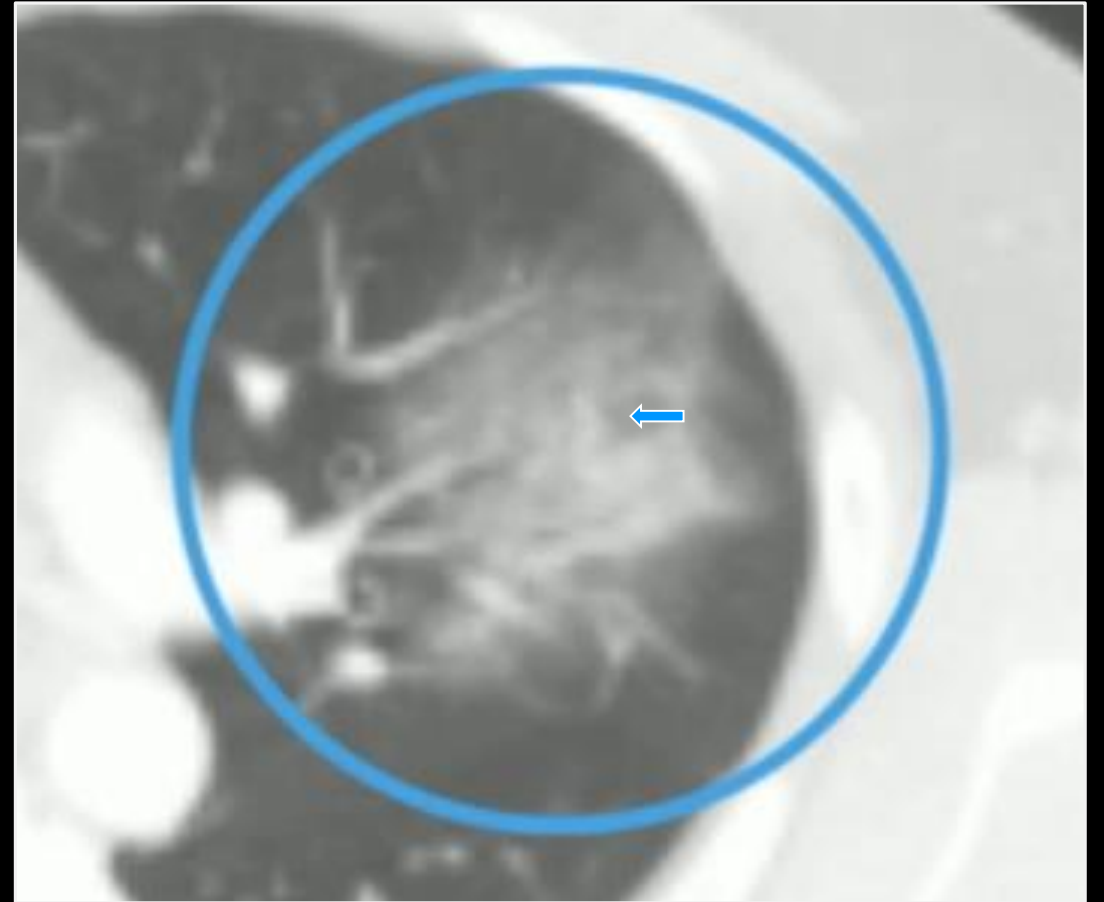
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Crazy paving

COVID-19 pneumonia



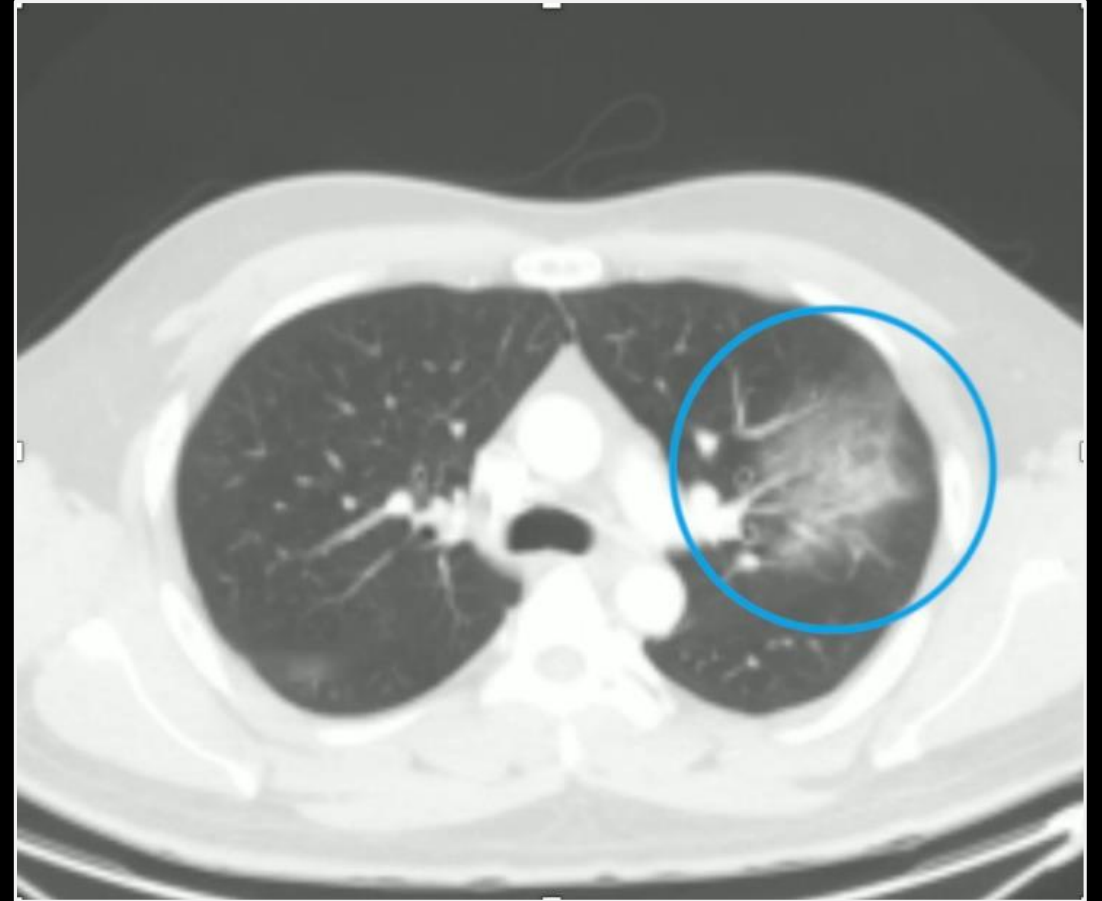
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COVID-19 pneumonia



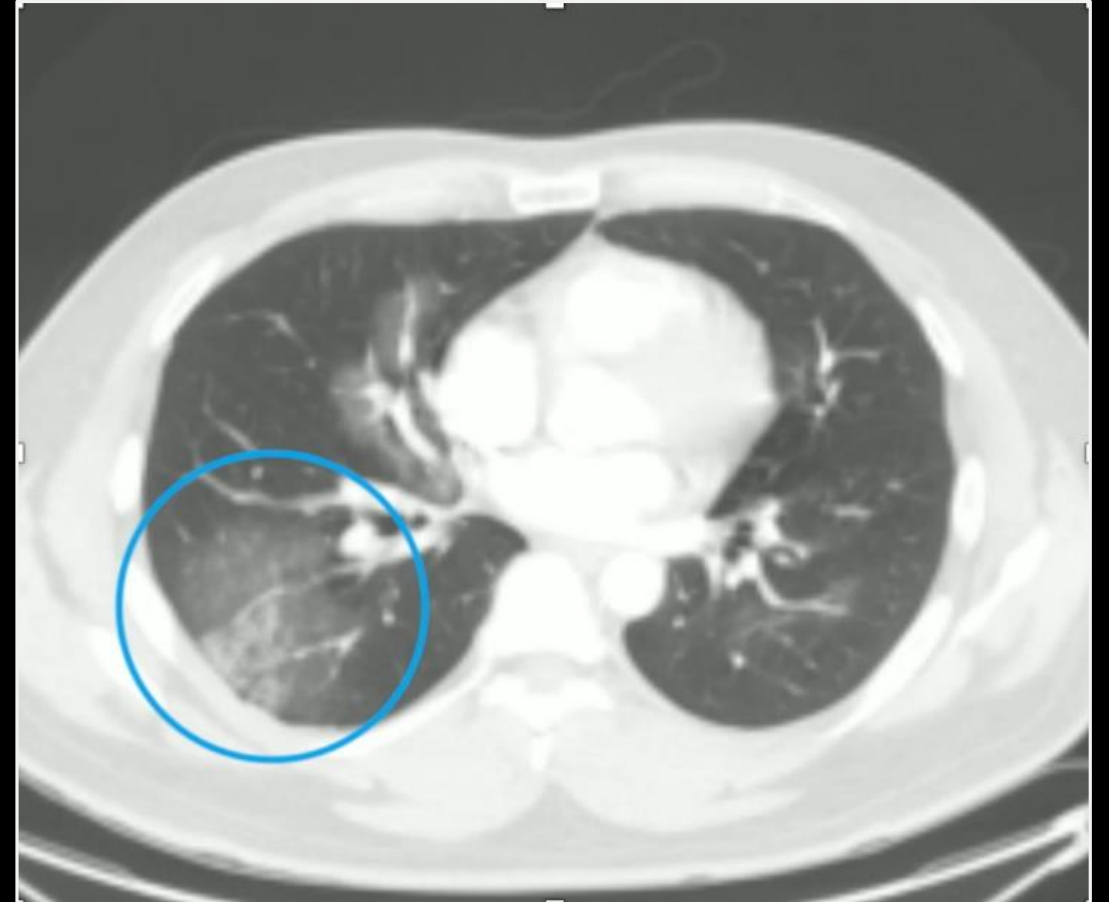
Ground glass opacity
Crazy paving

COVID-19 pneumonia



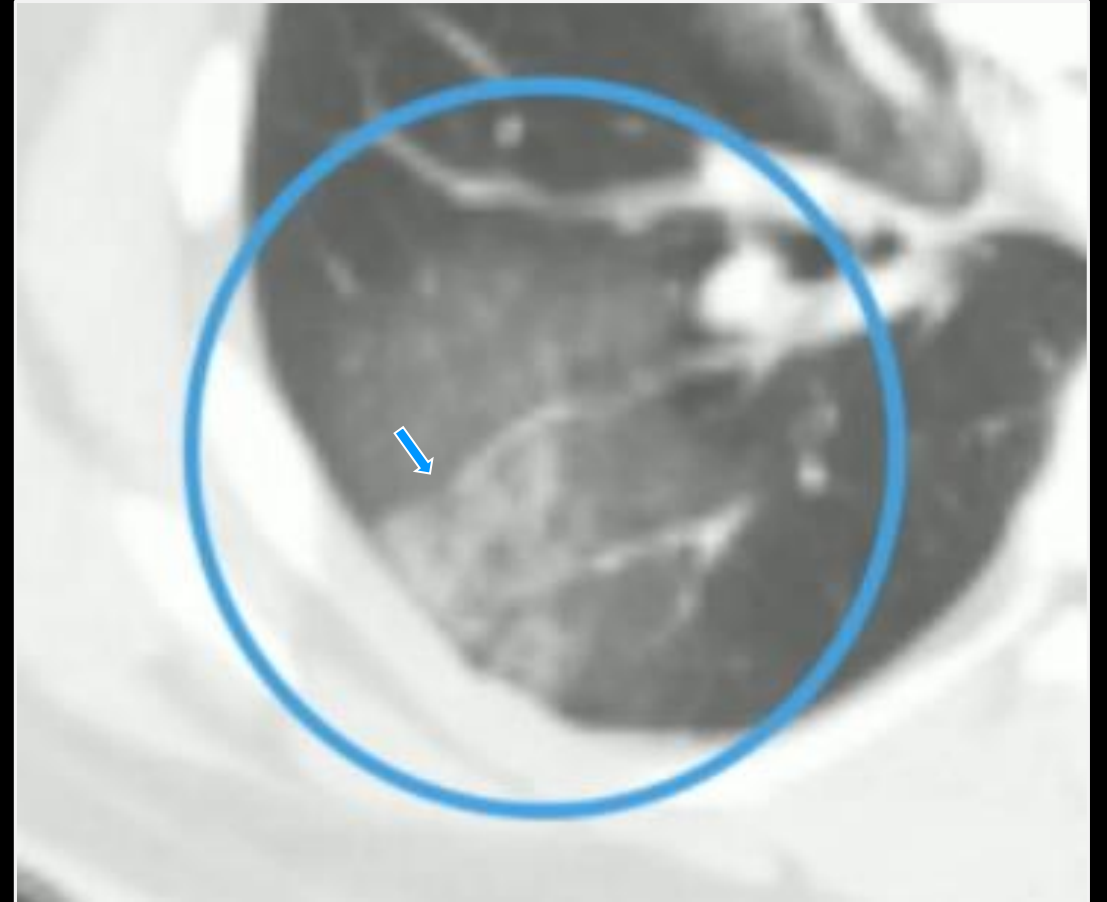
Ground glass opacity
Crazy paving

COVID-19 pneumonia



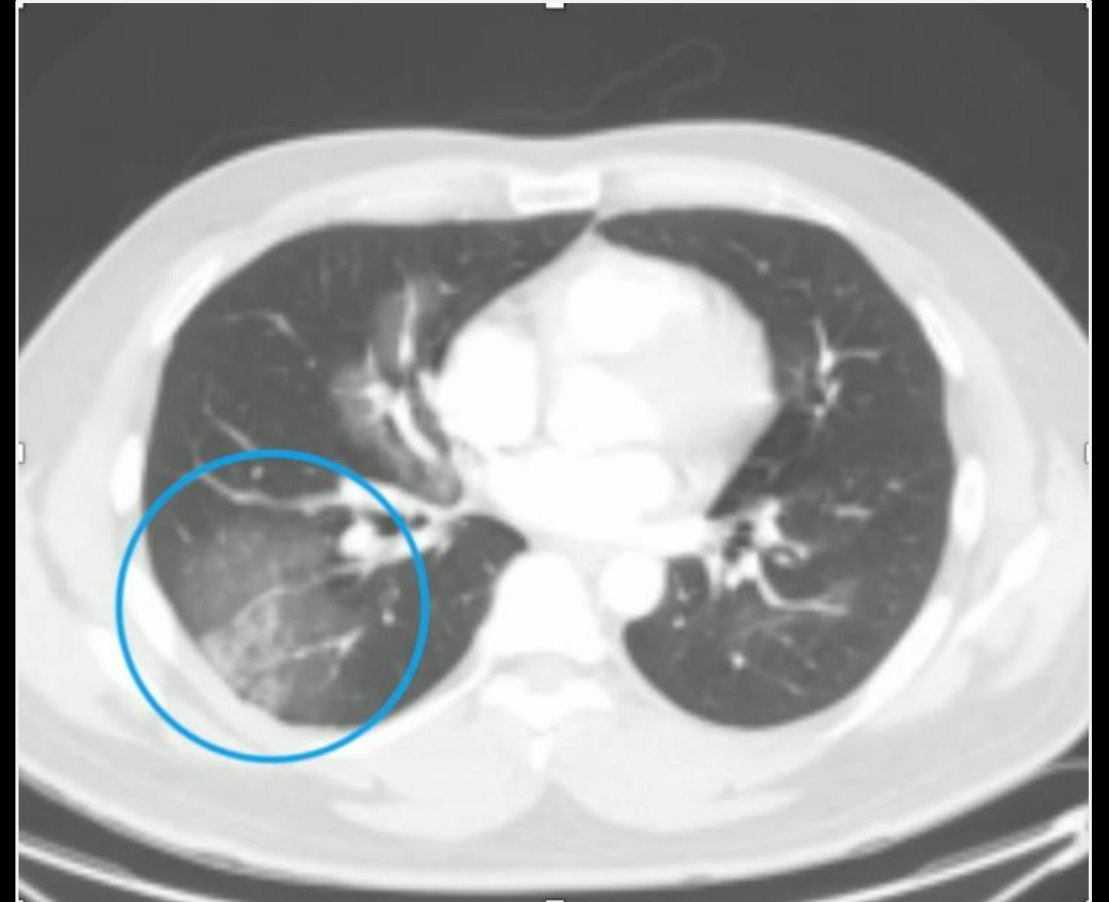
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Crazy paving

