CT Imaging of Coronavirus Disease-19 (COVID-19)

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Importance of CT in COVID-19 diagnosis

False negatives of RT-PCR test

- In one study of 167 patients, 93% had both positive CT findings and lab testing, 4% had positive RT-PCR laboratory testing for 2019-nCoV infection but negative CT findings, 3% had negative laboratory test results but positive CT findings. All of these patients went on to develop positive test results.
  - "Reasons for false negative RT-PCR may include insufficient cellular material for detection and improper extraction of nucleic acid from clinical materials."

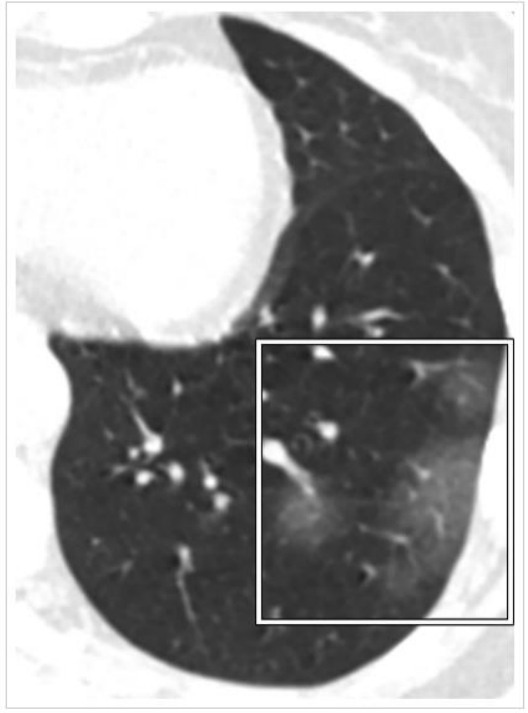
Delay in processing or lack of testing availability

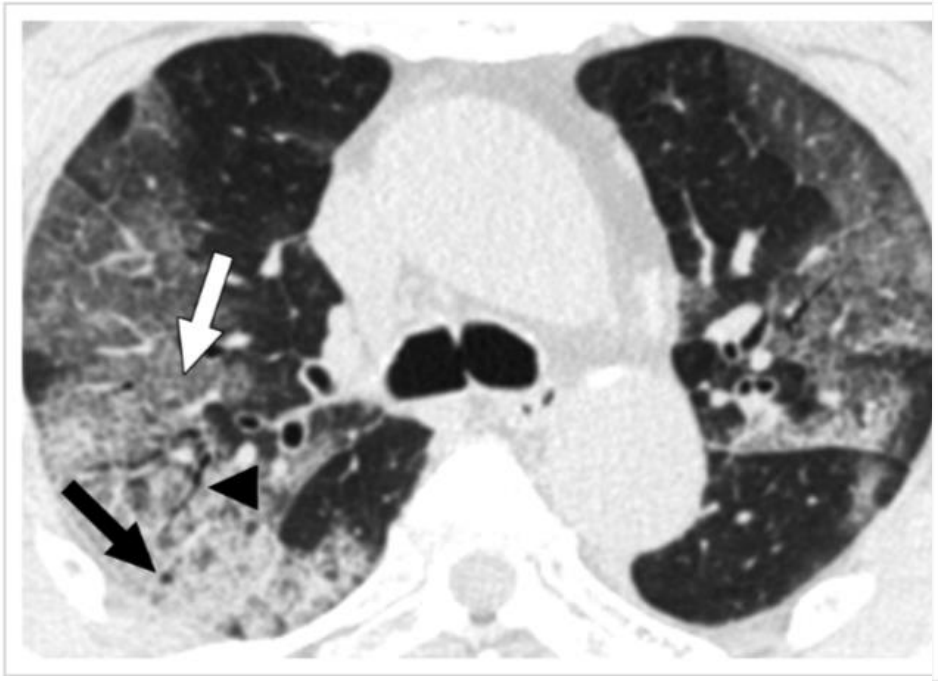
- Hopefully not an issue in USA if we're able to slow the rise of new cases over time.

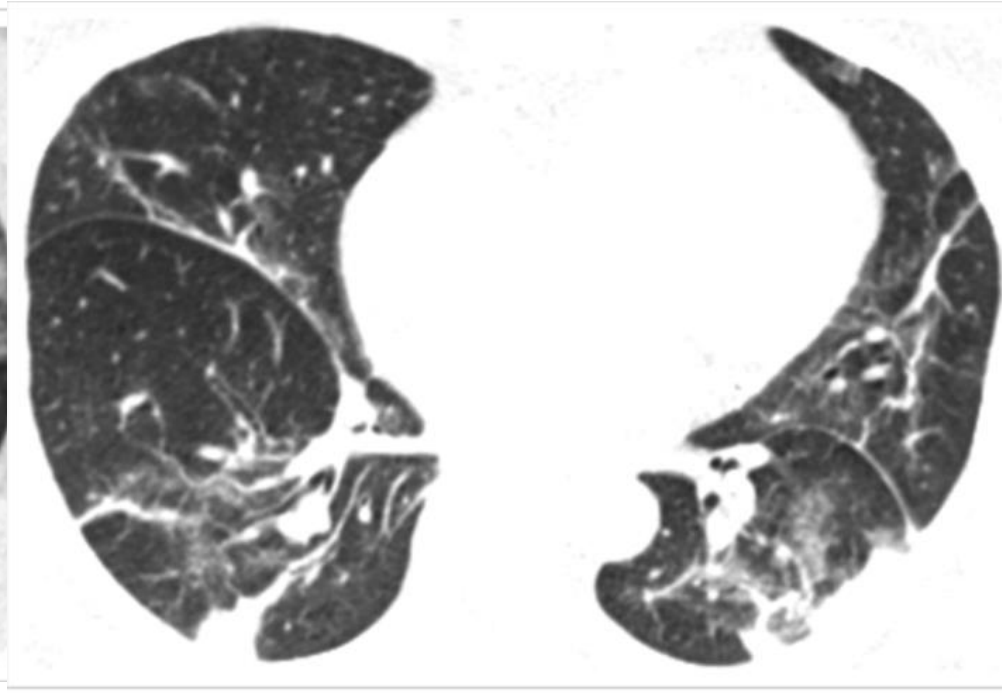
However, in patients early in disease course, CT may also be negative. In addition, other viral illnesses are more likely to cause CT abnormalities in areas with low prevalence. Therefore, CT is NOT recommended as a primary diagnostic tool.

CT Findings in COVID-19 - Summary

- Disease follows a typical pattern for viral infection causing acute lung injury.
- Temporal progression from small subpleural ground glass opacities (GGO) with a basilar predominance that grow larger and become more widespread and develop into crazy-paving patterns, reverse halo signs, and consolidation.
- As patient recovers, becomes an organizing pneumonia pattern with fibrous streaks, sub pleural clear lines, and decreasing GGO and consolidation.







