Imaging findings of COVID-19

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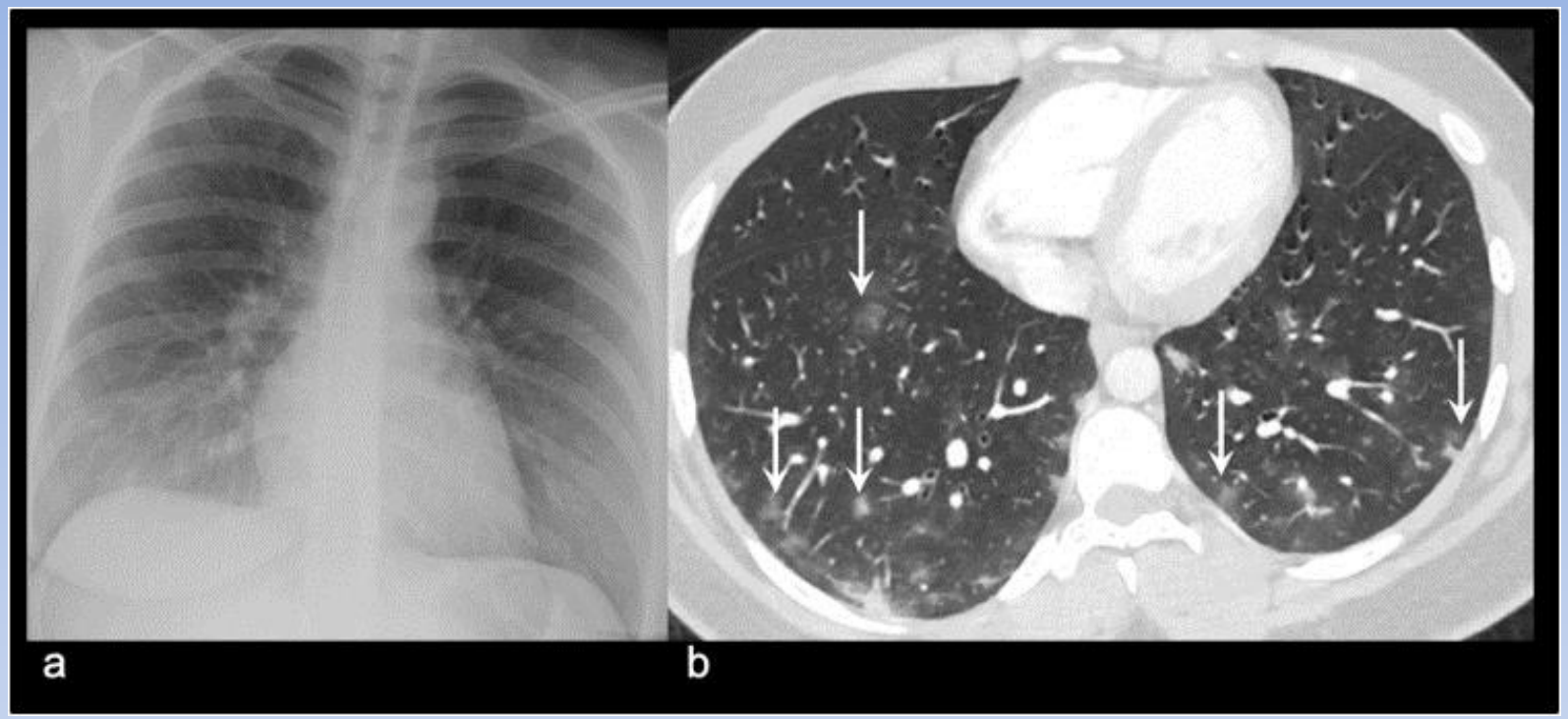
Chest radiography findings

- CXR is negative in 40 %–66.7 % of cases despite positive findings on chest CT
- . The most common radiographic finding is opacification, often with a peripheral and lower lung distribution
- Thus, CXR is not recommended for routine Dx, but may be helpful for follow-up.



25-year-old female presenting with 7 days of fever and shortness of breath, with portable chest radiography (a) showing no abnormality. A subsequent CT angiogram of the chest (b) shows multifocal lower lobe rounded opacities, predominately ground-glass in attenuation (arrows). Patient tested positive for COVID-19.

60-year-old male with fever / cough for 7 days due to COVID-19. (a)C-Xray shows ill-defined opacities in the lateral aspect of the right lung (arrows). (b) Axial CT shows GGOs with a peripheral distribution in both upper lobes (arrows). There is superimposed interlobular and intralobular septal thickening (crazy-paving pattern). (c) Reconstructed CT image shows corresponding multifocal bilateral ground-glass opacities with a peripheral distribution (arrows).

Chest CT findings

- A low dose, chest CT without intravenous contrast is used for evaluation

Parameters of protocol of low – dose vs standard

Parameters	Low – dose protocol	standard
Kv	Sn100	100
mAs/ref	112/96	85/62
CTDvol*,mGy	0.39 L	3.44 L
DLP,MGy cm	14.5	129.1
T1,s	0.25	0.5
cSL, mm	0.6	0.6
ED,mSv	0.203	1.8074
SNR	0.47	0.78
CNR	1.09	3.79

A low dose chest CT

- improved detector
- highpitch settings
- lower tube voltage (80–100 kVp) and current (10–25 mAs)
- Reconstruction
- dose reduction options
- it is now feasible to minimize the radiation dose. We implemented a low-dose scanning protocol that reduced the patient’s dose to 1/8 to 1/9 of the standard dose.
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A low dose chest CT

- It is now feasible to minimize the radiation dose.
- We implemented a low-dose scanning protocol that reduced the patient's dose to 1/8 to 1/9 of the standard dose.

