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The Role of Imaging in COVID-19 Pneumonia Diagnosis and Management: Main Positions of the Experts, Key Imaging Features and Open Answers

Nicholas Landini,[1,2] Martina Orlandi,[3] Michele Fusaro,[1] Pierluigi Ciet,[4,5] Cosimo Nardi,[2] Silvia Bertolo,[1] Vito Catalanotti,[6] Marco Matucci-Cerinic,[3] Stefano Colagrande,[2] and Giovanni Morana[1]

[1]Department of Radiology, Ca' Foncello General Hospital, Treviso, Italy
[2]Department of Experimental and Clinical Biomedical Sciences, Radiodiagnostic Unit N. 2, University of Florence - AOUC, Florence, Italy
[3]Department of Experimental and Clinical Medicine, Division of Rheumatology, University of Florence, Scleroderma Unit, AOUC, Florence, Italy
[4]Department of Paediatric Pulmonology, Erasmus University Medical Centre, Sophia Children's Hospital, Rotterdam, Netherlands
[5]Department of Radiology, Erasmus University Medical Centre, Rotterdam, Netherlands
[6]Department of Pulmonology, Ca' Foncello General Hospital, Treviso, Italy
Address for correspondence: Dr. Nicholas Landini, Department of Radiology, Ca' Foncello General Hospital, Treviso, Italy. Department of Experimental and Clinical Biomedical Sciences, Radiodiagnostic Unit N. 2, University of Florence - AOUC, Florence, Italy. E-mail: nikolandini@hotmail.it

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Abstract

Lung imaging is widely involved in facing the coronavirus disease (COVID-19) pandemic. In fact, the COVID-19 infection may lead to a rapidly evolving and potentially fatal pneumonia. Moreover, computed tomography (CT) can be more sensitive than the COVID-19 reverse transcriptase-polymerase chain reaction test, especially at the beginning of the disease. Only patients with mild features consistent with COVID-19 infection, negative COVID-19 test, or positive COVID-19 test but at low risk for disease progression should avoid imaging. However, imaging becomes mandatory if respiratory symptoms worsen. A CT pattern classification has been designed to help both radiologists and clinicians. The typical pattern of COVID-19 is depicted by multifocal, bilateral, and peripheral ground-glass opacities (with or without consolidations or crazy paving) or findings of organizing pneumonia. Moreover, CT has demonstrated a

prognostic role in patients with a diagnosis of COVID-19 pneumonia. Lung ultrasounds (LUS) are an emergent tool in the diagnosis of the disease. The adoption of LUS combined to chest X-rays in COVID-19 in pneumonia diagnosis is an interesting prospect that needs to be confirmed.

Keywords: Computed tomography, COVID-19, diagnostic imaging, ultrasound, X-ray

Introduction

The 2019 novel coronavirus disease (COVID-19) pandemic represents a world emergency. A zoonotic origin of the virus has been suggested, with person-to-person transmission. The most common symptoms of COVID-19 infection are fever, cough, and fatigue, with an incubation period of <2 weeks.[1] Moreover, the infection may involve the lower respiratory tract determining severe pneumonia, a potentially fatal disease. Since December 2019, when the first case was diagnosed, more than 3 million of confirmed cases have been recorded, with more than 215,000 deaths (up to May 17, 2020).[2] The sudden and major social impact of the pandemic raised the need to define the role of chest imaging, to support radiologists and clinicians facing the COVID-19 pneumonia.

This review aims to report the main expert opinions on chest imaging role in COVID-19 pneumonia, as well as a proposed classification imaging criteria for both diagnosis and differential diagnosis (DD), based on common and uncommon radiologic features described in previous studies.

Then, discussing the last evidence and experiences, we add some open answers, regarding the prognostic role of imaging and the possible combination of chest X-rays (CXR) and lung ultrasound (LUS) in pneumonia diagnosis.