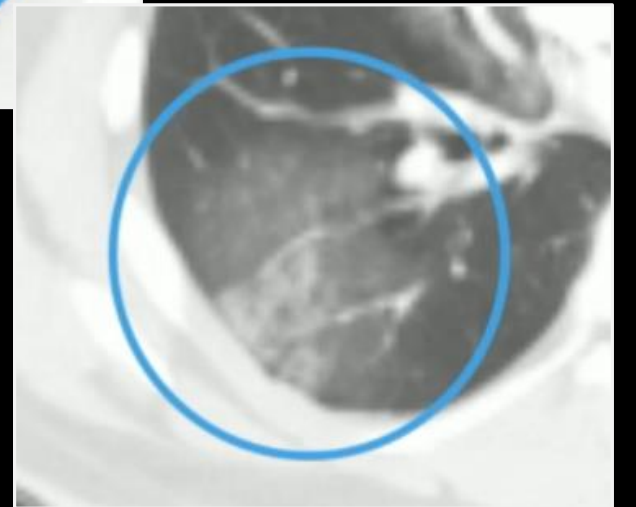
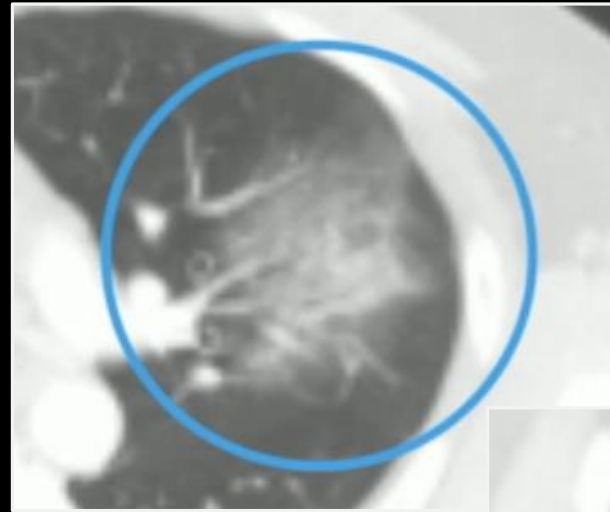
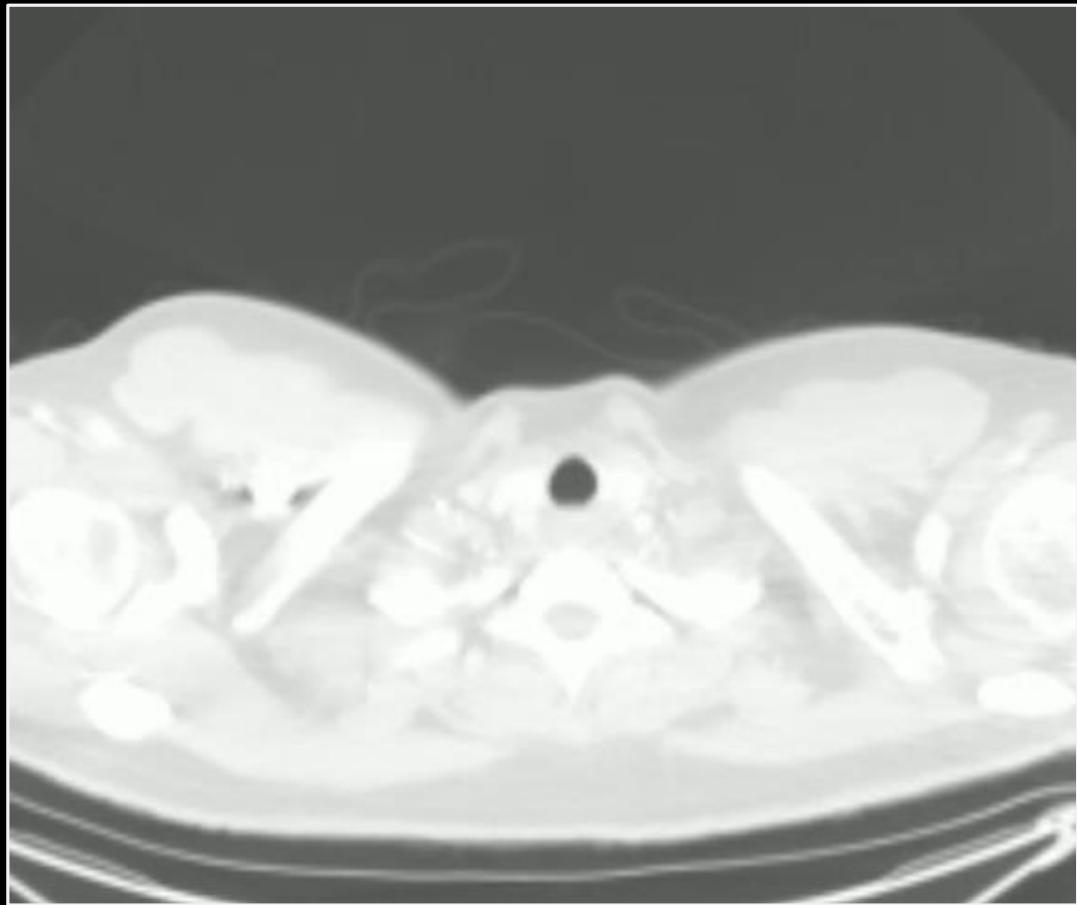
COVID-19 pneumonia



Ground glass opacity
Crazy paving

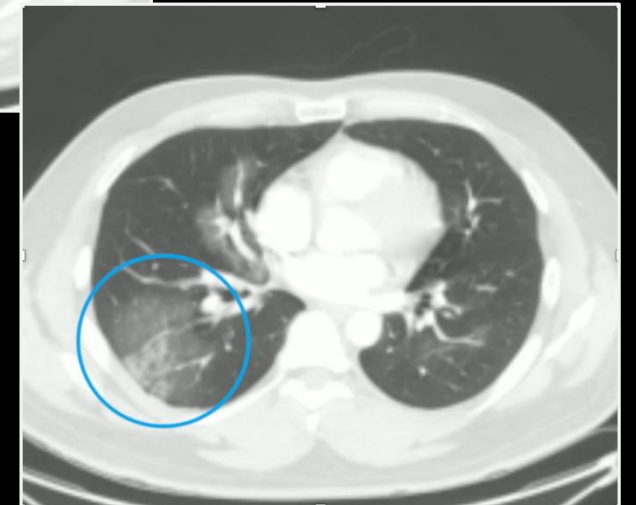
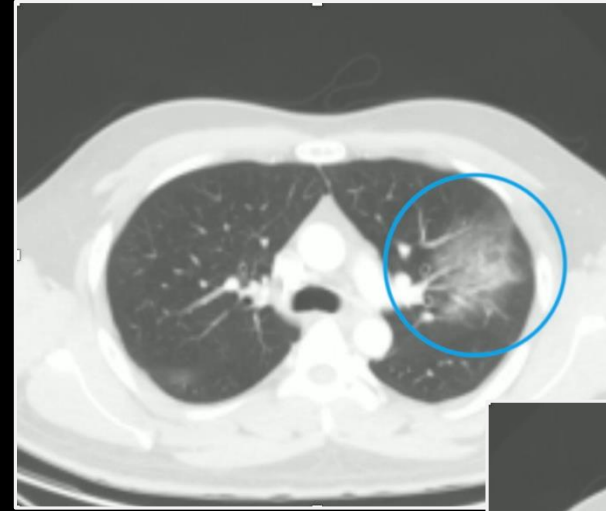
COVID-19 pneumonia





