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Coronavirus Disease 2019 (COVID-19) Pneumonia Presentations in Chest Computed Tomography: A Pictorial Review

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A B S T R A C T

Despite imaging not being a tool for novel coronavirus disease 2019 (COVID-19) diagnosis, there has been an increased number of chest computed tomography (CT) scans done worldwide. There are no pathognomonic CT features for COVID-19 pneumonia, as findings are also common in other infectious diseases and noninfectious aetiologies. Nonetheless, point-of-care physicians should be familiarized with the most common imaging presentations of the COVID-19. In this pictorial review, we have summarized the most reported imaging features of COVID-19 pneumonia, including possible differential diagnosis according to the CT finding.

Introduction

The novel coronavirus disease 2019 (COVID-19) is an RNA virus-based disease, which emerged in December of 2019 in Wuhan (China) and quickly spread worldwide. Due to its high infectivity, the World Health Organization declared it a pandemic on March 11, 2020.[1] By April 1, 2020, there were nearly 800,000 confirmed cases in 205 countries and territories around the world and more than 37,000 deaths, according to the World Health Organization reports.[1] The mean mortality rate is approximately 3% in the general population but could be higher in elderly patients with chronic comorbidities, such as diabetes, hypertension, and respiratory diseases.[2] In patients requiring mechanical ventilation, mortality could be up to 81%.[1,2] In most COVID-19 cases, patients are asymptomatic. However, the most commonly reported symptoms are mild, ranging from fever (83%-98%), cough (76%-82%), and minimal respiratory distress to shortness of breath (31%-55%), oxygen saturation <93%, and acute respiratory distress syndrome requiring mechanic ventilation.[1-3]

So far, the gold-standard test for COVID-19 diagnosis is real-time reverse-transcription-polymerase-chain-reaction. However, real-time reverse-transcription-polymerase-chain-reaction is not readily available and demonstrates moderate to high rates of false-negative results.[1-3] Despite imaging not being a tool for COVID-19 diagnosis, there has been an increased number of chest computed tomography (CT) scans done worldwide to assess the severity and extension of lower respiratory tract involvement.[4] Plain chest radiography is often inaccurate in initial stages of the infection, while high-resolution CT is extremely sensitive for diagnosing ground-glass opacities (GGO).[5] However, there is still no consensus on the use of chest x-ray or CT for the management of suspected COVID-19 pneumonia, and the choice of imaging modality will depend on the physicians' judgment and local resources and expertise. Nonetheless, point-of-care physicians should be familiarized with the most common imaging presentations of the COVID-19. In this pictorial review, we have summarized the most reported imaging features of COVID-19 pneumonia, including possible differential diagnosis according to the CT finding.

Chest CT Features

COVID-19 pneumonia presentation on imaging varies across the distinct stages of the disease, usually corresponding to different phases of organizing pneumonia or diffuse alveolar damage.[5,6] Some authors have proposed the following classification of COVID stages according to the interval between the onset of symptoms and the CT scan: early phase, 0-5 days; intermediate phase, 6-11 days; and late

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TABLE 1
Phases of COVID-19 and their main findings, according to Wang et al.[7]

Phase	CT sensitivity	Main CT pattern	Percentage
Early phase (0-5 days)	84%	Ground-glass opacities	62%
		Consolidation	23%
		Mixed	1%
		None	14%
Intermediate phase (6-11 days)	99%	Ground-glass opacities	59%
		Consolidation	24%
		Mixed	16%
		None	1%
Later phase (12-17 days)	100%	Ground-glass opacities	45%
		Consolidation	17%
		Mixed	38%
		None	0%

phase, 12-17 days.[6] In the early phase, the disease is mainly characterized by single or few rounded low-density GGO with a subpleural location.[6] However, it is worth emphasizing that 11%-15% (sporadically up to approximately 50%) of patients may have normal CT scans 0-2 days after onset of flu-like symptoms from COVID-19.[6] In the intermediate phase, rounded GGO is commonly observed and may present more significant extension and density and a higher number of lesions.[6] At the late phase, the CT may present bilateral and diffuse areas of "white lung," secondary to large and confluent high-density GGOs, consolidations, air bronchograms, and interlobular/intralobular thickening.[6] The "crazy paving" pattern has been described to present, especially around day 10.[2] Also, during this stage, CT may demonstrate the "halo sign" and "reversed halo sign." At the final phase, lesions gradually reduce, and only some inter or intralobular septal thickening might be found.[6] Septal thickening as predominant finding appears after day 18 (Table 1).[7] Pleural effusions and lymphadenopathy are rare findings. Furthermore, some reports have also described pulmonary thromboembolism as a CT pulmonary angiography finding in patients with COVID-19 (Fig 1).[8]