Role of Chest X-Rays and Computed Tomography in COVID-19 Pneumonia Diagnosis and Management

CXR and computed tomography (CT) offer different pros and cons in the diagnosis of COVID-19 pneumonia. On one hand, CXR is easily available and may reduce the risk of cross infection, especially with portable CXR.[3] In fact, the use of CT implies a dedicated scan or an additional time to clean and disinfect the equipment itself. On the other hand, CT is more sensitive to early alterations [Figure 1], even if it remains of low specificity in COVID-19 pneumonia diagnosis. However, CT may precede COVID-19 reverse transcriptase-polymerase chain reaction test positivity.[4] In its recent statement,[4] the Fleischner society left the decision to the clinical teams for the choice between the two of them, depending on local resources and expertise. Whatever the imaging tool, it is suggested to identify 3 possible scenarios, based on symptoms, pretest probability (defined as low, moderate, or high by the background prevalence of infection, and further modified if there is a known exposure through contact with a confirmed case) and resources:

1. Patients with mild clinical respiratory features consistent with COVID-19 infection, any pretest probability, and no significant resource constraints

2. Patients with moderate-to-severe clinical features consistent with COVID-19 infection, any pretest probability, and no significant resource constraints

3. Patients with moderate-to-severe clinical features consistent with COVID-19 infection, high pretest probability and resource constraints.

Following these criteria, only patients belonging to scenario 1 with negative COVID-19 test (or low test probability) or positive COVID-19 test but with low risk of disease progression should avoid imaging. Risks factors for disease progression are considered age >65 years, cardiovascular disease, diabetes, chronic respiratory disease, hypertension, and immune-compromised patients. However, in case of worsening of respiratory status, an imaging examination becomes mandatory. If a different diagnosis is established, patients may follow the proper guidelines. In case of a negative COVID-19 test but with imaging features consistent with COVID-19 pneumonia (or in absence of an alternative diagnosis), it is suggested to repeat the test or pursue with other investigations (in case of scenario 2) or consider a presumptive diagnosis of COVID-19 (in case of scenario 3). Regarding patients monitoring, CXR is not daily recommended in COVID-19 pneumonia, neither in stable intubated patients. Furthermore, the ESR and ESTI societies[5] suggest to perform a CT in case of suspected complications, i.e., superinfections or pulmonary embolism.

Chest X-Ray and CT COVID-19 Pneumonia Diagnosis: Key Imaging Features and the Radiological Society of North America CT Imaging Classification

There are several studies reporting common and uncommon CXR and CT findings. Being aware that CXR is less sensitive than CT, and that CT may be not specific for COVID-19 pneumonia,[3] we report the main common and uncommon features highlighted in the literature, for both CXR and CT. [3,5,6,7,8,9,10,11,12,13,14,15]

CXR common findings are ground-glass opacities (GGO), consolidations, and reticular opacities. Uncommon alterations are nodules, cavitation, pleural effusion, and pneumothorax. Usually, alterations are multifocal and bilateral, patchy, or peripheral, with a predilection for the lower lung zones. A diffuse distribution may be seen in the extended disease, due to the coalescence of the opacities. In children, unilateral patchy infiltrates have been observed.

The most common CT finding is GGO. Usual features are also GGO mixed to consolidations, mostly with air bronchogram. Consolidations, consolidations surrounded by GGO (”halo sign”), pleural thickening adjacent to parenchymal alterations, interlobular septal thickening and bronchovascular bundles thickening may be observed. Crazy paving is less common, while unusual alterations are nodules, cavitation, lymphadenopathies, pericardial effusion, pleural effusion, and pneumothorax. Although unilateral pneumonia may be observed in early involvement, COVID-19 pneumonia is usually multifocal and bilateral, commonly affecting peripheral and dorsal parts of the lungs. Alterations often have lower lobes predominance, even if all lobes may be affected. GGO and patchy consolidations are common findings in children.