CT Findings in COVID-19

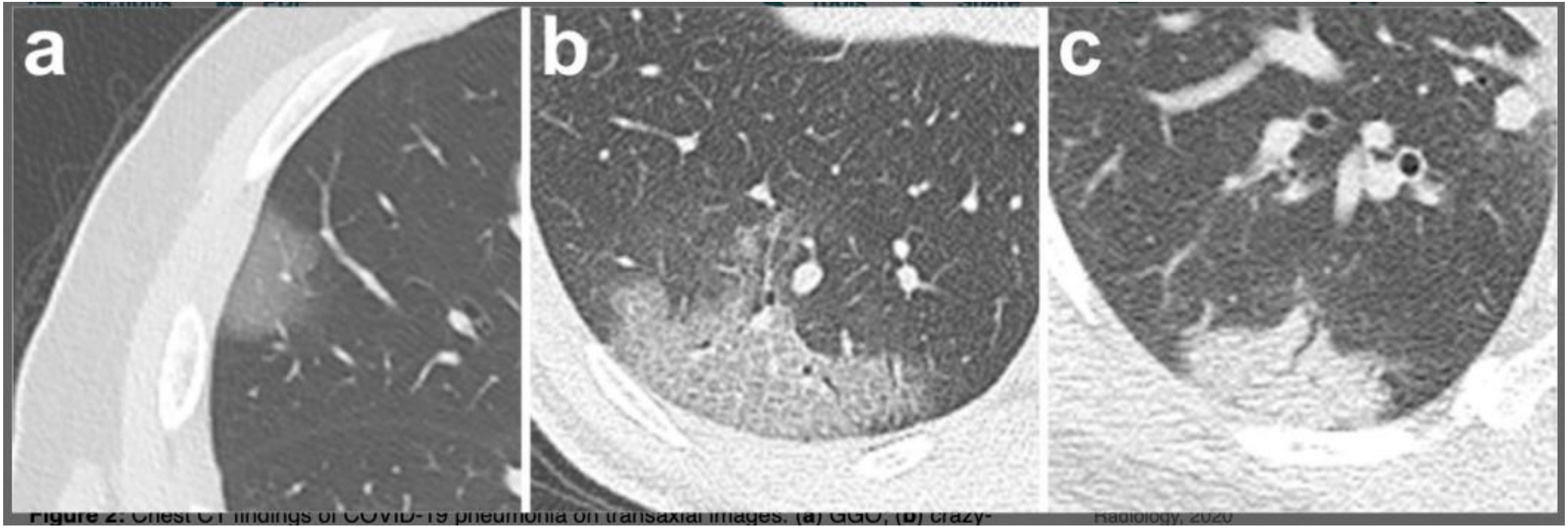
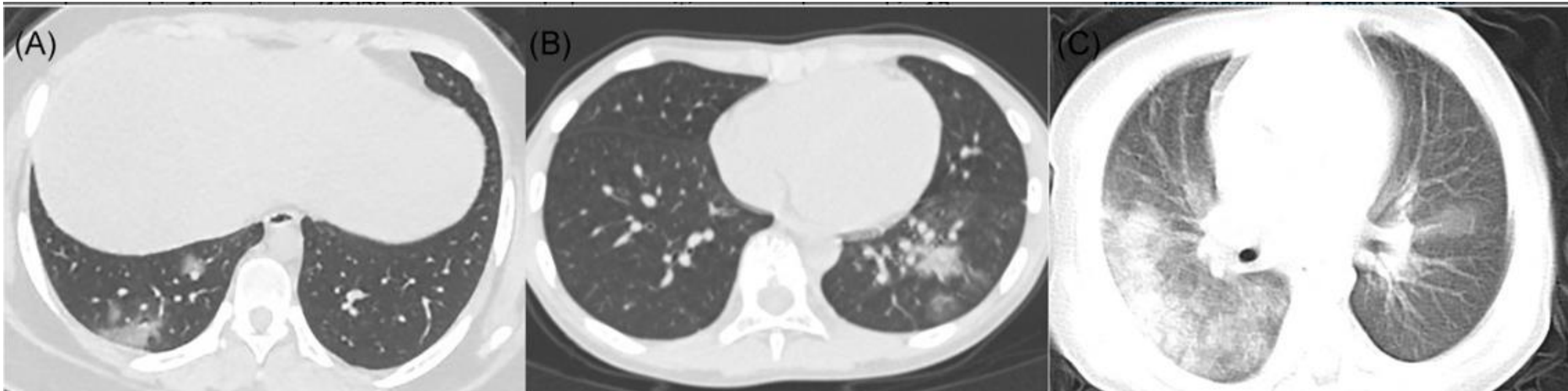


Figure 2: Chest CT findings of COVID-19 pneumonia on transaxial images: (a) GGO, (b) crazy-

Radiology, 2020

CT Findings in COVID-19 - Summary

- ***Cavitation, calcification, bronchovascular distribution, centrilobular or military nodules, lymphadenopathy and pleural effusions are not typical features***.
- In children, 40% present with co-infection and may show more of the atypical features. However, most commonly, they present similarly with basilar and subpleural consolidation with GG halo.



CT Findings – *Summary by Ithan Peltan, IH Pulmonologist*

	Zhao (AJR)	Shi (Lancet ID)	Pan (Radiology)	Chung (Radiology)	Bernheim (Radiology)
Patients	101	81	82	21	121
Distribution (general)					
Peripheral dominant	87%	54%	61%	33%	52%
Peripheral or diffuse	99%	89%	95%	??	100%
Central dominant	1%	12%	0%	NR	0%
Bilateral	82%	79%	70%	76%	60%
Consolidation pattern					
GGOs alone	22%	65%	NR	57%	41%
GGOs with or without consolidation	86%	79%	73%	86%	75%
Consolidation only	14%	17%	NR	0%	3%
Mediastinal lymphadenopathy	1%	6%	0%	0%	0%
Pleural effusion	13%	5%	NR	0%	1%
Cavitation	NR	NR	NR	0%	0%

- Items in green tend would be suggestive but are not truly specific for COVID-19
- Items in orange appear to be inconsistent with COVID-19.
- Additional patterns/findings that were difficult to translate to tabular form:
  - Micronodules generally and centrilobular or bronchovascular distributions are not typical
  - Single or multiple purely solid nodules are not typical.

CT Findings

TABLE 3: CT Features of Coronavirus Disease 2019 Pneumonia

CT Feature	No. (%) of Patients (n = 62)
Lesion presentation on initial scan	
Single lesion	10 (16.1)
Multiple lesions	52 (83.9)
Lesion distribution	
Peripheral	48 (77.4)
Peripheral and central	14 (22.6)
CT sign	
Lung change	
GGO	25 (40.3)
Consolidation	21 (33.9)
GGO and reticular pattern	39 (62.9)
Vacuolar sign	34 (54.8)
Microvascular dilation sign	28 (45.2)
Fibrotic streaks	35 (56.5)
Subpleural line	21 (33.9)
Subpleural transparent line	33 (53.2)
Bronchial change	
Air bronchogram	45 (72.6)
Bronchiectasis	20 (32.2)
Bronchus distortion	11 (17.7)
Pleural change	
Thickening of pleura	30 (48.4)
Pleural retraction sign	35 (56.5)
Pleural effusion	6 (9.7)

Note—GGO = ground-glass opacities.

CT Features of Coronavirus Disease 2019 (COVID-19) Pneumonia in 62 Patients in Wuhan, China.
Zhou S, Wang Y, Zhu T, Xia L.
AJR Am J Roentgenol. 2020 Mar 5:1-8. doi: 10.2214/AJR.20.22975. [Epub ahead of print]
PMID: 32134681