These CT findings are non-specific for COVID-19, as they may represent a significant number of differential diagnoses, both acute and chronic, such as other viral pneumonia, atypical bacterial pneumonia, inflammatory interstitial diseases, and organizing pneumonia.[1] Besides, some series have shown a 20% rate of other concomitant infections in PCR confirmed COVID-19 patients, which could further complicate the interpretation of the CT findings.[4] Therefore, it is crucial to have a high index of clinical suspicion and pre-test probability before interpreting the images. Based on references from other main articles, a summary of the key CT findings suggestive of COVID-19 pneumonia is presented in Table 2.

Ground Glass Opacities

GGOs are hazy opacities with increased lung attenuation and preservation of bronchial and vascular margins and include a vast

FIG 1. A 38-year-old woman with the diagnosis of COVID-19 by RT-PCR presenting fever for 2 weeks and intense dyspnea for 2 days. (A) axial and (B) coronal CT scans show minimal peripheral GGO in lower lobes. A computed tomography pulmonary angiography (CTPA) was made and showed thrombus in the right and left main pulmonary arteries (C) and in bilateral lower lobe pulmonary arteries (D).

TABLE 2
Classification of COVID-19 chest CT findings

Classification	CT findings
Findings suggesting viral infectious disease	Predominant subpleural and bilateral ground-glass attenuation. May be associated with consolidation and some peribronchovascular commitment
	Peripheral and bilateral "crazy-paving" opacities
	Multifocal rounded ground-glass pattern. Consolidation and thickening of intralobular septa may be present
	Reversed halo sign associated with patches of ground-glass opacities
Findings undetermined for viral infectious disease	Widespread and diffuse non-rounded ground-glass attenuation, sparing or not the subpleural parenchyma
	Multifocal perihilar and unilateral distribution, sparing the subpleural parenchyma, associated or not with consolidation
	Some small, non-rounded and non-peripheral patches of ground-glass attenuation
Unusual findings	"Tree-in-bud" opacities with centrilobular nodules
	Segmental or lobar consolidations without ground-glass opacities
	Mediastinal lymphadenopathy
	Lung cavitation
	Pneumothorax and pneumomediastinum
	Pleural effusion and smooth interlobular septal thickening