Chest CT findings

- The vast majority, 98%, show bilateral lung involvement. The typical chest CT findings of non-ICU patients are bilateral ground-glass opacity and sub-segmental consolidation.
- ICU patients are bilateral multi-lobe and sub-segmental consolidation

Chest CT findings

The affected lungs are mostly located in the peripheral zone. Other imaging features include linear opacities, “crazy-paving” pattern, and the “reverse halo” sign

Chest CT findings

- Actually, the number of CT scans ranges from 3 to 6 within a short period of time.
- Even healthy people may get one CT or even two to ensure they do not have COVID-2019

Chest CT findings

- GGOs may have a rounded morphology in up to 54 % of the cases
- Superimposed interlobular septal thickening can also be present, resulting in a crazy-paving pattern .
- Vascular enlargement, air bronchograms, and a halo sign have also been described
- The GGOs and consolidative lesions are larger than 1cm in 91 % of cases.
- The lower lobes and posterior portions are more frequently involved

Chest CT findings

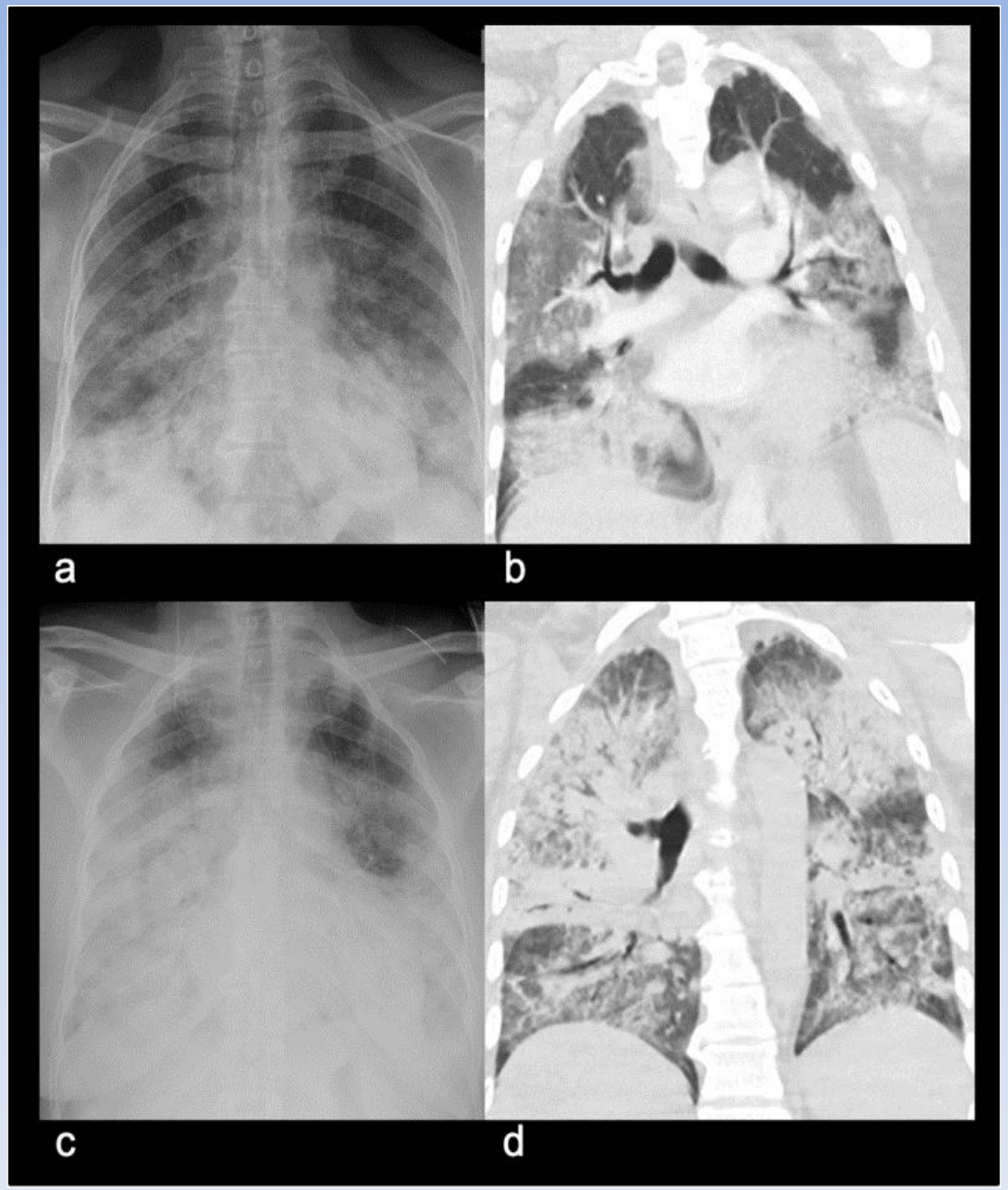
- Mediastinal and hilar lymphadenopathy
- pleural effusions or thickening
- discrete pulmonary nodules
- pulmonary cavitation have been rarely described

