COVID-19 Infection:

Thoracic Imaging Manifestations and Complications

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COVID-19: Thoracic Imaging Manifestations and Complications

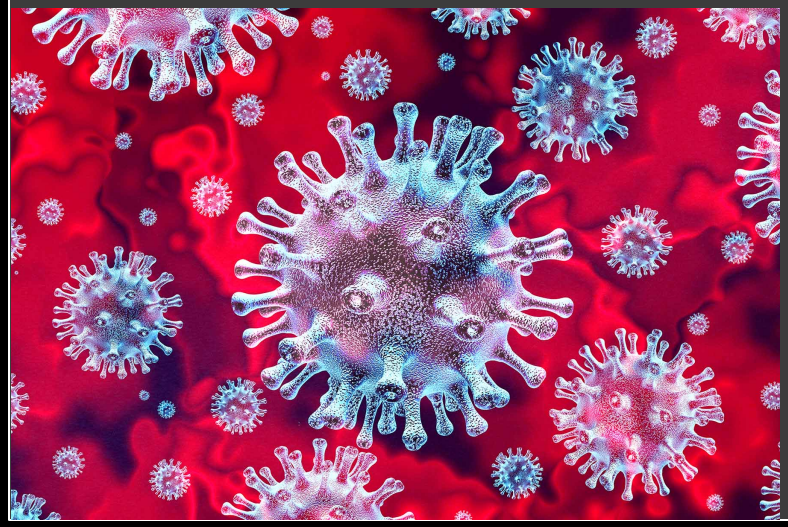
Objectives

Highlight current epidemiologic trends of COVID-19 in the United States

Synopsis of the position statements of various radiologic societies on the use of imaging during the COVID-19 pandemic

Review the various Thoracic radiologic manifestations of COVID-19 infection with illustrative case examples

Discuss various cardiopulmonary complications of COVID-19 infection including barotrauma and pulmonary thromboembolic disease



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COVID-19: Thoracic Imaging Manifestations and Complications

Global Spread Since January 21, 2020 [1]

1. https://coronavirus.jhu.edu/map.html

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Delta Variant [2,3]

Mutant strain is now racing through the US

2. https://www.Medscape.com/viewarticle/955094_print
3. https://arstechnica.com/science/2021/07/pandemic-of-unvaccinated-rages-with-deltas-spread-cases-up-in-all-50-states/

COVID-19: Thoracic Imaging Manifestations and Complications

Delta Variant [2,3]

Mutant strain is now racing through the US
COVID "Hot Spots" concentrated in 5 states
Cases are increasing in all 50 states & D.C.
Responsible for 93% of all "new" US cases

Ave. Daily Cases: >100,000 (11K)
Ave. Daily Hospitalizations: ⬆ 34%
Ave. Daily Deaths: ⬆ 33% (500d)

2. https://www.Medscape.com/viewarticle/955094_print
3. https://arstechnica.com/science/2021/07/pandemic-of-unvaccinated-rages-with-deltas-spread-cases-up-in-all-50-states/

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Delta Variant: Dominant Variant in Virginia & Maryland [4,5]

4X the number of cases compared with mid-June

- 700K cases / 11,500 deaths (8/05/21)

Ave. 487new cases per day

City or County (8/05/21)	COVID-19 Cases	COVID-19 Deaths
Fairfax	78,995	1,126
Prince William	46,848	514
Virginia Beach	37,939	421
Chesterfield	29,405	455
Loudon	28,859	283
Henrico	26,907	642
Chesapeake	22,160	311
Norfolk	18,669	276
Richmond	17,871	281

4. https://www.wavy.com/covid-19-vaccine/virginia-july-20-covid-19-update-721-new-cases-reported-hospitalizations-back-above-300-patients/
5. https://www.vdh.virginia.gov/coronavirus/covid-19-in-virginia-locality/

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Delta Variant and Surges in COVID Cases Share a Common Dominator [6,7]

- 90% of patients have one thing in common:

6. https://www.healthline.com/health-news/heres-who-is-being-hospitalized-for-covid-19-right-now#How-does-the-delta-variant-affect-hospitalizations?
7. https://www.nbcnews.com/health/health-news/virtually-all-hospitalized-covid-patients-have-one-thing-common-they-n1270482

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Delta Variant and Surges in COVID Cases Share a Common Dominator [6,7]

- 90% of patients have one thing in common:
  They are either un- or partially vaccinated

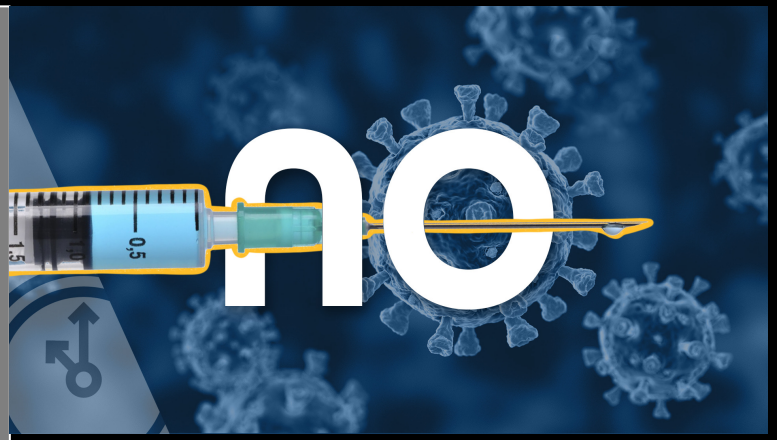
Cleveland Clinic reported in May 2021:

Of the nearly 4,300 COVID-19 admissions in Ohio b/w Jan. 1 and April 13, 2021

> 99.75% were un- or partially vaccinated

Most are younger b/w 18-49-years-old

Similar numbers reported at all major US hospitals



6. https://www.healthline.com/health-news/heres-who-is-being-hospitalized-for-covid-19-right-now#How-does-the-delta-variant-affect-hospitalizations?
7. https://www.nbcnews.com/health/health-news/virtually-all-hospitalized-covid-patients-have-one-thing-common-they-n1270482

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Current COVID-19 Infection Trends [8, 9]

Nearly all COVID-19 DEATHS in the U.S. now are in people who are unvaccinated

Deaths in the U.S. have plummeted from a peak of >3,400 per day in mid-January, 1-month into the vaccination drive, to < 300 per day

"Strong evidence" efficacy of these vaccines

Further evidence is that "surges" in delta variant are in those areas with the lowest vaccination rates

Pandemic of unvaccinated rages with delta's spread; cases up in all 50 states

In polls, the unvaccinated are the least worried about the delta variant.

BETH MOLE - 7/19/2021, 6:05 PM

Unvaccinated adults previously infected with COVID-19 are >2X likely to be reinfected compared with persons previously infected but also fully vaccinated

Cavanaugh AM et al Reduced Risk of Reinfection with SARS-CoV-2 After COVID-19 Vaccination — Kentucky, May–June 2021. *Morbidity and Mortality Weekly Report (MMWR)* August 6, 2021

8. https://apnews.com/article/coronavirus-pandemic-health-941fcf43d9731c76c16e7354f5d5e187
9. https://abcnews.go.com/US/summer-hotspots-us-covid-19-resurging/story?id=786288929

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Current COVID-19 Infection Trends [10,11]

1st detected in India-contributed to the most devastating COVID wave the world has seen so far

~ Dozen mutations: Vastly more contagious & possibly more lethal

Δ variant 60% *more transmissible* than α variant (60% *more transmissible* than the original Sars-CoV-2 strain isolated in Wuhan)

Most hyper-transmissible & contagious virus version seen to date

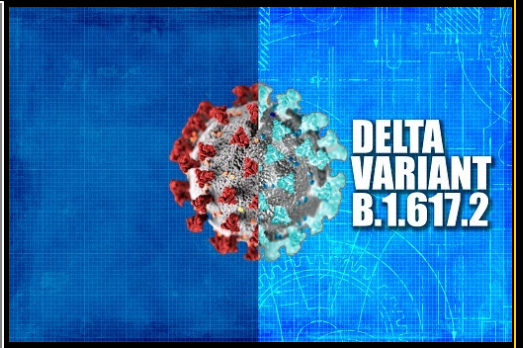
90 countries (USA)

United Kingdom: 90% of all new cases
Quadrupling of daily cases in 1-month
Doubling of hospitalizations

Scotland: Hospitalization rate Δ variant 85% > α variant

Caution: If vaccination rates fail to keep pace with its spread ➡ new COVID surges in unvaccinated population will continue

Good news: Vaccination appears to provide good protection against Δ variant although 1-dose seems to offer less protection than it did against other variants



10. . https://www.newyorker.com/science/medical-dispatch/the-delta-variant-is-a-grave-danger-to-the-unvaccinated
11. https://www.scientificamerican.com/article/how-dangerous-is-the-delta-variant-and-will-it-cause-a-covid-surge-in-the-u-s

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Societal Statements and Guidelines for Imaging [18]

Released position statements March 11, 2020 on the utility of CT as a screening tool for COVID-19:

Do not recommend routine CT for screening PUI

Only used to evaluate suspected complications (e.g., abscess, empyema)

18. The American Society of Emergency Radiology (ASER) (2020) STR / ASER COVID- 19 position statement. https://thoracicrad.org/wp-content/uploads/2020/03/ STR-ASER-Position-Statement-1.pdf 2020.

COVID-19: Thoracic Imaging Manifestations and Complications

Societal Statements and Guidelines for Imaging [19,20]

Do not recommend using CT to screen for COVID-19

Suggested 4 categories for standardized chest CT reporting for PUI / COVID

Using "viral pneumonia" as an alternative term for incidentally discovered imaging findings compatible with COVID-19

COVID-19: Structured Reporting for Chest CT

RSNA Expert Consensus Document on Reporting Chest CT findings related to COVID-19.
Endorsed by the STR & ACR 3/24/2020

Classification	Rationale	CT Finding	Suggested Reporting Language
Typical	Commonly reported imaging features of greater specificity for COVID-19 pneumonia	• Peripheral, bilateral (multilobar), GGO w/ or w/o consolidation or visible intralobular lines ("crazy-paving") • Multifocal GGO of rounded morphology w/ or w/o 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]
Indeterminate	Nonspecific imaging features of COVID-19 pneumonia	**Absence of typical features AND the presence of:** • Multifocal, diffuse, perihilar or unilateral GGO w/ or w/o consolidation, lacking a specific distribution, & are non-rounded or non-peripheral • Few very small GGO with a non-rounded & 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]
Atypical	Uncommonly or not reported features of COVID-19 pneumonia	**Absence of typical or indeterminate features AND presence of:** • Isolated lobar or segmental consolidation w/o GGO • Discrete small nodules (centrilobular, tree-in-bud) • Lung cavitation • Smooth interlobular septal thickening w/ pleural effusion	*Imaging features are atypical or uncommonly reported for (COVID-19) pneumonia. Alternative diagnoses should be considered.* [Cov19Aty]
Negative	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]

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Radiological Society of North America

19. Simpson S, Kay FU, Abbara S, et al. Radiological Society of North America expert consensus statement on reporting chest CT findings related to COVID-19. Endorsed by the Society of Thoracic Radiology, the American College of Radiology, and RSNA. Radiology: Cardiothoracic Imaging 2020;2:e200152.
20. ACR. Practice parameterfor communication of diagnostic imaging findings. The American College of Radiology (ACR); 2014. https://www.acr.org/-/media/ACR/ Files/Practice-Parameters/CommunicationDiag.pdf.