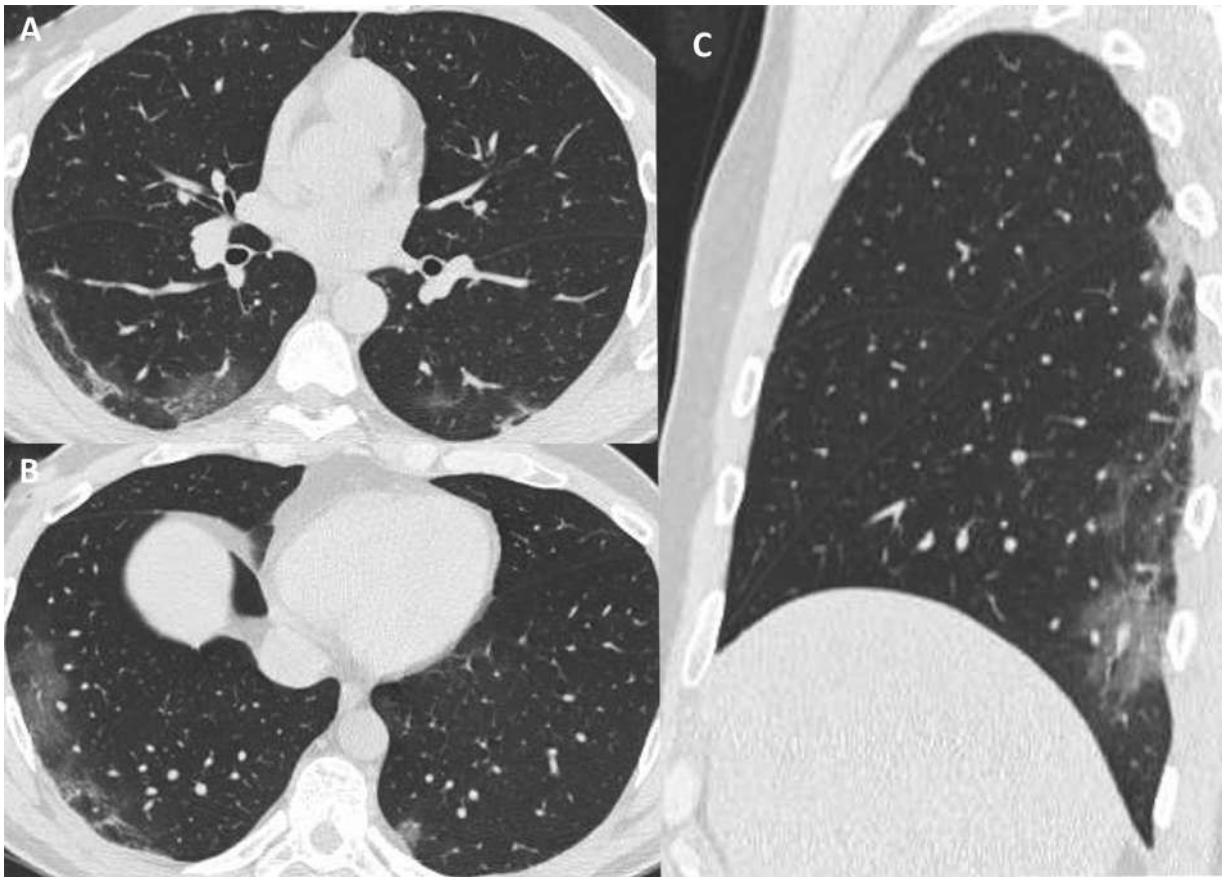

FIG 2. A 49-year-old man with the diagnosis of COVID-19 by RT-PCR presenting fever and diarrhoea for 3 days. (A and B) axial CT scans show a GGO with peripheral and bilateral distribution in lower lobes. (C) Sagittal CT images demonstrated the same findings in the lower lobes.

number of differential diagnoses.[9] GGOs are the most common finding in COVID-19 patients, presenting as rounded opacities that can be seen since the early phase, most with bilateral involvement (Figs 2-4). However, unilateral involvement could also be seen (Fig 5). The distribution is often peripheral and subpleural but can also be along with the bronchovascular bundle. With disease progression, extensive areas of GGO can appear, commonly associated with consolidative opacities and sometimes presenting a "crazy paving" pattern.

"Crazy-Paving" Pattern

Crazy-paving attenuation pattern is the superimposition of interlobular and intralobular septal thickening on a background of GGOs.[9] It represents pulmonary interstitial expansion, mostly caused by inflammation.[9] In COVID-19, this pattern is best seen in advanced disease, as the intermediate and later phases, which indicates increased involvement of the lung parenchyma.[6] (Fig 6). "Crazy-paving" pattern is a characteristic finding of pulmonary alveolar proteinosis, lipoid