CT Findings

Table 2: Findings on Chest CT in 121 Patients

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

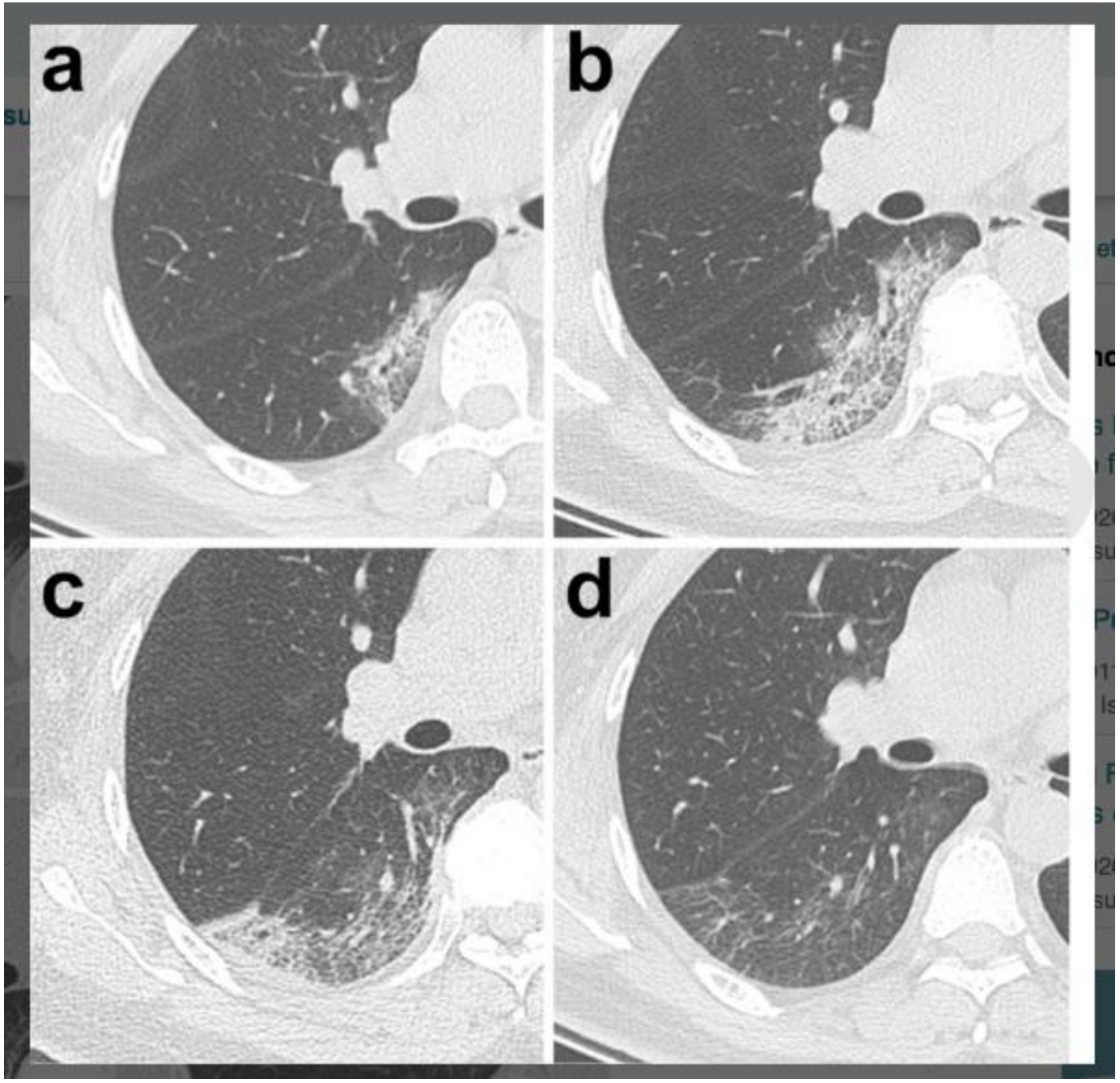
Note: Numbers in Parentheses are Percentages

Chest CT Findings in Coronavirus Disease-19 (COVID-19): Relationship to Duration of Infection.
Bernheim A, Mei X, Huang M, Yang Y, Fayad ZA, Zhang N, Diao K, Lin B, Zhu X, Li K, Li S, Shan H, Jacobi A, Chung M.
Radiology. 2020 Feb 20:200463. doi: 10.1148/radiol.2020200463. [Epub ahead of print]

CT Findings

Time course of findings

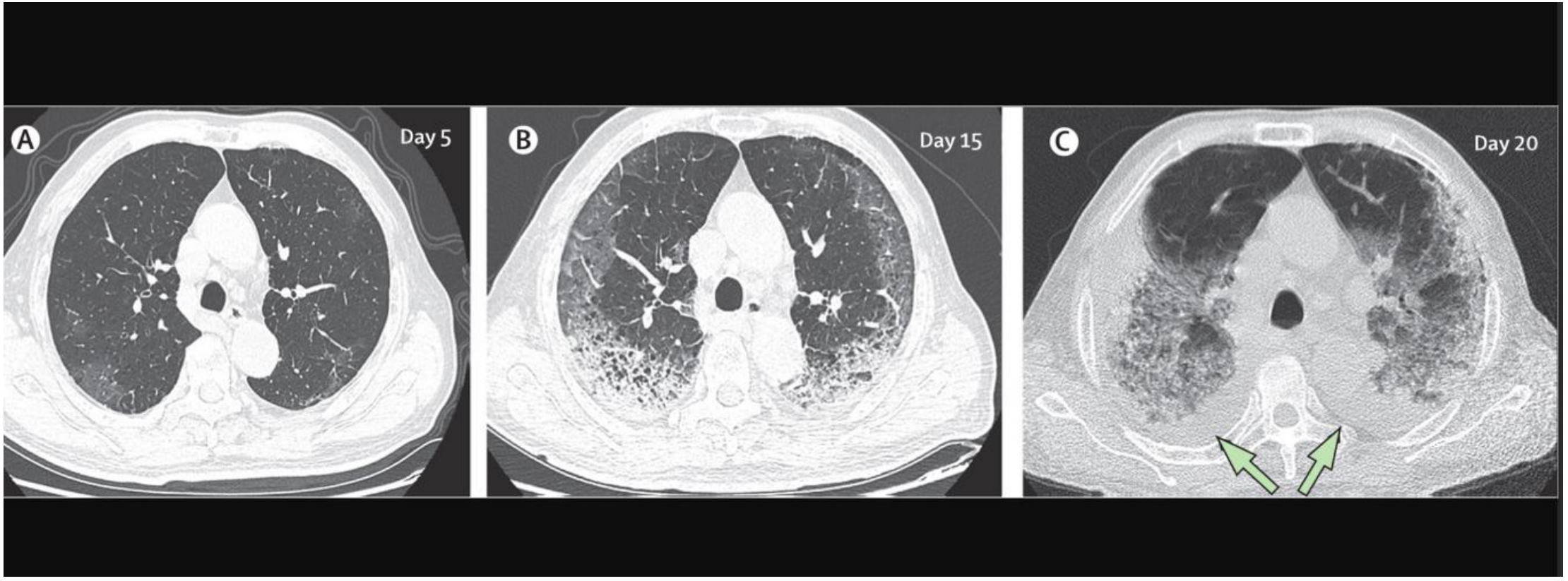
- **0-4 days** – Early stage: Small amount of subpleural GGO, basilar predominant, right slightly greater than left. No subpleural sparing.
- **5-9 days** – Progressive stage: Increased distribution of GGO with developing crazy paving pattern (new interlobular septal thickening likely representing interstitial edema from DAD).
- **9-13 days** – Peak stage: Consolidation develops. Radiologic abnormalities appear to peak at day 10. See some repair starting and findings of organizing pna, sub pleural bands,
- **≥ 14 days** – Absorptive stage: Gradual resolution.



Typical progression

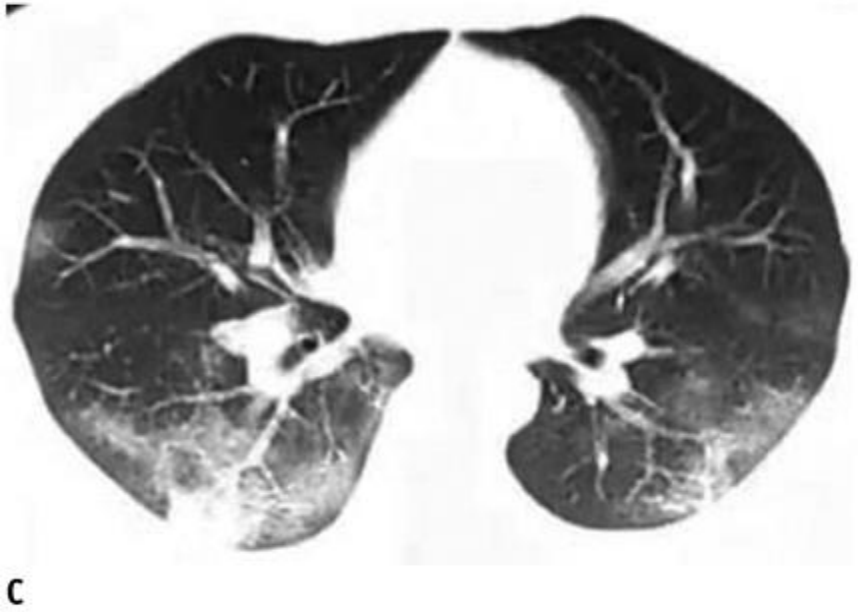
CT Findings

Typical progression



CT Findings

Initial CXR and CT at day 3 of fever to left. Below are 2 images from subsequent scans on days 6 and 12