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Societal Statements and Guidelines for Imaging [21]

Released a multinational statement on using chest imaging during the COVID-19 pandemic based on the severity of illness, resource availability, and pre-test probability for COVID-19

Recommend against the use of any imaging in mild COVID-19 cases

Reserve imaging for patients with severe or progressive respiratory failure or suspected pulmonary thromboembolic disease

21. Rubin GD, Ryerson CJ, Haramati LB, et al. The role of chest imaging in patient management during the COVID-19 pandemic: a multinational consensus statement from the Fleischner society. Radiology 2020:201365.

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Societal Statements and Guidelines for Imaging [22]

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CT should **NOT** be used to screen for or as a first-line test to diagnose COVID-19

CT should be used sparingly and reserved for hospitalized, symptomatic patients with specific clinical indications (e.g., worsening respiratory status, abscess, empyema, ARDS, PE)

Urge caution on using chest CT to aid in decisions on whether to test a patient for COVID-19, admit a patient or provide other treatment

Normal chest CT does NOT exclude active COVID-19 infection and should NOT affect the decision to quarantine a patient if appropriate

Abnormal CT is NOT specific for COVID-19 diagnosis

22. ACR. Recommendations for the use of chest radiography and computed tomography (CT) for suspected COVID-19 infection. https://www.acr.org/Advoc acy-and-Economics/ACR-Position-Statements/Recommendations-for-Chest-Radio graphy-and-CT-for-Suspected-COVID19-Infection; 2020.

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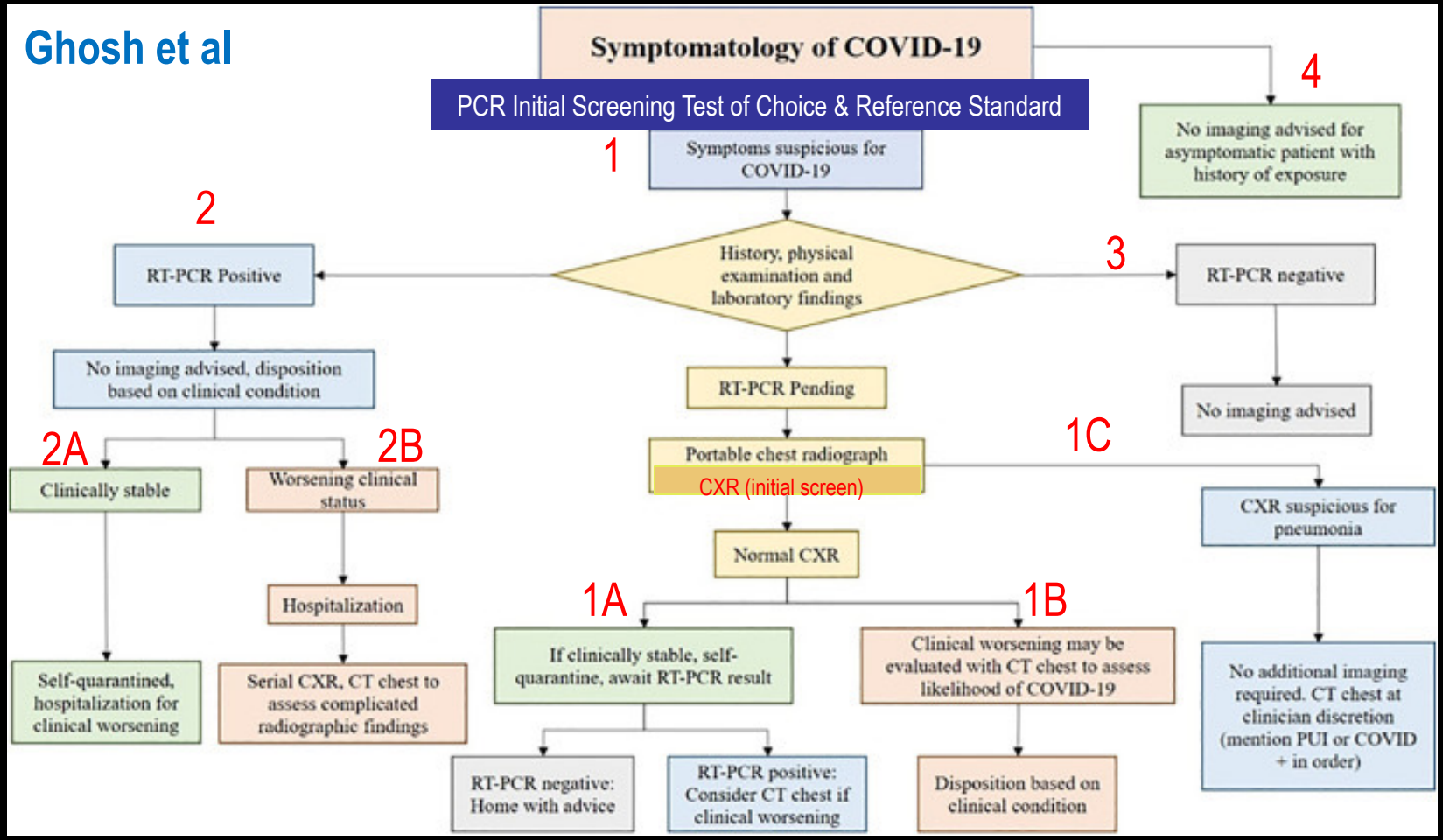
Role of NP-PCR and Thoracic Imaging [12-17, 23]



12. Liu W, Zhang Q, Chen J, et al. Detection of Covid-19 in Children in Early January 2020 in Wuhan, China. *N Engl J Med* 2020;382:1370-1.
13. Young BE, Ong SWX, Kalimuddin S, et al. Epidemiologic Features and Clinical Course of Patients Infected With SARS-CoV-2 in Singapore. i*JAMA*. 2020;323(15):1488-1494. doi:10.1001/jama.2020.3204
14. Wang W, Xu Y, Gao R, et al. Detection of SARS-CoV-2 in Different Types of Clinical Specimens. *JAMA* 2020.
15. Chen W, Lan Y, Yuan X, et al. Detectable 2019-nCoV viral RNA in blood is a strong indicator for the further clinical severity. *Emerg Microbes Infect* 2020;9:469-73.
16. Ding Q, Lu P, Fan Y, Xia Y, Liu M. The clinical characteristics of pneumonia patients coinfected with 2019 novel coronavirus and influenza virus in Wuhan, China. *J Med Virol* 2020.
17. COVID Real-time Learning Netwrokhttps://www.idsociety.org/covid-19-real-time-learning-network/diagnostics/RT-pcr-testing/
23. Ghosh S, Deshwal H, Saeedan M, et al. Imaging algorithm for COVID-19: A practical approach. Clinical Imaging 72 (2021); 22–30.

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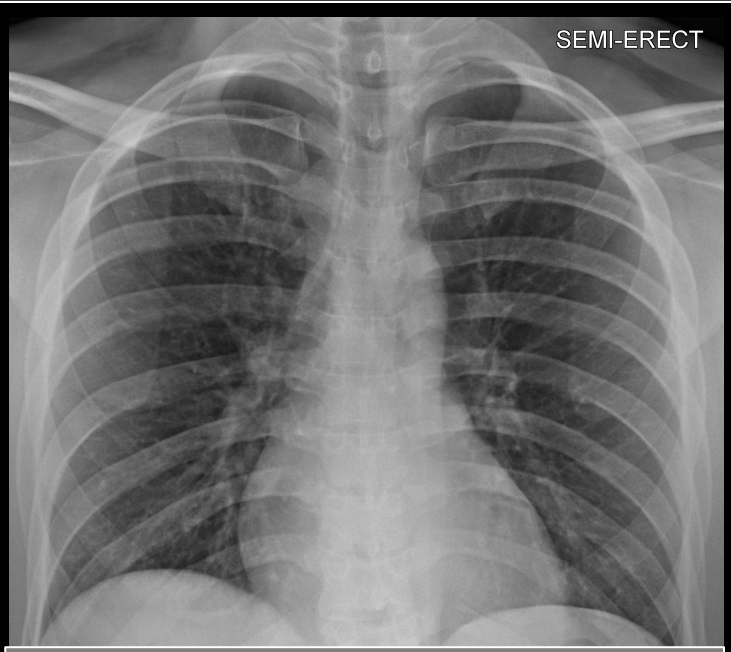
Radiologic Manifestations: Chest [24, 25]

CXR: May be unremarkable early in the disease (0-4 days after onset of symptoms)



Suggested RSNA Report:
No radiographic evidence of pneumonia

24. Guan WJ ,Ni ZY, Hu Y,et al. Clinical Characteristics of Coronavirus Disease 2019 in China. *N Engl J Med* 2020;382:1708-20.
25. Lei J , Li J, Li X, Qi X. CT Imaging of the 2019 Novel Coronavirus (2019-nCoV) Pneumonia. *Radiology* 2020;295:18.

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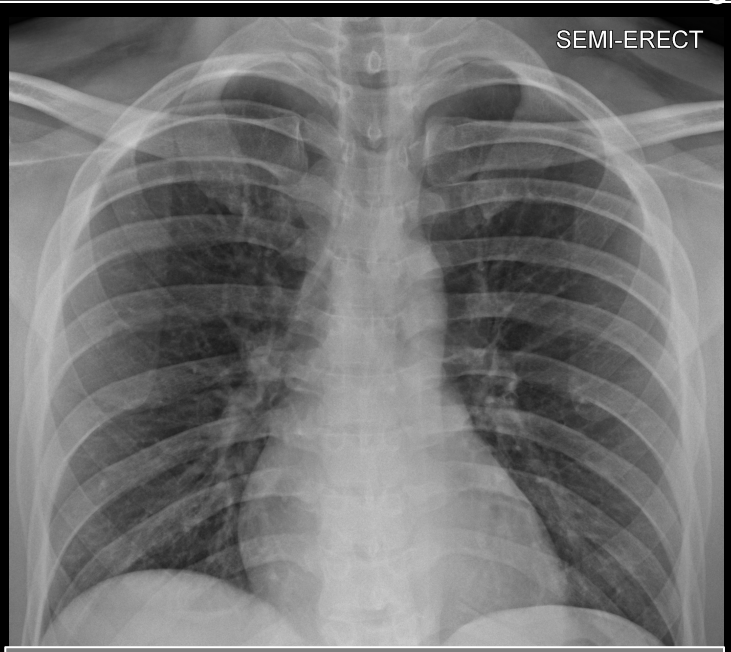
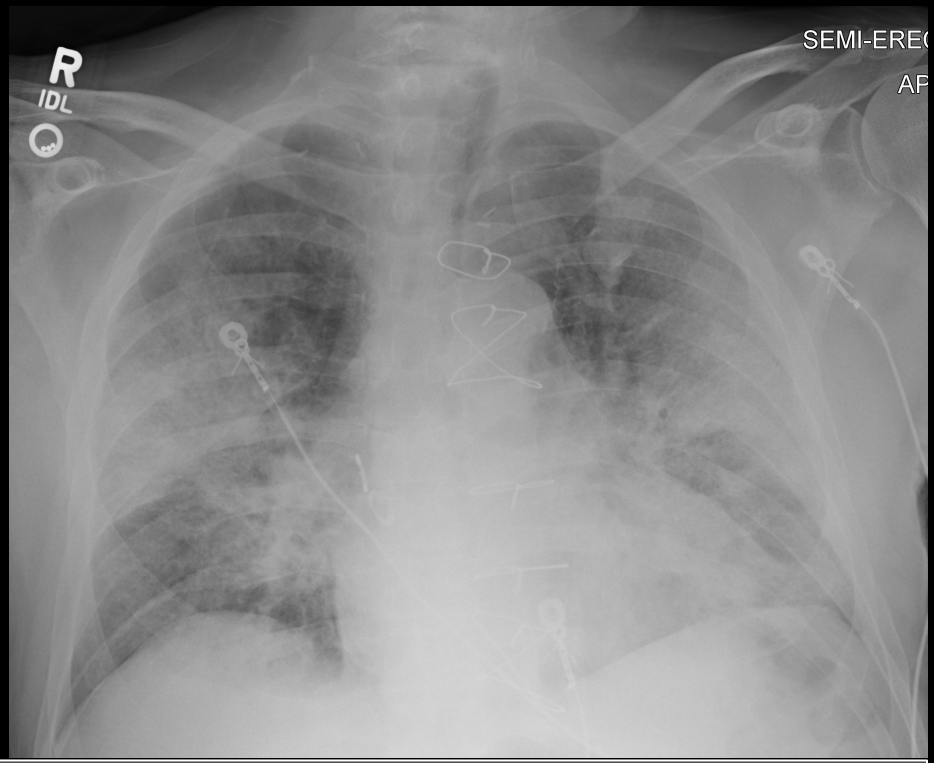
Radiologic Manifestations: Chest [24, 25]

CXR: May be unremarkable early in the disease (0-4 days after onset of symptoms)

Abnormal: Most often reveals bilateral, peripheral, non-specific air-space opacities, often with a mid- and lower lung zone predilection





Suggested RSNA Report:
No radiographic evidence of pneumonia

24. Guan WJ ,Ni ZY, Hu Y,et al. Clinical Characteristics of Coronavirus Disease 2019 in China. *N Engl J Med* 2020;382:1708-20.
25. Lei J , Li J, Li X, Qi X. CT Imaging of the 2019 Novel Coronavirus (2019-nCoV) Pneumonia. *Radiology* 2020;295:18.