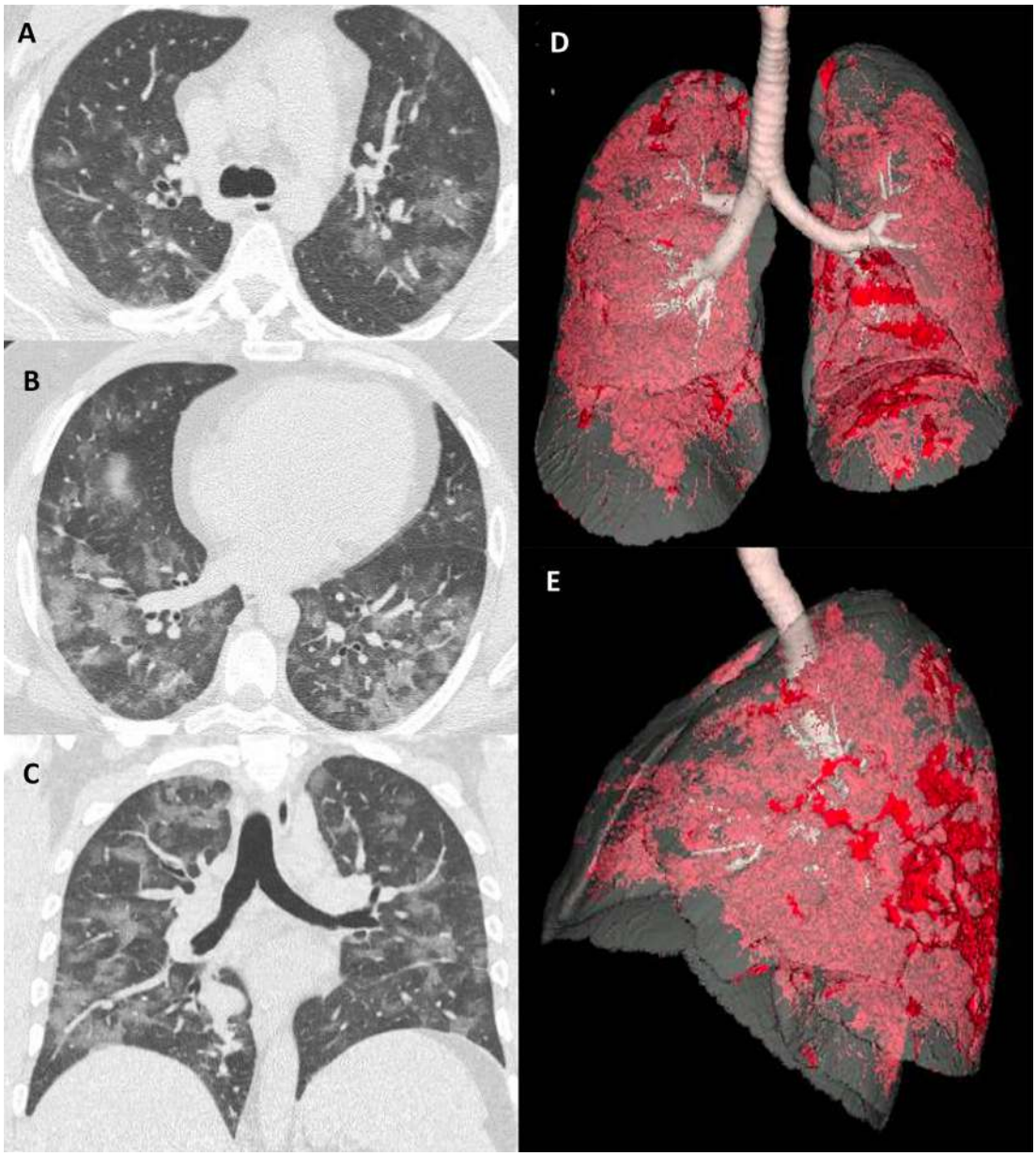

FIG 3. A 63-year-old man with the diagnosis of COVID-19 by RT-PCR presenting fever and cough for 7 days. (A and B) axial and (C) coronal CT scans show a patchy GGO with random distribution in both lungs. (D and E) demonstrate a frontal and lateral view of 3DCT reconstructions with automatic detection of GGO (red). (Color version of figure is available online.)

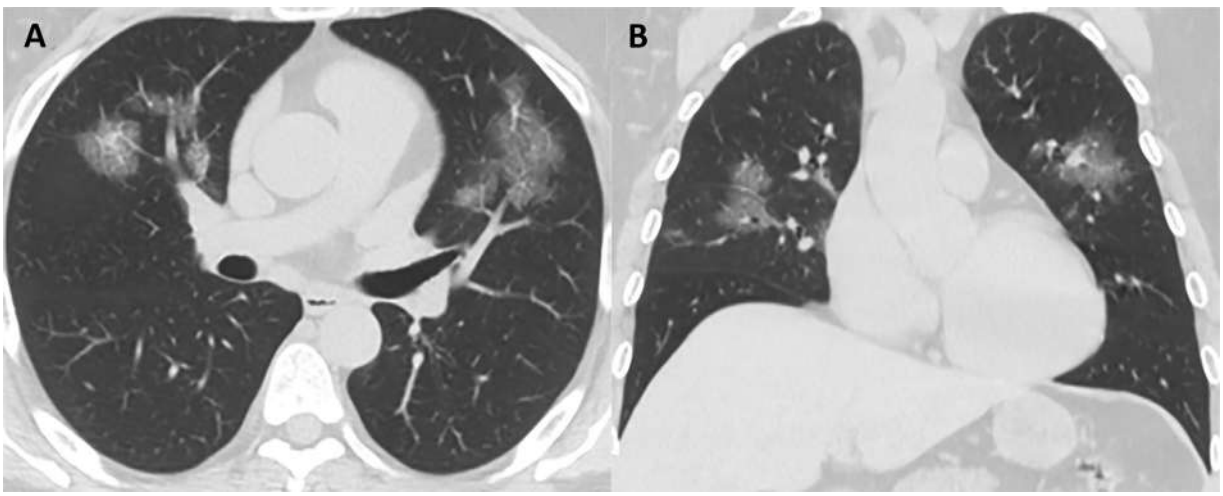

FIG 4. A 42-year-old woman with the diagnosis of COVID-19 by RT-PCR with dry cough for 8 days. (A) axial and (B) coronal CT scans present rounded GGO in both lungs.