Chest CT findings

- CXR and chest CT can be negative in up to 17.9 % of patients, especially in early and/or non severe diseas.
- In mild cases, CT findings consist more frequently of GGO alone (65 %), followed by GGO with consolidation (44 %) .
- Severe cases with a clinical ARDS picture present with widespread dense consolidative opacification on CT

Stages of COVID-19 on chest CT

- These were classified into 4 main successive stages:
- Early stage
- intermediate stage
- late stage
- resorptive stage



65-year-old female presenting with fever and dyspnea due to COVID-19. (a) Initial ED anteroposterior chest radiography with corresponding (b) coronal chest CT reformatted image show multifocal mid to lower lung predominant ground-glass and consolidative opacities. (c) Follow-up (c) anteroposterior chest radiography and (d) coronal CT reformatted image on day 14 of admission show progressive pulmonary opacities, now more consolidative and involving more of the upper lobes bilaterally

Stages of COVID-19 on chest CT

- Early stage (≤2 days):
- More than half of the patients have negative chest CT (56 %). The remaining patients have predominantly GGO (44 %) and consolidation (17 %). Imaging findings when present were often unilateral

Stages of COVID-19 on chest CT

- Intermediate stage (3–5 days):
- As the disease progresses, more GGO (88 %) and consolidation (55 %) are noted bilaterally (76 %) and with a peripheral lung distribution (64 %).
- Only 9% of patients have negative chest CT

Stages of COVID-19 on chest CT

- Late phase (6–12 days):
- Most of the patients in this phase have positive chest CT findings. 88 % and 60 % of patients have GGO and consolidation, respectively.
- The imaging findings are bilateral in 88 % and peripheral-predominant in 72 % of cases

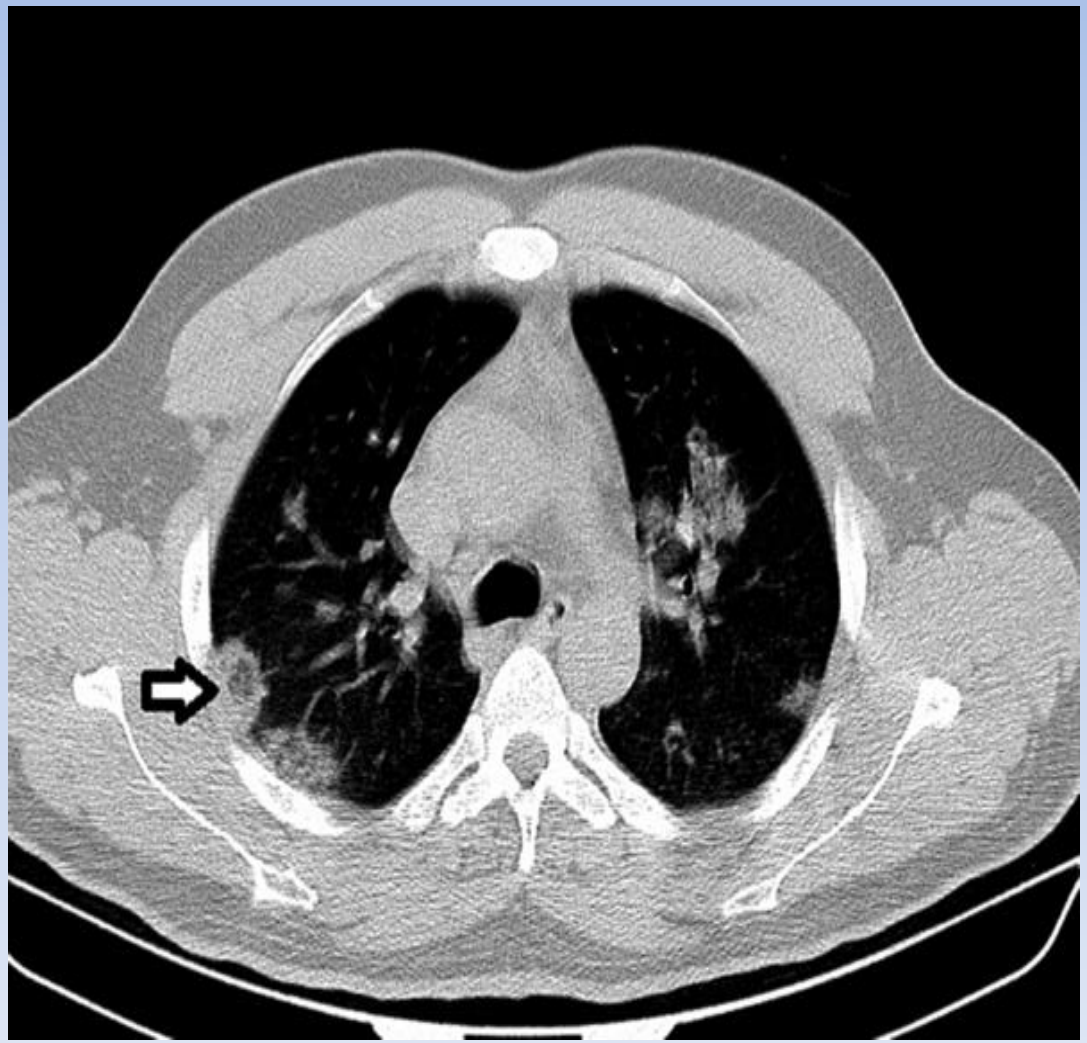
Stages of COVID-19 on chest CT

- Absorption stage/fourth stage (> 14 days)
- 65 % and 75 % of patients have GGO and consolidation, respectively.
- The imaging findings are bilateral in 88 % and peripheral-predominant in 72 % of cases

Absorption stage/fourth stage

- When patients improve, the lung disease evolves and organizes, and fibrous bands may appear . A “reverse-halo sign” is occasionally observed and can be an indication of organizing pneumonia .