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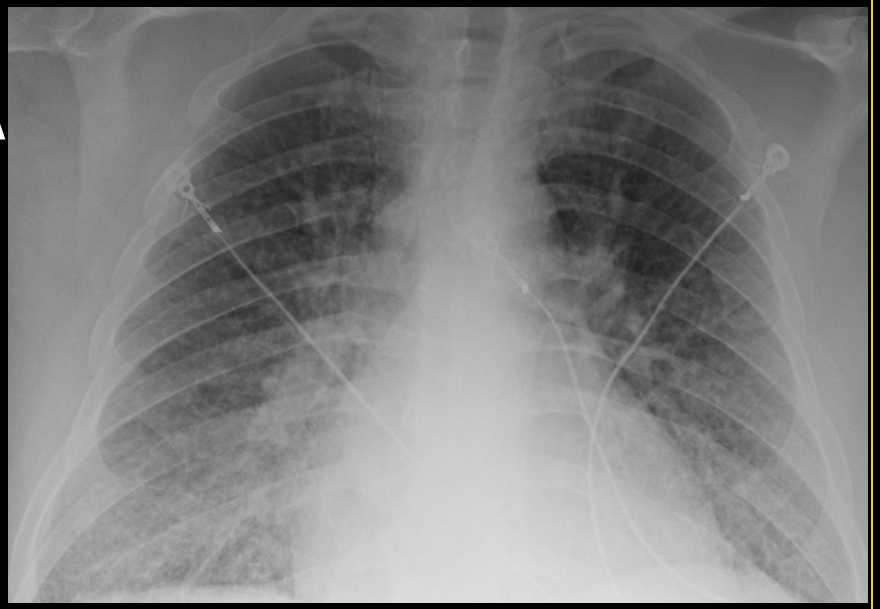
Indeterminate for COVID Pneumonia

- Basilar opacities which could represent ATX, edema, ILD or PNA
- Chronic disease (ILD) with possible new findings



Suggested RSNA Report:
Radiographic findings are indeterminant for pneumonia (COVID-19 pneumonia or other disease may be present)

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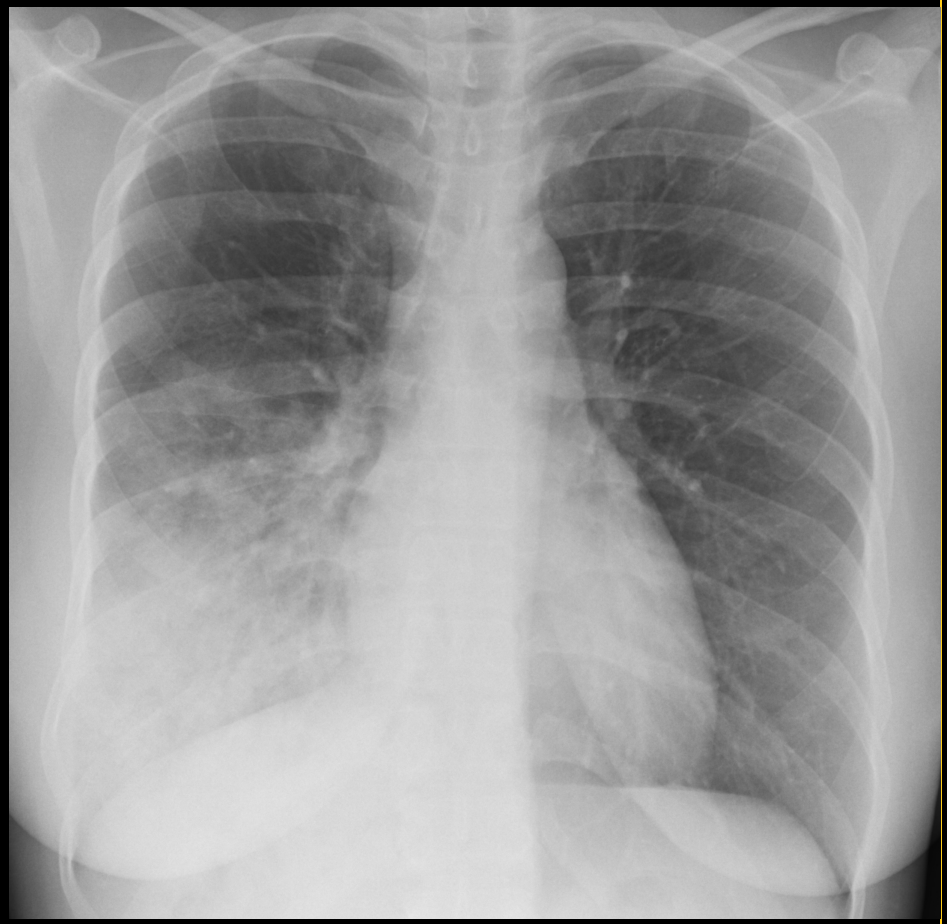
Atypical for COVID Pneumonia

Unilateral focal PNA
Patchy perihilar opacity
Pleural effusion is also uncommon



Suggested RSNA Report:
Focal pneumonia (atypical imaging feature of COVID-19 pneumonia but may be seen early on). Other infections(s) are favored.

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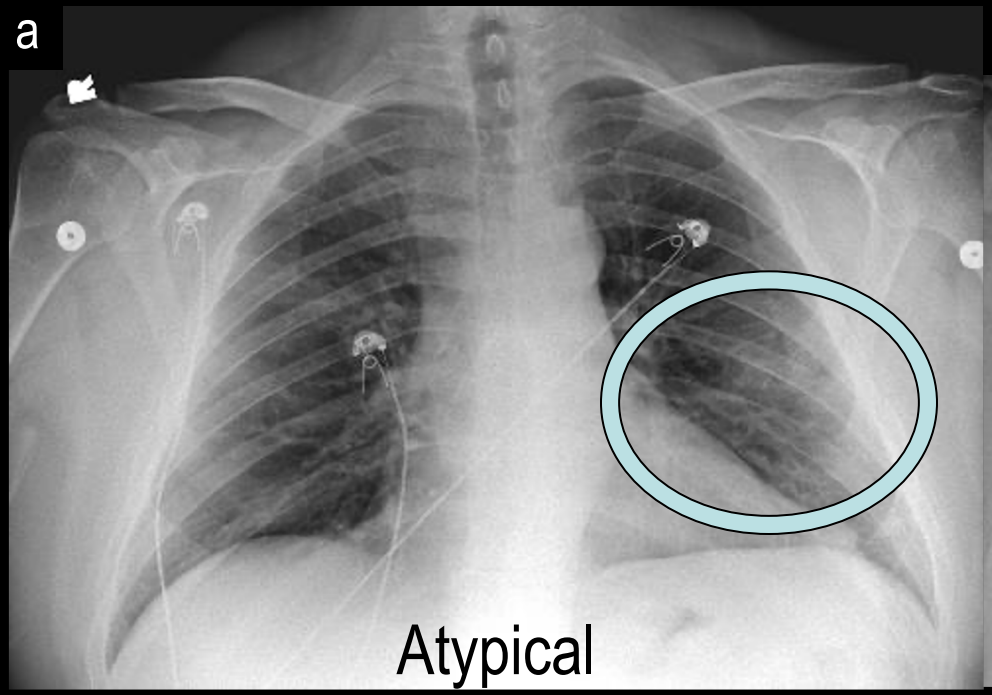
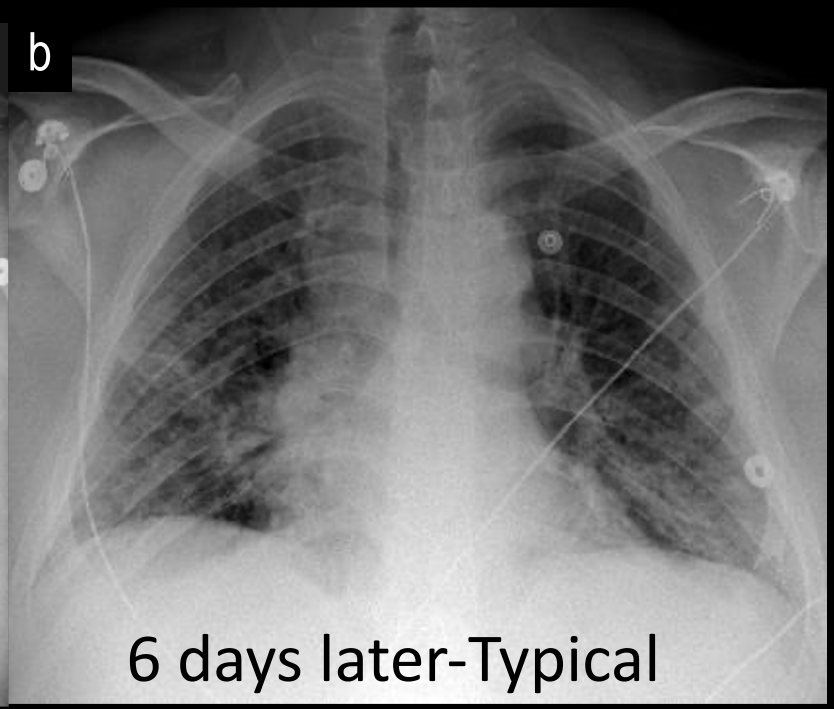
"Atypical" then "Typical" for COVID Pneumonia





COVID-19 in a 51-year-old man. (a, b) Frontal chest x-rays obtained at 10 days after symptom onset (a) and 6 days later (b). Unilateral ill-defined hazy opacities with mild linear opacities in the left lower lobe that reflect COVID-19 (a). Frontal radiograph obtained 6 days later shows how the opacities have progressed to a more typical pattern(b).