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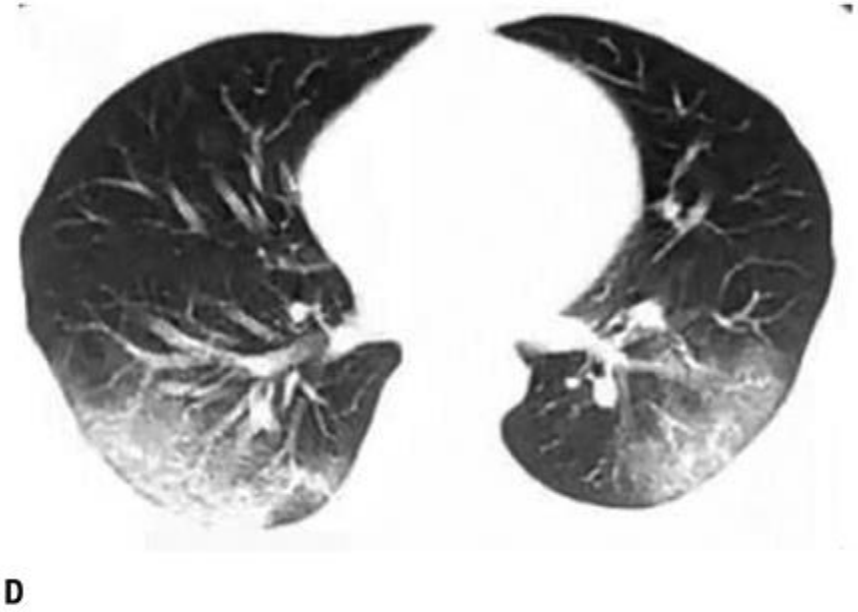

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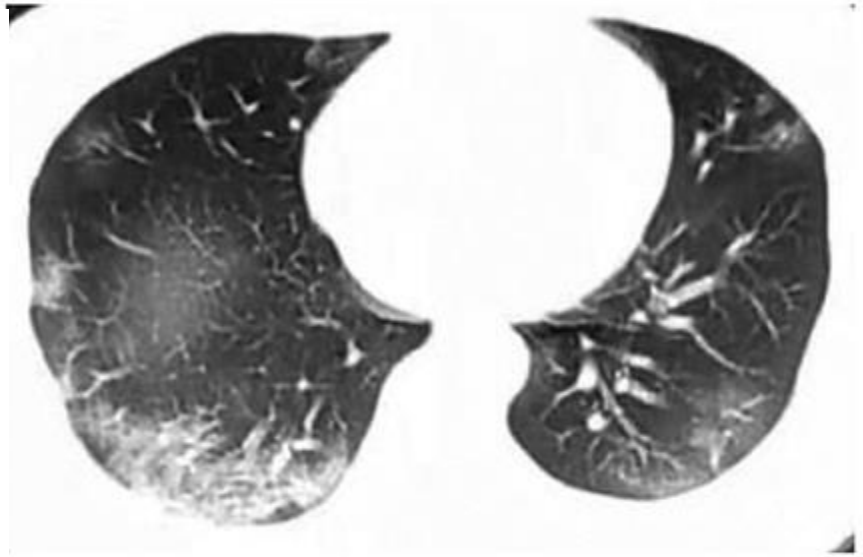
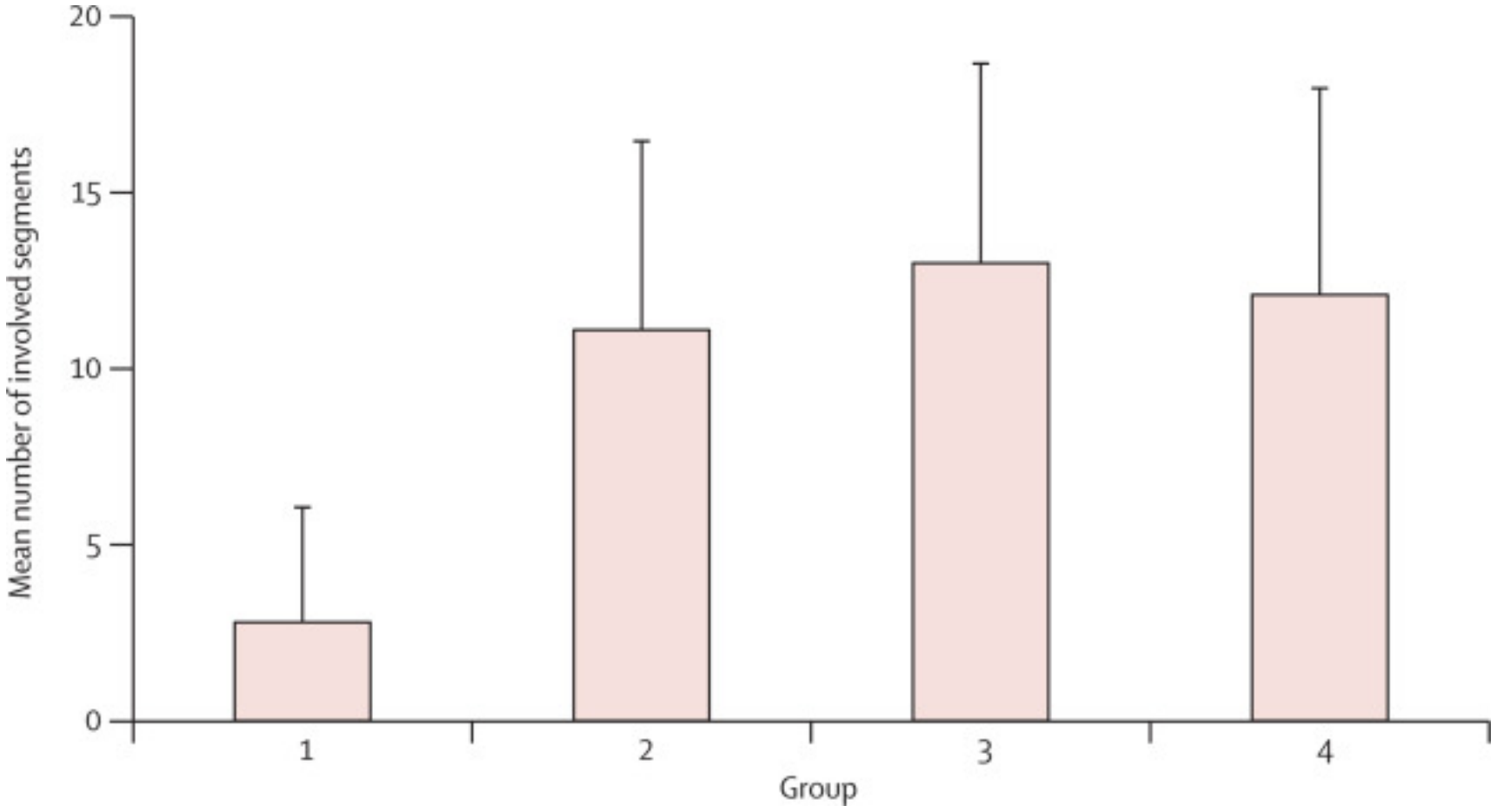