“reverse-halo sign”



“reverse-halo sign”

severe cases

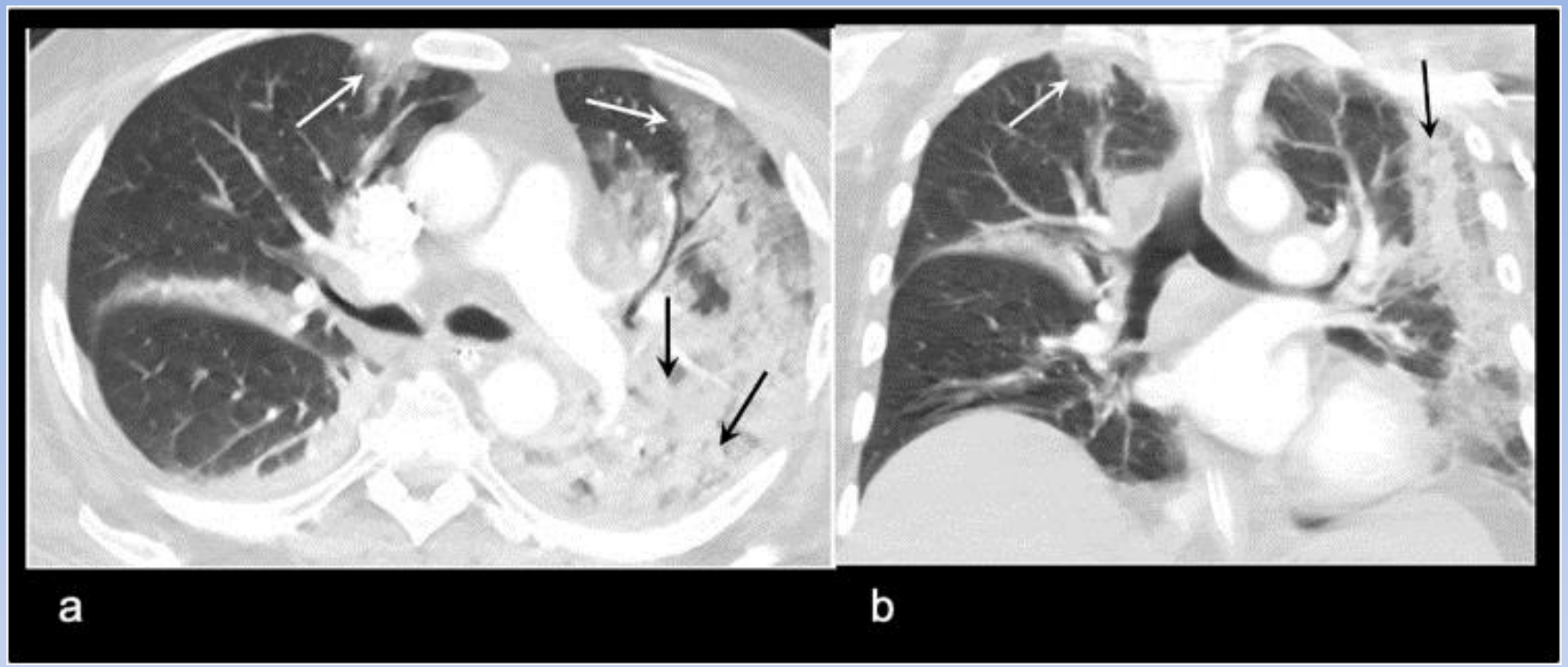
- The consolidation and GGO increase and involve all five lung lobes, resulting in a dense consolidative appearance and characterized by diffuse alveolar damage, usually with a poor prognosis

COVID-19 in special populations

- Oncology patients: similar findings of GGO (75 %) and patchy consolidation
- Pediatric and pregnant patients:manifested with bilateral and peripheralpredominant GGO. Pleural effusions were more commonly encountered in pregnant than in non-pregnant women