Suggested RSNA Report:
Multifocal +/or bilateral PNA (Typical appearance for COVID-19 PNA)

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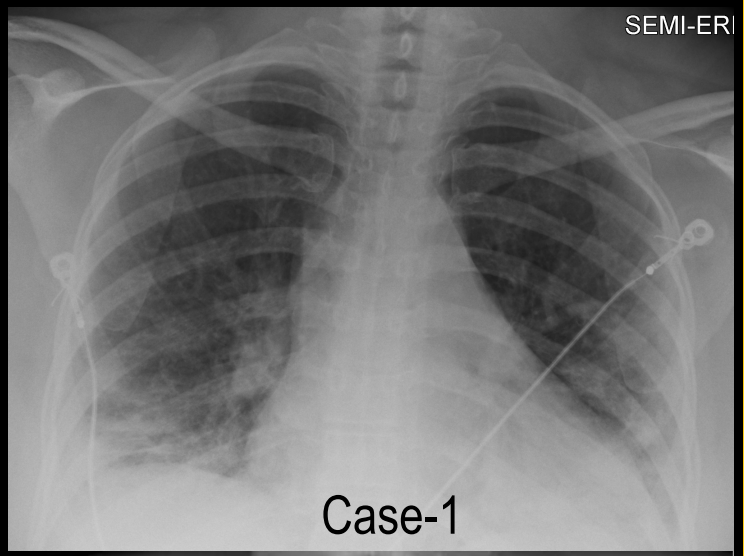
Typical for COVID Pneumonia

Bilateral patchy opacities with mid-to lower lung zone predominance (Case 1)

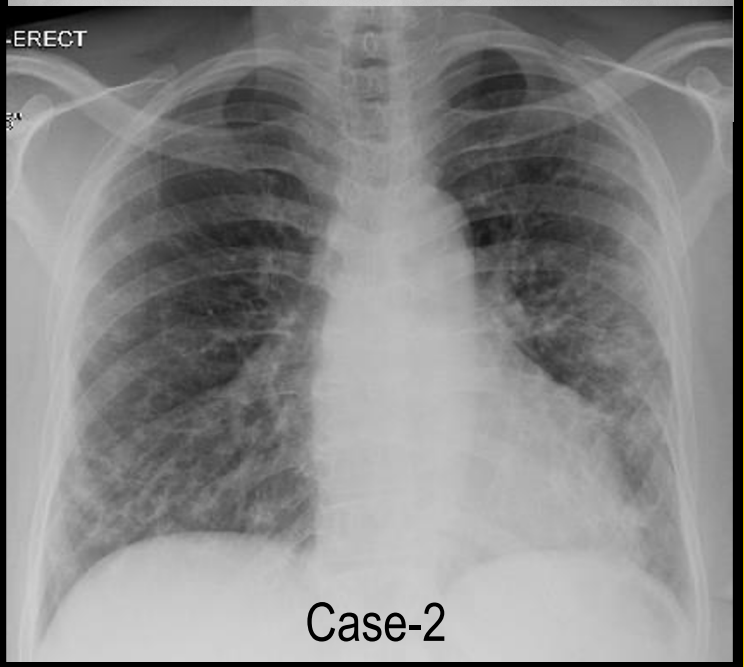
Often peripheral & rounded (Case -2)

Bilateral multifocal consolidation +/-
interstitial thickening or

May progress to diffuse air space disease



Case-1



Case-2

Suggested RSNA Report:
Multifocal +/or bilateral PNA (Typical appearance for COVID-19 PNA). Other diseases may be present.

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Expected Evolution of CXR Findings [26]

240 symptomatic COVID (+) Patients
75% abnormal CXR's
>73% bilateral disease

Upper Lobe	**36.7%**
Middle Lobe	**79.4%**
Lower Lobe	**87.8%**

Vancheri et al

Time from Symptom Onset

CXR Finding	Total	0-2 days	3-5 days	6-9 days	> 9 days
GGO (Hazy)	68.8%	67.7%	62.9%	71%	76.9%
Reticulation	62.7%	70.9%	72.2%	57.9%	46.1%
Consolidation	39.4%	35.4%	31.4%	47.8%	38.5%

Early Phase | Intermediate-Late Phase

26. Vancheri SG et al. *Eur Radiol*. 2020: 30: 1-9

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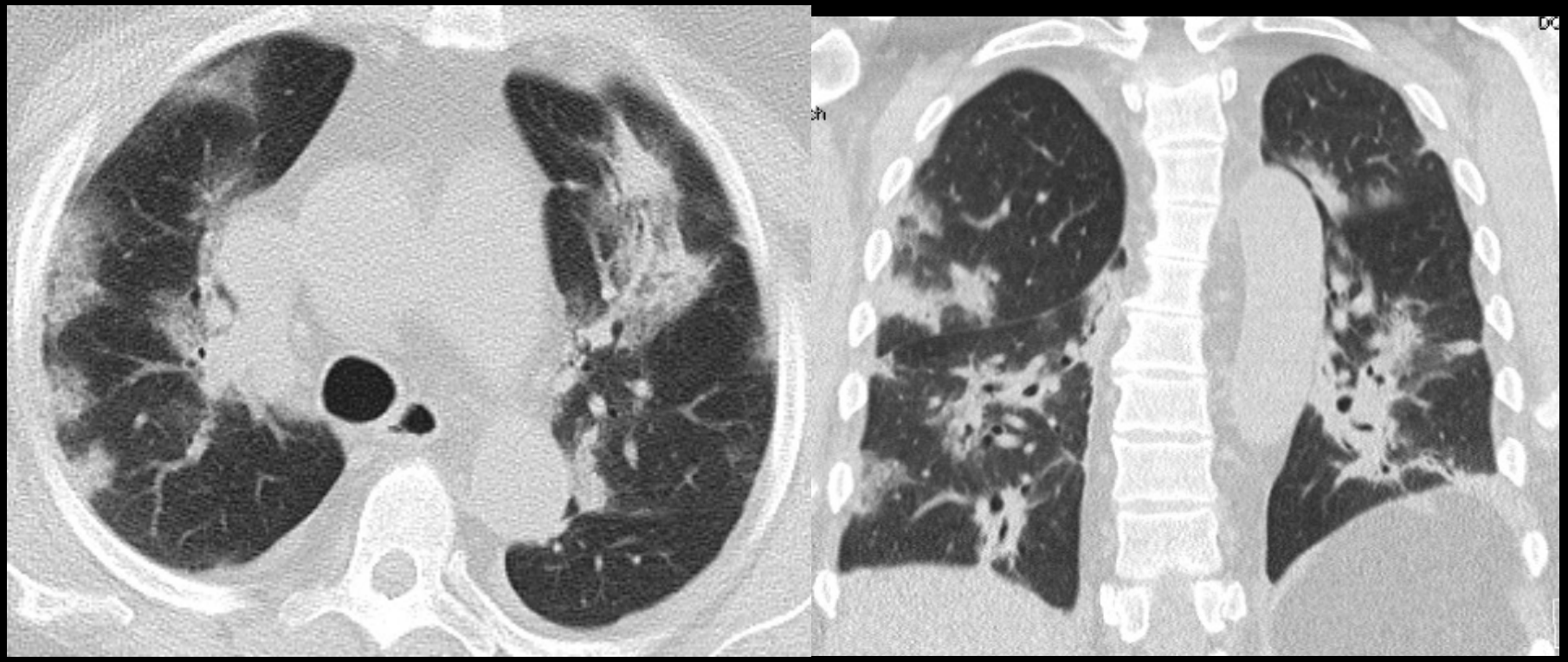
Typical for COVID Pneumonia:

Chest CT: Multifocal bilateral, peripheral ground glass opacities



Suggested RSNA Report: Commonly reported imaging features of (COVID-19) pneumonia are present. Other processes such as Influenza PNA and organizing PNA, as can be seen with drug toxicity and connective tissue disease, can cause a similar imaging pattern [Cov19Typ]

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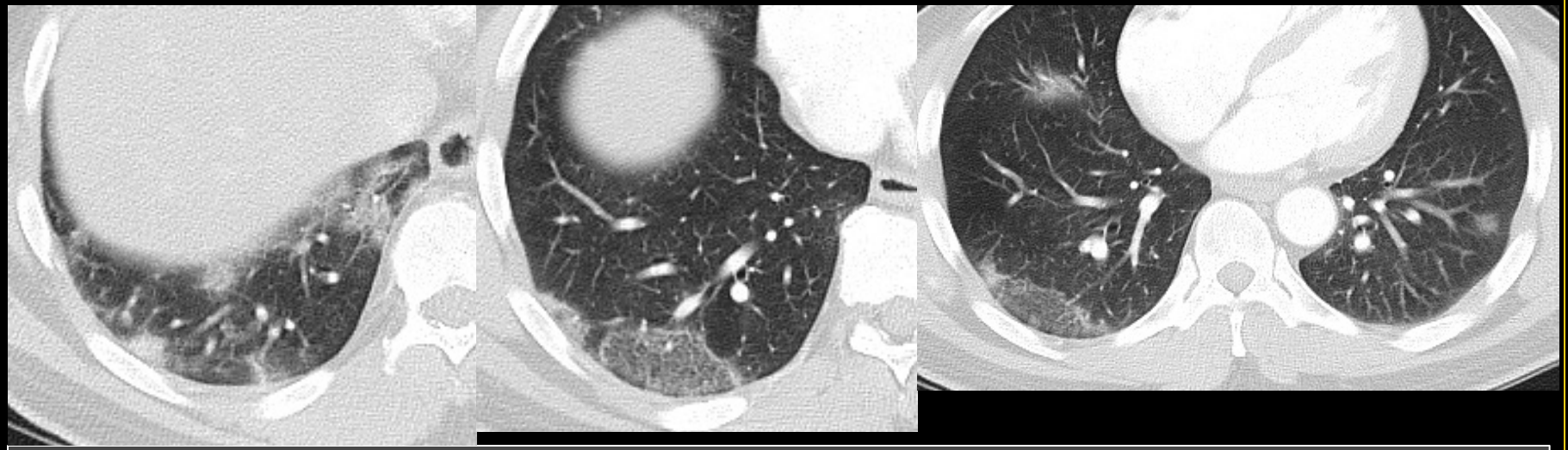
Typical for COVID Pneumonia

Peripheral Ground Glass Nodules and "Reverse Halo Sign"



56-year-old man with dry cough and history of attending a gathering with people coming from New York. Multiple axial images from CT scan show multiple ground glass opacities with rounded morphology. Additionally, there is a focal ground glass opacity in the posterior right lower lobe surrounded by a thin rind of consolidation compatible with a reverse halo sign.

Suggested RSNA Report: Commonly reported imaging features of (COVID-19) pneumonia are present. Other processes such as Influenza PNA and organizing PNA, as can be seen with drug toxicity and connective tissue disease, can cause a similar imaging pattern [Cov19Typ]

COVID-19: Thoracic Imaging Manifestations and Complications

Typical for COVID Pneumonia

Multi-focal ground glass opacities with a predominant peripheral and lower lobe distribution

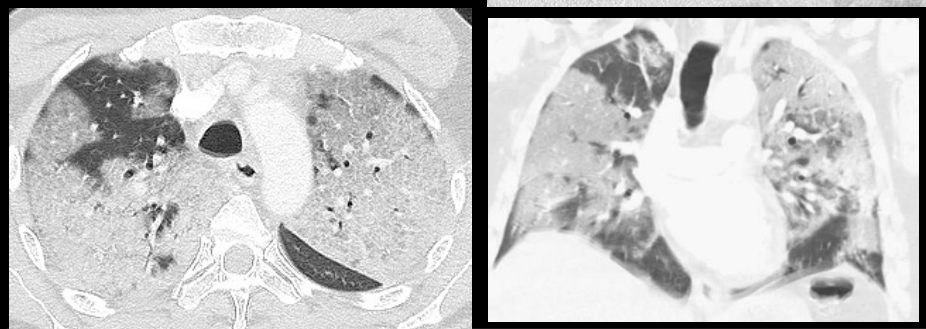
Suggested RSNA Report: Commonly reported imaging features of (COVID-19) pneumonia are present. Other processes such as Influenza PNA and organizing PNA, as can be seen with drug toxicity and connective tissue disease, can cause a similar imaging pattern [Cov19Typ]

COVID-19: Thoracic Imaging Manifestations and Complications

Indeterminate for COVID Pneumonia

Diffuse Perihilar Airspace and Interstitial Opacities

COVID (-): Drug-Induced ALI



Confirmed COVID-19 pneumonia in a 64-year-old man

CT images shows widespread ground glass opacities with visible interlobular septal thickening involving the upper and lower lobes.