Moreover, CT features may be the expression of different phases of the disease [Figure 2]. Usually, during the early stage, the main manifestation is GGO (mostly in young patients) that increases over time and tends to give way to consolidations in the peak phase (7–14 days after disease onset)[9] and may evolve in aspects resembling organizing pneumonia.[5] Then, in favorable cases, the abnormalities decrease.[9]

Based on common and uncommon findings reported in the literature, some efforts to propose a CT pattern classification for the diagnosis of COVID-19 pneumonia have been made.[16,17,18] Among them, the Radiological Society of North America[16] has defined for COVID-19 pneumonia three patterns, as follows:

- Typical appearance: peripheral and bilateral GGO or multifocal rounded GGO (both regardless of the coexistence of consolidation or crazy paving), findings of organizing pneumonia (OP) [Figure 3]
- Indeterminate appearance: nonrounded and nonperipheral GGO with either multifocal, diffuse, perihilar, or unilateral distribution (with or without consolidation), few very small nonrounded GGO with a nonperipheral distribution; absence of typical features [Figure 4]
- Atypical appearance: isolated lobar or segmental consolidation without GGO, discrete small nodules (centrilobular or with a tree-in-bud appearance), lung cavitation, or smooth interlobular septal thickening with pleural effusion; absence of typical or indeterminate features.

Obviously, these criteria have some limits, as admitted by the author themselves.[3] In fact, it is possible to experience findings that may meet features of more than one category, due to the coexistence of other diseases. In such cases, radiologists should interpret if these findings are or not part of the same process: a clear definition may be hard to assess [Figure 5].

Furthermore, both typical and indeterminate appearances cannot avoid DD. Regarding the typical appearance, suggested DD includes viral pneumonia, especially influenza, acute lung injury patterns, drug toxicity, and idiopathic or secondary diffuse lung diseases, especially those related to connective tissue diseases (CTD). About viral pneumonia, Bai *et al*.[19] reported that a peripheral distribution of alterations [Figure 6], GGO, fine reticulations, and vascular thickening inside the lesions may be helpful in distinguishing COVID-19 pneumonia. However, the DD remains challenging. Patterns of COVID-19 and non-COVID-19 pneumonia may share the same aspect. Lung drug toxicity may have an appearance similar to COVID-19 pneumonia, too. A recent comment on immunotherapies in oncologic management stated that the DD with COVID-19 pneumonia might be only clinical.[20] CTD could also determine interstitial lung disease (ILD) that is potentially indistinguishable from COVID-19 pneumonia. For instance, nonspecific interstitial pneumonia (NSIP), the most common pattern in diffuse lung diseases related to CTD, shares many aspects with COVID-19 pneumonia. It usually involves the peripheral parts of the lungs, it is predominant in the lower lobes, and has GGO and reticulations as main alterations, with or without traction bronchiectasis.[21] Although less common, OP is one more example of CTD-related lung involvement that could be observed with the same aspect in COVID-19 pneumonia.[16] In all these eventualities, imaging may be weak in discriminating between COVID-19 pneumonia, ILD without COVID-19 pneumonia, or the coexistence of both diseases [Figure 7]. Finally, diffuse alveolar damage and alveolar hemorrhage may be an acute manifestation in systemic lupus erythematosus,[21] making also a clinical DD very challenging, in case of positive COVID-19 test and symptomatic patient. As a whole, in acute lung injuries, the main issue may be represented by the difficulties to recognize the etiology that lies behind the alterations. Thus, even if COVID-19 pneumonia may show typical imaging patterns, radiologists should always consider clinical data (including pretest probability), as typical COVID-19 patterns may be due to other pathologies. However, we believe that this classification may be useful to guide radiologists during the pandemic, at least helping to rule out other diseases that may justify the symptoms, if an atypical appearance for COVID-19 pneumonia is recognized. Following the same rationale, we report that also CXR classifications have also been proposed.[22,23]

In particular, the British Society of Thoracic Imaging suggests the following three classes:

- Classic/Probable, which requires the presence of multiple, peripheral, and bilateral opacities with lower lobes predominance
- Atypical, defined by the presence of pneumothorax, pleural effusion, lobar pneumonia, or pulmonary edema [Figure 8]
- Indeterminate, that groups all the features that do not fit the previous classes.