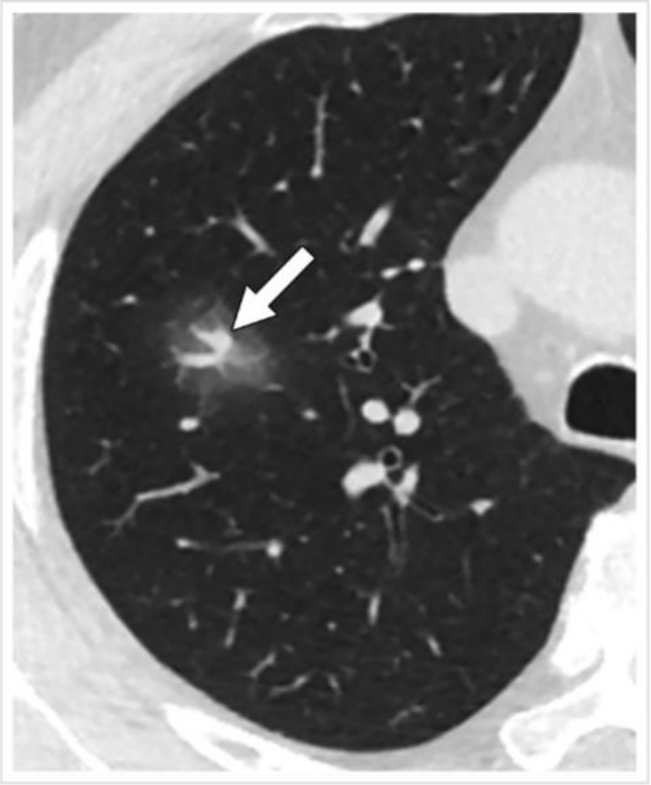
CT Findings

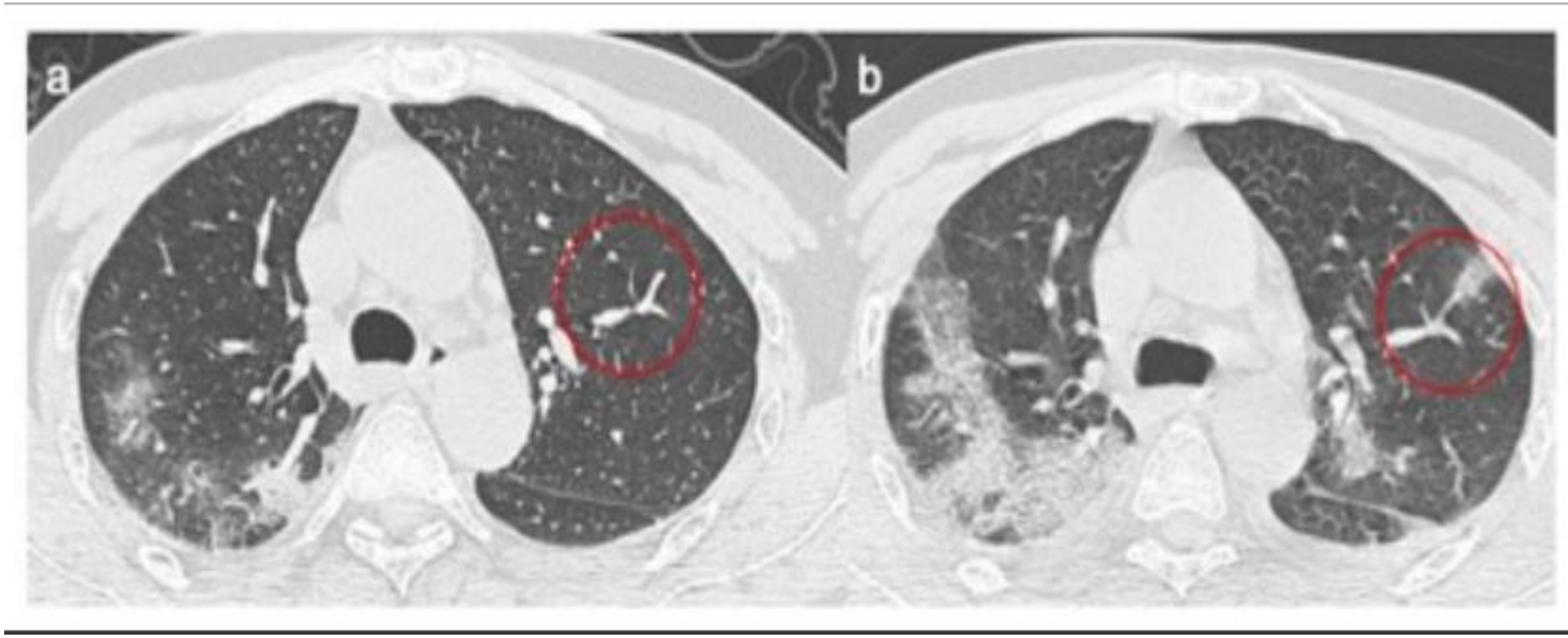


Bars show the mean number of involved lung segments on CT scans from patients in group 1 (scan before symptom onset; n=15), group 2 (scan ≤1 week after symptom onset; n=21), group 3 (scan >1 week to 2 weeks after symptom onset; n=30), and group 4 (scan >2 weeks to 3 weeks after symptom onset; n=15).

CT Findings in COVID-19 – Additional features

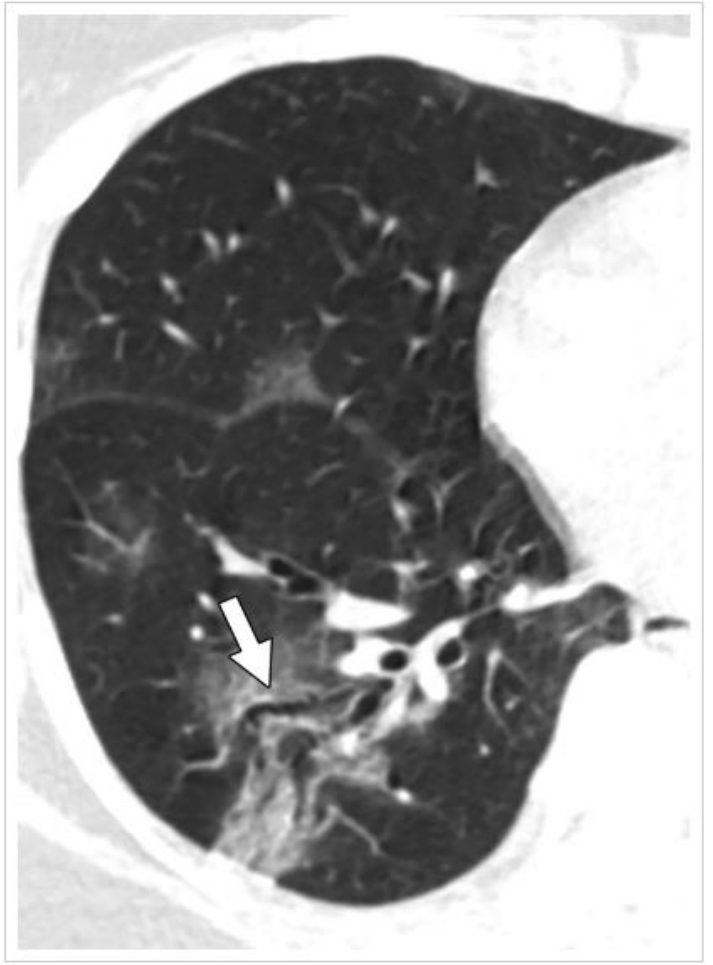
- Early on can be unifocal, most common RLL
- Cystic changes, bronchiectasis or bronchiolectasis, and microvascular engorgement sign can also occur. Vascular dilatation may precede parenchymal involvement.