Suggested RSNA Report: Imaging features can be seen with (COVID-19) pneumonia, although are non-specific and can occur with a variety of infectious and non-infectious processes [Cov19Ind]

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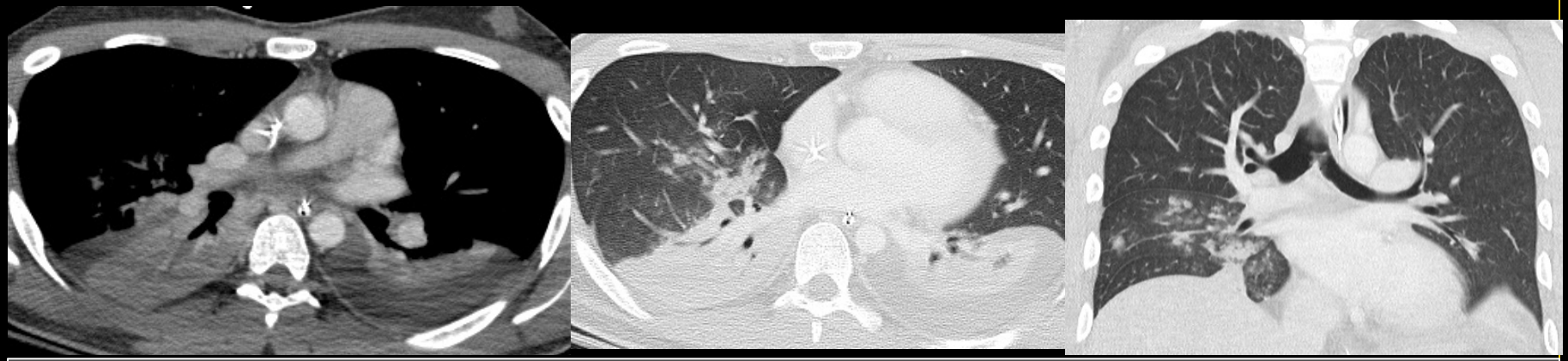
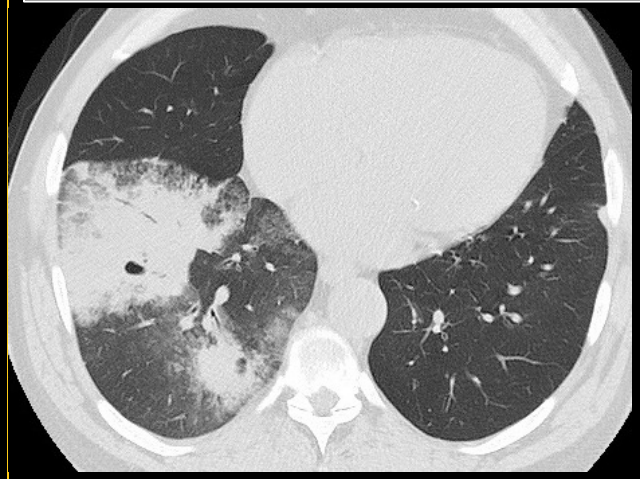
Atypical for COVID Pneumonia

Lobar Consolidation, Centrilobular Nodules, Pleural Effusions, Cavities



CT images shows bilateral lower lobe consolidation, bilateral pleural effusions, and centrilobular nodules within the right middle lobe



Community-acquired bacterial pneumonia. Axial CT image demonstrates consolidation with air bronchograms and small round lucencies reflective of cavitation due to necrotizing infection. Such findings are atypical for COVID-19. The imaging findings resolved after treatment for presumed staphylococcal pneumonia.

Suggested RSNA Report: Imaging features are atypical or uncommonly reported for (COVID-19) pneumonia. Alternative diagnosis should be considered [Cov19Aty].

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COVID-19: Thoracic Imaging Manifestations and Complications

Temporal CT Changes and Predictors of Outcome [27, 28]

Pan et al

Days after Symptom Onset	Normal	GGO	Crazy-Paving	Consolidation
0-4	17%	75%	24%	42%
5-8	0%	82%	53%	49%
9-13	0%	71%	19%	90%
≥ 14	0%	65%	0%	75%

Early CT Findings Predictive of a Worse Outcome (P<0.05)

Consolidation	Crazy-Paving	Geographic Opacification	Dilated Bronchi	Air Bronchograms
Vessel Enlargement	Bilateral Disease	Upper or Middle Lobe Involved	Severe Opacification	

27. Pan F, et al. *Radiology* 2020; 295(3) https://doi.org/10.1148/radiol.2020200370
28. Meiler S, et al. *Eur J Radiology* 2020; 131(Aug) 2020 doi: https//doi.org/10.1016/j.ejrad.2020109256

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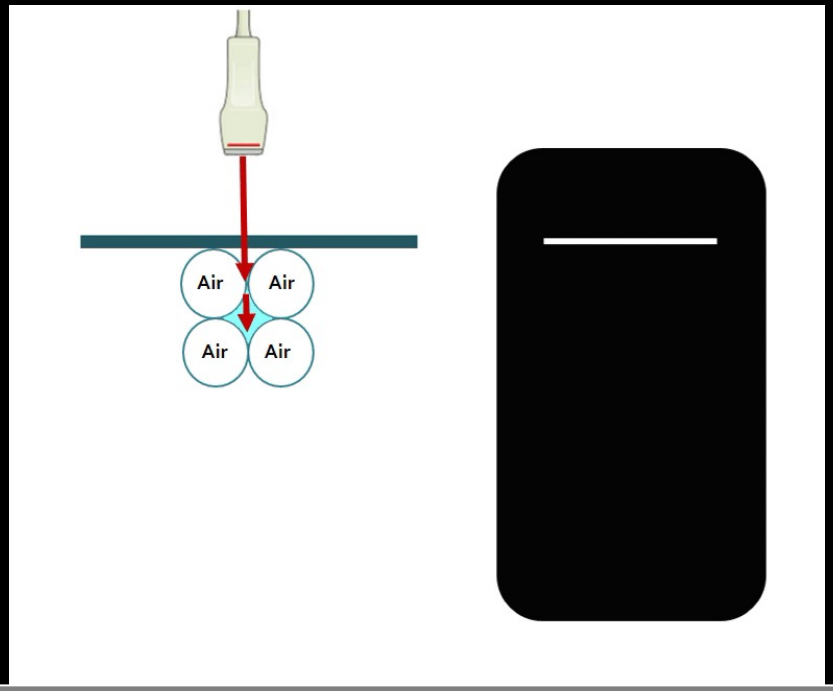
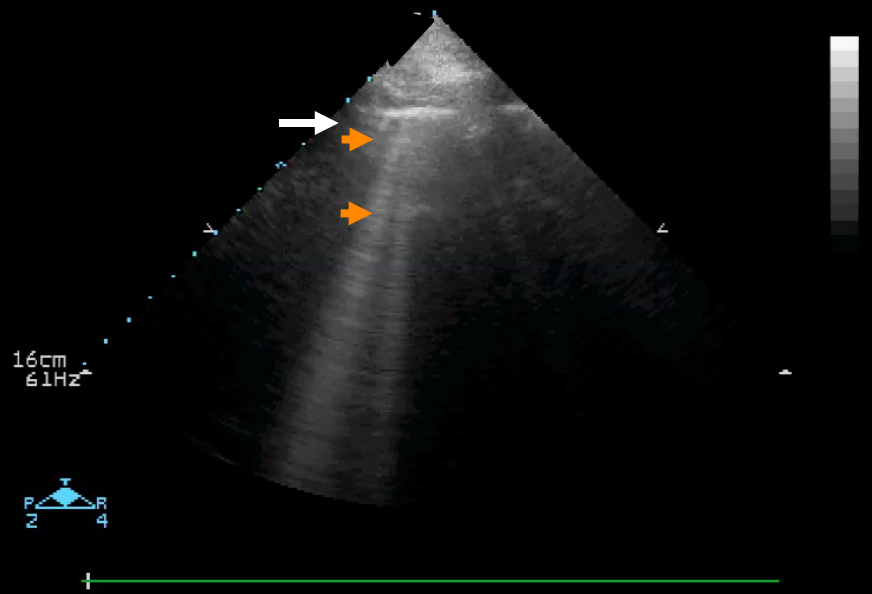
B-Lines: Cardiogenic Pulmonary Edema



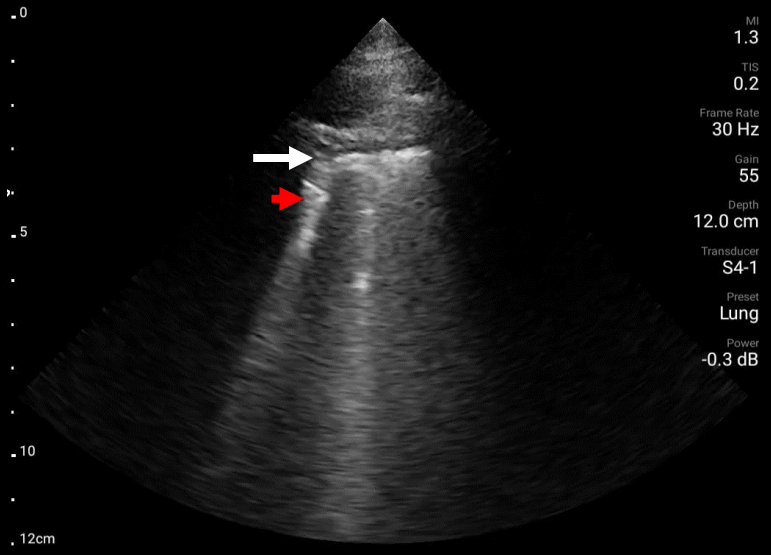


Reverberation due to fluid molecules trapped in air: Pulmonary edema, infected fluid or pus, inflammatory interstitial lung disease, or blood are causes of B-lines. Fluid molecules (left animated diagram, blue) trapped in air result in reverberation of ultrasound waves and creation of B-lines. In the lung US video (right) in a patient with cardiogenic pulmonary edema, B-lines (right, orange arrows) are "smooth" and "fine". The pleural line is indicated by the white arrow (Images courtesy of Jane Ko, MD, NYU Langone and Gigi Liu, MD, Johns Hopkins University School of Medicine, Baltimore, MD)

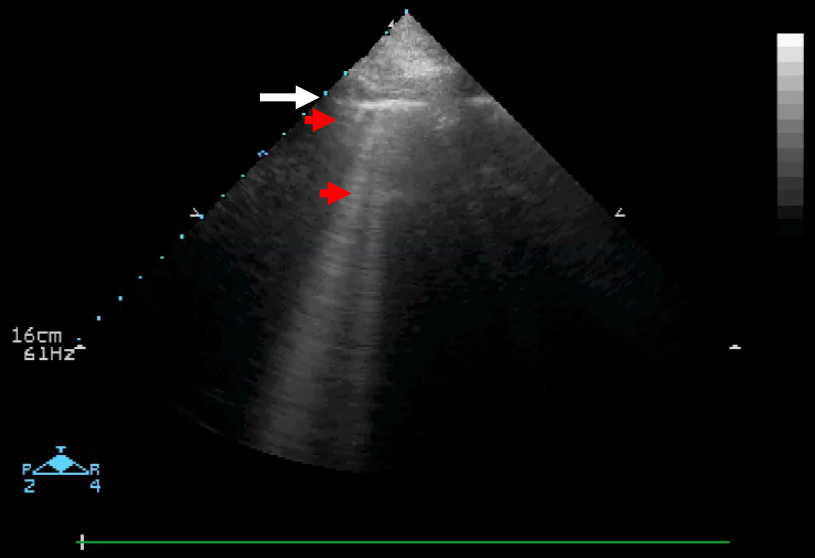
COVID-19: Thoracic Imaging Manifestations and Complications