Prognostic Role of Imaging: Is There Room for Chest X-Rays?

CXR and CT showed that in COVID-19 pneumonia, the peak extent of alterations is usually reached at 6–12 days after symptoms onset.[24] Some authors have suggested the role of a CT grading of disease extent, in terms of prognosis,[5,17] that could allow the best management planning for patients. It has been observed that the frequency of consolidations and the disease extent are higher in patients with COVID-19 pneumonia,[25] and the potential role of CT in prognostic stratification has been confirmed by Colombi *et al*.[26] If CT visual assessment is considered with clinical parameters, a well-aerated lung <73% of the total parenchyma was associated with intensive care unit admission or death, with an odds ratio = 5.4. Considering that CRX could be utilized at hospital admission, we are wondering if CXR may be used for the same purpose. Tough less sensitive for early alterations, CXR is widely disposable, at low costs and reduced risks of cross infection. In fact, portable CXR permits to avoid patients transporting.[3] Extent scores of COVID-19 pneumonia on CXR have been proposed.[23,27] In particular, Borghesi and Maroldi[27] have designed a CXR score that considers both extents and type of alterations, finding out that CRX scores were significantly higher in patients who died than in those discharged from the hospital. Both lungs are divided into three zones on frontal chest projection, based on anatomical landmarks. The inferior wall of the aortic arch divides upper from middle zones and the inferior wall of the right inferior pulmonary divides the middle from lower zones. Then, for each zone, a score from 0 to 3 is assigned, depending on pulmonary alterations: no lung abnormalities 0, interstitial infiltrates 1, interstitial and alveolar infiltrates with interstitial predominance 2, interstitial and alveolar infiltrates with alveolar predominance 3. Thus, the global score ranges from 0 to 18, with a maximum of 9 for each lung.

May the Combination of Lung Ultrasounds and Chest X-Ray Be a Valuable Tool for COVID-19 Pneumonia Diagnosis?

Imaging is a fundamental tool for COVID-19 pneumonia diagnosis, although the DD may be challenging.[16] LUS has shown a promising role in both diagnosis and monitoring of COVID-19 pneumonia,[28] demonstrating many potential advantages. First, it is a rapid and radiation-free imaging technique that may play a crucial role in certain categories of COVID-19 patients, i.e., in pediatric patients[29] and pregnant women.[30] Moreover, it permits to avoid patient transporting, reducing the risk of cross infections. Finally, LUS allows to perform clinical and imaging examinations by the same clinician, decreasing the risk of health-care workers' exposure, too.[31] Although LUS is operator-dependent and has a low capability for detection of deep lung alterations, LUS features have demonstrated to correlate with CT findings in COVID-19 pneumonia.[32,33,34,35] Thus, considering that the use of CXR alone for the diagnosis of COVID-19 pneumonia remains risky, due to the low sensitivity for early alterations,[3] we

speculate that the combination of CXR and US could be adopted as a fast screening for COVID-19 pneumonia. In fact, LUSs are very sensitive to peripheral lung alterations that are the most common distribution of COVID-19 pneumonia.[16] However, CXR permits to check for central lung involvement and may help the DD. One chance, in our opinion, might be adopting this combined technique to all patients suspected for COVID-19 pneumonia, especially in mild clinical symptom setting. CT could be employed when CXR is negative, but LUS is positive or suspicious. This approach could be a reasonable compromise between imaging performance, availabilities, radiation exposure, and costs. However, further studies are desirable to confirm or reject this possibility.