COVID-19 in special populations

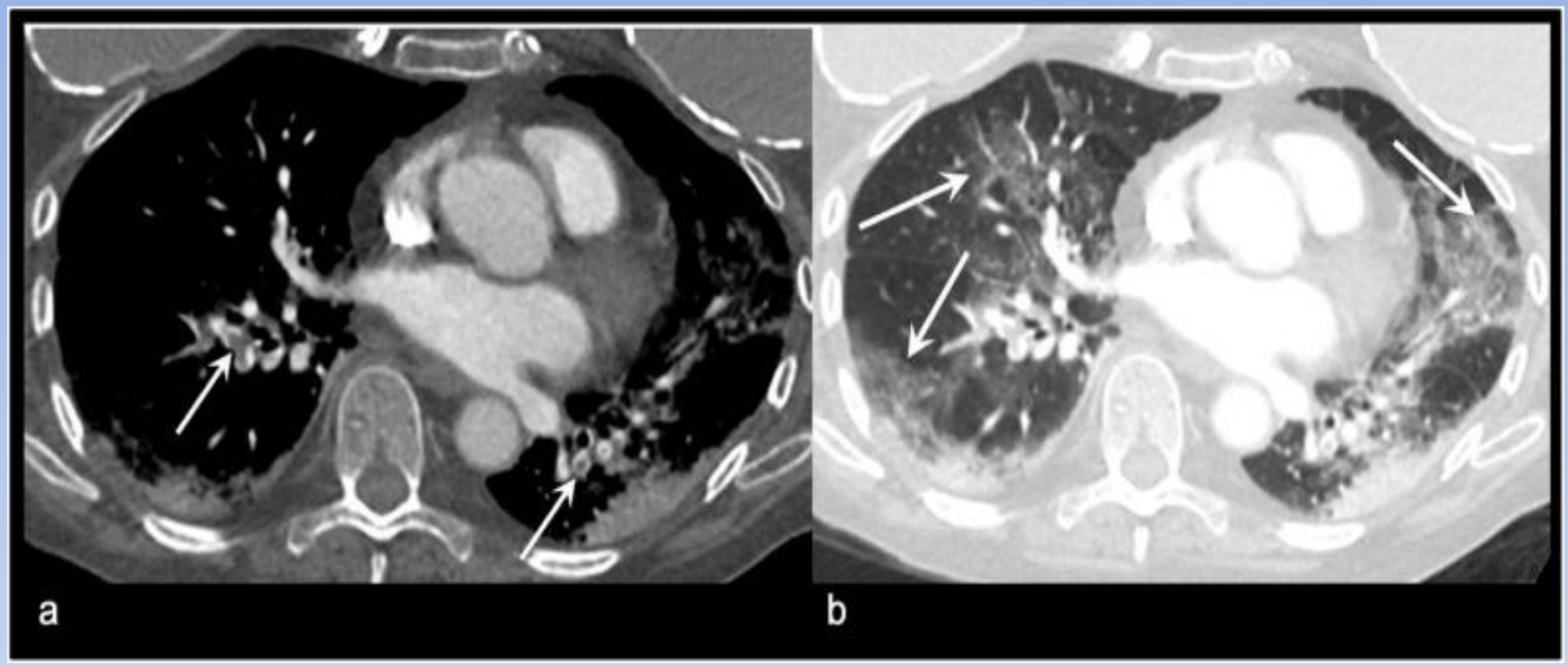
- Elderly population:
- they tend to have more areas of lung involvement with more lobes affected and more pleural thickening
- They tended to have more architectural distortion, bronchiectasis, mediastinal and hilar lymphadenopathy and pleural effusions



74 year-old male with fever and cough due to COVID-19. (a) Axial and (b) coronal CT angiography of the chest shows multifocal bilateral ground-glass (white arrow) and consolidative (black arrow) opacities.

COVID-19 and pulmonary embolism

- COVID-19 can be associated with pulmonary embolism especially when D-dimer is elevated , and preventive anticoagulation has been recommended in severely ill hospitalized patients



76-year-old female presenting with 3 weeks of cough, dyspnea and palpitations. CT angiography of the chest (a) shows bilateral lower lobe segmental and subsegmental pulmonary emboli (arrows). Corresponding image in lung windows (b) shows multifocal bilateral ground-glass and consolidative opacities consistent with the patient’s diagnosed COVID-19 pneumonia.

Differential diagnosis

- severe acute respiratory syndrome (SARS)
- MERS
- influenza, parainfluenza
- adenovirus, respiratory syncytial virus (RSV), rhinovirus, human metapneumovirus, cytomegalovirus and others)], as well as community-acquired pneumonias (CAP) caused by Streptococcus pneumonia or mycoplasma infection

Differential diagnosis

- COVID-19 tends to have a more peripheral distribution, greater GGO, increased vascular enlargement and a “reverse-halo sign”
- COVID-19 had more frequent bilateral GGOs compared to non–COVID-19 viral infections
- Key findings less frequent in COVID-19 compared to non–COVID included air bronchograms, centrilobular nodules, tree-in-bud opacities, bronchial wall thickening and a reticular patt

COVID-19/ SARS/MERS

- All three of these infections cause peripheral multifocal airspace opacities (GGO and/or consolidation), with rare pneumothorax, without cavitation or lymphadenopathy. Differences in the imaging appearances have been reported, as *SARS* tends to be unilateral and focal in distribution (50 %) and *MERS* patients can develop pleural effusion (33 %) . Both SARS and MERS are associated with constriction of the pulmonary vasculature, whereas enlargement of the vasculature has been reported in COVID-19