B-Lines: COVID-19 versus Pulmonary Edema

Right Zone 1: COVID-19



Pulmonary Edema

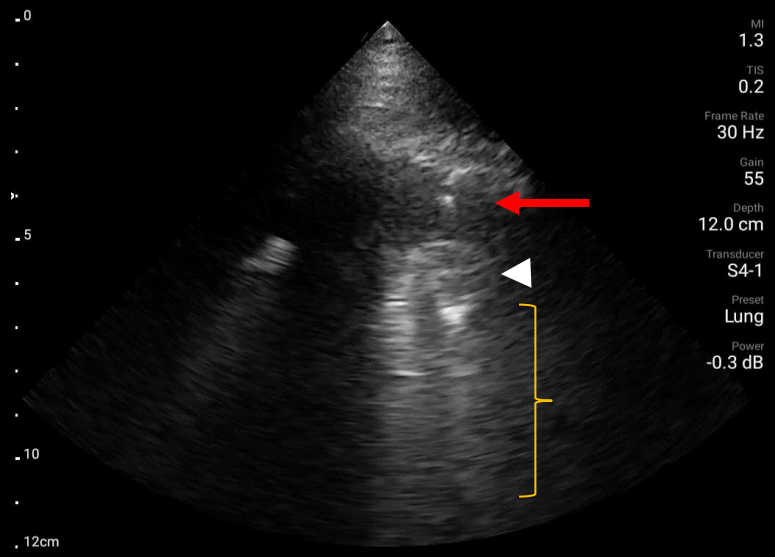


Video: B-line thickness. (Left) Lung US video in a patient with COVID-19 demonstrates discrete B-lines that are thick and irregular (red arrow), and the pleural line is likewise "thick" and "irregular" (white arrow). (Right) Lung US video in a patient with cardiogenic pulmonary edema depicts B-lines that are smooth and fine (red arrows), and the pleura line is smooth (white arrow) (Images courtesy of Jane Ko, MD, NYU Langone and Gigi Liu, MD, Johns Hopkins University School of Medicine, Baltimore, MD)

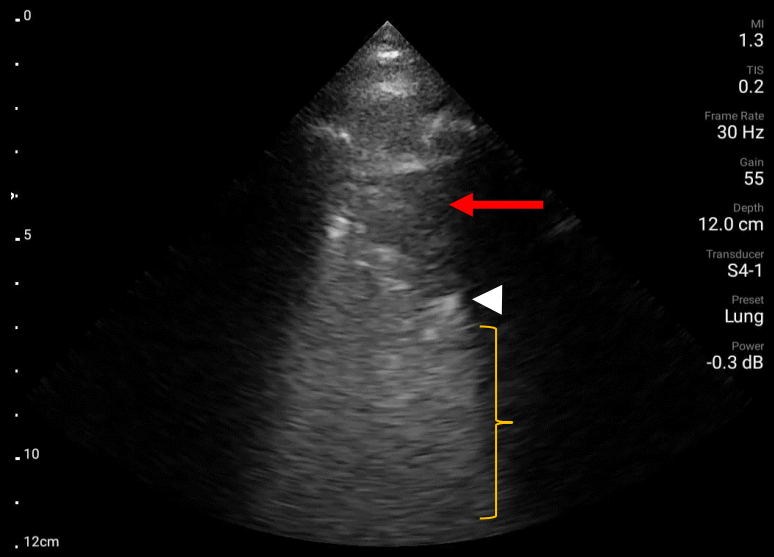
COVID-19: Thoracic Imaging Manifestations and Complications

COVID: Subpleural Consolidation

Left Posterior Zone 5



Left Posterior Zone 6



Video: Subpleural consolidation. Lung US videos show hypoechoic areas that represent consolidation from COVID-19 (red arrow). Normal aerated lung, which is hyperechoic (bracket) is deep to the hypoechoic consolidation with the border (white arrowhead) (Images courtesy of Jane Ko, MD, NYU Langone and Gigi Liu, MD, Johns Hopkins University School of Medicine, Baltimore, MD)

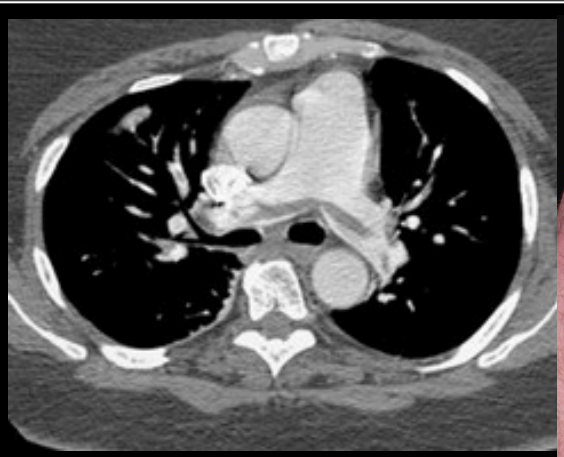
COVID-19: Thoracic Imaging Manifestations and Complications

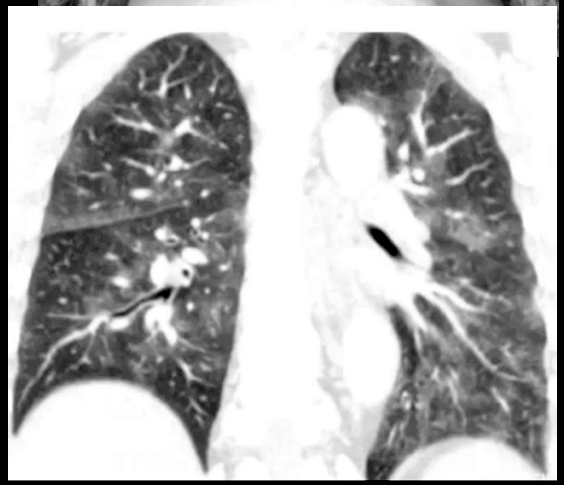
Acute and Subacute Subacute COVID-19 Complications

Barotrauma

Thromboembolic disease

Long hauler pulmonary manifestations



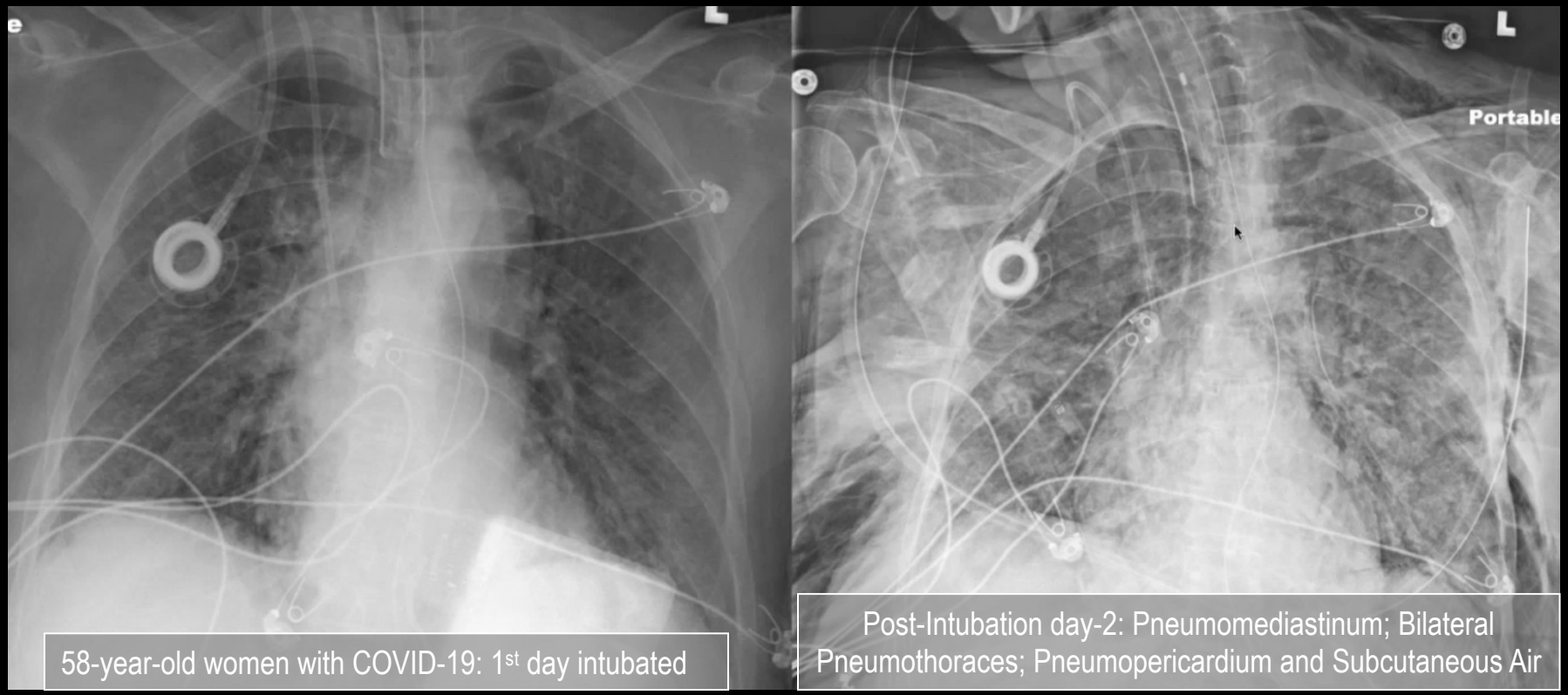


COVID-19: Thoracic Imaging Manifestations and Complications

Barotrauma

Intubated (IMV) Patients

High flow nasal cannula (HFNC) Patients



58-year-old women with COVID-19: 1st day intubated

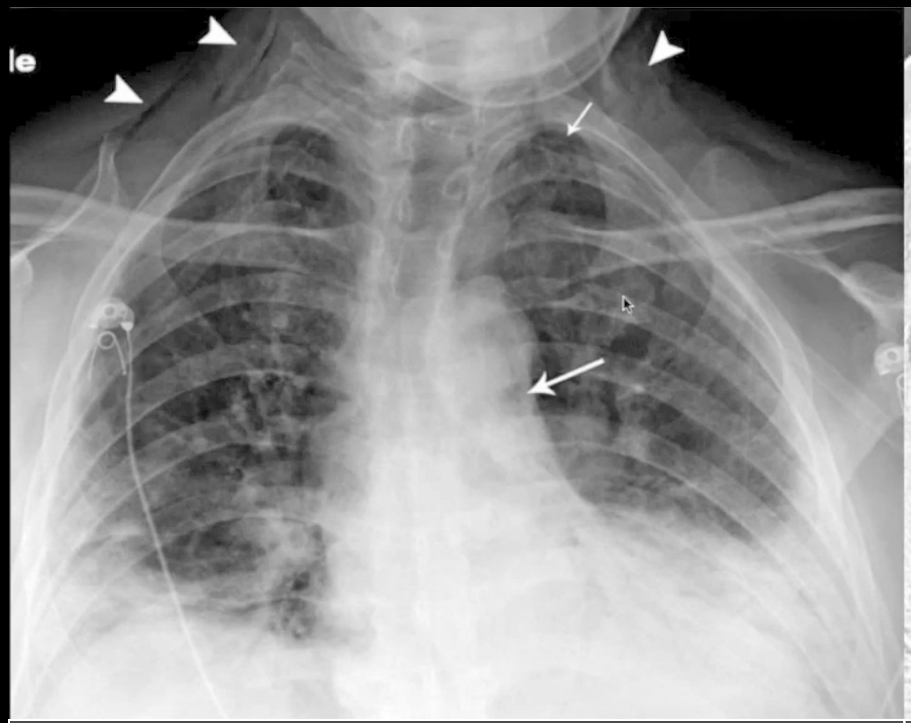
Post-Intubation day-2: Pneumomediastinum; Bilateral Pneumothoraces; Pneumopericardium and Subcutaneous Air

(Images courtesy of Georgeann McGuiness, MD, NYU Langone).