Conclusions

Imaging plays a determinant role in both diagnosis and management of COVID-19 pneumonia during the pandemic. CT may be more sensitive than both the COVID-19 test and CXR. Typical imaging patterns may help the diagnosis, even if the DD may remain challenging and radiologists and clinicians need always to consider the background and clinical context. CT and possibly, CXR, may also give prognostic information, evaluating the extent of lung involvement. However, CXR may fail in detecting early alteration, even if it allows to avoid patients transporting, reducing the risk of cross infection. Possibly, CXR and LUS might be utilized in combination for COVID-19 pneumonia screening, reducing the use of CT in selected cases.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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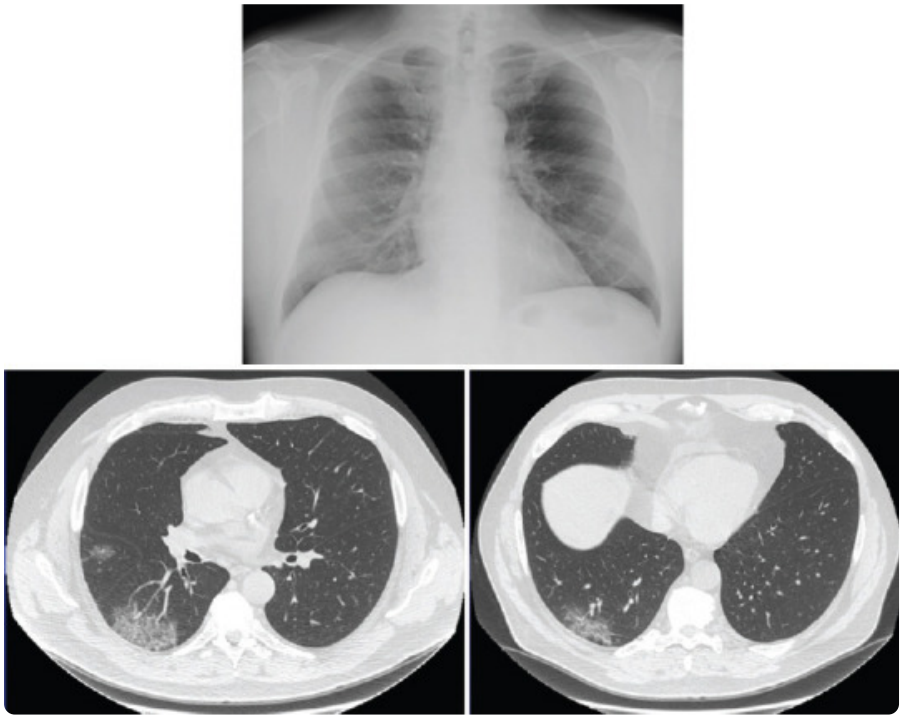
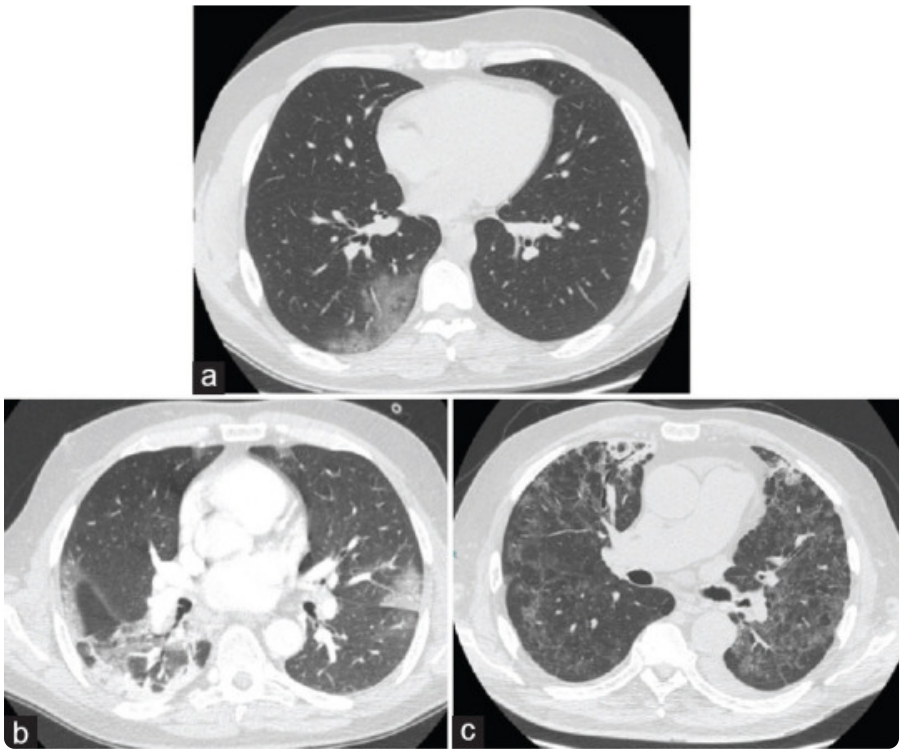
Figures and Tables