COVID-19/ SARS/MERS

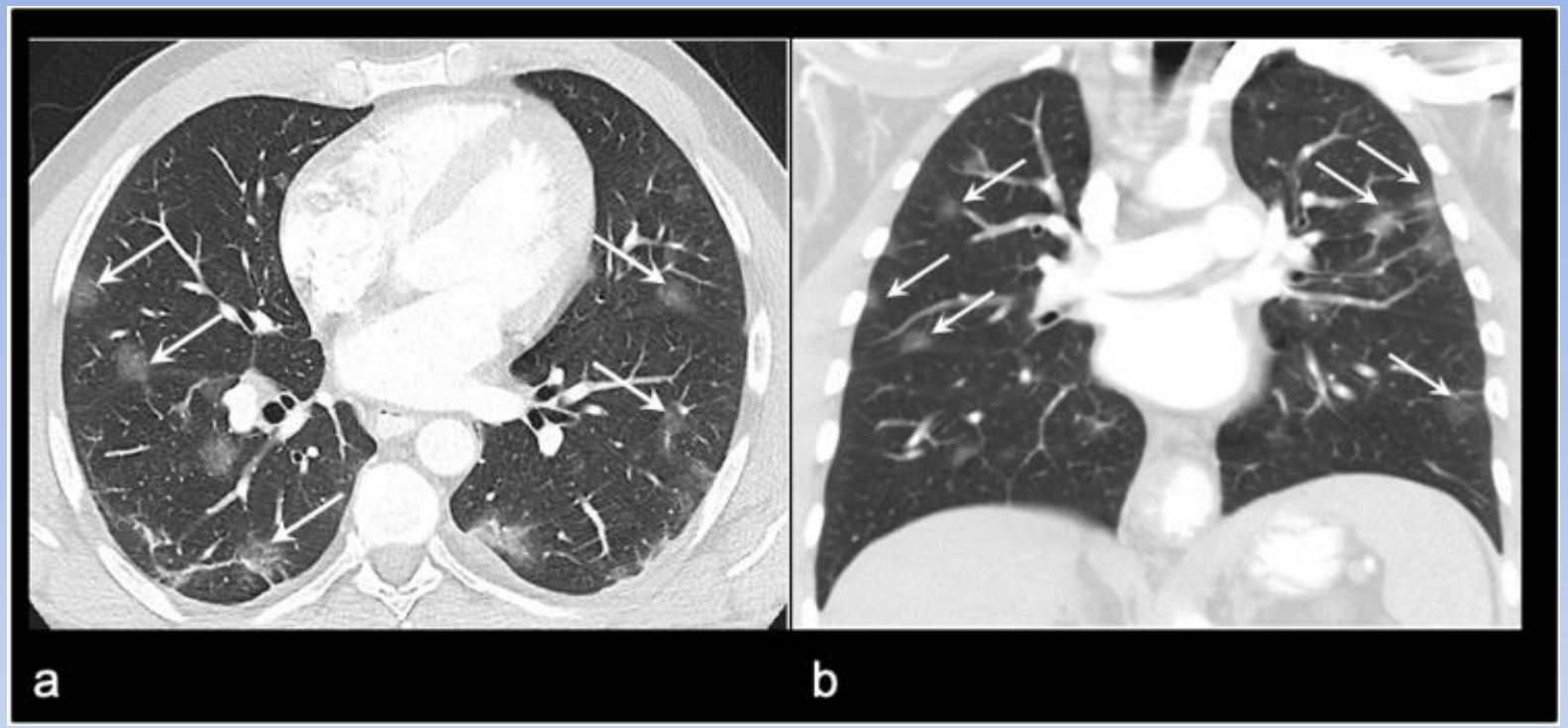
- Pulmonary fibrosis was reported as a late manifestation in MERS, but not in SARS. The long-term sequelae of COVID-19 remain to be determined; however, early publications indicate a fibrotic phase characterized by reticulation, interlobular septal thickening and traction bronchiectasis

Guidelines and scientific societies from imaging societies

- In the US, the Centers for Disease Control and Prevention (CDC), the American College of Radiology (ACR), the Society of Thoracic Radiology (STR), and the American Society of Emergency Radiology (ASER) issued their position statements recommending against the use of CT for widespread screening and diagnosis of COVID-19, instead reserving CT for those cases with clinical suspicion for complications like abscess or empyema