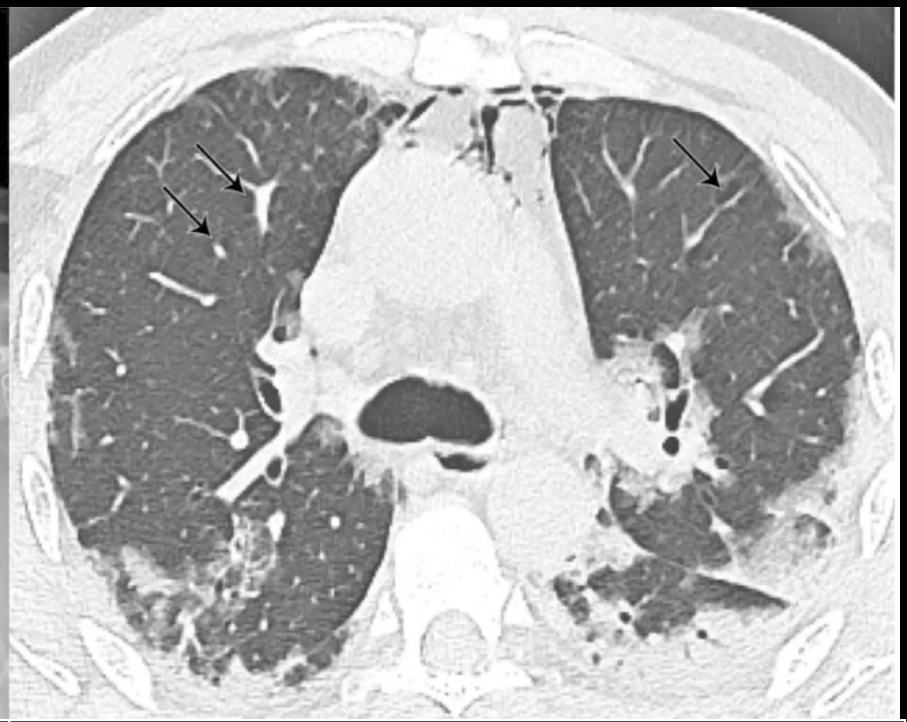
COVID-19: Thoracic Imaging Manifestations and Complications

Barotrauma

Never Intubated-HFNC



Pneumomediastinum; Left Pneumothorax; Subcutaneous Air; Peripheral Lower Lobe Air-Space Disease COVID-19 Pneumonia



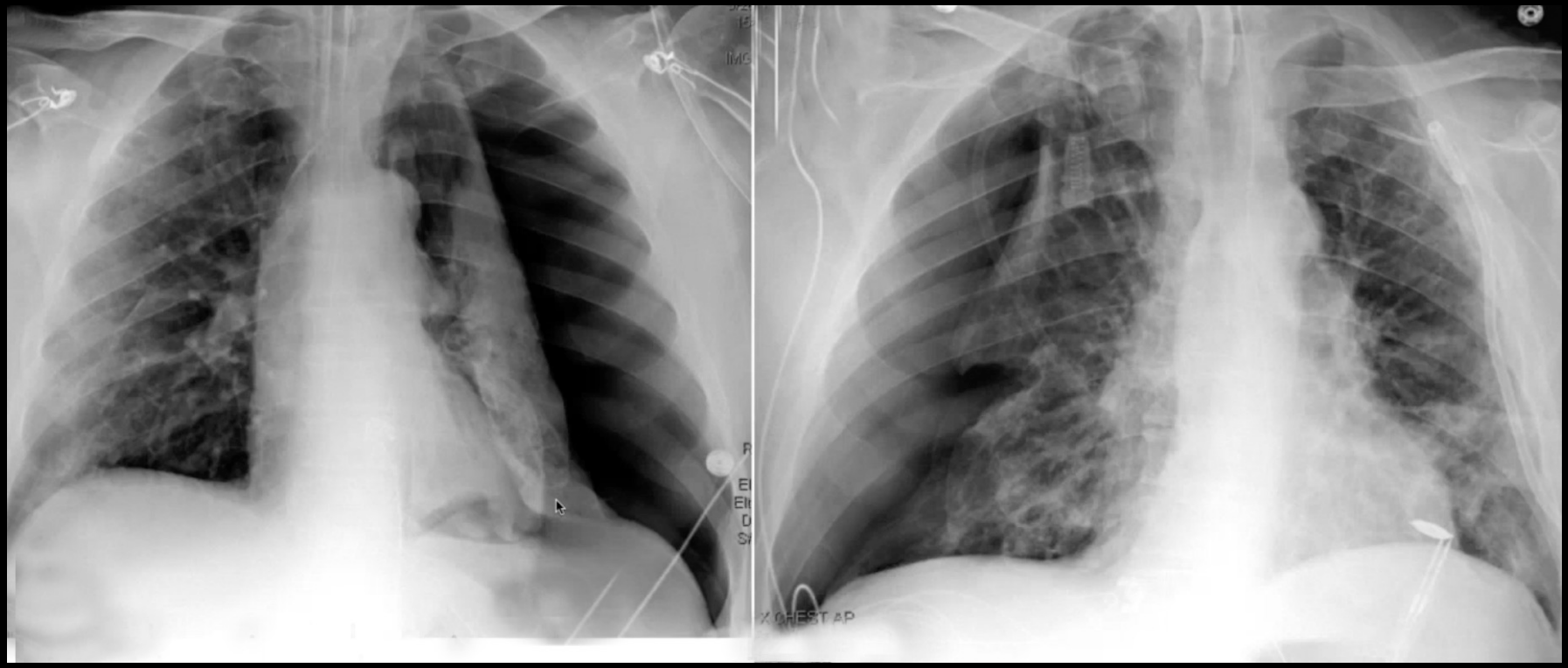
Chest CT Same Day: Pneumomediastinum; Small Left Pneumothorax; Pulmonary Interstitial Emphysema and Peripheral Lower Lobe Air-Space Disease

(Images courtesy of Georgeann McGuiness, MD, NYU Langone).

COVID-19: Thoracic Imaging Manifestations and Complications

Barotrauma

Tension Pneumothoraces



64-year-old man with COVID-19 pneumonia: Intubated 4-days after admission and then developed a spontaneous left tension pneumothorax. 14-days later he developed a spontaneous right tension pneumothorax.

(Images courtesy of Georgeann McGuiness, MD, NYU Langone).

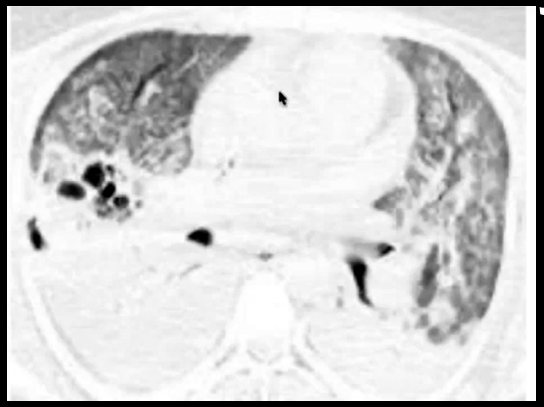
COVID-19: Thoracic Imaging Manifestations and Complications

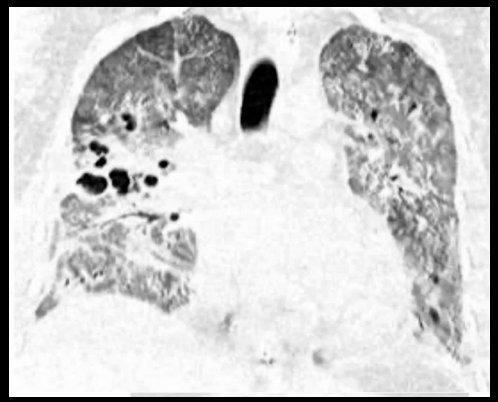
Barotrauma: Incidence in COVID-19 In-Patients [29-32]

Study	Cohort Size	Barotrauma Events
ARDSNet		**6.5-11%**
McGuiness G, et al. *Radiology* 2020 Jul1: 202352.doi: 10.1148/radiol.2020202352 [29]	N=601 / 132 IMV	24%
Udi J, et al. *J Intensive Care Med* 2020 https://doi.org//10.1177/0885066620954364 [30]	N=20 (IMV)	40%
Martinelli A, et al. *European Resp J.* 2020; 56:2002697; DOI: 10.118321399399392697.2020 [31]	N=71 / 62 IMV / 9 Not	"substantially in excess"
Lemmers D, et al. 2020 *ERJ*. Open Research 2020 6"00385-2020; DOI:10.1183123120541.00385.2020 [32]		
Parker MS, et al In progress	N=507 / 15 IMV / HFNC	20%

COVID-19: Thoracic Imaging Manifestations and Complications

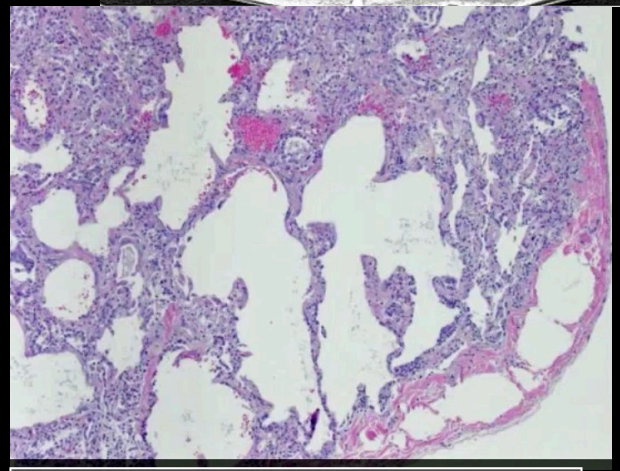
Barotrauma: Why the Increased Incidence?





Gross specimen:
Subpleural pockets of air

Histology: Dilatation of bronchioles, alveolar ducts, sacs and distal air spaces



Histology: Subpleural cysts

(Images courtesy of Georgeann McGuiness, MD, NYU Langone).