Ground glass opacity
Crazy paving

COVID-19 pneumonia





COVID-19

Ground Glass

Crazy Paving

COVID-19

Ground Glass

Crazy Paving

Consolidation

Influenza

Crazy Paving

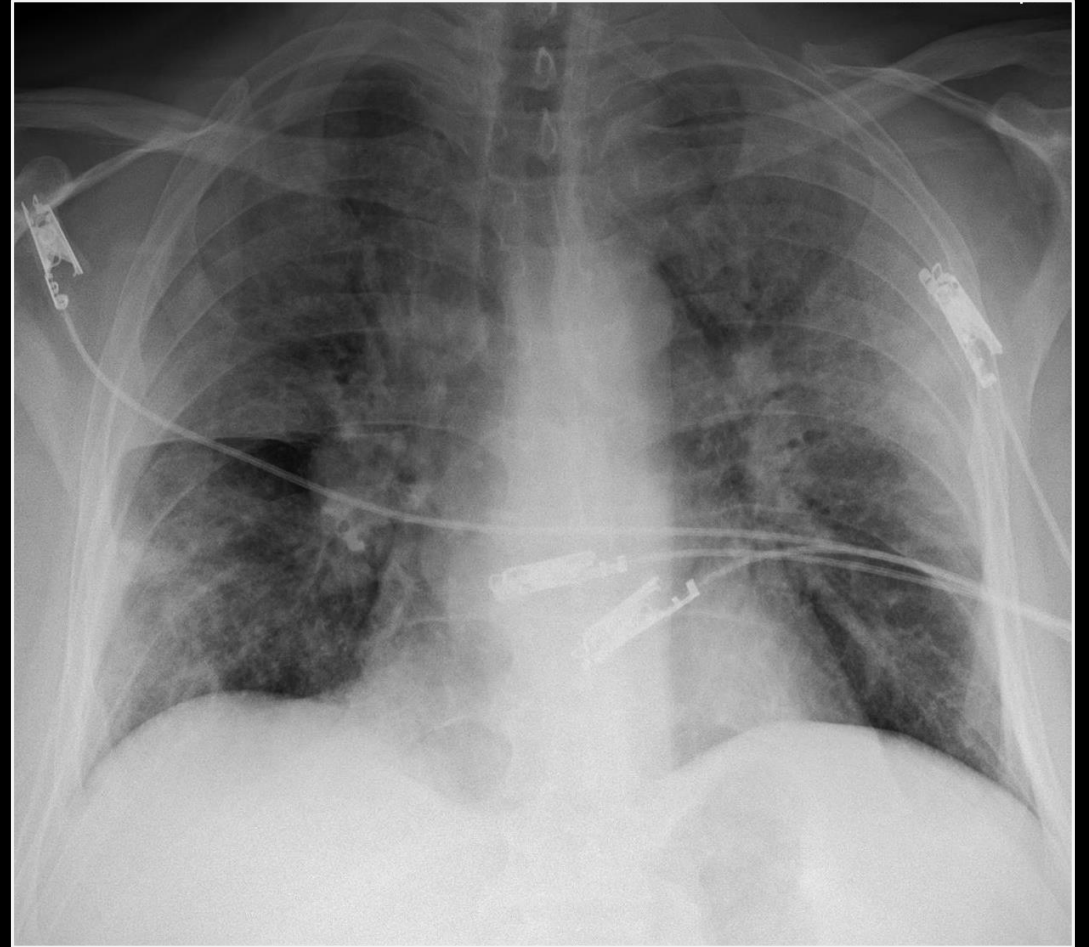
Consolidation

Ground glass opacity

Crazy paving

Consolidation

COVID-19 pneumonia

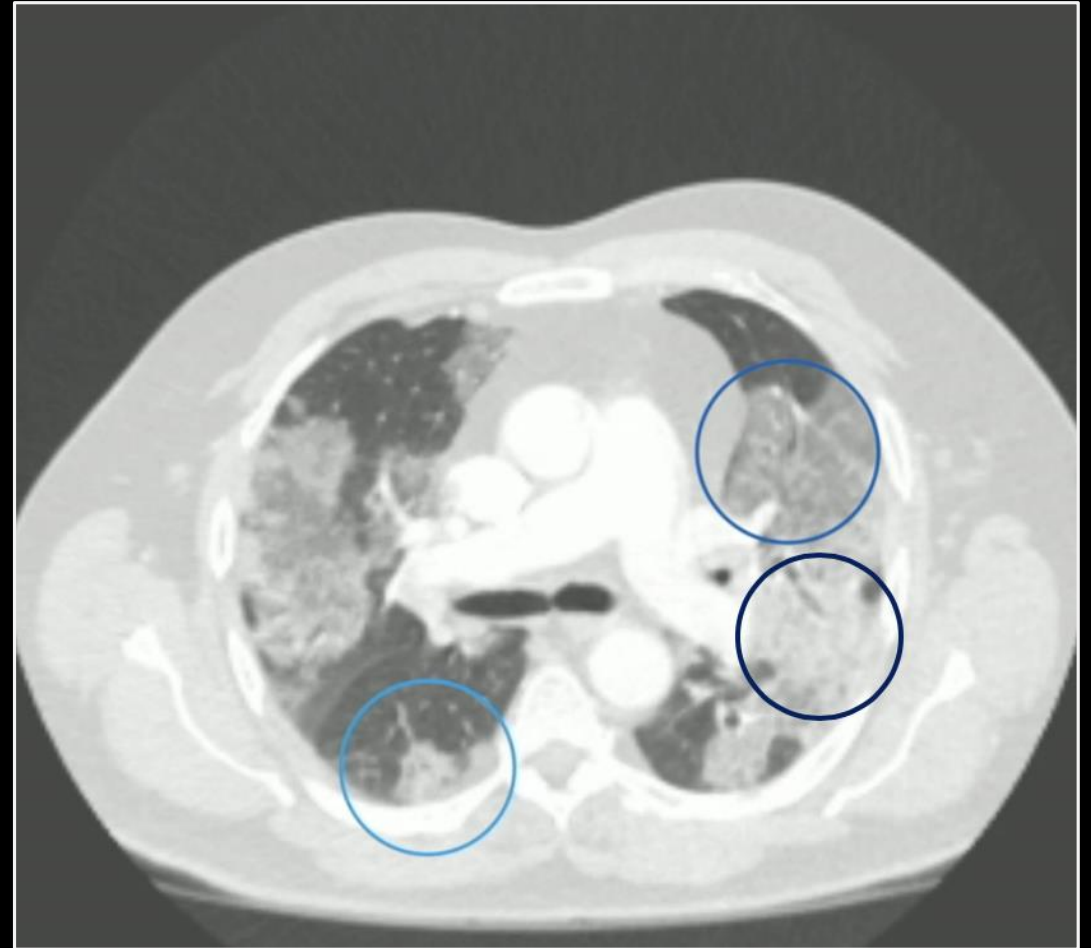


Ground glass opacity

Crazy paving

Consolidation

COVID-19 pneumonia

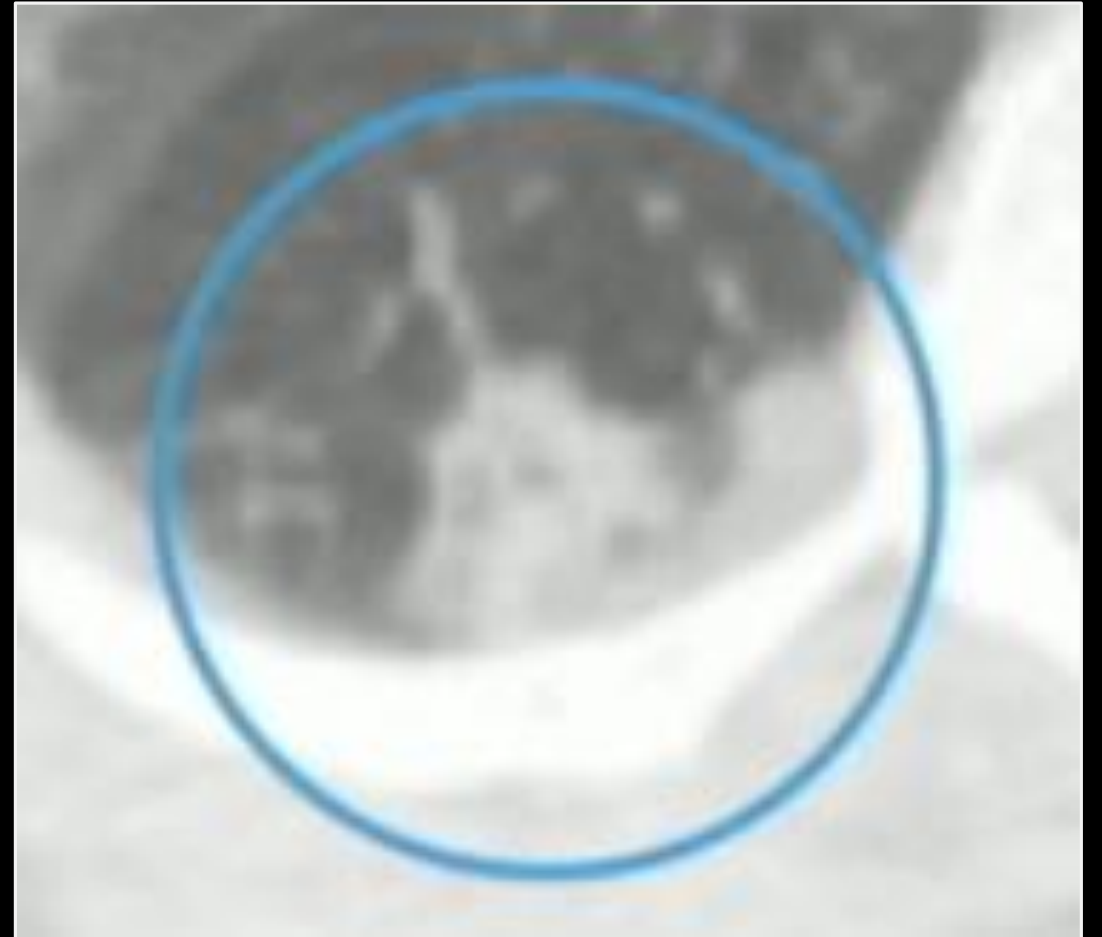


Ground glass opacity

Crazy paving

Consolidation

COVID-19 pneumonia

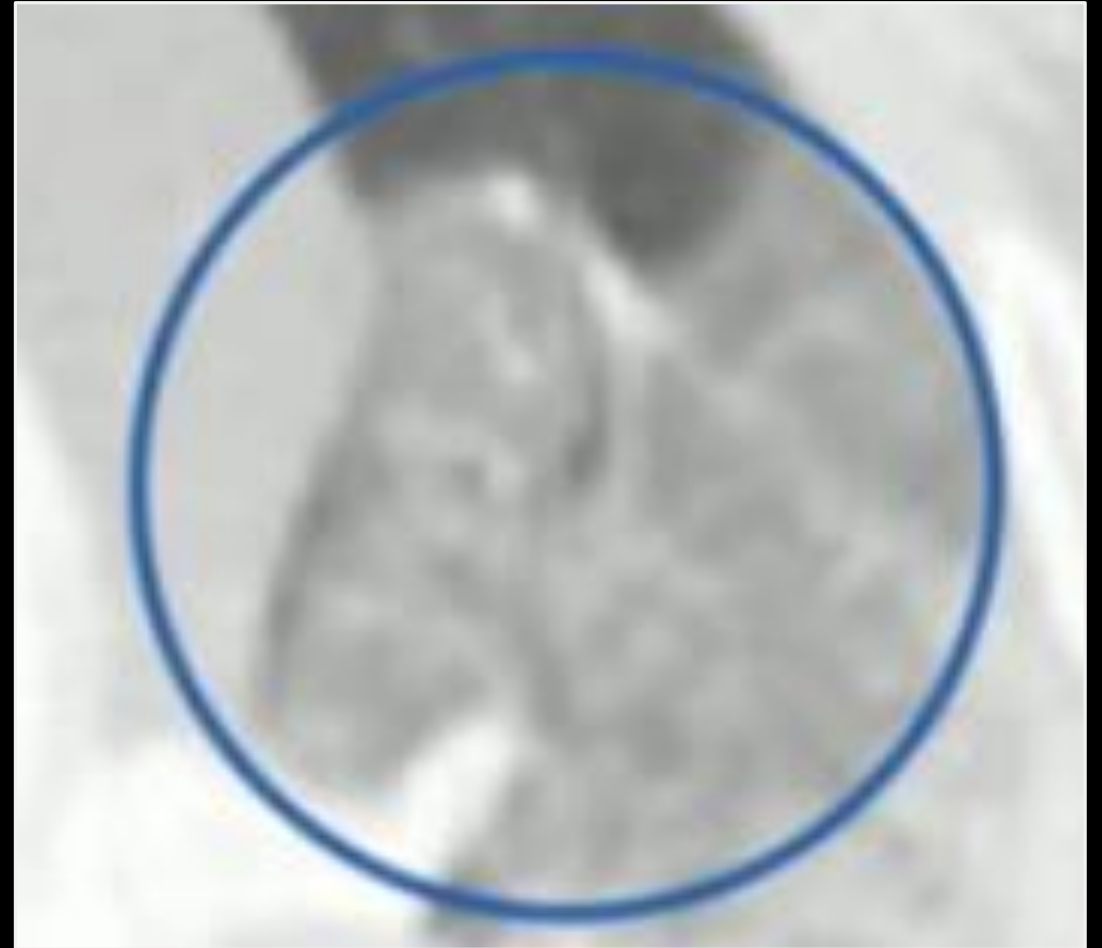


Ground glass opacity

Crazy paving

Consolidation

COVID-19 pneumonia

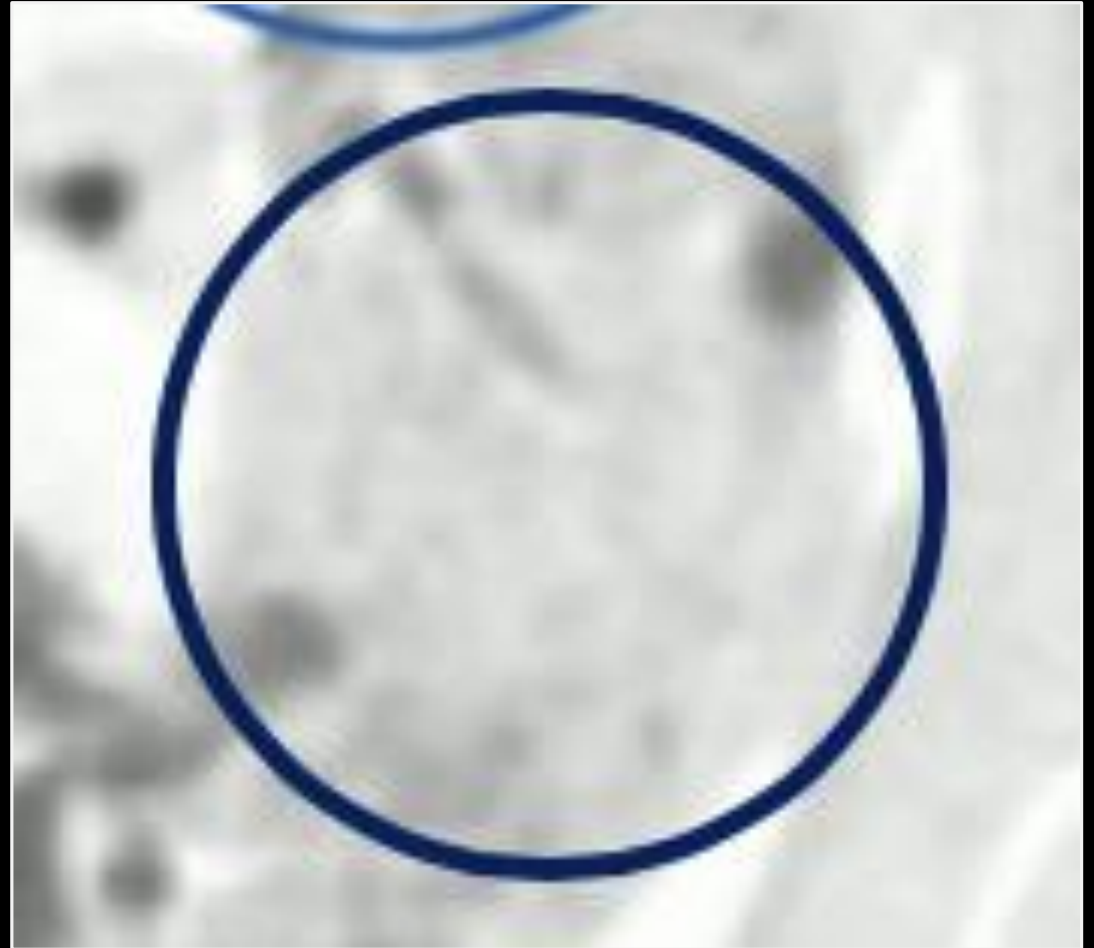


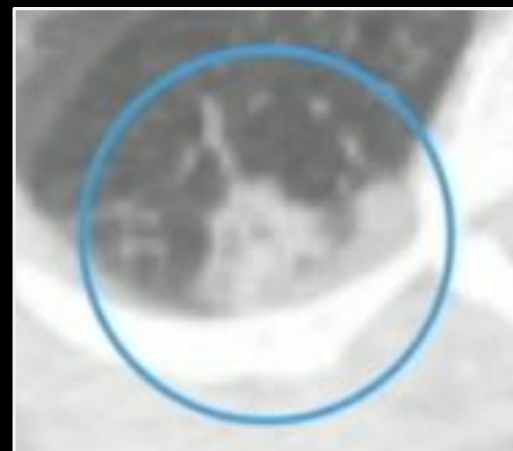
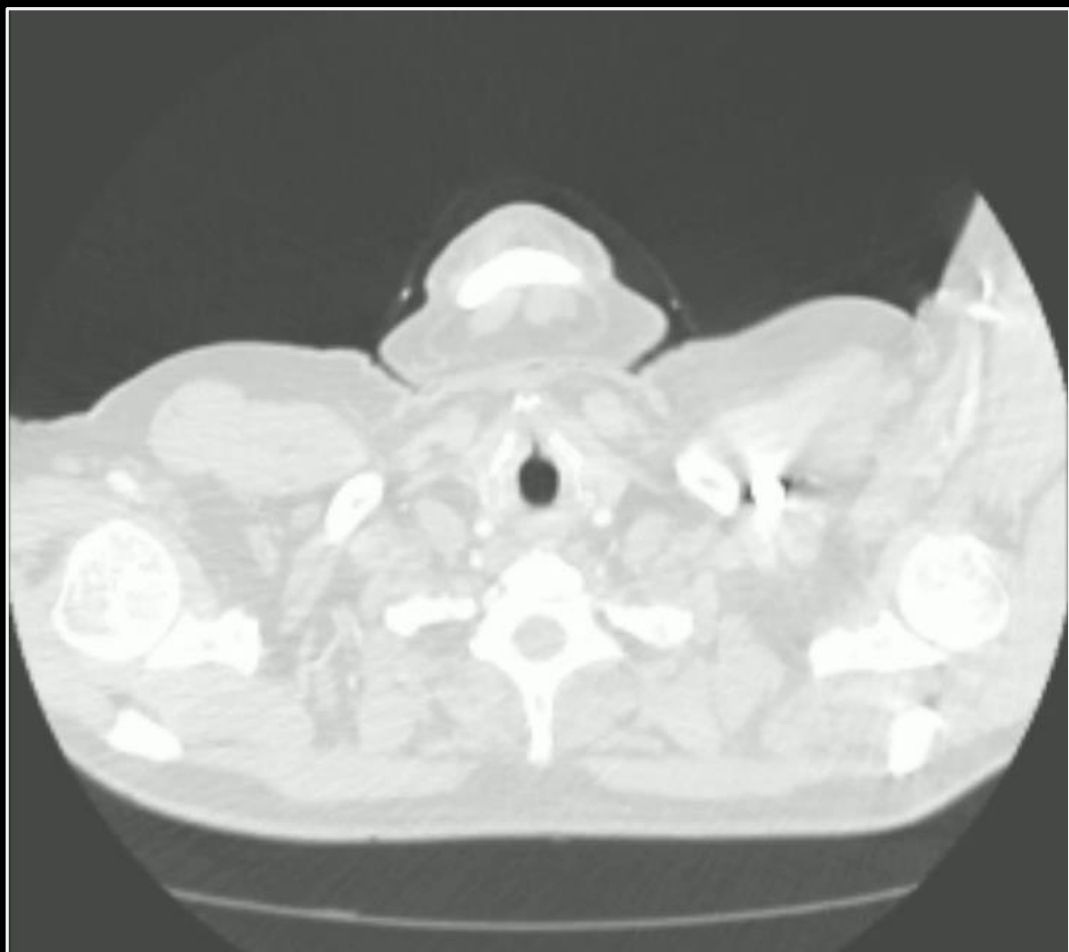
Ground glass opacity

Crazy paving

Consolidation

COVID-19 pneumonia



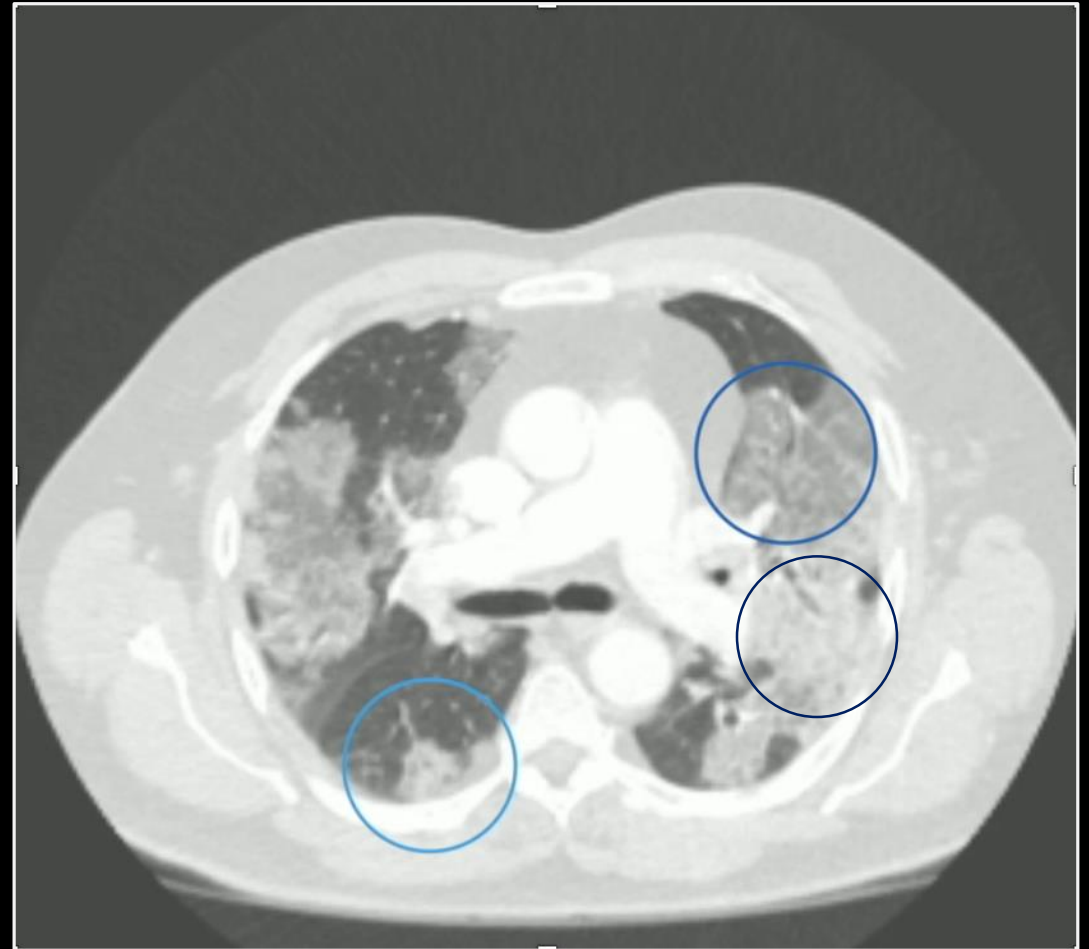


Ground glass opacity

Crazy paving

Consolidation

COVID-19 pneumonia





COVID-19

Ground Glass

Crazy Paving

COVID-19

Ground Glass

Crazy Paving

Consolidation

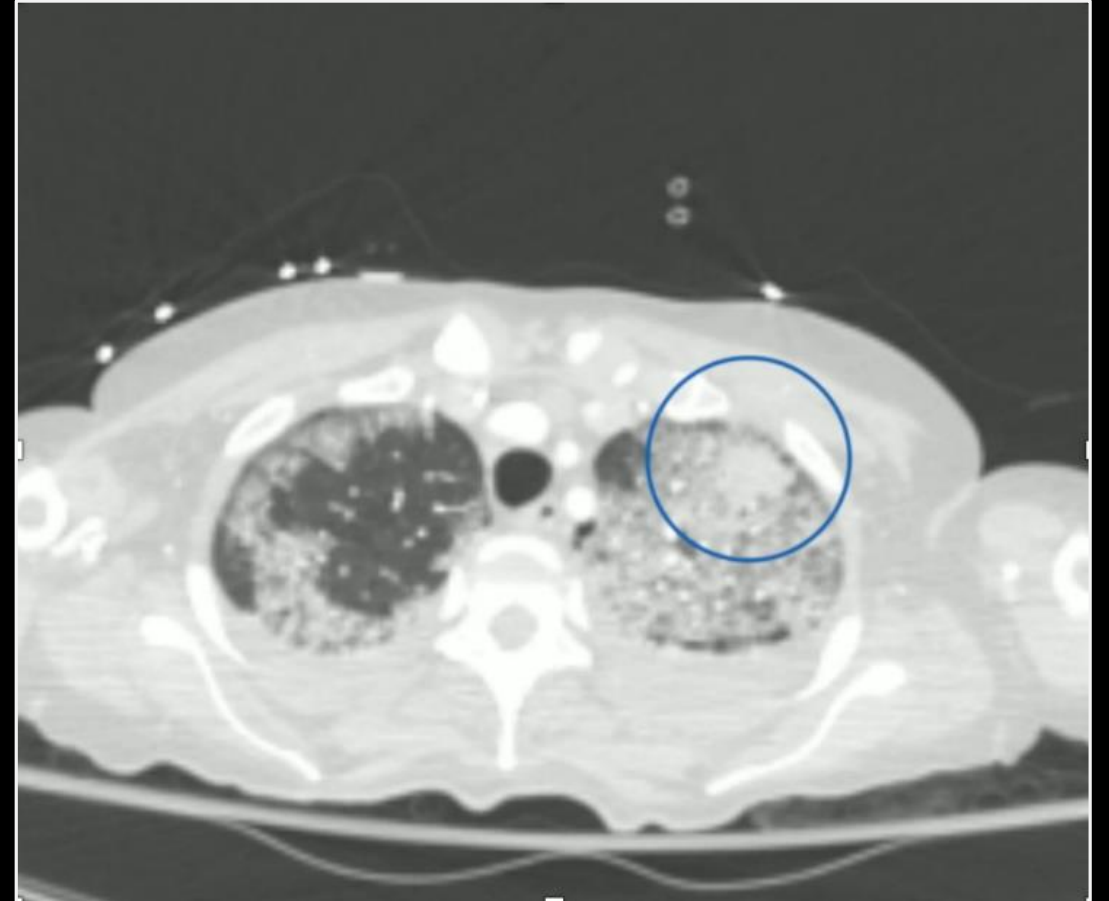
Influenza

Crazy Paving

Consolidation

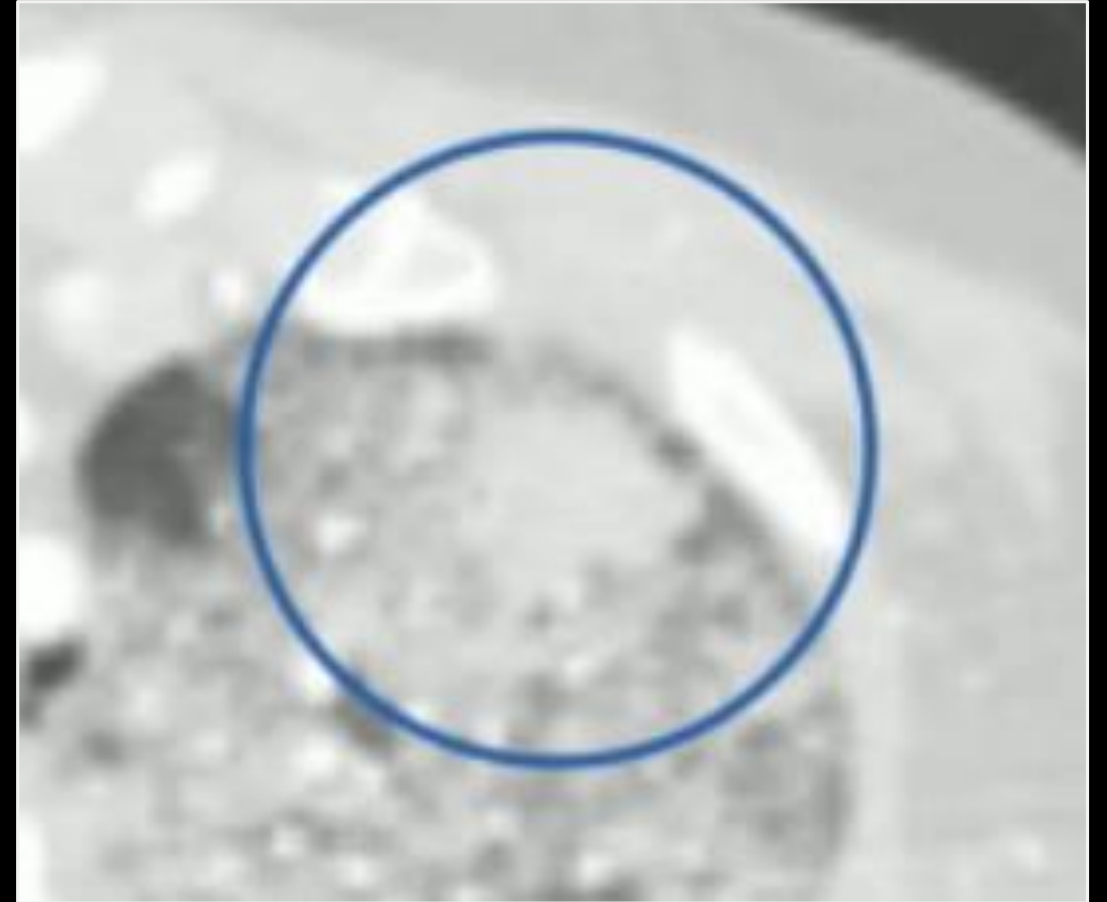
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Influenza pneumonia