Figure 1



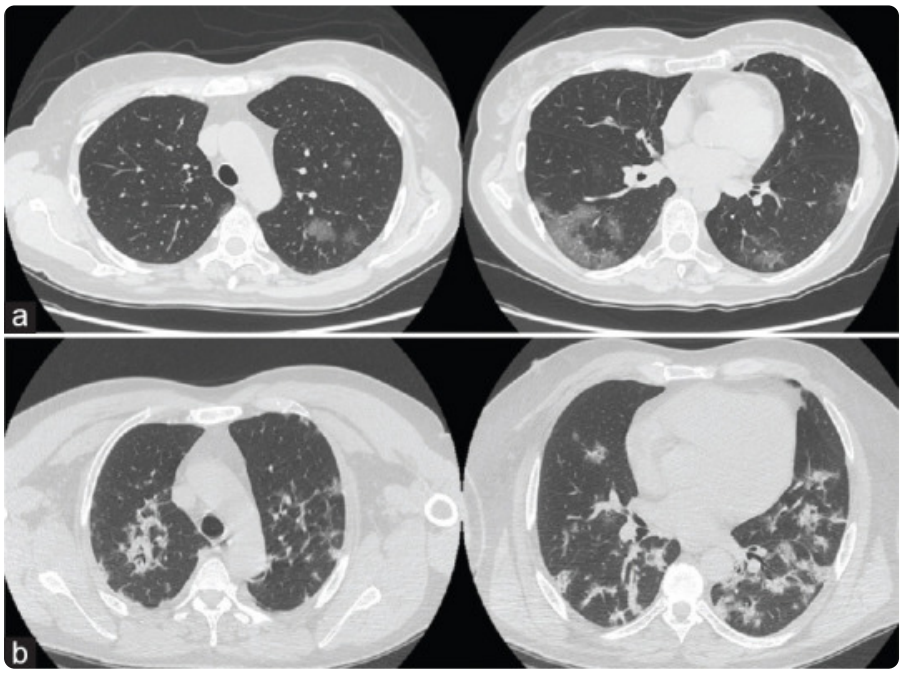
A 64-year-old man with COVID-19 pneumonia. Example of the lower sensitivity of CXR: chest X-rays is negative, but computed tomography reveals ground-glass opacities, partially hidden by the right hilum on CXR