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COVID-19: Thoracic Imaging Manifestations and Complications

Thromboembolic Disease: Why the Increased Incidence? [33]

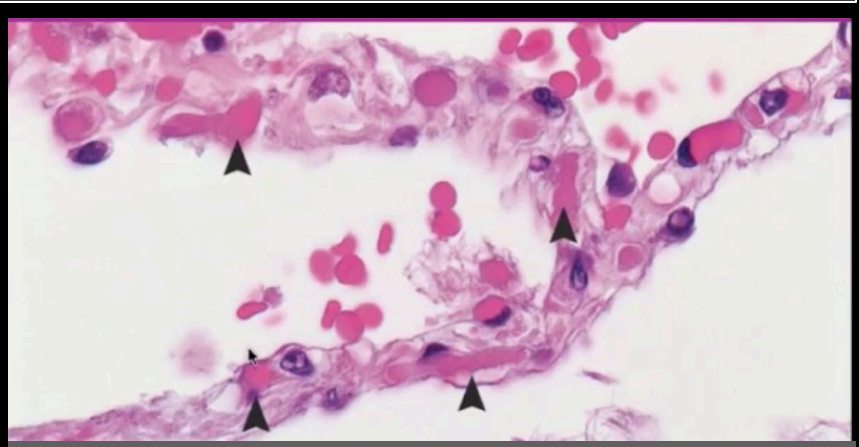
Ackerman et al Autopsy Series:

7 COVID (+) patients vs. 7 Influenza-ARDS patients vs. 10 Controls

Unique Finding in COVID-19 (+) patients:

Severe endothelial injury ➡ disrupted cell membranes ➡ widespread thrombosis and formation of alveolar capillary microthrombi

9x > Influenza



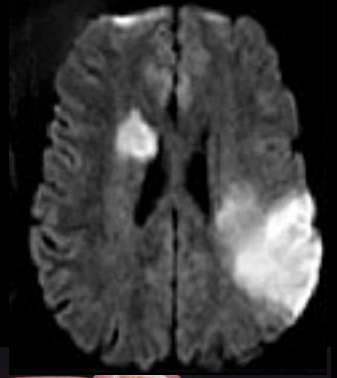
Fibrinous microthrombi in alveolar capillaries (arrowheads)

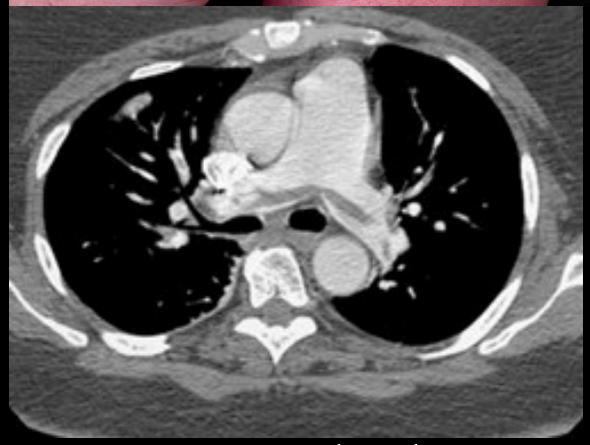
30. Ackermann M, et al. *N Engl J Med* 2020; 383:120-128.

COVID-19: Thoracic Imaging Manifestations and Complications

Thromboembolic Disease [33]

Hypercoagulable ⬆ Thrombosis
⬆ CVA's / Peripheral vascular thrombi / PE
Further compromise already diminished lung function
⬆ Mortality ⬆ serum thrombogenic proteins (D-dimer)

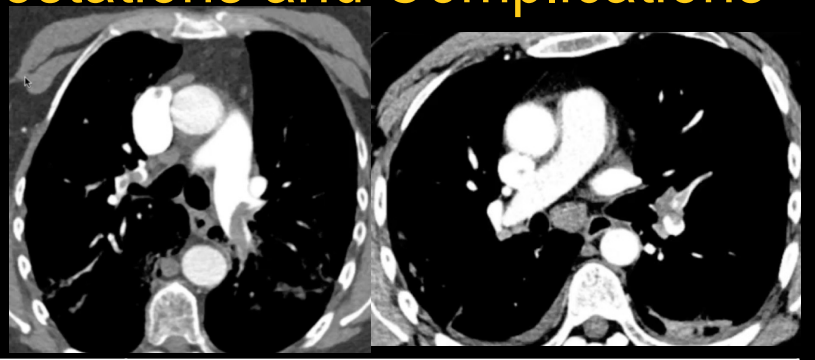




33. Ackermann M, et al. *N Engl J Med* 2020; 383:120-128.

COVID-19: Thoracic Imaging Manifestations and Complications

Thromboembolic Disease [34-36]



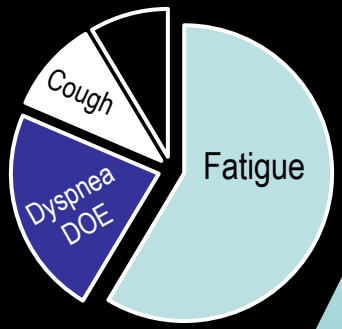
30-38% Incidence of PE!!!

>2x ED / Critically-ill Covid (-) ICU pts.

Study	Patients	Incidence of PE on CTPA
Kaminetzky M, et al. *Radiology Cardiothoracic Imaging* https://doi.org/10.1148/ryct.2020200308 [34]	62-COVID (-) patients matched to 62-COVID (+) patients	9/62 (14.5%) COVID (-) **23/62 (37.1%) COVID (+)** P=0.007 **PE > 2X rate in COVID (-) pts.**
Leonard-Lorant I, et al. *Radiology* 2020; 296:E189-191 [35]	54 COVID (-) patients 106 COVID (+) patients	11% (D-Dimer 1,940 µg/L) **30% (D-Dimer 15,385 µg/L)** * COVID (+): D-Dimer > 2,660 µg/L: 100% sensitive 67% specific for PE at CTPA
Patel BJ, et al. American J of Resp and Crit Care Med 2020; 202(5) [36]	39 Consecutive COVID (+) patients on IMV	**15/39 (38%) (+) PE**

COVID-19: Thoracic Imaging Manifestations and Complications

Long Haulers: Post-Acute Sequelae of SARS-CoV-2 Infection (PASC) Syndrome (>30%) [37-42]



Pulmonary fibrosis
Cystic changes
Bronchiectasis
Persistent or Recurrent GGO's
Tracheal strictures
Bronchopleural fistula
Secondary infections
Vascular disease
Lung transplant

Clear Lungs
Asymptomatic

Clear Lungs
Profoundly Symptomatic

Abnormal Lungs
Asymptomatic

Abnormal Lungs
Symptomatic

37. Proal AD. Front . Microbio., 23. June2021; https://doi.org/10.3389/fmicb.2021.698169
38. Carbajal E. https://www.beckershospitalreview.com April 2021
39. Han W, et al. *Ann Surg*.2020; 10.1097/SLA; doi: 10.1097/SLA
40. Fraser E, et al. *BMJ* August 2020; 370:m3001. doi 10.1136/bmj.m3001.
41. Rubin R. JAMA October 13, 2020; 324(14)
42. Komoaroff M. https://www.health.Harvard.edu/blog/the-tragedy-of-the-post-covid-long-haulers-2020101521173
40. Huang C, et al. *Lancet* 2021. https://doi.org/10.1016/S0140-6736(20)32656-8.

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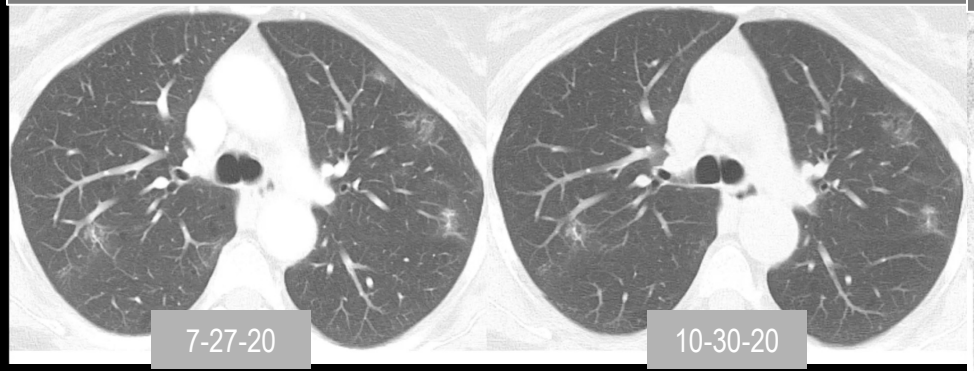
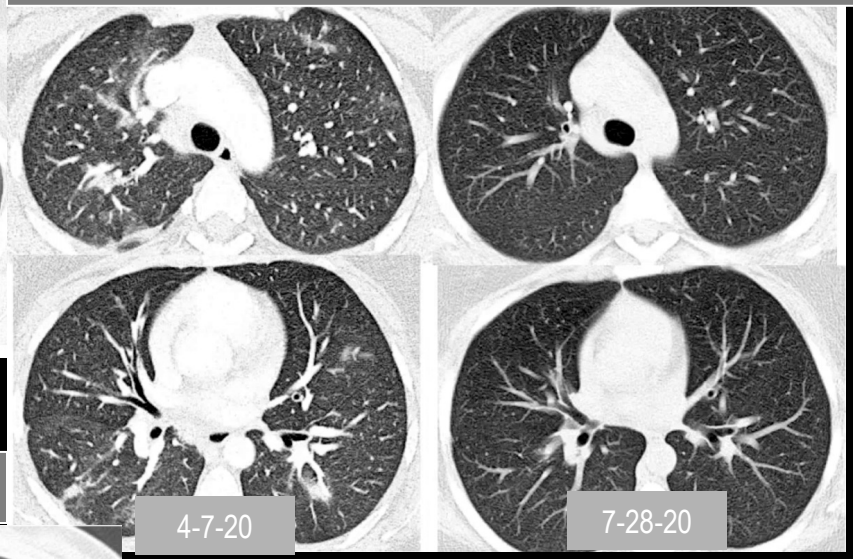
COVID-19: Thoracic Imaging Manifestations and Complications

Long Haulers: Post-Acute Sequelae of SARS-CoV-2 Infections (PASC) [34-33]

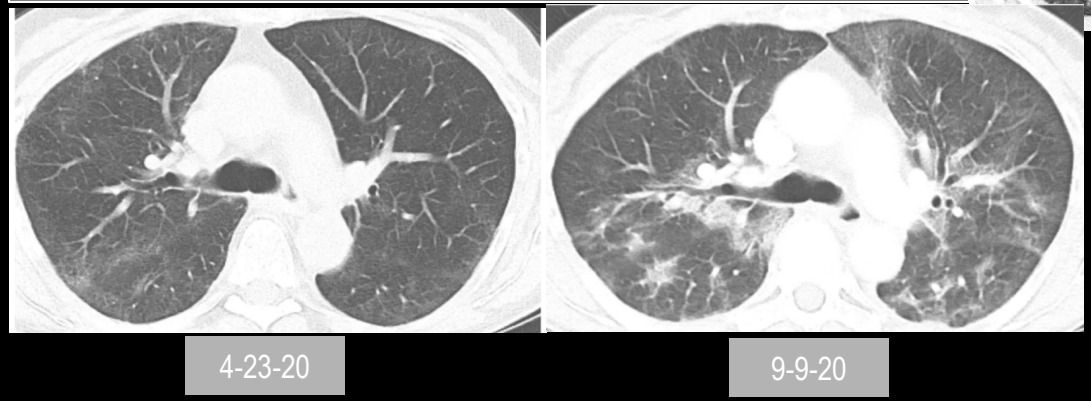
65YO; asymptomatic: No changes in GGOs after 3-months



30YO; Profound DOE after COVID despite GGOs cleared



38YO; symptomatic: Progressive Fibrosis over 5-months



Residual CT abnormalities seen <50% patients for as long as 5-months after COVID-most commonly GGO's and irregular subpleural lines

(Images courtesy of Georgeann McGuiness, MD, NYU Langone).

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COVID-19: Thoracic Imaging Manifestations and Complications

Conclusion

Although initially trending down, there is now an upward trajectory in new COVID-19 cases, hospitalization and deaths, especially in younger, incompletely and unvaccinated patients, primarily due to the highly contagious delta variant

Unfortunately, we will continue to see imaging studies on COVID patients and complications related to such for an undefinable time as this variant becomes more dominant in our communities and other mutations may also take hold

PCR "Gold Standard" for diagnosing COVID

CXR: Most commonly reveals multi-focal ill-defined air-space opacities with a predominant peripheral and lower lobe distribution

CT: Most commonly shows bilateral, peripheral, non-specific air-space opacities, often with a rounded configuration and a mid- and lower lung zone predilection evolves over time

Barotrauma: <40% of both ventilated and non-ventilated COVID patients

Thromboembolic disease and PE at CTPA : <38% greater than that seen with non-COVID critically ill patients

Long haulers may be profoundly symptomatic despite normal and or minimal abnormal imaging findings