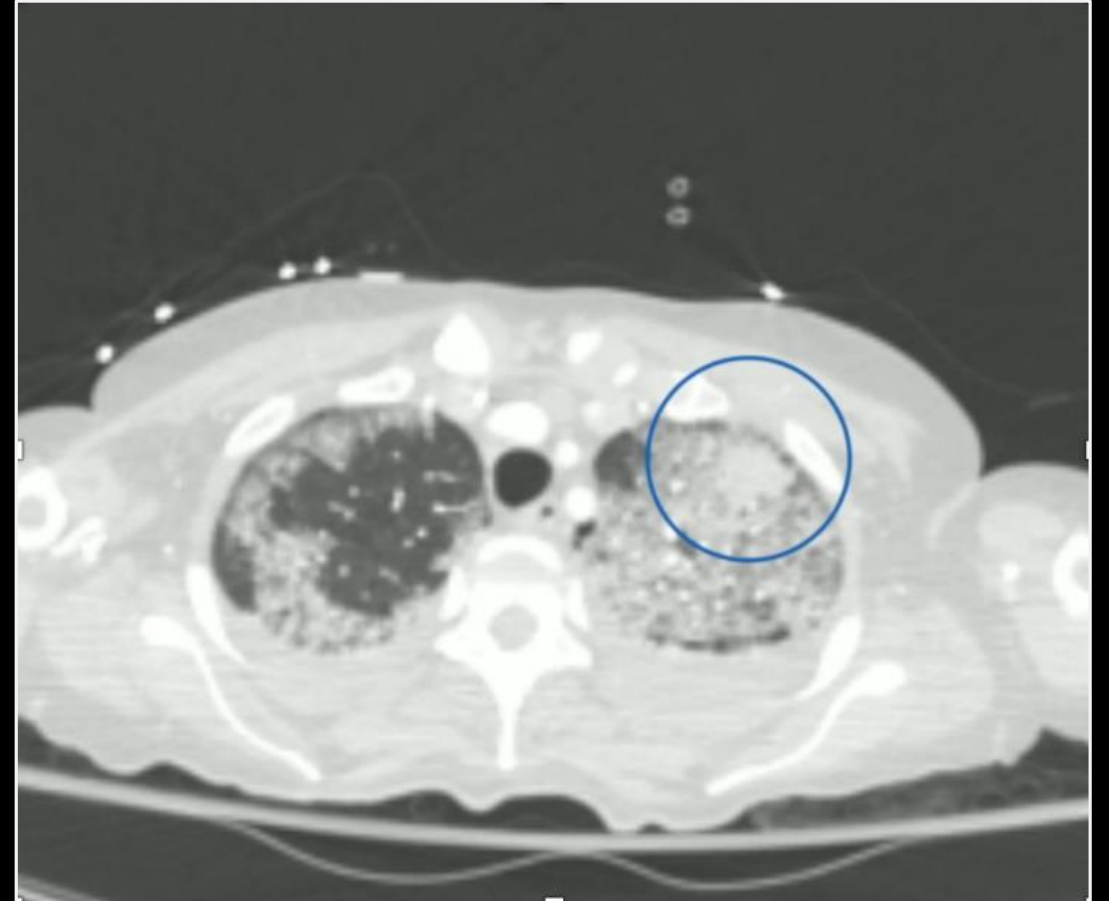
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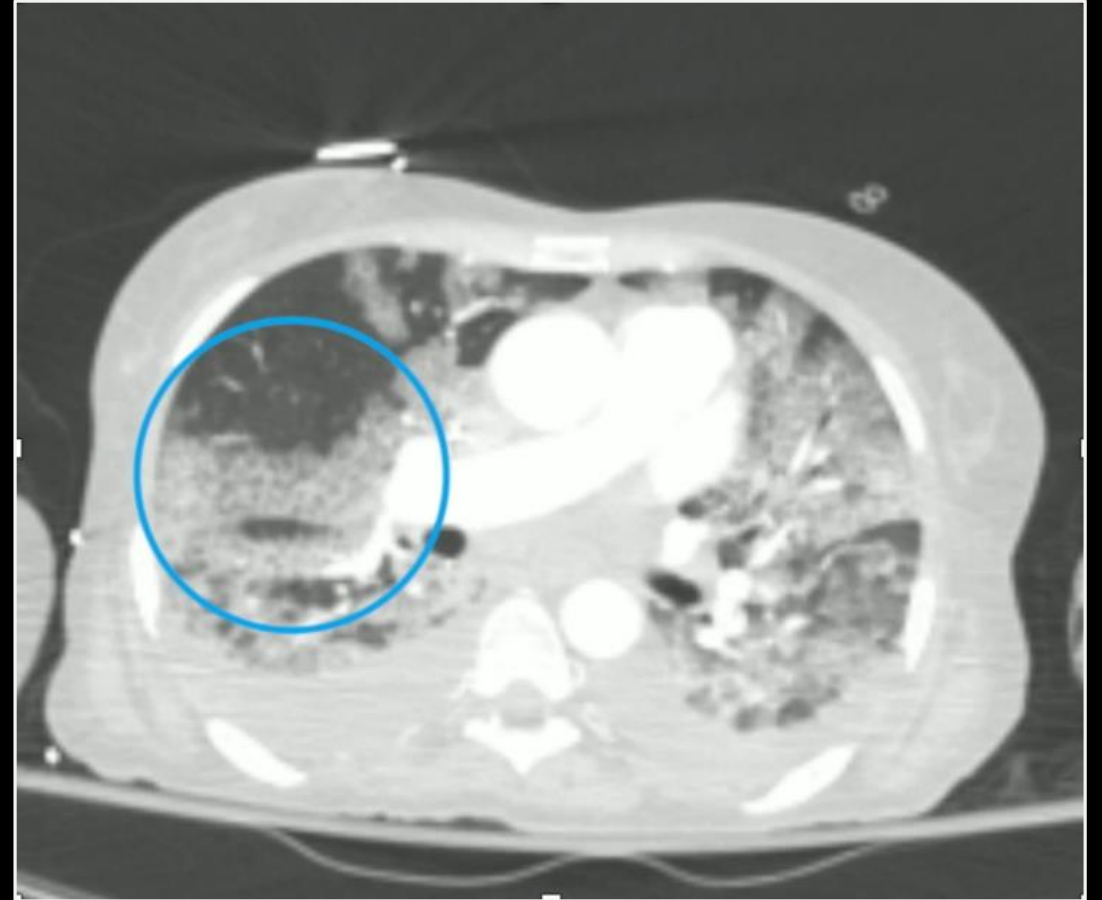
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Influenza pneumonia



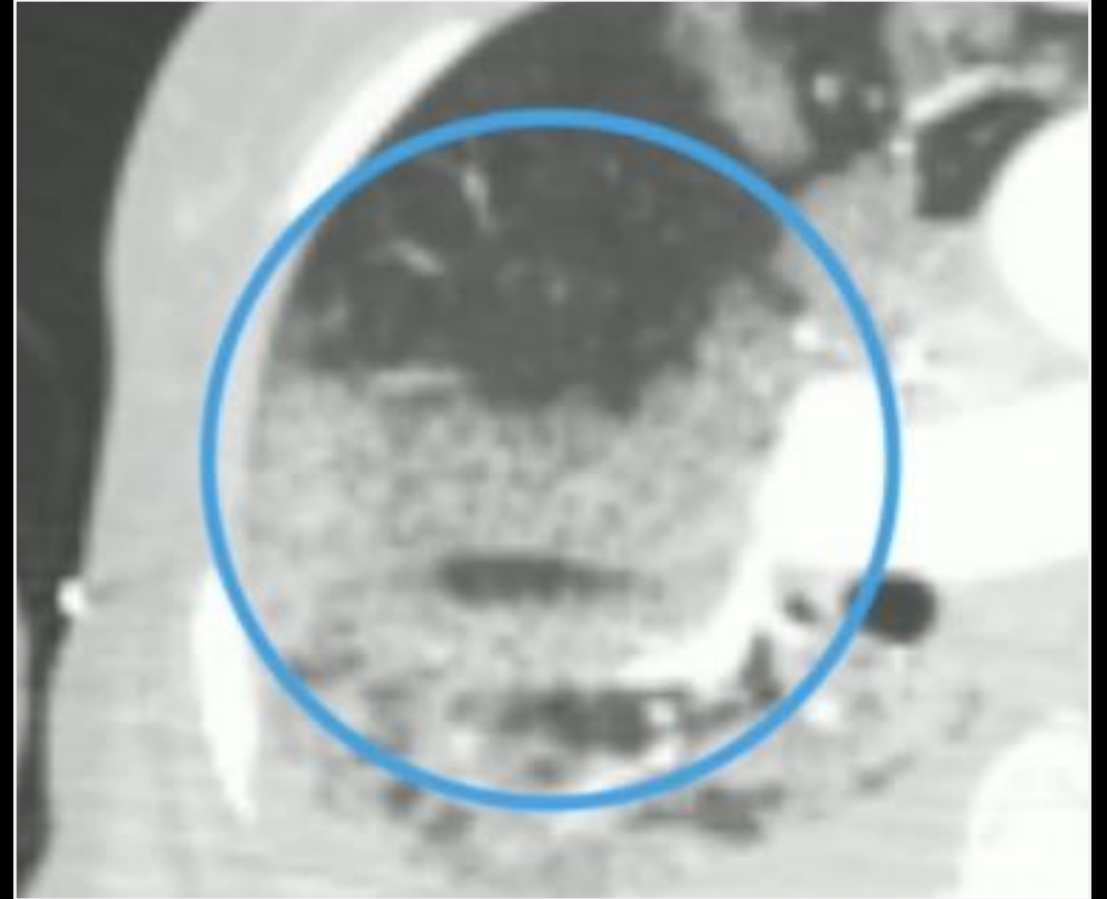
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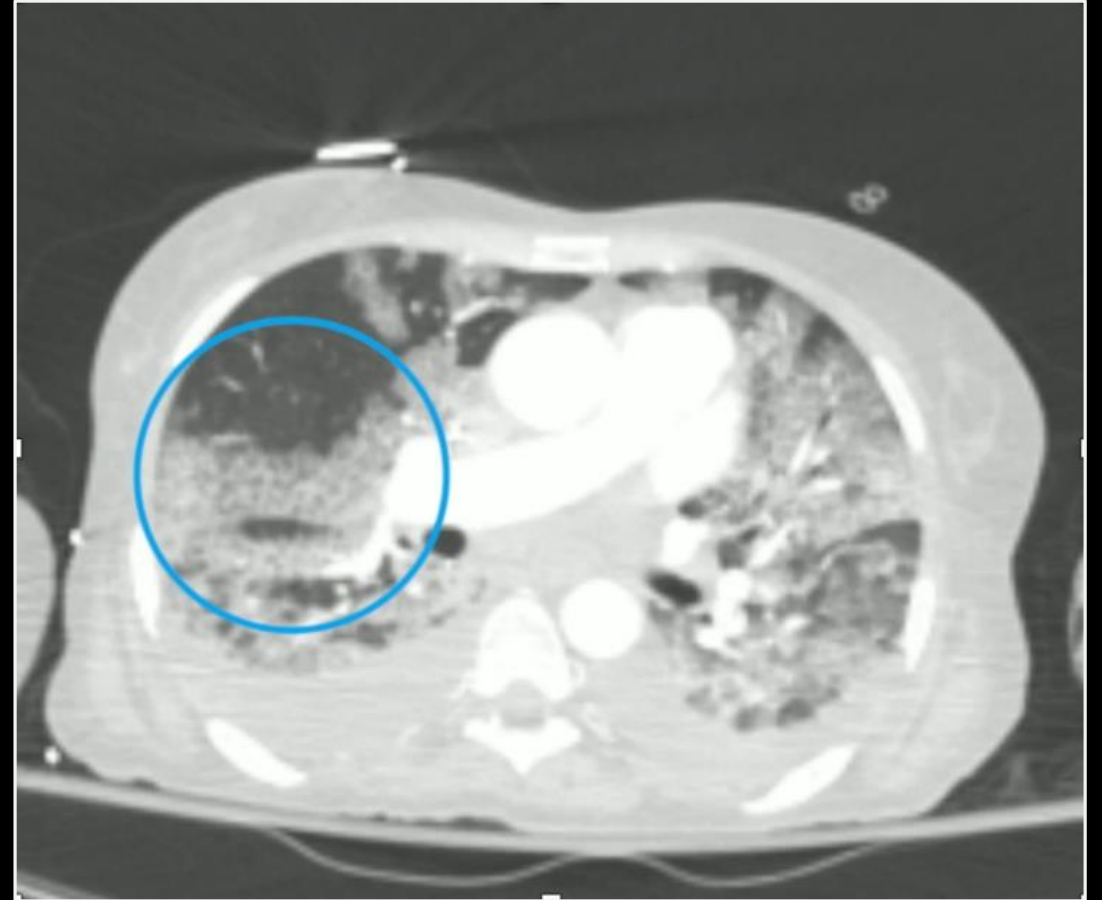
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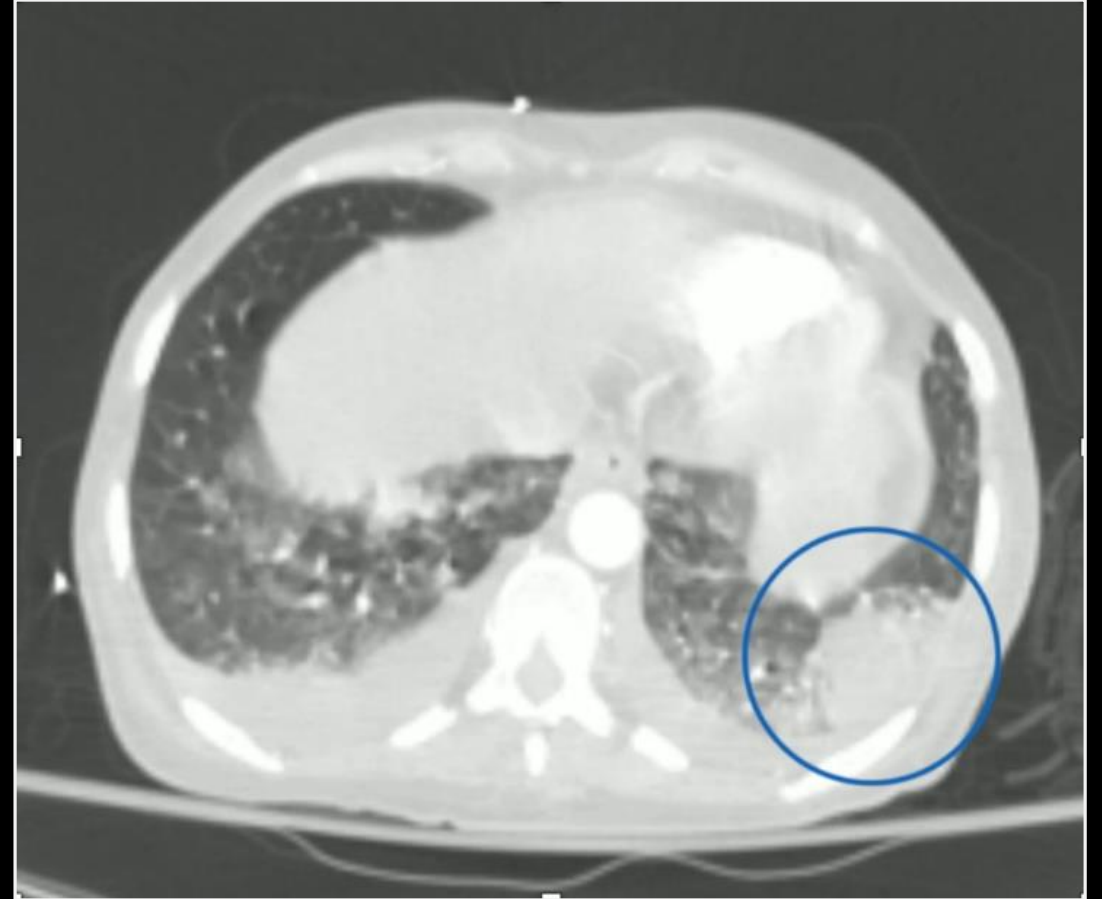
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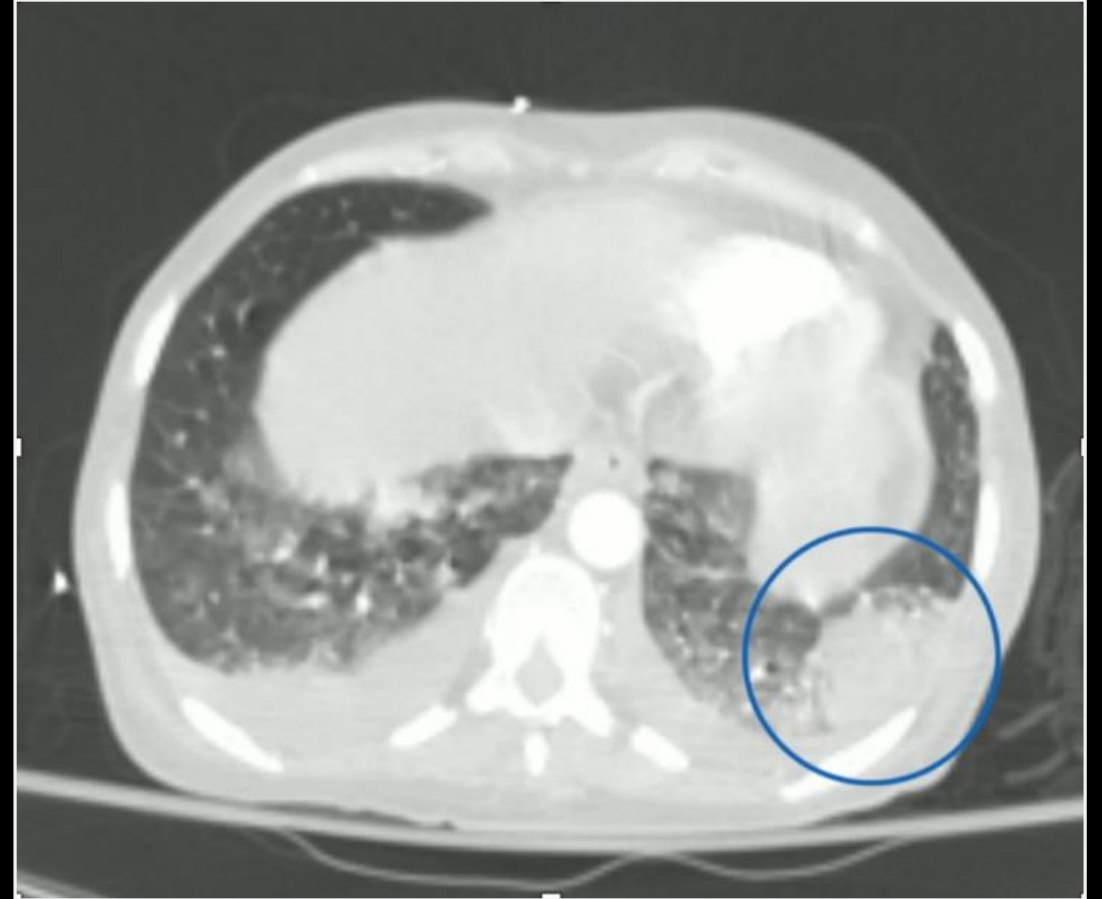
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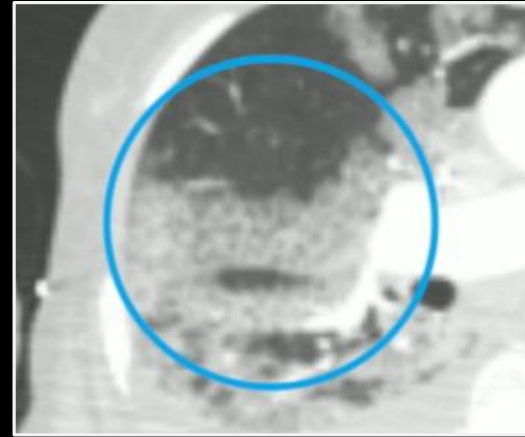
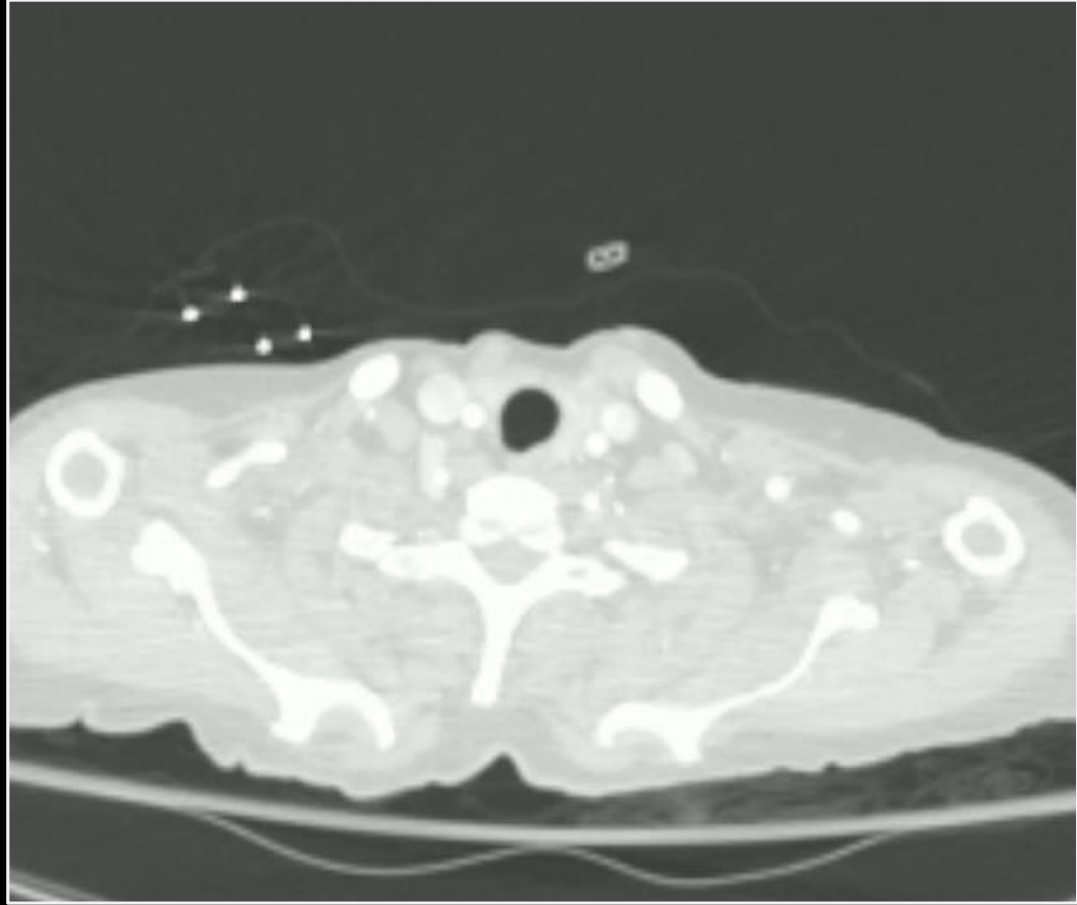
Influenza pneumonia