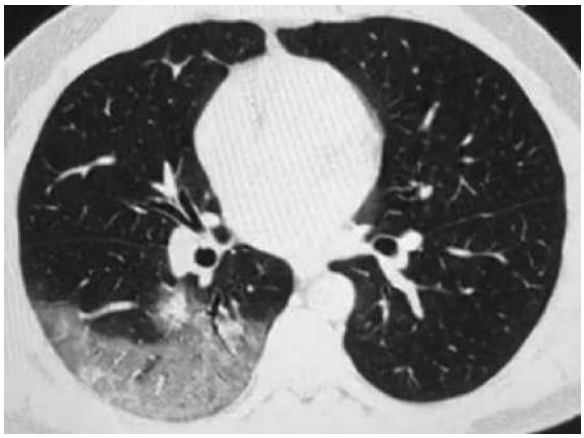

FIG 5. A 34-year-old man with the diagnosis of COVID-19 by RT-PCR presenting fever and diarrhoea for 2 days. The axial CT scan shows a unilateral GGO with peripheral distribution in the right lower lobe.

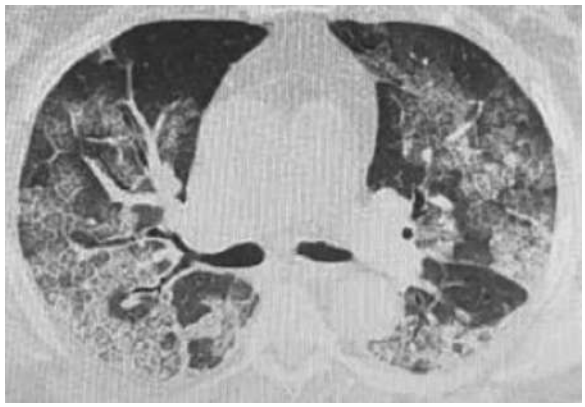

FIG 6. A 71-year-old woman with the diagnosis of COVID-19 by RT-PCR presenting fever and dyspnea for 9 days. The axial CT scan shows a diffuse GGO with septal thickening, compatible with "crazy paving."