Figure 2



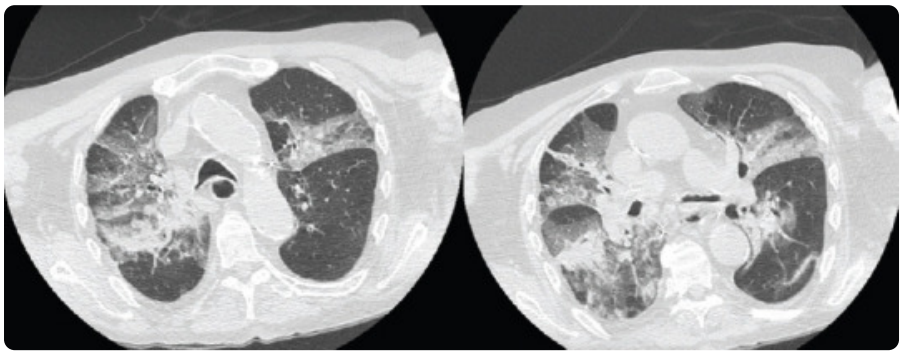
A 29-year-old man at hospital admission (a), 61-year-old man during recovery (b), a 67-year-old woman at hospital disposal (c). Temporal phases of COVID-19 pneumonia. Early phase (a): only ground-glass opacities are visible. Peak phase: consolidations mixed to ground-glass opacities (b). Resolution: ground-glass opacities are diffuse but disappearing, findings of organizing pneumonia are also present (c)

Figure 3



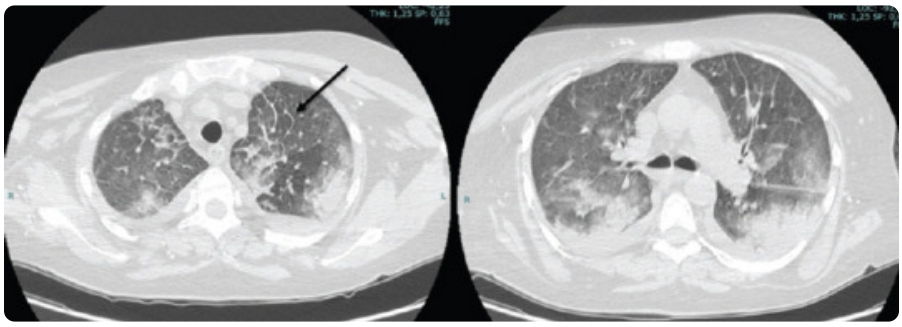
A 60-year-old-woman (a) and a 53-year-old man (b) with COVID-19 pneumonia, typical CT appearances. Multiple, bilateral ground-glass opacities, rounded and with a peripheral and lower lobe predominance (a) and findings of organizing pneumonia (b)

Figure 4



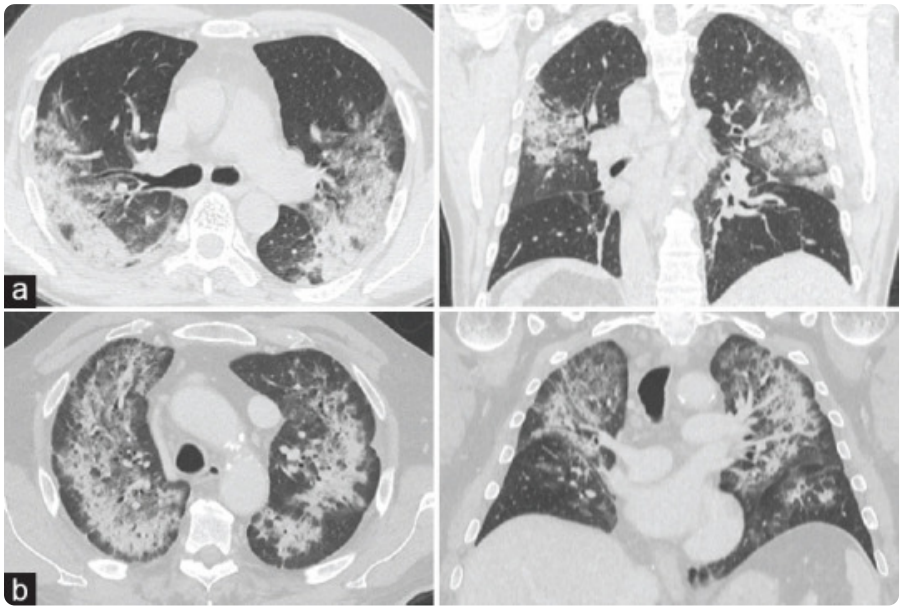
A 71-year-old man with COVID-19 pneumonia. Indeterminate appearance: Both computed tomography slices display multifocal nonrounded ground-glass opacities and consolidations with the perihilar predominance