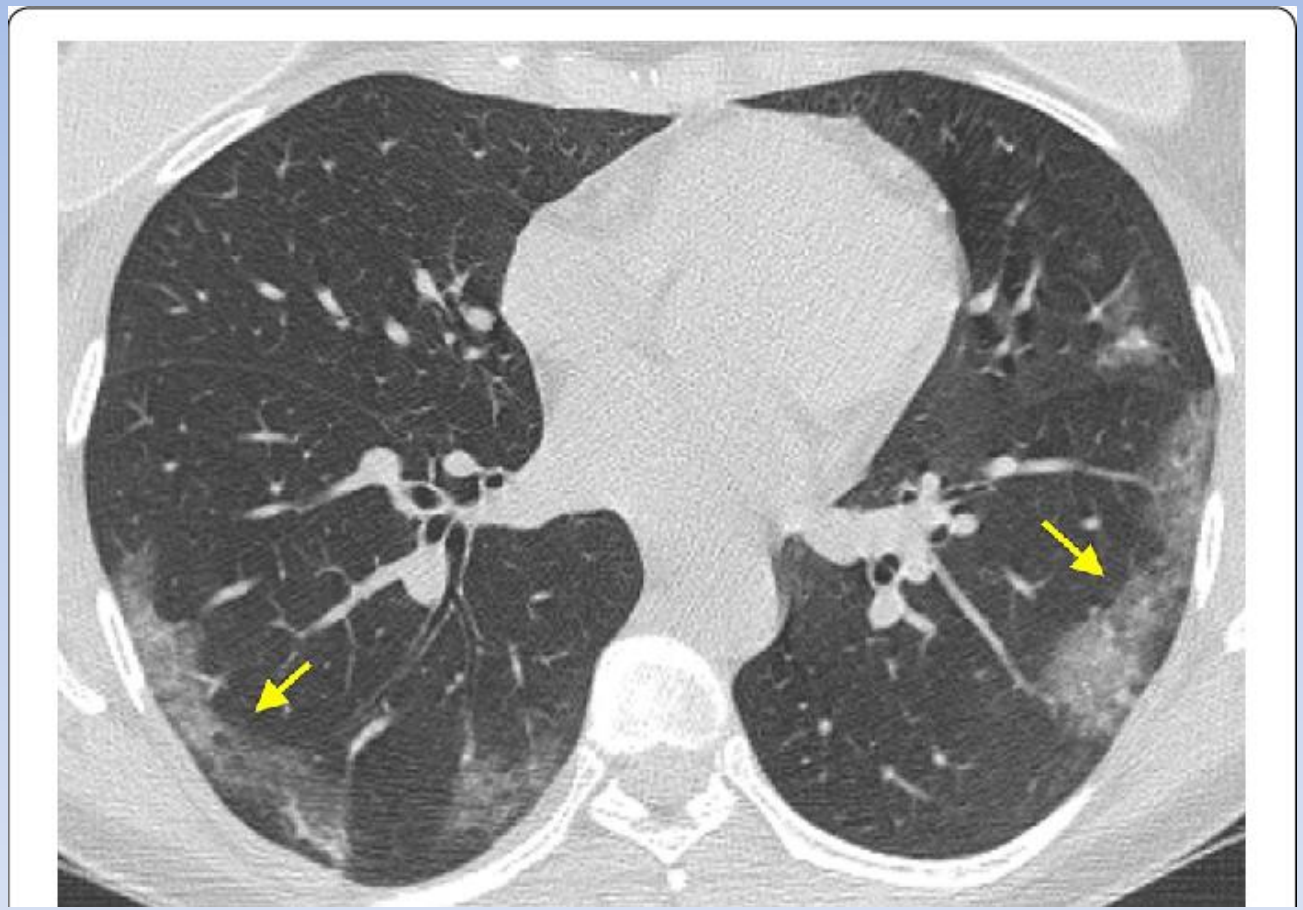
Structured reporting and standardized language

- Chest CT findings were classified for COVID-19 pneumonia into four groups:
- typical appearance
- indeterminate appearance
- atypical appearance
- negative for pneumonia.

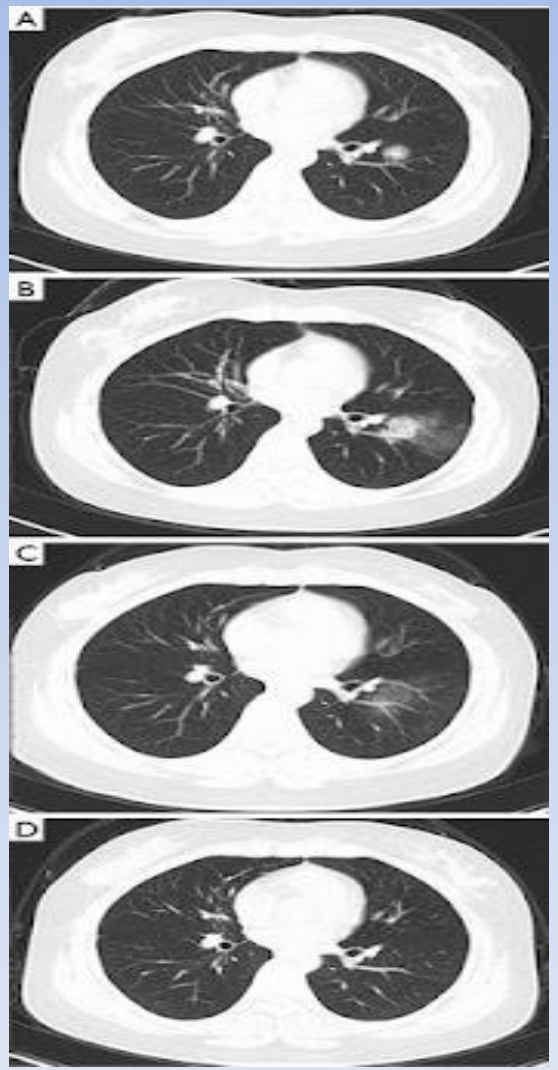


37-year-old male presenting with fever, cough and dyspnea for 7 days due to COVID-19. (a) Axial chest CT image shows multifocal bilateral GGOs with a rounded morphology (arrows). (b) Corresponding coronal CT shows the bilateral ground-glass lesions, many of which are peripheral in distribution as well.