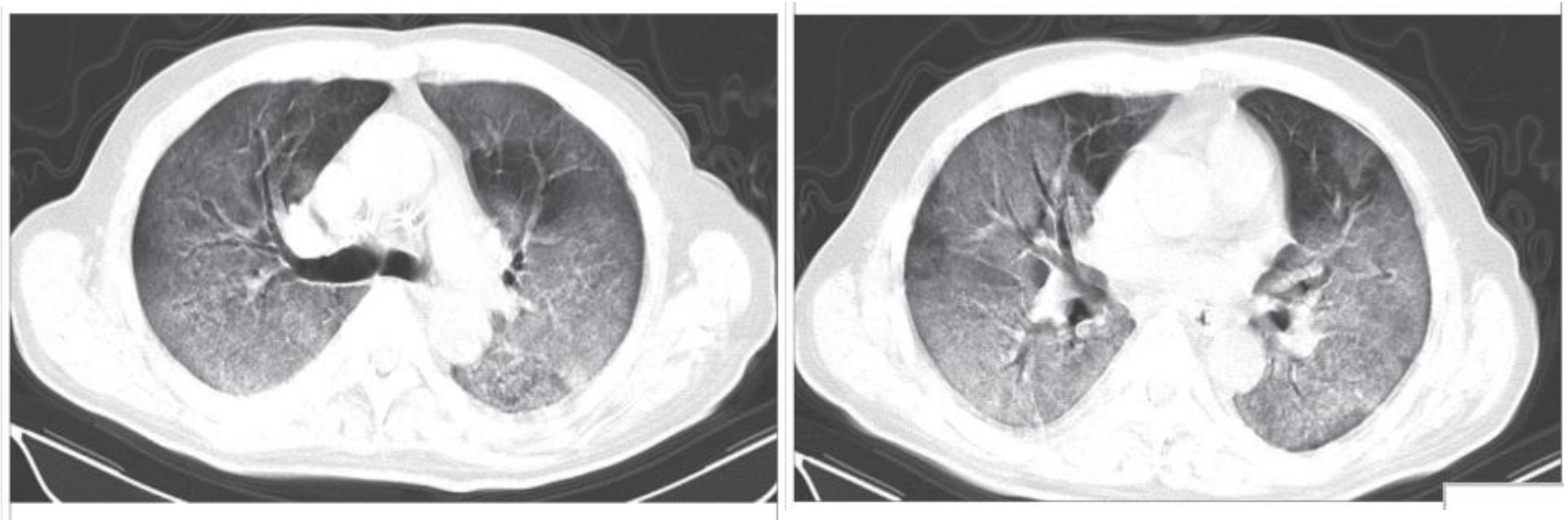


CT Findings in COVID-19 – Additional features

- Cystic change “vacuolar sign”.
- Air bronchograms and bronchial distortion.



CT Findings



Transverse CT scans from a 60-year-old man (day 8 after symptom onset)

Diffuse alveolar damage pattern.

This patient died 4 days later

Other possibilities

Synoptic element from the template for **CT COVID-19 Chest W/O**

CT findings compatible with COVID-19 viral pneumonia? [Yes/**No**/Possibly]

CT findings of pneumonia are often non-specific, and there is overlap between findings of viral pneumonia and bacterial pneumonia, as well as amongst viral pneumonias. Therefore, specific causative agents cannot be determined on imaging alone.

RadioGraphics

Chest Imaging

Free Access

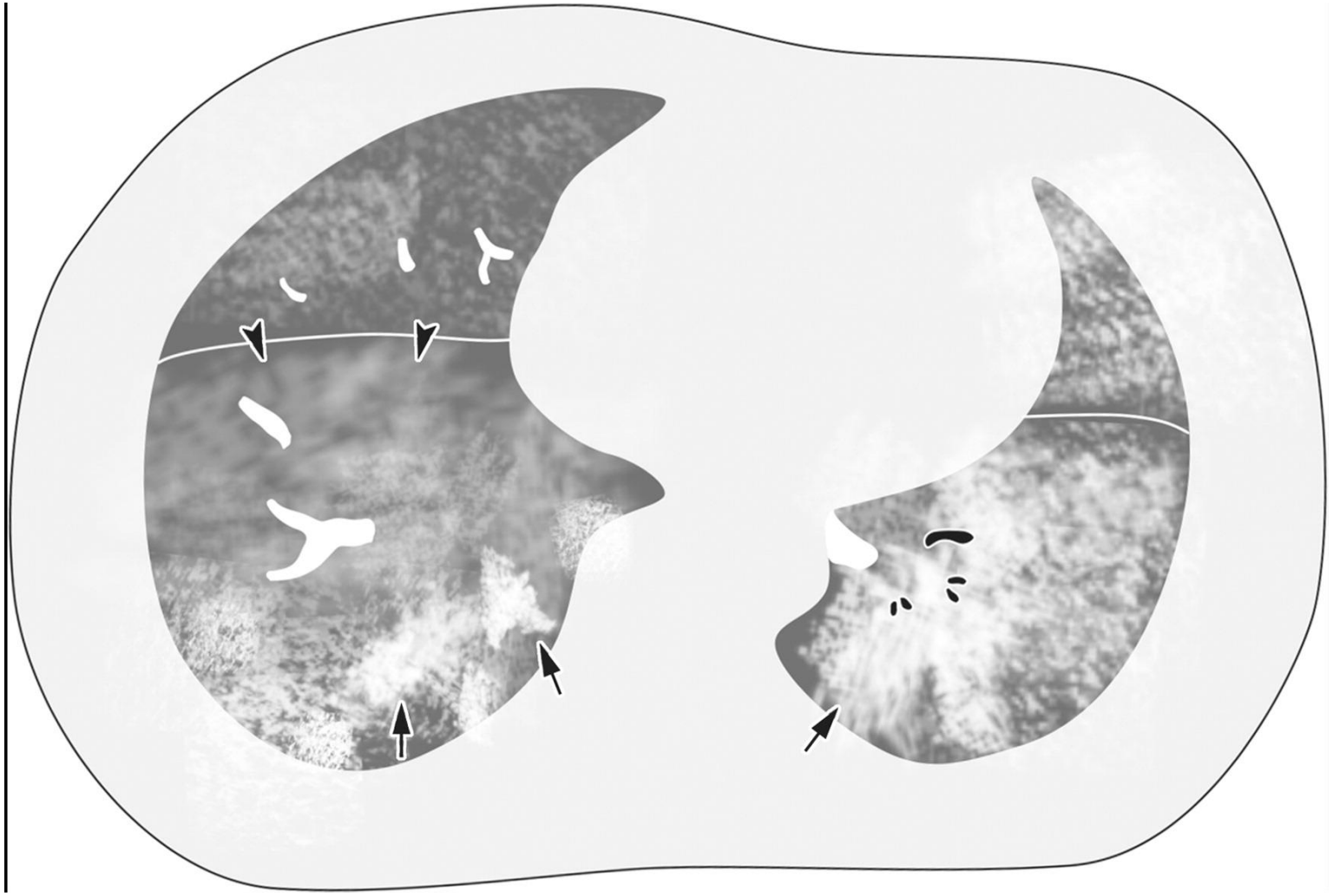
Radiographic and CT Features of Viral Pneumonia

Hyun Jung Koo, Soyeoun Lim, Jooae Choe, Sang-Ho Choi, Heungsup Sung, Kyung-Hyun Do