Crazy paving
Consolidation

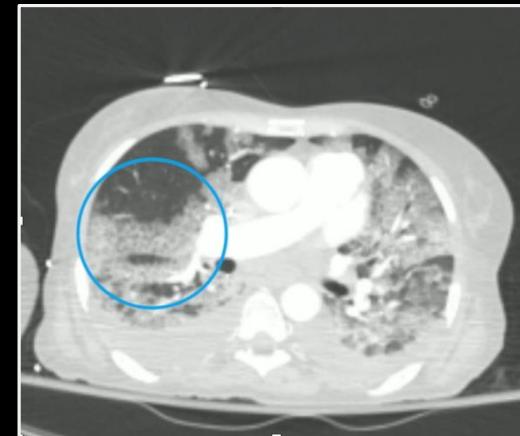
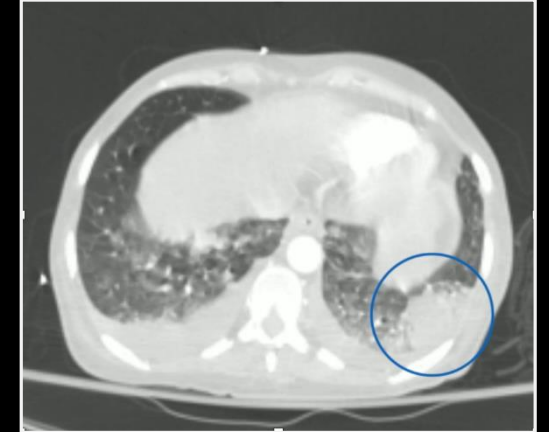
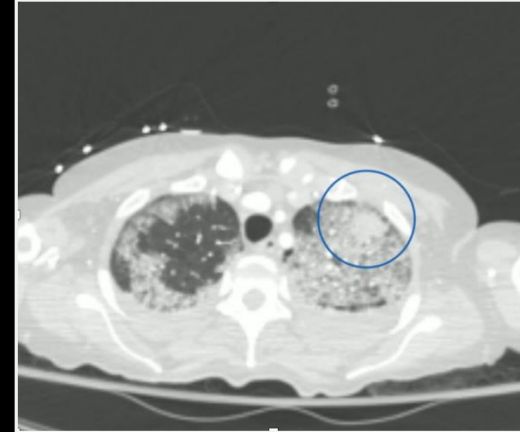
Influenza pneumonia





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vRad/MEDNAX Radiology

Thanks to:

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Greg Klisch, MD (vRad Radiologist)

Guido Santacana Lafitte, MD (vRad Radiologist)

- 
- (1) Bluemke D. Special Edition Podcast. Radiology 2020; published online Feb 26 2020.
 - (2) Bernheim A, Mei X, Huang M, Yang Y, Fayad ZA, Zhang N, Diao K, Lin B, Li K, Li S, Shan H, Jacobi A, Chung M. Chest CT Findings in Coronavirus Disease-19 (COVID-19): Relationship to Duration of Infection. Radiology 2020; published online Feb 20 2020.
 - (3) Ai T, Yang Z, Hou H, Zhan C, Chen C, Lv W, Tao Q, Sun Z, Xia L. Correlation of Chest CT and RT-PCR Testing in Coronavirus Disease 2019 (COVID-19) in China: A Report of 1014 Cases.
 - (4) Fang Y, Zhang H, Zie J, Lin M, Yin L, Pang P, Ji W. Sensitivity of Chest CT for COVID-19: Comparison to RT-PCR. Radiology 2020; published online Feb 19 2020.
 - (5) Ng M, Lee EYP, Yang J, Yand F, Li X, Wang H, Lue MM, Lo CS, Leung B, Khong P, Hui CK, Yuen K, Kuo MD. Imaging Profile of the COVID-19 Infection: Radiologic Finding and Literature Review. Radiology 2020; published online Feb 13 2020.
 - (6) Pan F, Ye Tm Sun P, Gui S, Liang B, Li L, Zheng D, Wang J, Hesketh R, Yang L, Xheng C. Time Course of Lung Changes on Chest CT During Recovery From 2019 Novel Coronavirus (COVID-19) Pneumonia. Radiology 2020; published online Feb 13 2020.
 - (7) Zu ZY, Jiang MD, Xu PP, Chen W, Ni QQ, Lu GM, Zhang LJ. Coronavirus Disease 2019 (COVID-19): A Perspective from China. Radiology 2020; published online Feb 21 2020.
 - (8) Chung M, Bernheim A, Mei X, Zhang N, Huang M, Zeng X, Cui J, Xu W, Yang Yan Z, Jacobi A, Li K, Li S, Shan H. CT Imaging Features of 2019 Novel Coronavirus (2019-nCoV). Radiology 2020; published online Feb 4 2020.



Imaging of COVID-19

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Chief of Radiology, Doctors Hospital
Associate Professor, FIU College of Medicine

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Keys to Imaging

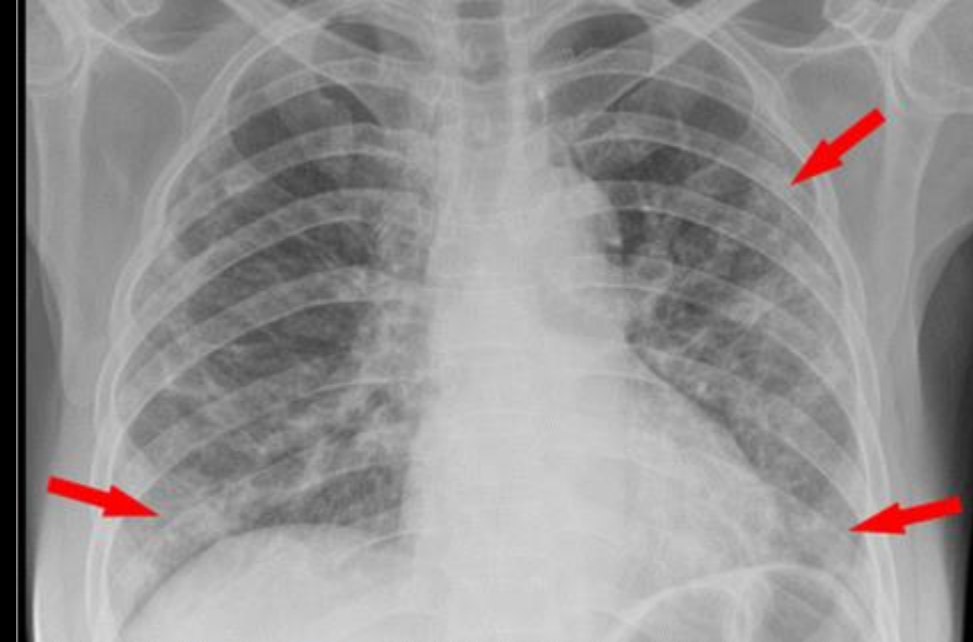
- CXR: May be subtle
- CT: Consistent, but non-specific → viral pneumonia pattern
- CT: Bilateral peripheral rounded ground glass and progressive small areas of consolidation
- CT: Pleural effusion and lymphadenopathy LESS common and may suggest bacterial superinfection. Cavitation uncommon.
- Findings overlap with influenza, RSV, metapneumovirus, etc.
- Over time, evolution to ARDS / Diffuse Alveolar Damage both clinically and radiologically in deteriorating patients

Keys to imaging

- In patients suspected of Covid-19, Chinese authorities now confirm infection in patients with typical CT findings, even with first-negative RT-PCR result
- In early infection, even CT may be normal or near-normal (e.g., days 0-2)

Wuhan, China

- CXR Normal or Near-normal: Bilateral patchy opacities
- CT: ground glass opacities, crazy paving, consolidations



Ground glass



Crazy paving

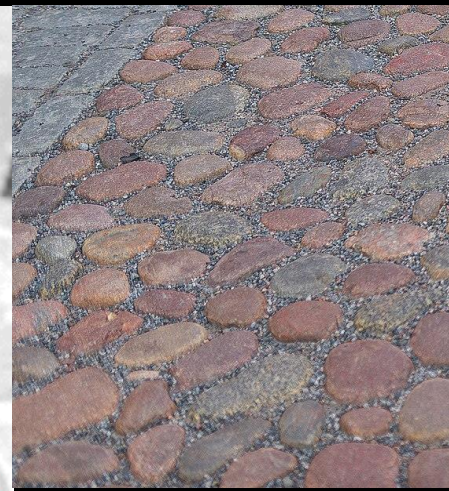
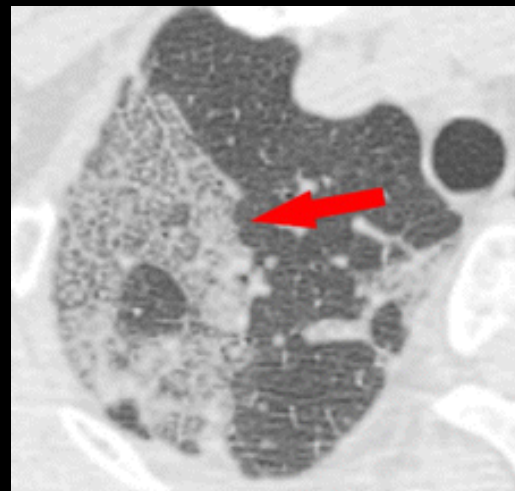
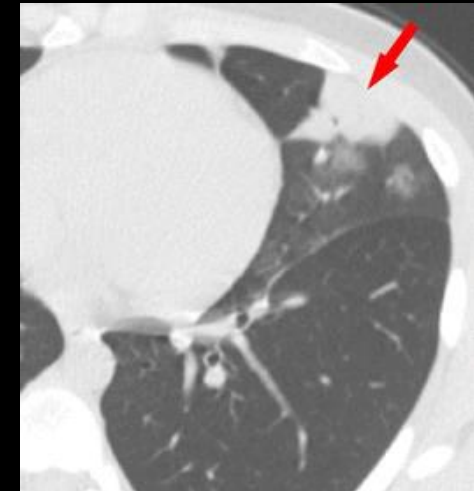


Photo: Bengt Nyman, CC BY 3.0

Consolidation



Wuhan, China

Table 3: Chest CT Imaging Features of Coronavirus Disease 2019 (COVID-19)

Pneumonia

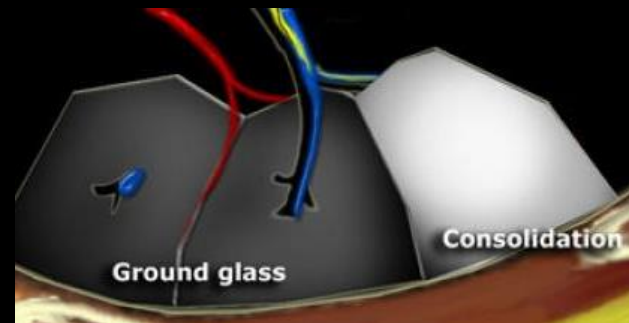
Ground glass opacities +/-consolidation	+ + +
Pure consolidation	+
Multiple lesions	+ + +
Bilateral involvement	+ + +
Posterior part / lower lobe predilection	+ + +
Peripheral / subpleural distribution	+ + +
Crazy-paving pattern	+ +
Air bronchogram	+ +
Reversed halo sign on high-resolution CT	+
Pleural effusion	+
Cavitation, calcification, lymphadenopathy	Absent

Data from Refs.^{1,16,32,40-43,55-56}

Note.—Plus signs indicate the relative frequency of the findings from the lowest (+) to the highest (+++).

Four provinces in China, 121 patients

- CT Findings:
 - Bilateral
 - Ground glass opacities and/or consolidation



<https://radiologyassistant.nl>



GROUND-GLASS OPACITIES AND CONSOLIDATION	
Absence of Both Ground-Glass Opacities and Consolidation	27 (22)
Presence of Either Ground-Glass Opacities or Consolidation	94 (78)
Presence of Ground-Glass Opacities without Consolidation	41 (34)
Presence of Ground-Glass Opacities with Consolidation	50 (41)
Presence of Consolidation without Ground-Glass Opacities	2 (2)
NUMBER OF LOBES AFFECTED	
0	27 (22)
1	18 (15)
2rad	14 (12)
3	11 (9)
4	18 (15)
5	33 (27)
More than 2 lobes affected	62 (51)
Bilateral Lung Disease	73 (60)
FREQUENCY OF LOBE INVOLVEMENT	
Right Upper Lobe	53 (44)
Right Middle Lobe	50 (41)
Right Lower Lobe	79 (65)
Left Upper Lobe	58 (48)
Left Lower Lobe	76 (63)
TOTAL LUNG SEVERITY SCORE	
Mean	3
Range	0 - 18
Standard Deviation	3

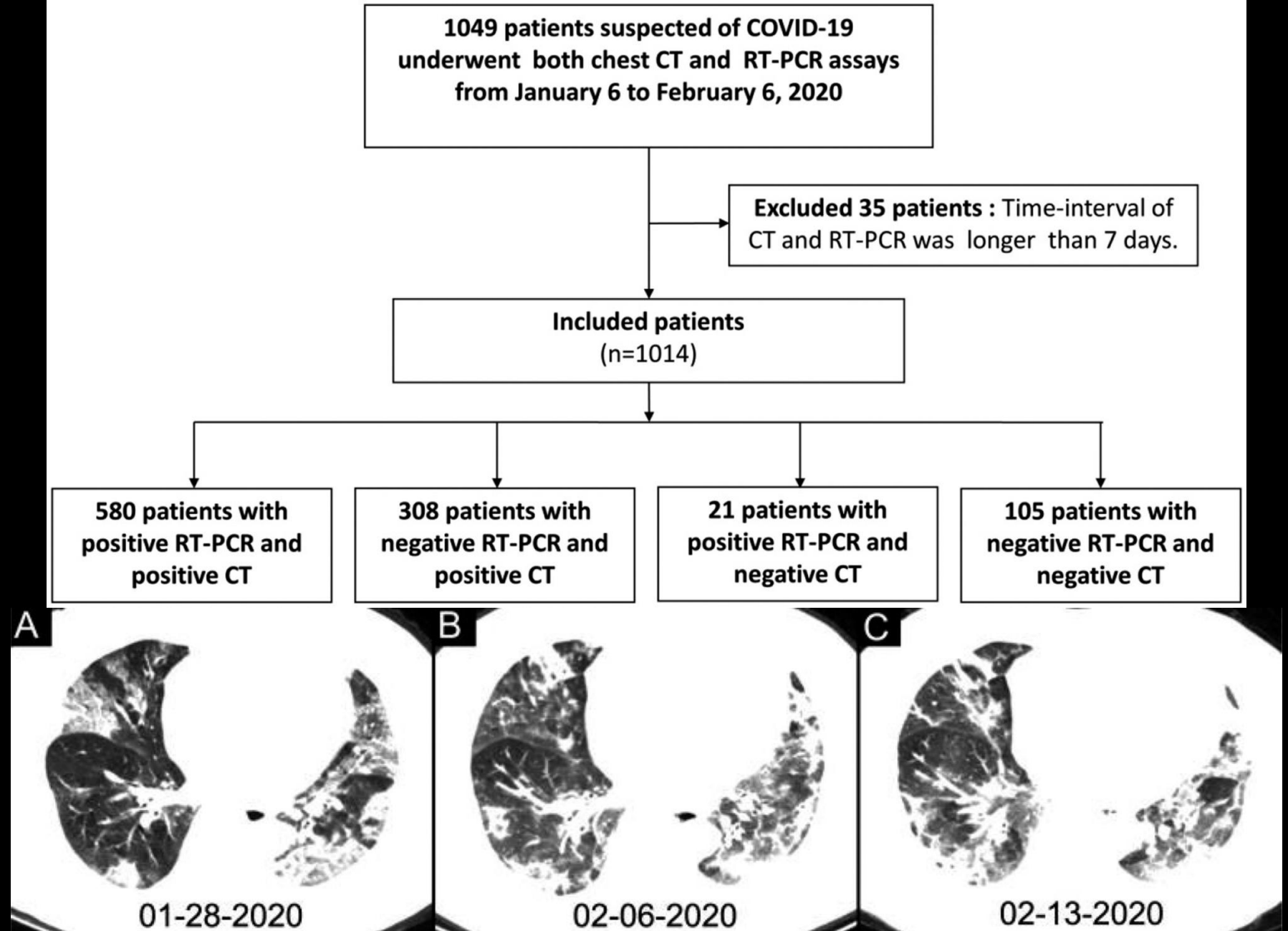
Note: Numbers in Parentheses are Percentages

Bernheim et al. *Radiology* Feb 20, 2020. Chest CT findings in Coronavirus Disease-19 (COVID-10) – Relationship to duration of infection. Four provinces in China.