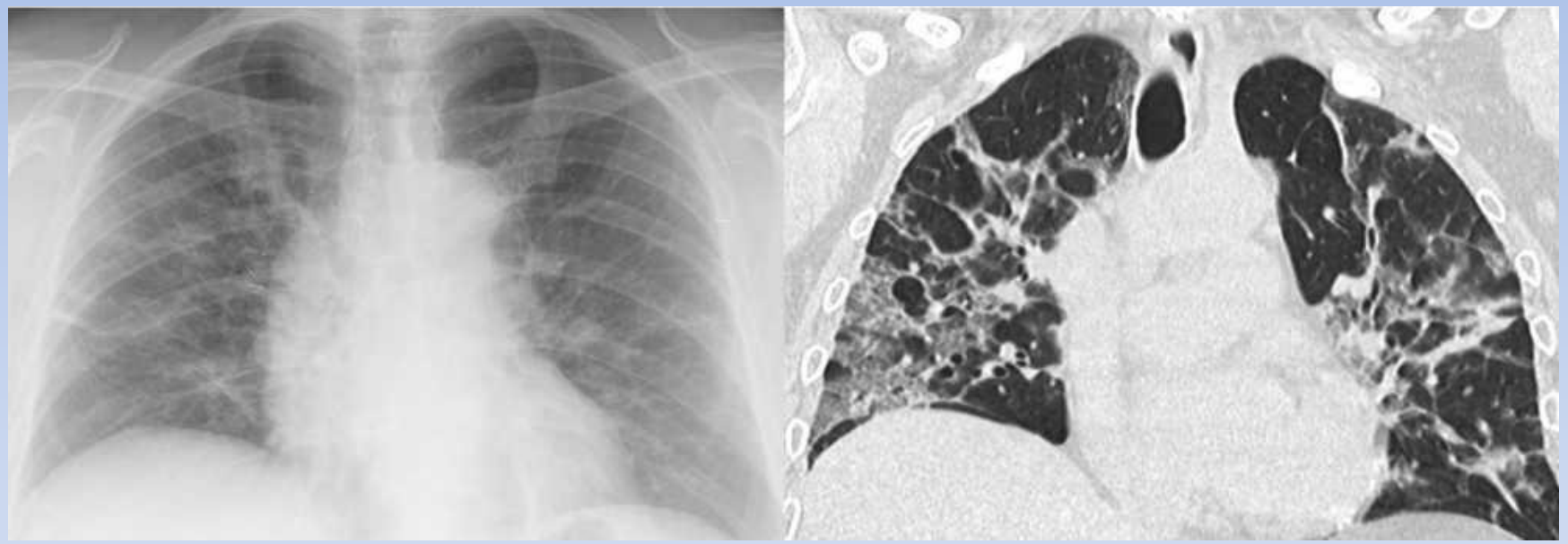
typical appearance



indeterminate appearance



atypical appearance



Structured reporting and standardized language

- Standardized language templates are provided in with the goal of decreasing reporting variability and increasing clarity by using consistent language. The question of whether to include terminology such as “coronavirus” or “COVID-19” in reports remains an area of debate. The authors acknowledge that for patients with unexpected findings that could be attributable to COVID-19, the matter is complex and consultation with local clinical colleagues is needed to establish an approach. The term “*viral pneumonia*” is considered a reasonable alternative.

Reported prevalence of imaging findings of COVID-19 on chest CT.

Imaging findings	Mean (Range in %)	References
Common features		
Ground glass opacities (GGO)	71.7 (27.3–100)	[26,27,28,29,30,32,33,34,35,37,38,39,40,42,44,45,46,47,51,53]
Crazy-paving	26.7 (5–89.4)	[27,29,30,34,35,38,40,42,45,53]
Enlarged subsegmental vessels	80.9 (71.3–89)	[31,37,42]
Rounded morphology	34 (11–59.6)	[27,29,30,33,38,40,42]
Consolidation	41.2 (6–69)	[6,27,28,29,32,33,34,35,37,39,40,42,44,45,46,47,53]
GGO and consolidation	46.6 (29–64.4)	[27,28,29,31,32,33,37,38,40,43]
Interlobular septal thickening	50.9 (13–75)	[31,32,34,35,42]
Halo sign	34.3 (12–69)	[40,42,45]
Air bronchogram	50 (8–80)	[28,30,31,32,35,38,39,40,42,45]
Distribution		
Posterior	80 (67–93)	[32,41,42]
Bilateral	79.2 (51–93)	[26,27,29,30,32,35,37,42,43,44,45,51,53]
Peripheral	73 (43.6–100)	[26,27,28,29,30,31,32,33,35,37,39,40,41,42,43,45,46,51]
More than 2 lobes affected	62.5 (51–93)	[27,29,35,40,42,43]
Central and peripheral distribution	19.9 (2–56.4)	[32,33,39,40,43,45]
Uncommon Findings		
Centrilobular nodules	15.7 (0–32)	[27,28,29,30,37,45,47]
Tree-in-bud nodularity	9.1	[28]
Bronchiectasis	30.9 (1–52.5)	[27,28,37,39,42]
Bronchial wall thickening	10.5 (0–28.7)	[27,34,37,38,42,45]
Cystic changes	9.1	[28]
Pleural thickening	30 (0–56)	[35,39,40,45]
Subpleural linear opacity	18.2 (17.5–33.9)	[28,37,39,47,50]
Reverse halo sign	5.1 (3.9–17)	[27,31,45,46]
Pleural effusion	3.7 (0–13.9)	[27,28,29,30,31,32,33,34,35,37,39,40,42,45,46,51]
Pericardial effusion	3.4 (1–6)	[32,34,35,42,46,51]
Lymphadenopathy	5.8 (0–58)	[27,28,29,30,31,32,34,35,37,40,42,45,46,51,53]

Conclusion

- COVID-19 is a new rapidly spreading pandemic. It has typical CT findings with GGOs and consolidation often with a peripheral and lower lung distribution. In early disease, imaging findings can be absent; therefore, CT chest cannot be used as a screening method, and RT-PCR remains the reference diagnostic test. AI may play a role in the rapid diagnosis of COVID-19, but more data is needed to assess its added value

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