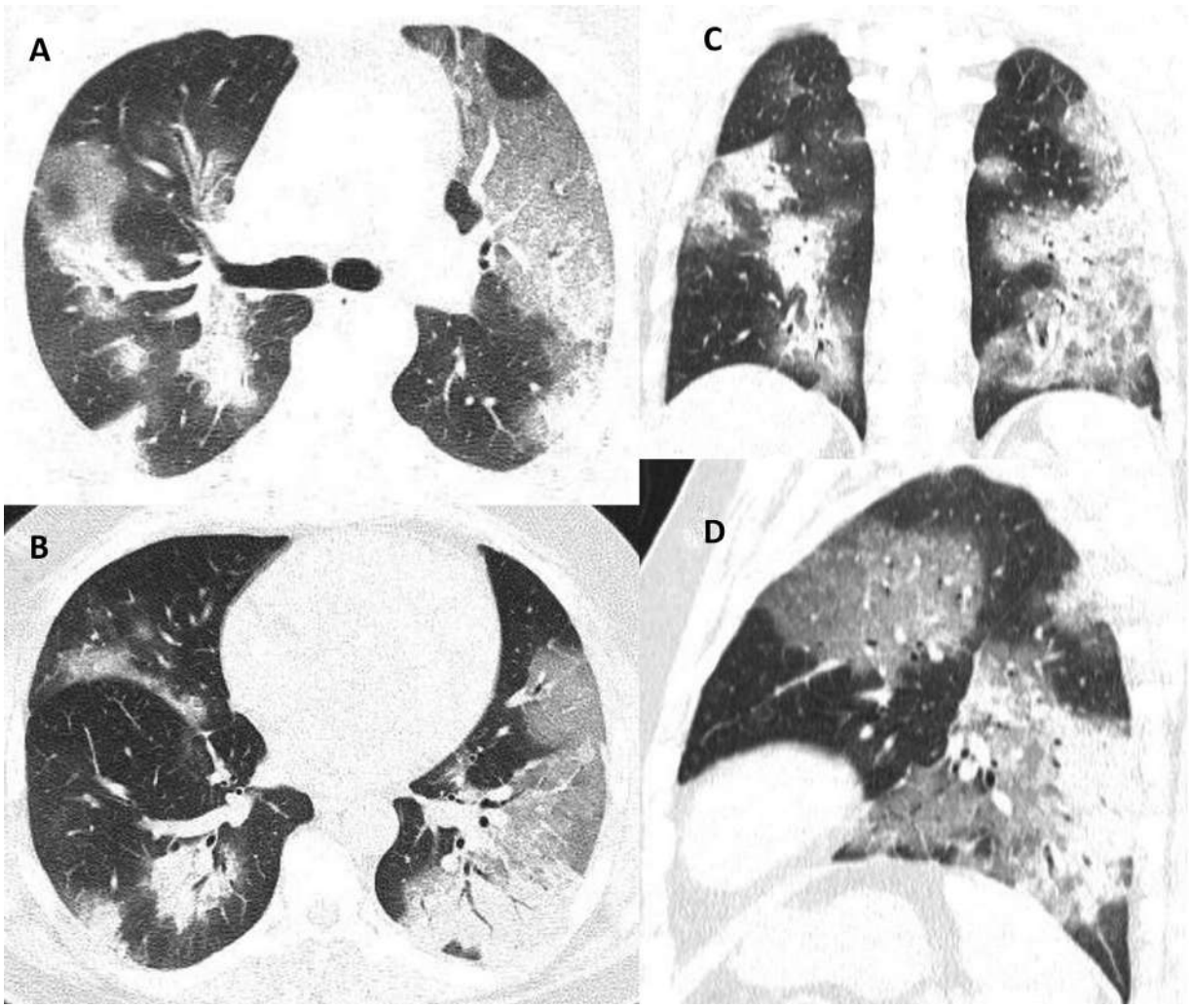

FIG 7. A 66-year-old man with the diagnosis of COVID-19 by RT-PCR presenting fever and cough for 11 days. (A and B) axial CT scans show areas of consolidation associated with GGO with diffuse distribution in both lungs. (C and D) coronal and sagittal CT reconstructions demonstrated the same findings in lower lobes.

pneumonia, nonspecific interstitial pneumonia, and a limited number of other differential diagnoses.

Consolidation

Consolidations are homogeneous areas of increased lung attenuation that obscures the margins of vessels and airway walls.[9] In COVID-19 pneumonia, the intermediate and later phases of the disease can present a CT pattern of the predominance of consolidation. This finding is associated with an inflammatory progression and is frequently seen with other concomitant areas of GGOs (Figs 7-8).[4] These areas are represented by a cellular effusion which fills alveoli and causes vasodilatation with local exudation.[6] There is an extensive differential diagnosis for a consolidation pattern that could vary according to an acute or a chronic condition.[5-8]