Figure 5



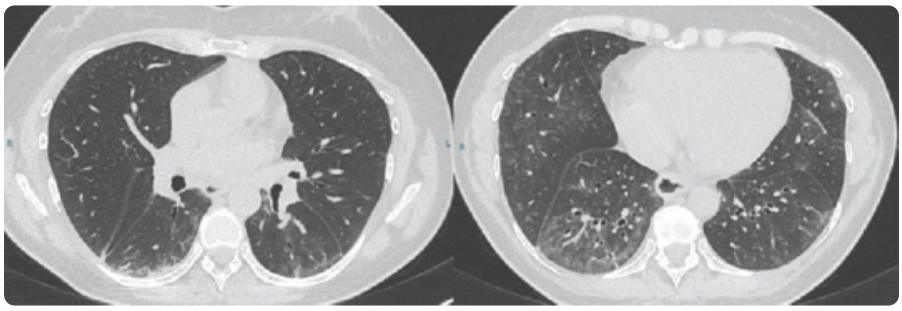
A 53-year-old woman with mixed neurogenic-cardiogenic pulmonary edema. Example of dubious computed tomography image interpretation: both typical and atypical features of COVID-19 pneumonia are present. Rounded ground-glass opacities and consolidations with peripheral and lower lobe predominance fit typical features. However, smooth thickening of interlobular septa (black arrow) and pleural effusion are atypical findings

Figure 6



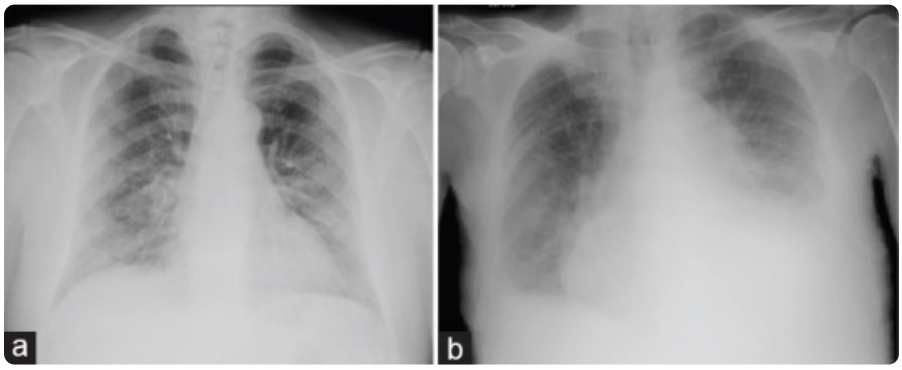
A 57-year-old man with COVID-19 pneumonia (a) and 46-year-old-woman with cytomegalovirus pneumonia (b). Both computed tomography show ground-glass opacities and consolidations, but the COVID-19 pneumonia (a) involves the peripheral parts of the lungs, while cytomegalovirus pneumonia (b) has a predilection for central-perihilar areas

Figure 7



A 53-year-old man with systemic sclerosis. A challenging differential diagnosis: Computed tomography shows GGO and band-like consolidations with a peripheral and lower lobe predominance. The diagnosis between nonspecific interstitial pneumonia related to systemic sclerosis, COVID-19 pneumonia, or a mixed pattern may be debatable

Figure 8



A 53-year-old man with COVID-19 pneumonia (a) and a 79-year-old man with pulmonary edema (b). Classic CXR appearance for COVID-19 pneumonia (a), with peripheral opacities in the middle-lower fields of both lungs (a) and atypical CXR appearance (b): The pleural effusion and the enlarged heart shadow are more suggestive for cardiogenic pulmonary edema