Author Affiliations

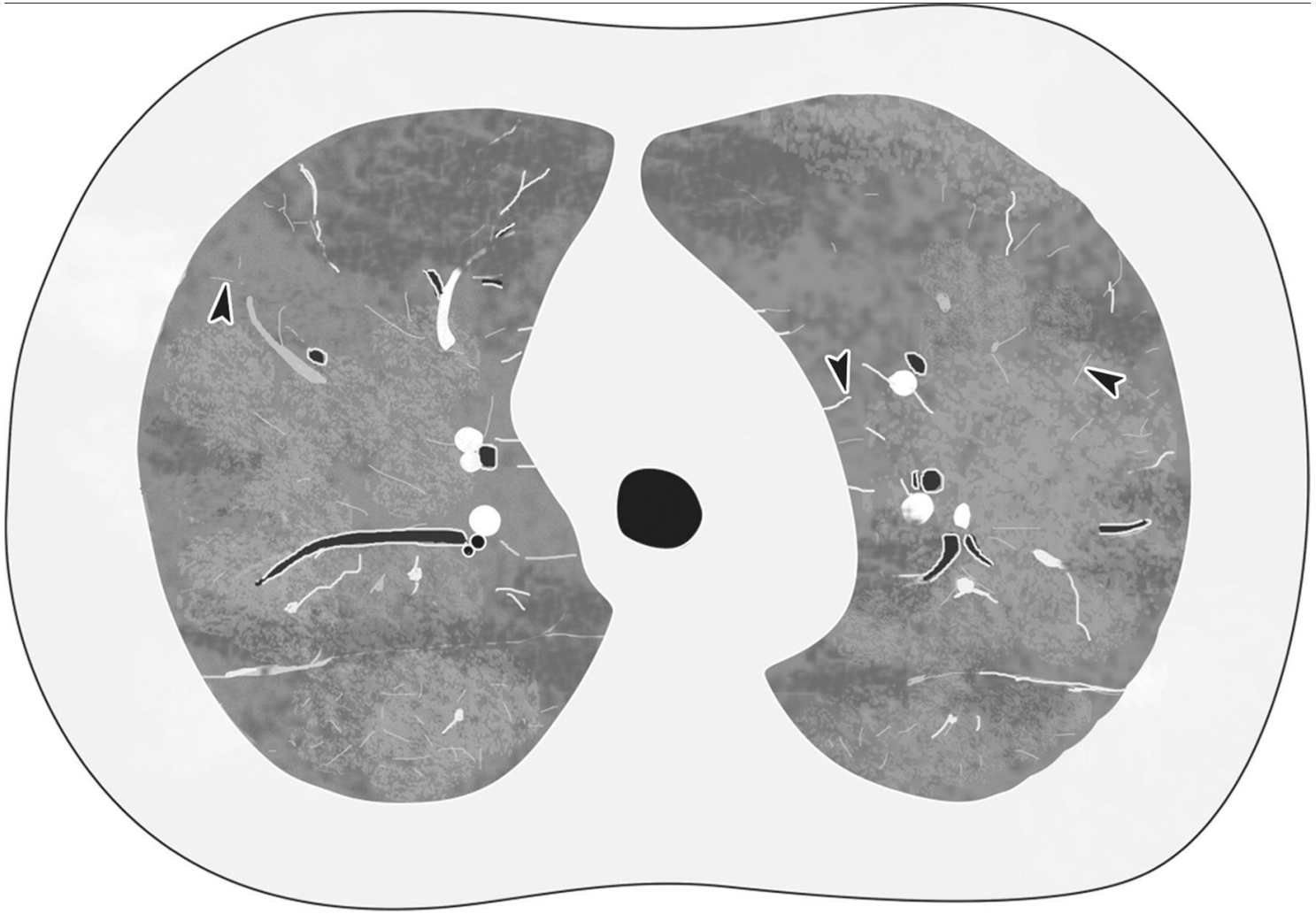
Published Online: May 14 2018 | https://doi.org/10.1148/rg.2018170048

Other viral infections



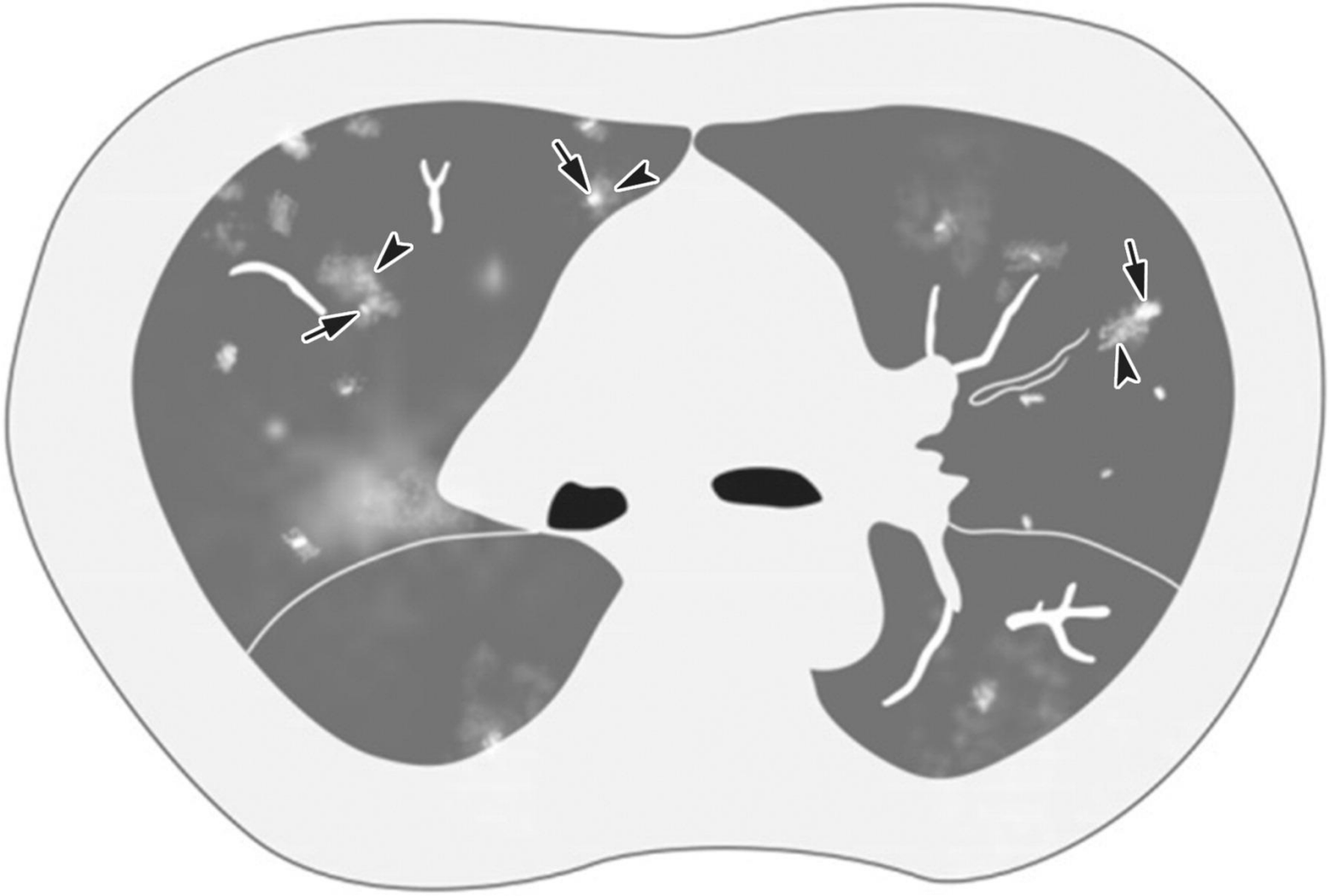
Pneumonia due to influenza A virus shows multiple irregular areas of consolidation (arrows) along the bronchovascular bundles and diffuse GGO (arrowheads) with interlobular septal thickening in both lungs