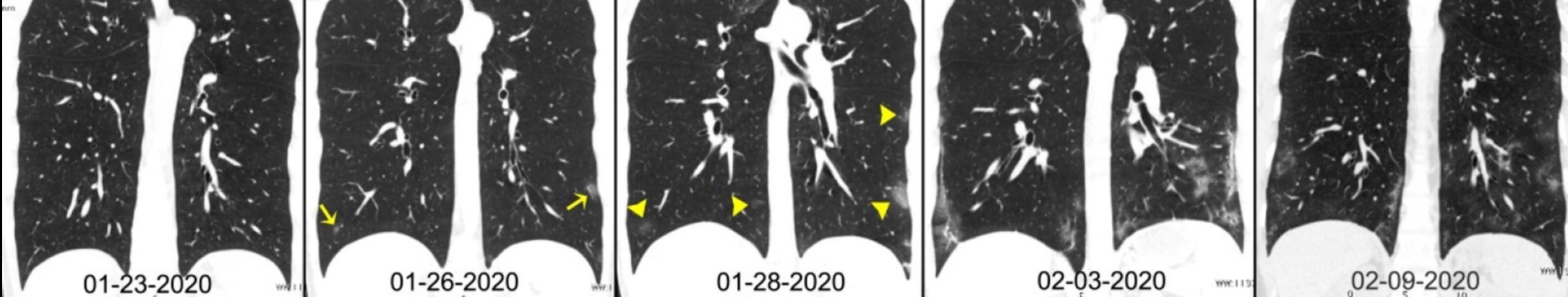
Tongji Hospital Wuhan, China

30% with +CT but
negative RT-PCR

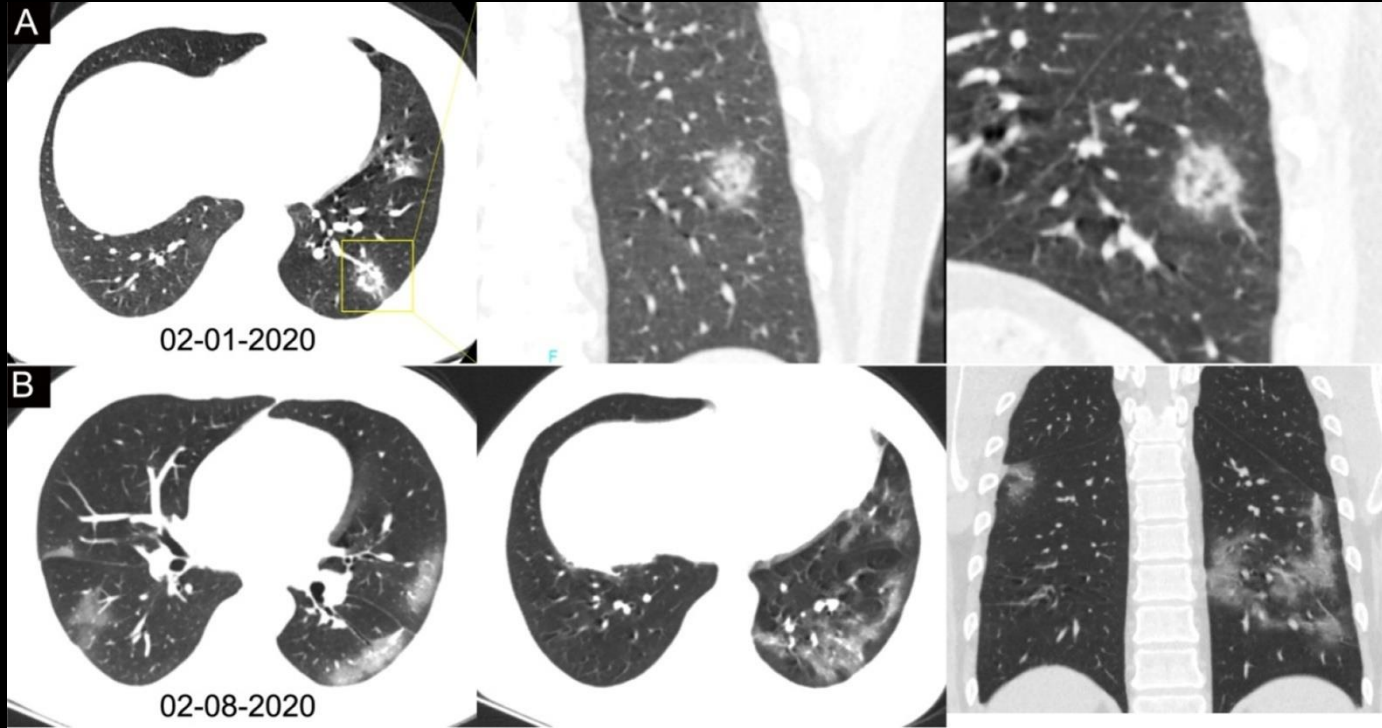
63yo female with
fever for 11 days



**29yo male
with fever
for 6 days**

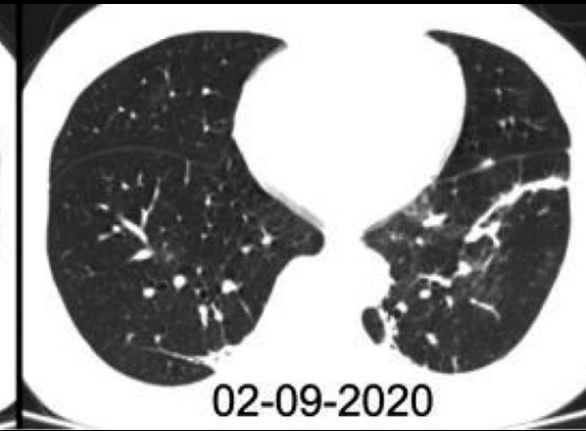
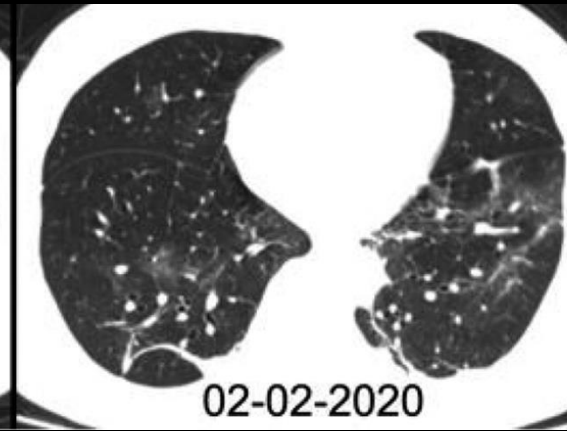
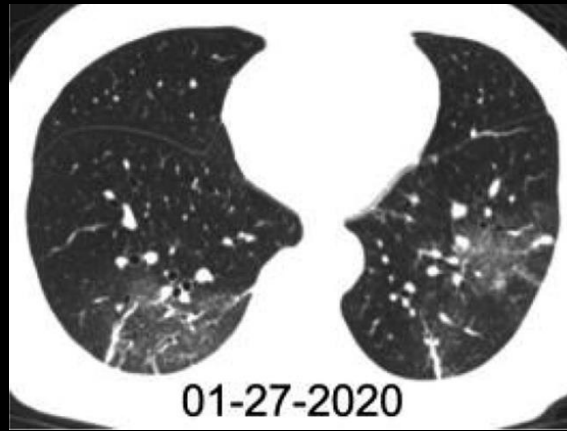


**34yo male
with fever
for 4 days**

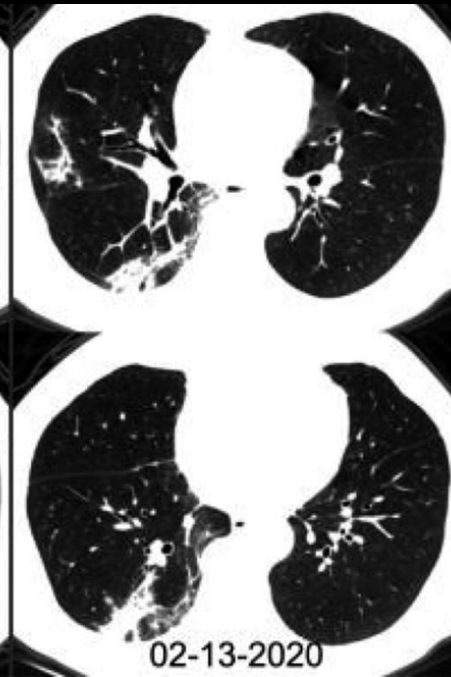
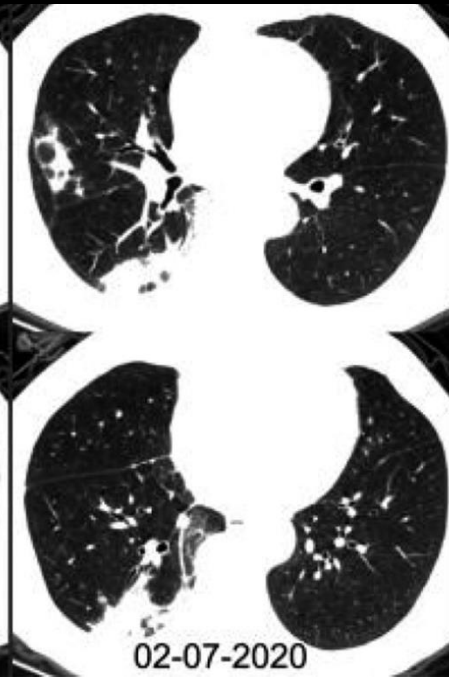
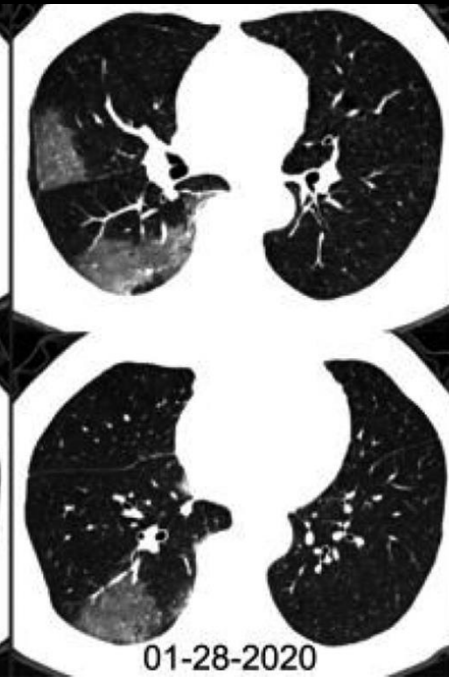
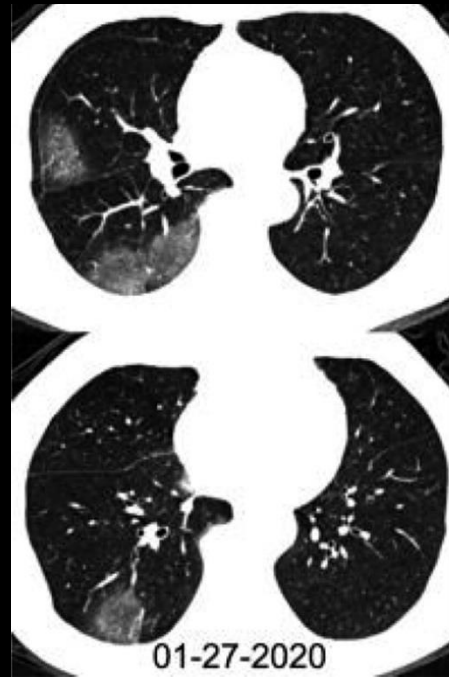


Ai T et al. *Radiology* Feb 26 2020. Correlation of chest CT and RT-PCR testing in Coronavirus Disease 19 (COVID-19) in China: A report of 1014 cases. Wuhan China.

**46yo female
with fever for
4 days**



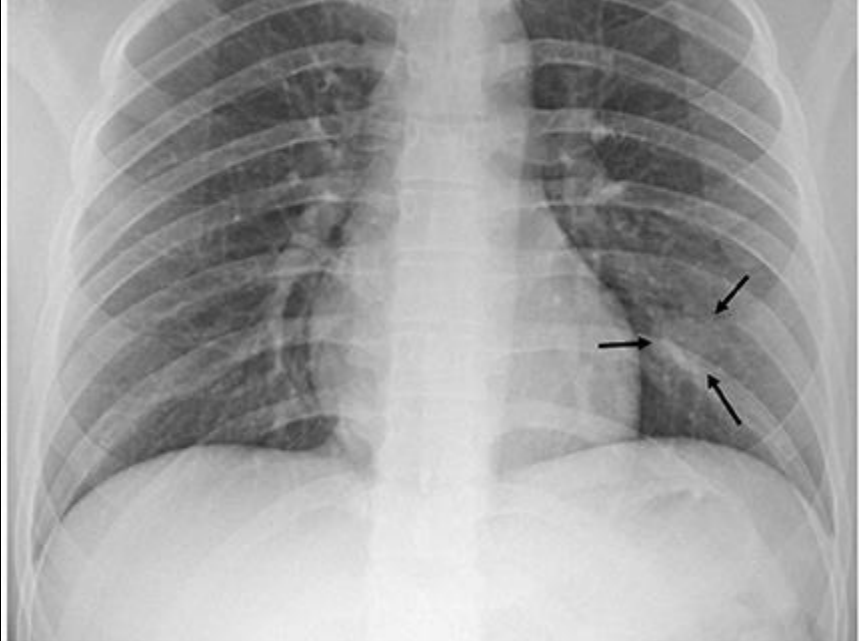
**62yo male
with fever for
2 weeks**



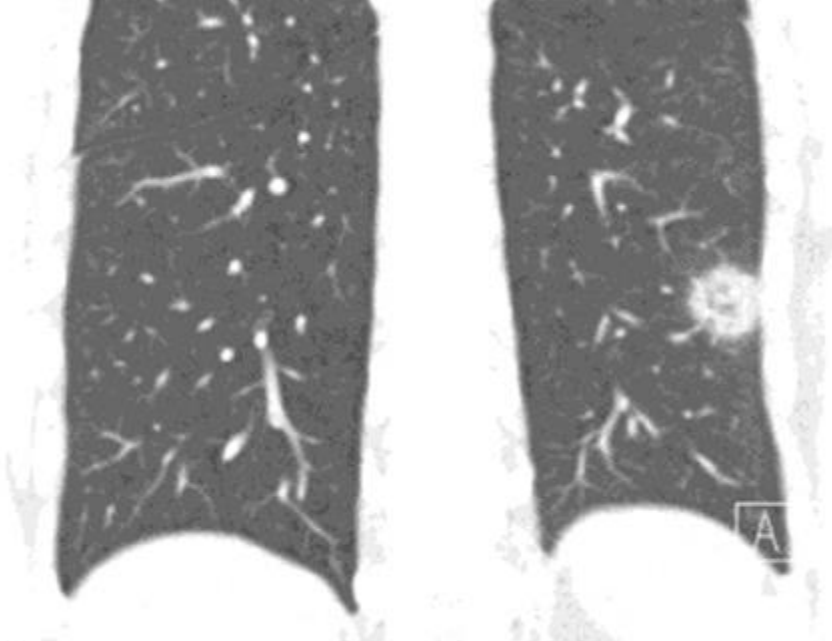
9 patients in Korea



**9 patients
in Korea**



A



B



A

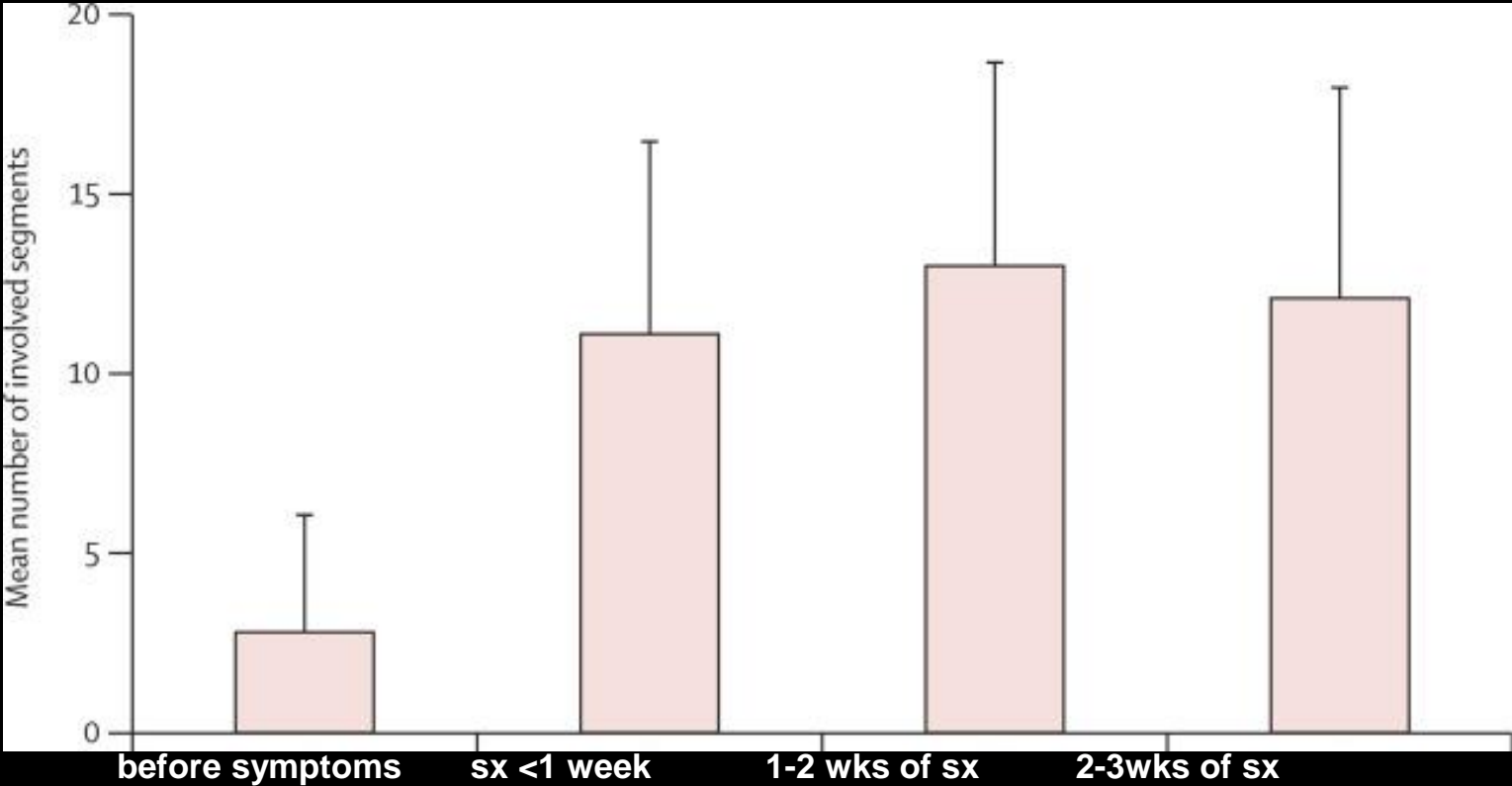


B

Ho Yoon S et al. *Korean J Radiol.* Feb 26, 2020. Chest radiographic and CT findings of the 2019 novel coronavirus disease (COVID-19): Analysis of 9 patients treated in Korea

81 patients at Wuhan Jinyintan hospital or Union Hospital of Tongji Medical College, China

of Involved Lung Segments Affected on CT According to Duration of Symptoms



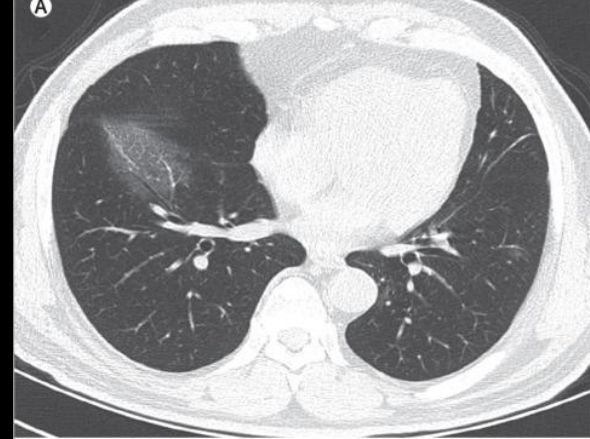
Shi H et al. *The Lancet* Feb 24, 2020. Radiological findings from 81 patients with COVID-19 pneumonia in Wuhan, China: A descriptive study.