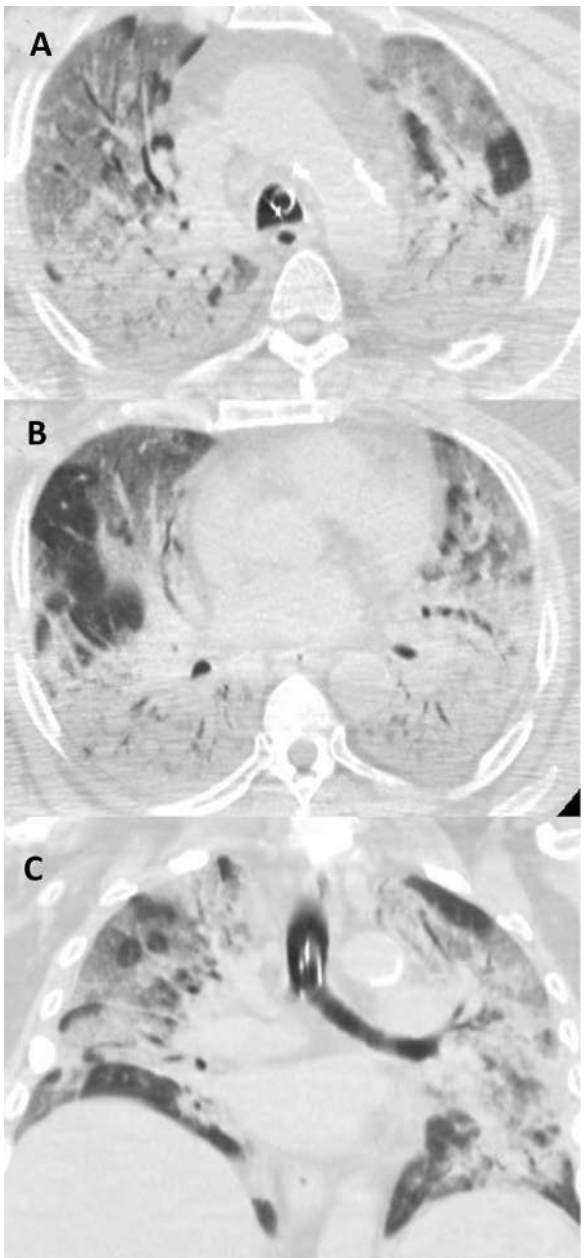

FIG 8. . An 82-year-old man with the diagnosis of COVID-19 by RT-PCR presenting fever and diarrhoea for 13 days. He was intubated in day 6 of disease. (A and C) axial CT scans show diffuse consolidation with anteroposterior gradient, compatible with diffuse alveolar damage. (B) CT reconstruction demonstrated the same findings.

Halo Sign

The halo sign is a GGO surrounding a nodule or mass.[9] It often indicates a circumjacent area of haemorrhage around a lesion and might be seen in some patients with COVID-19 (Fig 9).[10] The halo sign is mostly seen in invasive pulmonary aspergillosis as well as other fungal infections such as Mucormycosis and Cryptococcosis. Neoplastic diseases such as pulmonary adenocarcinoma and some types of pulmonary metastasis can also present with this sign. Other differential diagnoses include tuberculosis, granulomatosis with polyangiitis, and eosinophilic lung diseases.[9, 10]

Reversed Halo Sign

The reversed halo sign is represented by a GGO with a circumjacent ring of consolidation.[9] It was first described in cryptogenic organizing pneumonia and thought to be specific for this condition.[11] Later, chest CT showed this finding to be associated with other diseases like fungal infections (angioinvasive aspergillosis, paracoccidioidomycosis), tuberculosis, and other atypical and even typical bacterial infections, often in resolution phases. Further, the reversed halo sign, when seen in subpleural areas, remits to pulmonary infarction due to thromboembolism. Other differential diagnoses are

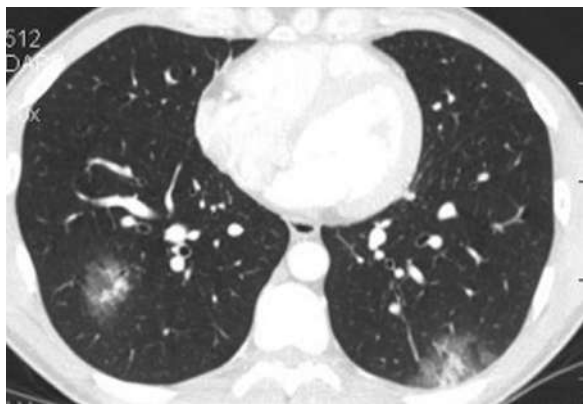

FIG 9. A 42-year-old man with the diagnosis of COVID-19 by RT-PCR presenting fever and diarrhoea for 9 days. Axial CT scan show 2 solid nodules surrounded by a ground-glass halo in the right and other in left lower lobes.

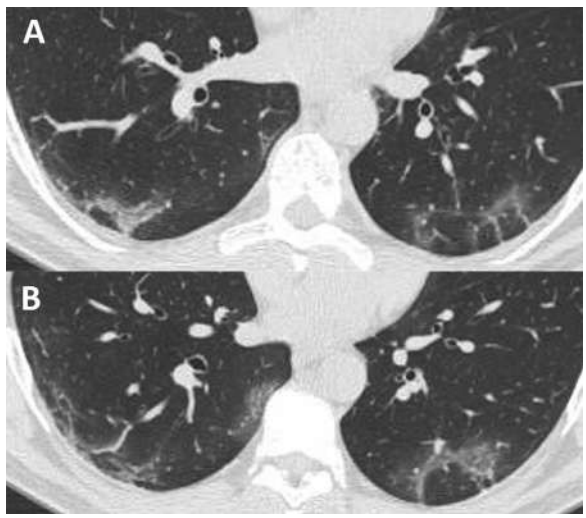

FIG 10. A 55-year-old man with the diagnosis of COVID-19 by RT-PCR presenting fever and diarrhoea for 6 days. (A and B) axial CT scans show 2 reversed halo signs in the posterior basal segment of the right and left lower lobe.