Other viral infections



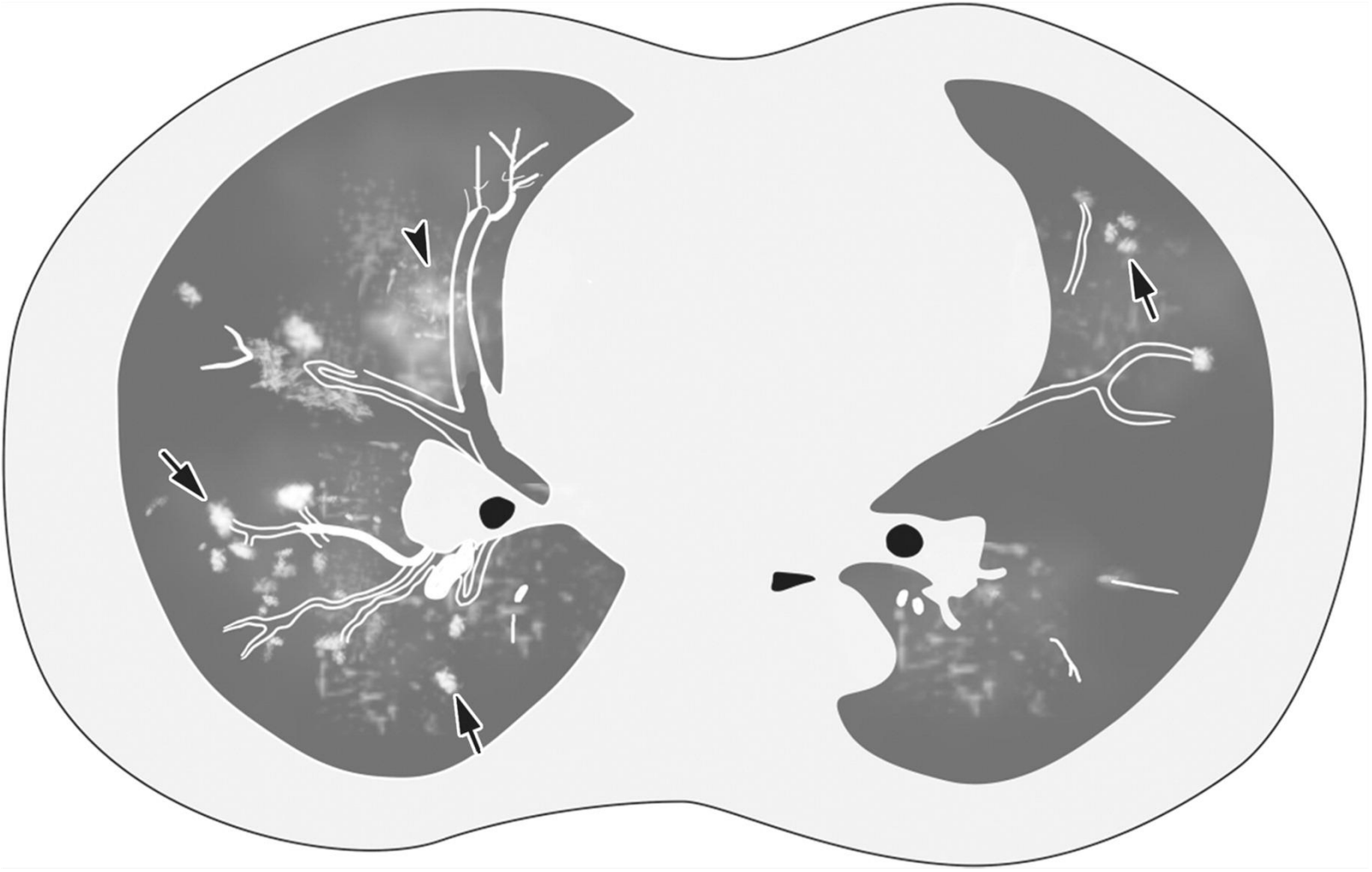
Pneumonia due to CMV shows diffuse ill-defined patchy GGO with interlobular septal thickening (arrowheads) in both lungs.

Other viral infections



Pneumonia due to varicella-zoster virus shows multifocal 1–10-mm well-defined or ill-defined nodular opacity (arrows) with a surrounding halo or patchy GGO (arrowheads) in both lungs.

Other viral infections



Pneumonia due to Human Meta Pneumo Virus (HMPV) shows multiple ill-defined nodules (arrows) or GGO (arrowhead) along the bronchovascular bundles in both lungs. These findings are similar to those of Human Parainfluenza Virus (HPIV) pneumonia, which belongs to the same viridae.

Other viral infections

Family [subfamily]	Common Name	Transmission*	Pathogenesis	Typical CT Findings						Systemic Involvement
				Distribution	Consolidation	GGO	Nodule	Bronchial Wall Thickening	Pleural Effusion	
Adeno-	Adenovirus	Respiratory, fecal-oral, conjunctival	Bronchiolar and alveolar damage	Multifocal	+++	+++	Centrilobular+	UC	C	Not definite
Herpes-[Alphaherpes-]	HSV	Contact (oral or genital secretion)	Cytopathic effect with diffuse alveolar damage	Multifocal random, or segmental	++	+++	+	UC	F	Gingivostomatitis, pharyngitis and herpes labialis (HSV1)
	Varicella-zoster virus	Contact, airborne (aerosol, droplets)	Hematogenous spread to alveolus, cytopathic effect with mononuclear cell infiltration	Multifocal	Rare	Surrounding halo	1–10 mm (in late phase, calcification)	UC	Rare	Skin rash
Herpes-[Betaherpes-]	CMV	Contact, transplacental, blood transfusion	Cytopathic effect with diffuse alveolar damage	Diffuse	++	++++	++	UC	Rare	Not definite
Herpes- [Gammaherpes-]	Epstein-Barr virus	Oral, blood transfusion, organ transplantation	Mononuclear inflammatory cell infiltration along bronchovascular bundles and interlobular septa	Diffuse (pneumonia is rare)	Rare	++	Rare	UC	V	Infectious mononucleosis, mediastinal LAP, splenomegaly
Parvo-[Parvo-]	Bocavirus†	Aerosol and contact	Induced cytokine expression	Diffuse	++	++	Rare	UC	C	Not definite
Paramyxo-	HPIV	Contact, droplet	Bronchiolar and alveolar damage with mucus plugging	Airway, multifocal	+	+	Centrilobular++	C	UC	Not definite
	Measles	Airborne (aerosol, droplets), contact with secretion or skin rash	Bronchiolar and alveolar epithelial damage with multinucleated giant cell formation	Multifocal	Rare	+	+	UC	C	Hilar LAP, gastroenteritis, encephalins
	Mumps†	Droplets or aerosol, transplacental	Mononuclear cell infiltration of bronchiole and alveolar septa	Multifocal	Rare	++	Rare	UC	Rare	Parotid gland (95% of patients)

Other viral infections

Family [subfamily]	Common Name	Transmission*	Pathogenesis	Typical CT Findings						Systemic Involvement
				Distribution	Consolidation	GGO	Nodule	Bronchial Wall Thickening	Pleural Effusion	
Pneumo-	RSV	Contact, aerosol	Destruction of bronchial and alveolar epithelium with small airway obstruction	Airway, multifocal	+	+	Centrilobular+++	C	C	Not definite
	HMPV	Direct or close contact, droplet, aerosol	Upregulation of cytokines leads to perivascular and peribronchiolar infiltration	Airway, multifocal	+	+	Centrilobular+++	C	UC	Not definite
Hanta-	HCPS, HFRS	Aerosol	Direct involvement of vascular endothelium resulting in increased endothelial permeability	Pulmonary edema	Rare	Rare	Rare	UC	F	ARF (HFRS), thrombocytopenia, hypotension, shock (HCPS)
Phenui-	SFTS	Tick-borne	Upregulation of cytokines resulting in increased endothelial permeability	Pulmonary edema	Rare	Rare	Rare	UC	F	Shock, multiorgan failure, thrombocytopenia
Orthomyxo-	Influenza	Droplet, airborne	Destruction of airway epithelial barrier, resulting in necrotizing bronchitis and diffuse alveolar damage	Airway, multifocal	+	+	++	C	UC	Not definite
Corona- [Corona-]	Human coronavirus	Droplet, airborne, contact	SARS: diffuse alveolar damage by involving angiotensin-converting enzyme; MERS: dysregulation of the host cellular transcriptome resulting in apoptosis	Peripheral, multifocal	+++	+	Rare	UC	Rare	Not definite
Picorna-	Rhinovirus	Droplet, aerosol, or contact	Disruption of epithelial barrier function causing increase vascular leakage and mucus secretion; no cytopathic effect	Multifocal	+	++	Rare	UC	Rare	Not definite
	Enterovirus	Fecal-oral, contact, droplet	Attachment to decay-accelerating factor of the lower respiratory tract	Multifocal	+	++	Rare	UC	Rare	Not definite

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