81 patients at Wuhan Jinyintan hospital or Union Hospital of Tongji Medical College, China

**60yo male
(died 4 days later)**

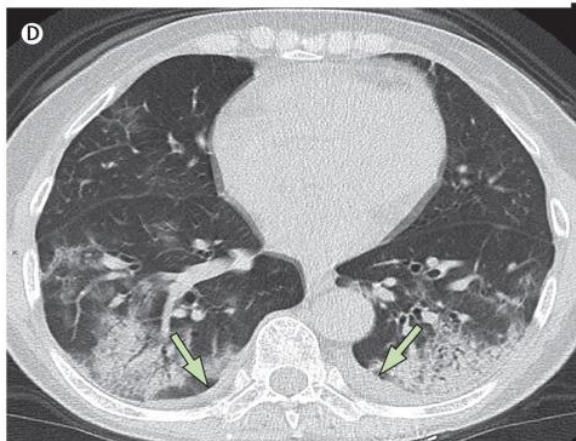
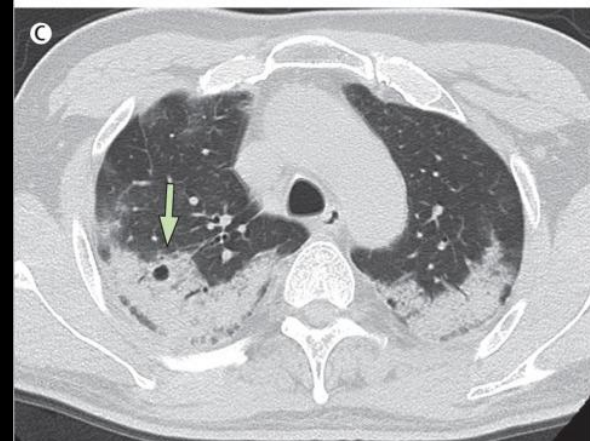


56yo M



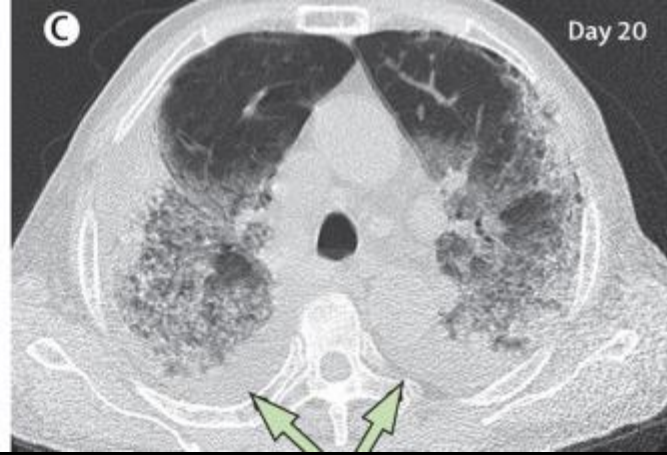
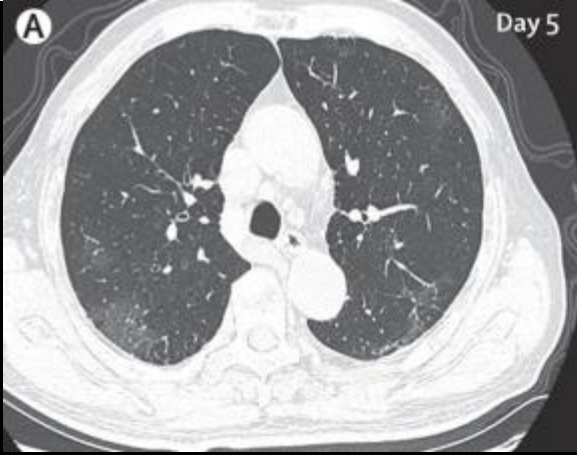
74yo F

61yo F



63yo F

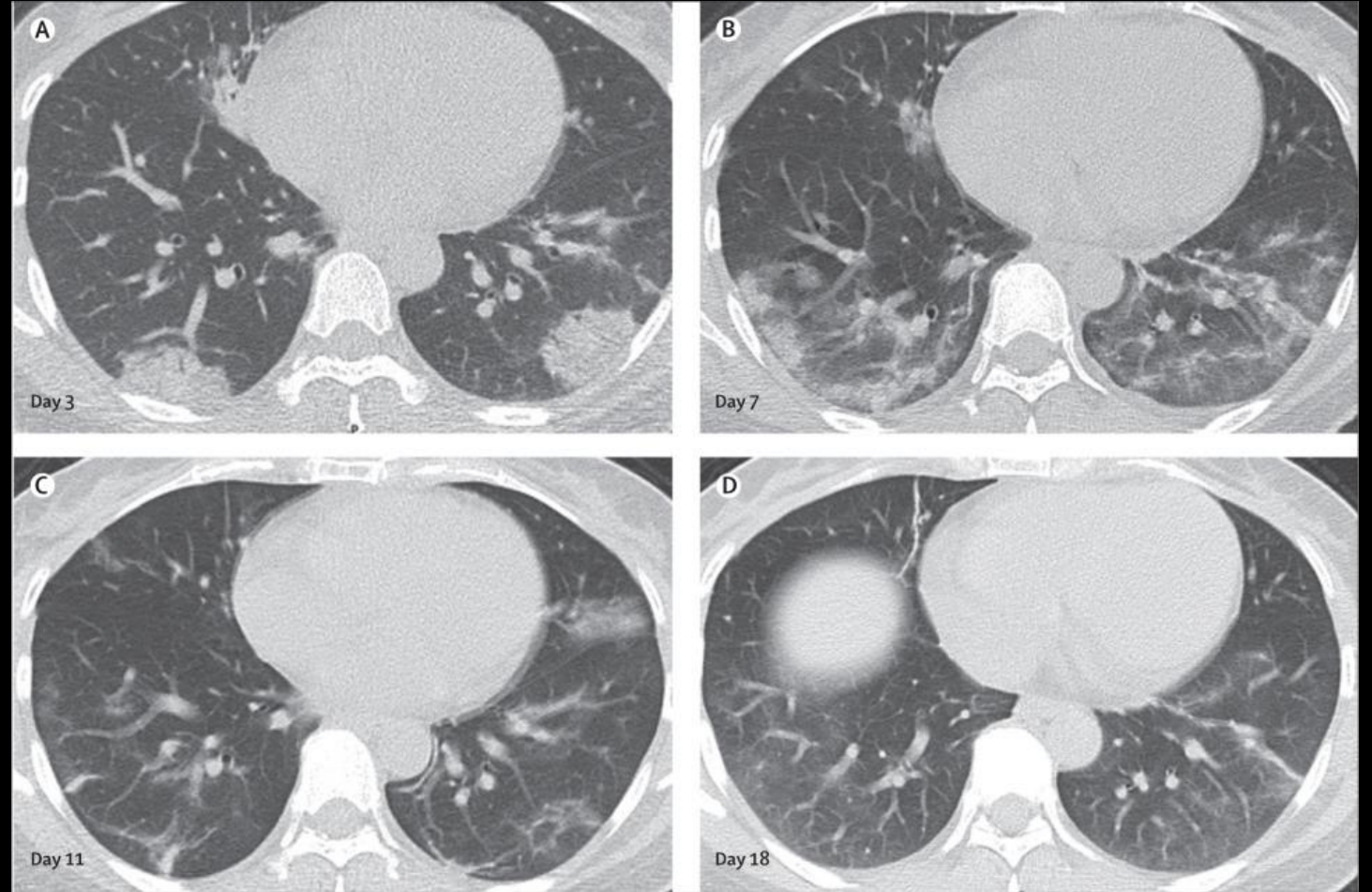
77yo M over 3 weeks, died at day 30



Shi H et al. *The Lancet* Feb 24, 2020. Radiological findings from 81 patients with COVID-19 pneumonia in Wuhan, China: A descriptive study.

81 patients at Wuhan Jinyintan hospital or Union Hospital of Tongji Medical College, China

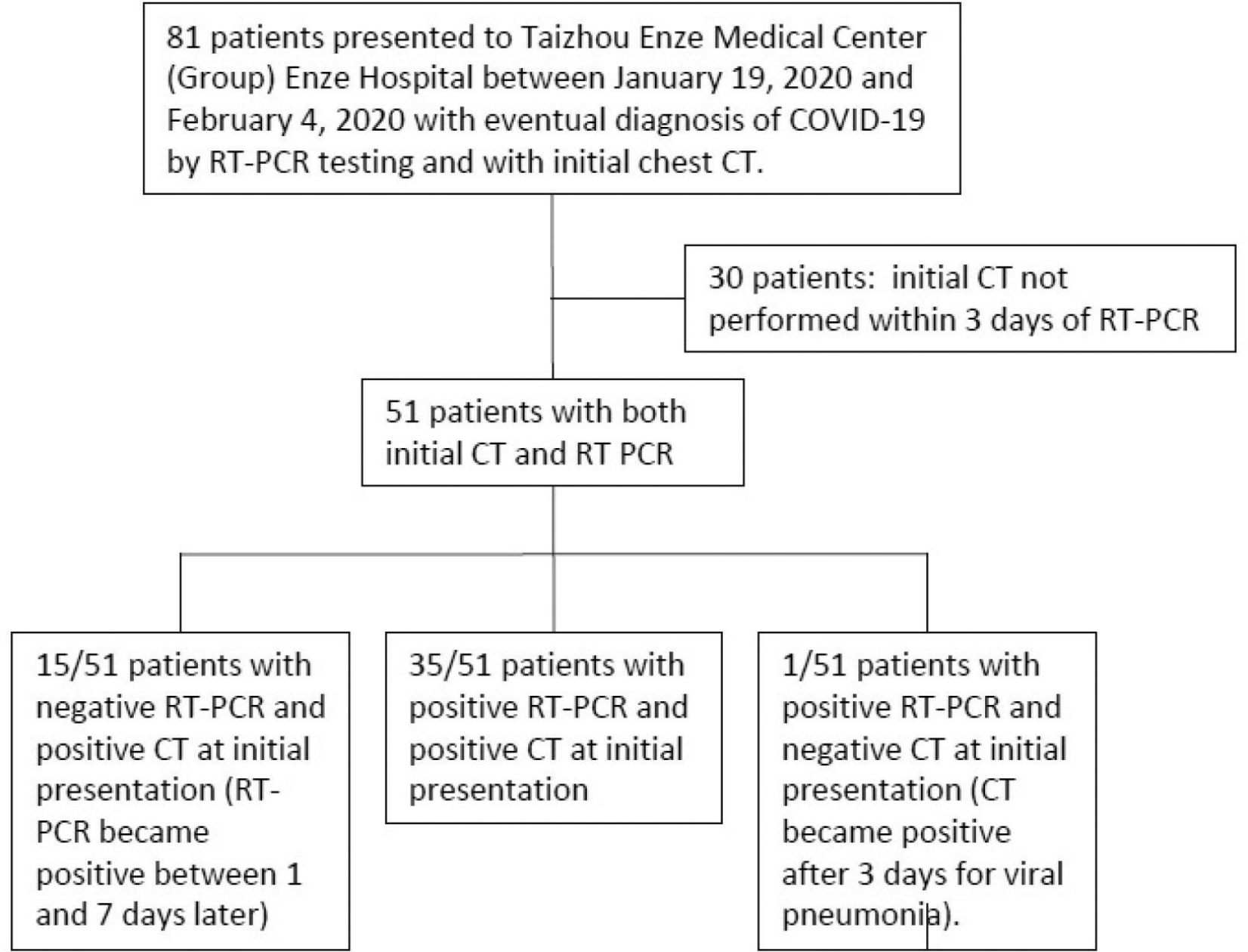
42yo F with resolution
of findings over 18 days
and eventual discharge
from hospital (day 20)



Shi H et al. *The Lancet* Feb 24, 2020. Radiological findings from 81 patients with COVID-19 pneumonia in Wuhan, China: A descriptive study.

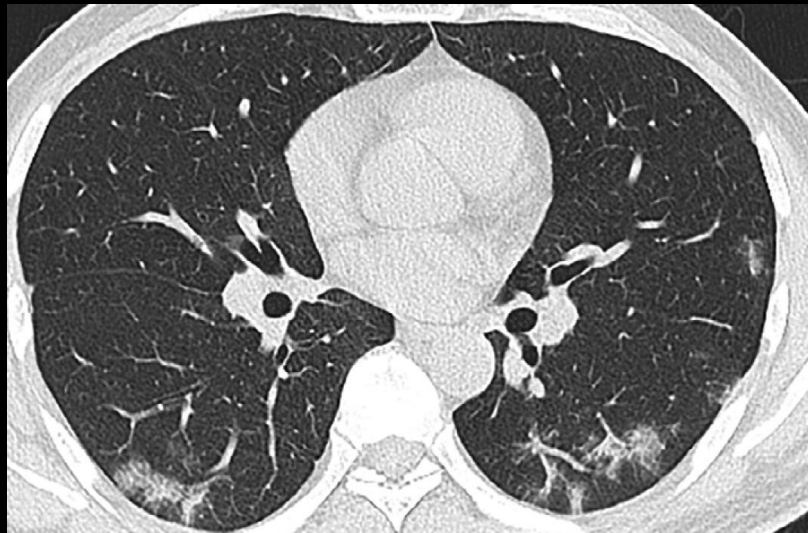
81 patients at Taizhou Enze Medical Center

30% of patients with positive CT findings had negative RT-PCR at presentation



81 patients at Taizhou Enze Medical Center

43yo M



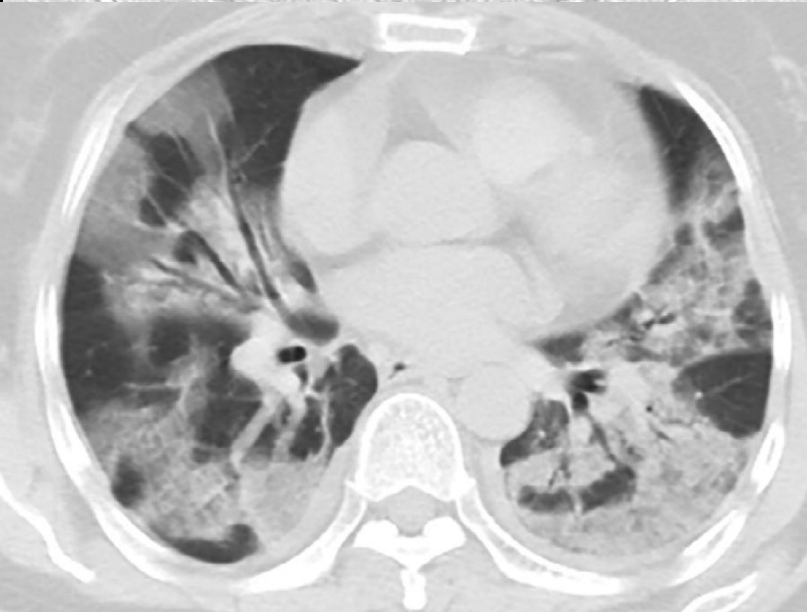
74yo M



43yo F



55yo F



21 patients, Wuhan, China

47yo F

Day 3

Day 7

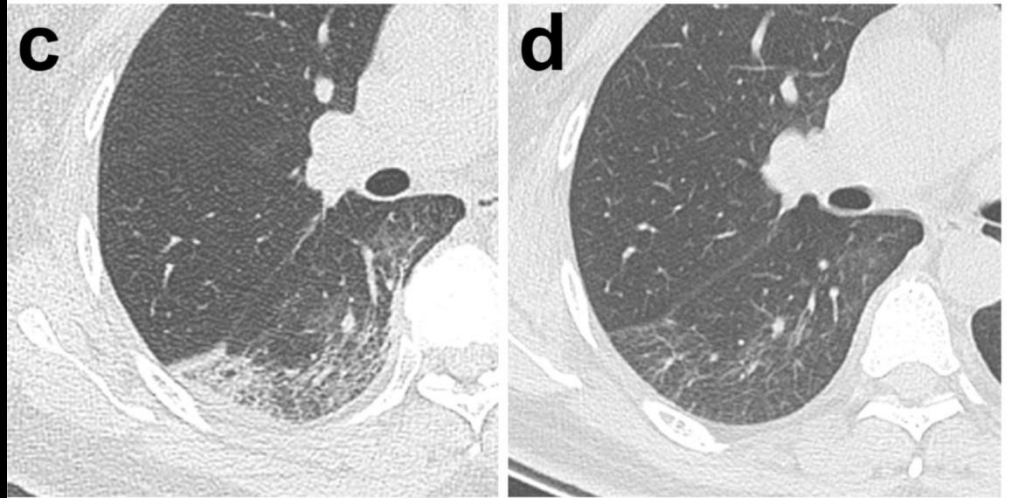
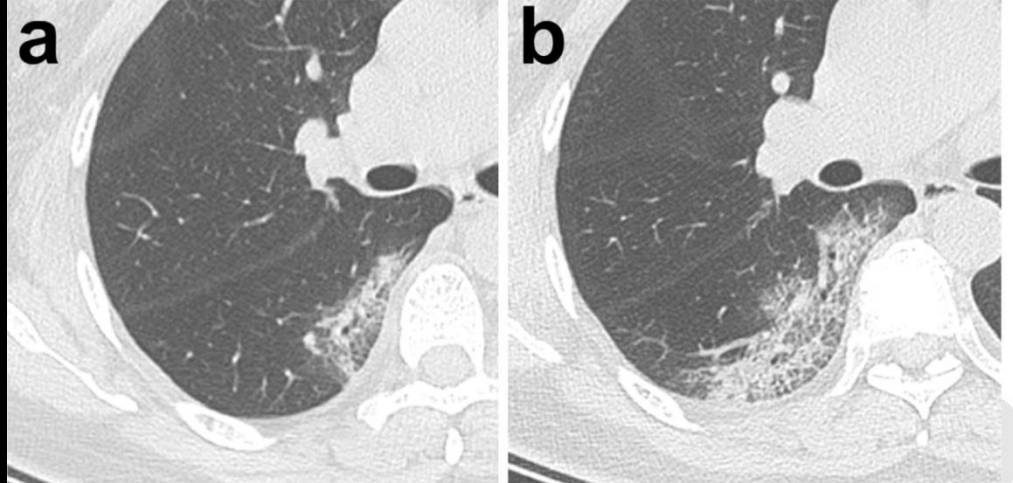
4 Stages:

Early (0-4 days): Ground glass opacity

Progressive (5-8 days): Add consolidation

Peak (9-13 days): Maximal GG / consolidation

Absorption (>13 days): Resolution of consolidation. Ground glass may persist (and can persist >26d)



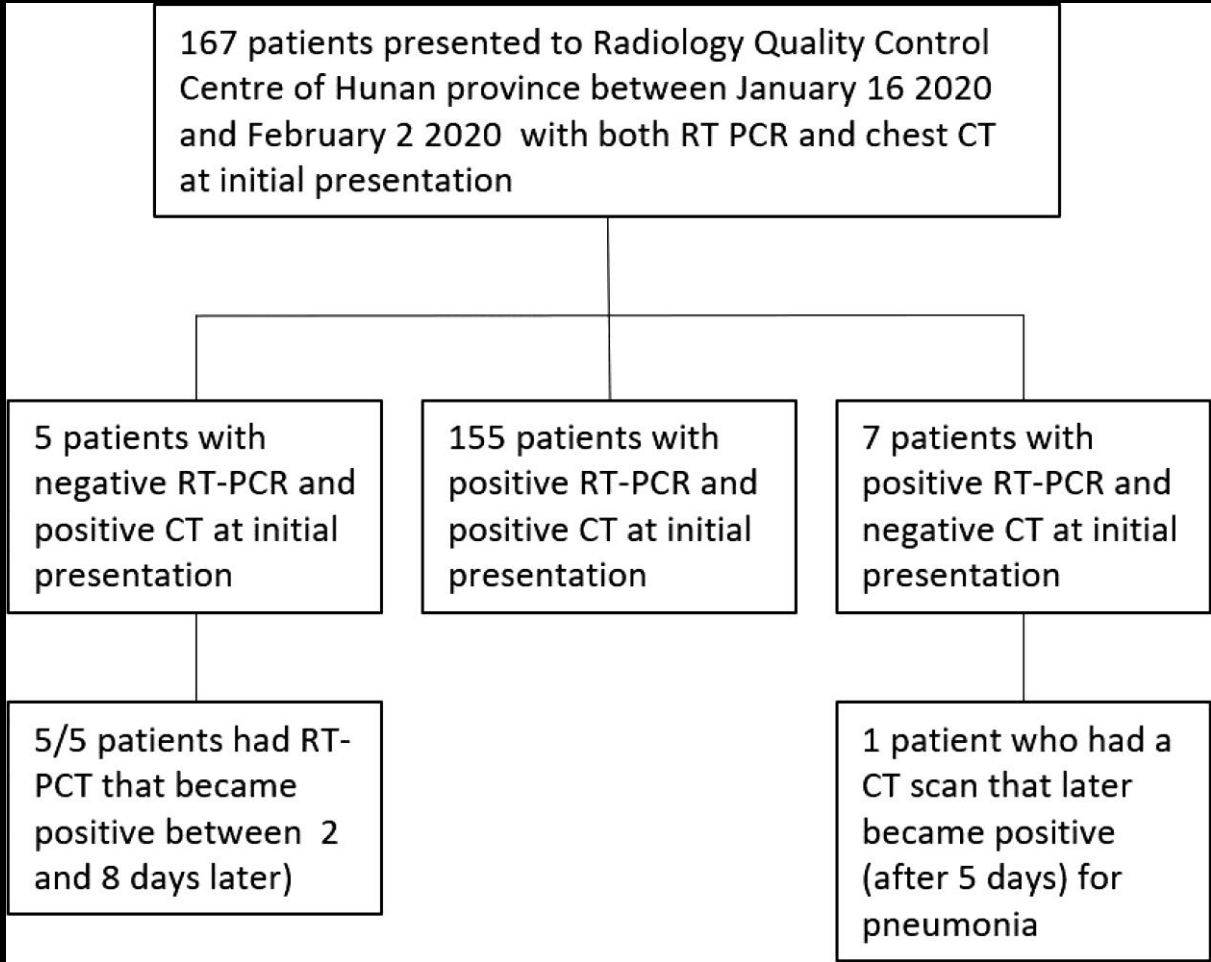
Day 11

Day 20

Pan F et al. *Radiology* Feb 13, 2020. Time course of lung changes on chest CT during recovery from 2019 Novel Coronavirus (COVID-19) pneumonia

167 patients, Radiology Quality Control Centre, Hunan province

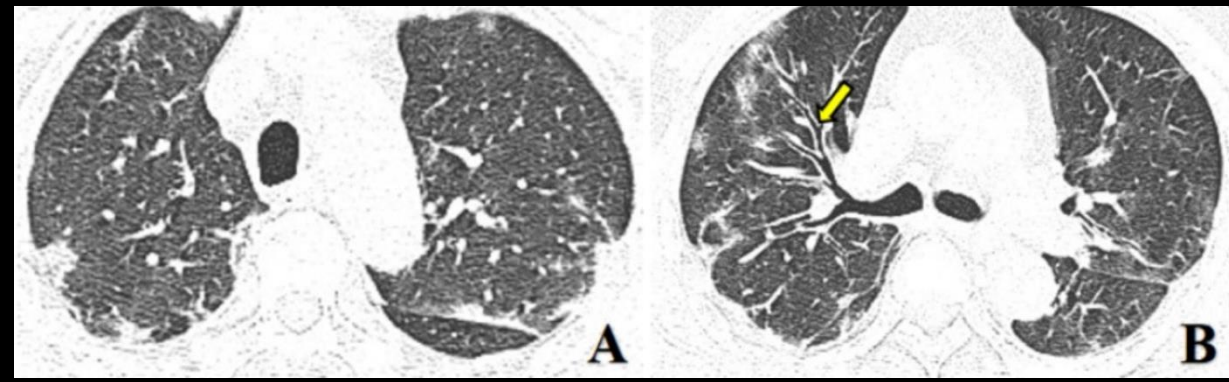
- 3% of patients RT-PCR negative but positive findings on CT



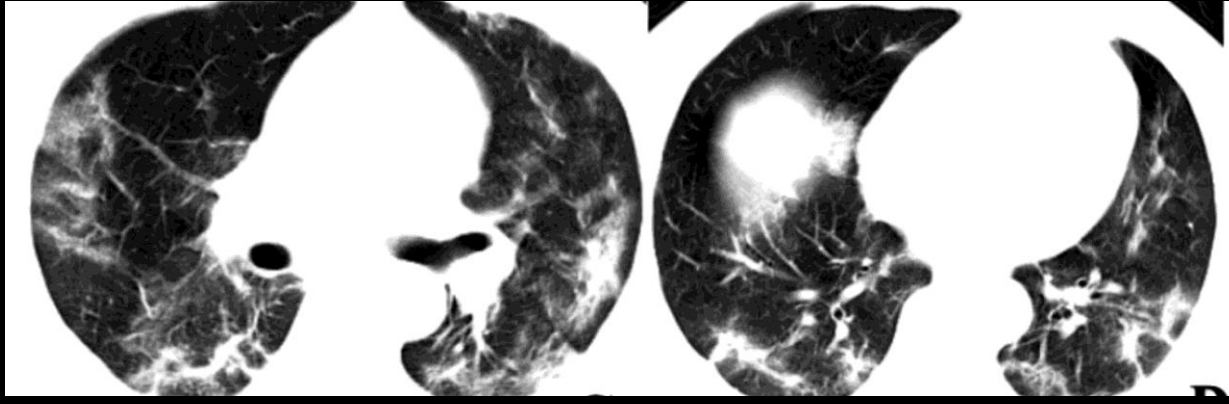
**167 patients, Radiology
Quality Control Centre,
Hunan province**

Examples of RT-PCR negative,
CT positive patients

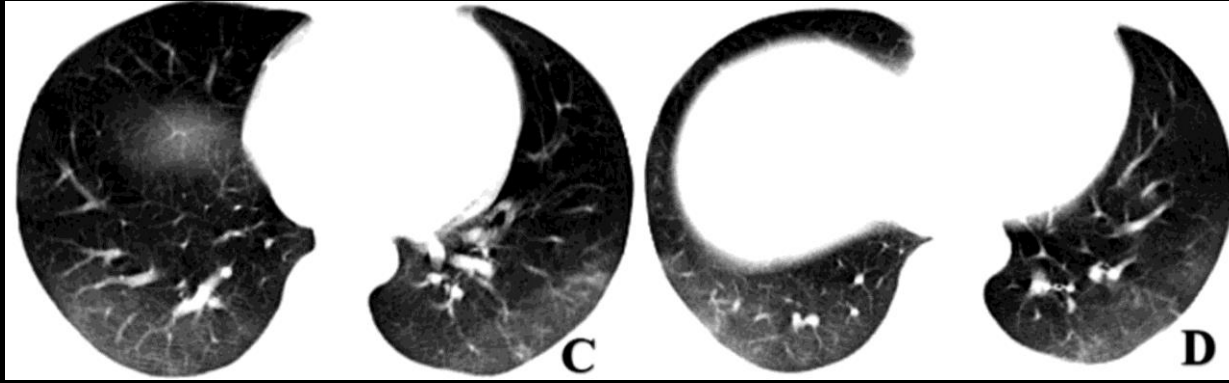
62yo F



60yo M



25yo F

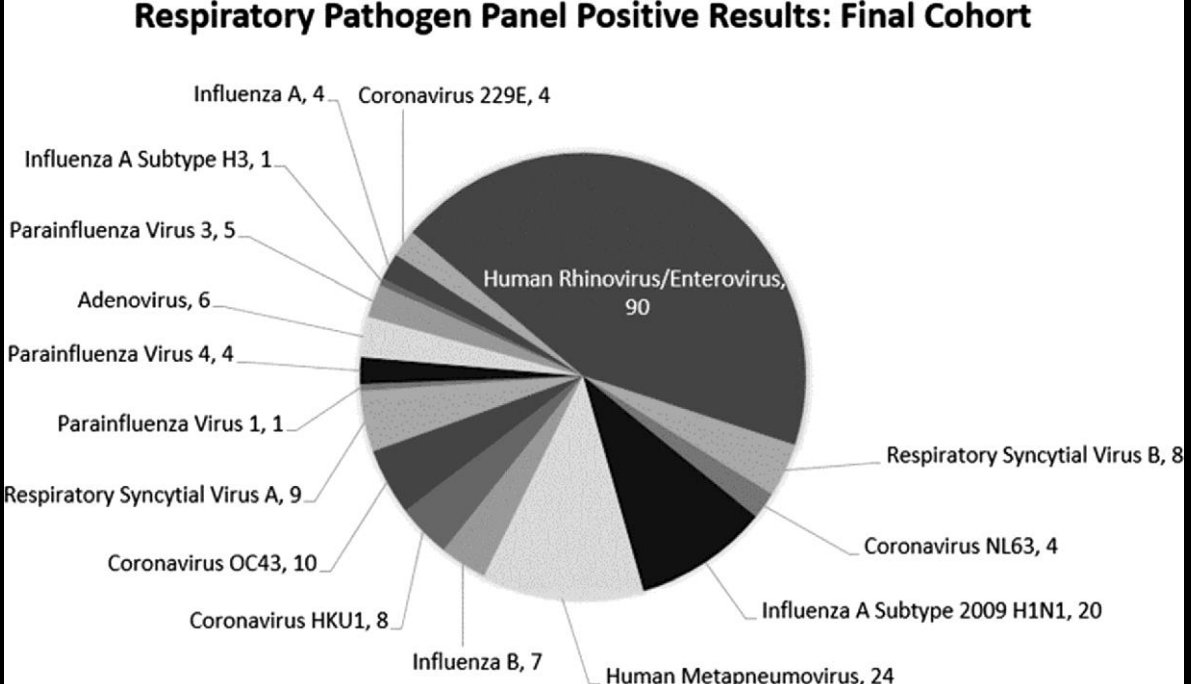


Xie X et al. *Radiology* Feb 12, 2020. Chest CT for typical 2019-nCoV pneumonia:
Relationship to negative RT-PCR testing

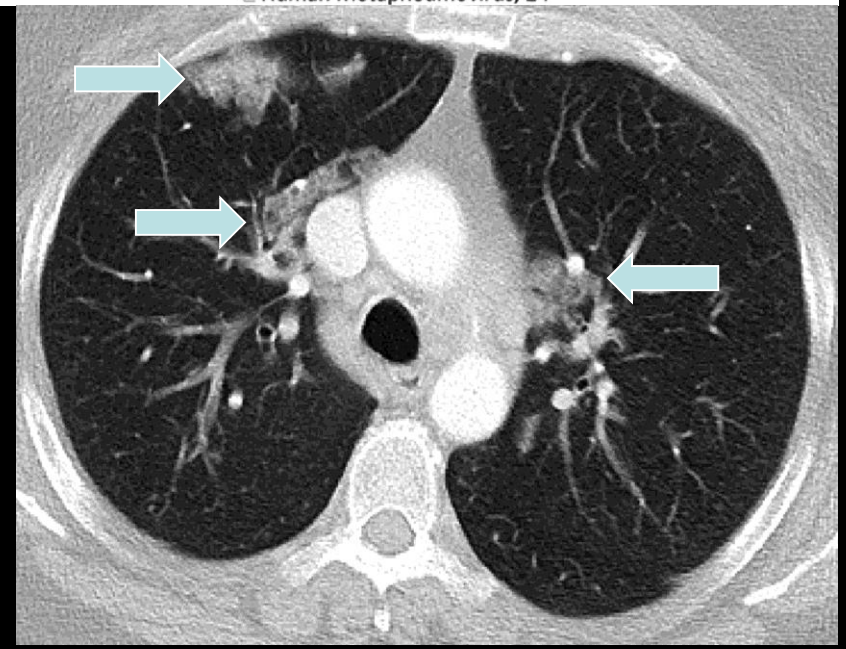
219 COVID-19 pts (Hunan, China) and 205 nonCOVID viral pneumonia pts (Providence, RI)

Chinese and US-based radiologists both had good (but variable) sensitivity and specificity in identifying COVID-19 versus viral pneumonia (blinded to RT-PCR results)

Mean age COVID-19: 45 years
Mean age non-COVID: 65 years



Non-COVID patient



Bai HX et al. *Radiology* Mar 10, 2020. Performance of radiologists in differentiating COVID-19 from viral pneumonia on chest CT.

**219 COVID-19 pts (Hunan, China)
and 205 nonCOVID viral pneumonia pts
(Providence, RI)**

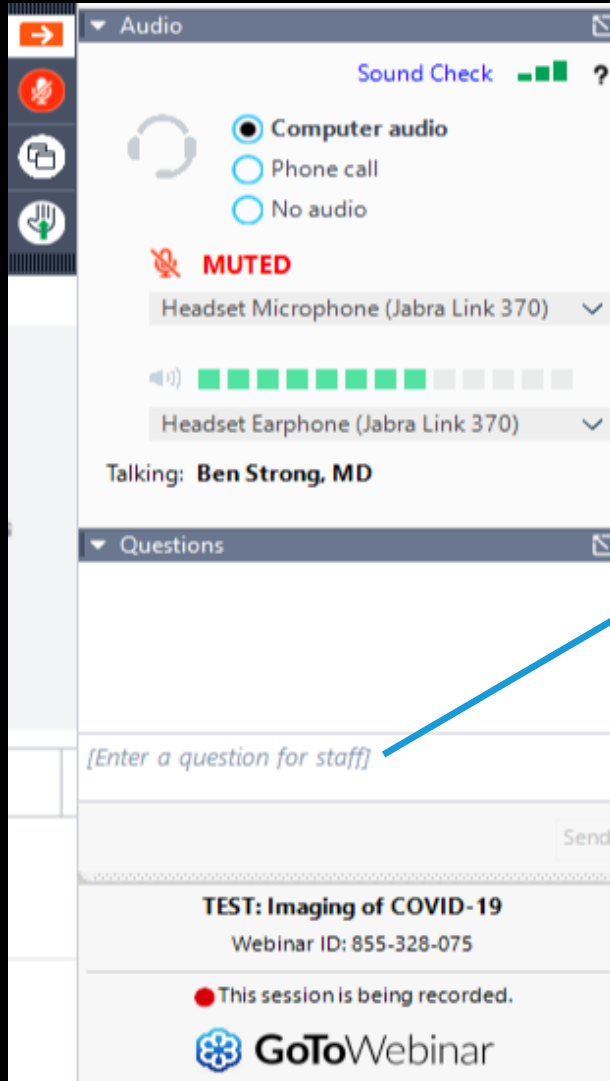
	COVID-19	Non-COVID-19
Central distribution	1%	6%
Peripheral distribution	80%	57%
Mixed distribution	14%	35%
Ground Glass Opacity	91%	68%
Fine Reticular Opacity	56%	22%
Pleural Effusion	4%	39%
Lymphadenopathy	3%	10%

Bai HX et al. *Radiology* Mar 10, 2020. Performance of radiologists in differentiating COVID-19 from viral pneumonia on chest CT.

Reporting

- COVID-19 pneumonia overlaps with many other viral pneumonias (influenza, RSV, metapneumovirus)
- “Atypical/viral pneumonia pattern”: Bilateral peripheral rounded/patchy ground glass
- Direct communication with referring can be very helpful for discussion of travel/exposure history

Q&A



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