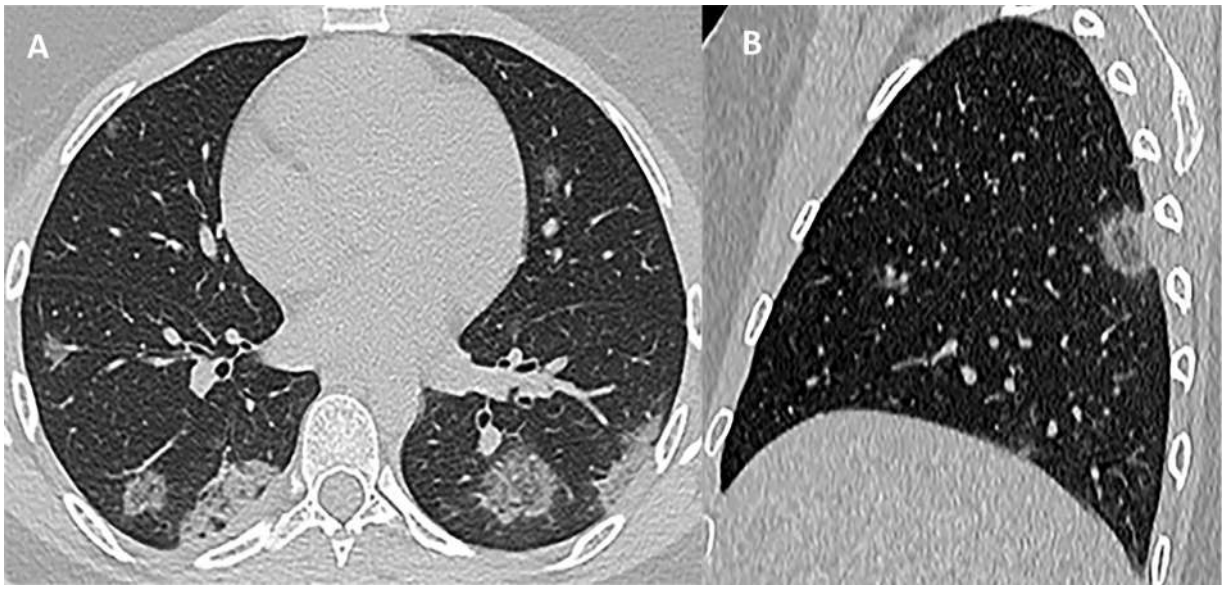

FIG 11. A 50-year-old woman with the diagnosis of COVID-19 by RT-PCR with fever and mild dyspnea for 9 days. (A) axial and (B) coronal chest CT image shows multiple rounded GGO with a peripheral ring of consolidation (reversed halo sign).

vasculitis, inflammatory interstitial diseases, neoplasms, and actinic damage.[11]

In COVID-19, the reversed halo sign is a less common feature and, when present, is identified in the later phases of the disease (Figs 10-11). In 1 study with 121 patients with CT scans obtained in different COVID-19 stages, only 4% of patients in the late phase presented the reversed halo sign. In contrast, none of the patients in an early (0-2 days) or an intermediate (3-5 days) phases had this finding.[4]

Inconsistent Findings

The "tree-in-bud" pattern is characterized by well or ill-defined centrilobular branching nodules that correspond to impaction within bronchioles and alveoli by fluid, mucus, or pus.[9] Presence of this finding in COVID-19 pneumonia is uncommon.[5] It could represent a concomitant condition, such as other infections (bronchopneumonia, fungal and mycobacterium infection), cystic fibrosis, chronic aspiration, autoimmune diseases, and some malignancies.[9, 11] Cavities are destructive lesions in the lung parenchyma characterized by air space within a consolidation, a nodule, or a mass, with variable wall thickness and can be filled by fluid.[9] Cavities may represent infections but also malignancies, autoimmune disorders, or pulmonary emboli.[9] So far, there are no reports of cavitary lesions in COVID-19 pneumonia, and its presence could indicate other associated diseases.[12] Mucoid impactions, bronchial wall thickening, lymphadenopathy, and pleural effusion, when isolated, are also not usual features in COVID-19 infection and leads to another diagnosis.[12]

Conclusion

There are no pathognomonic CT findings for COVID-19 pneumonia, as they can also be seen with numerous pathogens and in many noninfectious aetiologies. CT scans should not be used as a diagnosis or screening tool for COVID-19 in asymptomatic patients.

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