

# Pulmonary CT signs in patients with COVID-19 infection

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## Research Article

**Keywords:** COVID-19 infection, pulmonary CT, ground glass, SARS-CoV-2

**Posted Date:** July 15th, 2020

**DOI:** <https://doi.org/10.21203/rs.3.rs-41357/v1>

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# Abstract

**Background:** The aim of the study is to investigate the pulmonary CT signs in patients with confirmed COVID-19 infection. This study included 100 patients, 54 male and 46 female their ages ranged from 6 to 85 years. All Patients tested positive for COVID-19 infection by RT-PCR test included in this study. All the patients performed pulmonary CT scan and the CT findings were evaluated.

**Results:** 90 patients (90%) had abnormal pulmonary CT. Two lungs affected in 79 patients (79%). Lesions involved 1 lobe (11%), 2-3 lobes (35%) and 4-5 lobes (44%). The most involved pulmonary lobes were right lower lobe (77 patients, 77%), followed by left lower lobe (71 patients, 71%), the most involved pulmonary segments were posterior segments (69 patients, 69%), peripheral sub-pleural lesions were the commonest lesions location (64 patients, 64%). The most common lesions pattern were ground glass pattern (44 patients, 44%), followed by mixed ground glass and consolidation patterns (33 patients, 33%). The commonest lesion shape was patchy opacities (40 patients, 40%). Reversed halo sign (28 patients, 28%), air bronchogram sign (39 patients, 39%), crazy paving pattern (77 patients, 77%), vascular thickening (66 patients, 66%), and pleural thickening (7 patients, 7%)

**CONCLUSION:** The main pulmonary CT signs in patients with COVID-19 infection are bilateral, peripheral, multi-lobar patchy and nodular Ground glass opacification with or without consolidation. Other signs may also present include crazy paving pattern, reversed halo sign vascular thickening, and air bronchogram sign with no extra-pulmonary signs except for few pleural thickening.

## Introduction

Coronavirus disease or (COVID - 19) is highly infectious disease transmitted by droplets infection. It also known as severe acute respiratory syndrome coronavirus 2 or (SARS-CoV-2) [1]. COVID-19 epidemic started in Wuhan, Hubei, China at the end of December 2019 [2]. COVID-19 incubation period ranges from one to fourteen days, most symptoms appear in the period between three to seven days after infection [3]. The severity of COVID-19 symptoms is greatly varying, from totally asymptomatic to severe acute symptoms that may lead to death [1,2]. According to symptoms patients with Covid-19 infection classified into five stages; (stage I) asymptomatic infection, (stage II) acute upper respiratory tract infection, (stage III) mild pneumonia, (stage IV) severe pneumonia, and (stage V) critical cases [3]. Early diagnosis of COVID-19 provides an important method for early isolation, prevention, and treatment of the disease [1]. Diagnosis of COVID-19 depends mainly on the nucleic acid testing by using real time PCR test that has high specificity, and low sensitivity for COVID-19 diagnosis [4]. CT chest together with clinical manifestation and laboratory investigations are important diagnostic modalities used for diagnosis of COVID-19 [5]. Many researchers concluded that pulmonary CT has high sensitivity reaching up to 97%-98% in diagnosis of COVID-19 pneumonia [6]. It is noted that about 25% of patients show normal pulmonary CT in a very early stage of COVID-19 infection [7]. Pulmonary CT imaging signs detected in patients of COVID-19 infection were reported as single or multi-lobar, unilateral or bilateral, peripheral or diffuse patchy, pulmonary ground glass opacities with or without consolidation opacities [5].

The aim of the study is to investigate the pulmonary CT signs in patients with confirmed COVID-19 infection.

## Methods

This retrospective study performed in Elmebra hospital Universal Health Insurance Port-Said governorate, Egypt in the period between 1 April 2020 to 1 June 2020. This study approved by Research Ethic Committee (REC) at our institution.

### Inclusion Criteria

- All patients who tested positive for COVID-19 by using (RT-PCR) test.
- Age: all ages
- Both sexes.
- Written informed consent from patient or relatives

### Exclusion Criteria

- Patients who tested negative for COVID-19 by using (RT-PCR) test.
- Consent is refused

### CT scanning

In this study all the patients performed high resolution chest CT examinations with multi slice CT scanner (Alexion 16 slice CT machine Toshiba, Canon Medical System, Japan). The patient lied in supine position. Chest scanning started from both lung apices down to lung bases with single breath hold. Both Pulmonary and mediastinal windows were done with slice thickness about 1.25 mm.

### CT Analysis

Two radiologists with more than 10 years' experience in chest imaging reported all CT images independently and all CT features were assessed.

The assessed pulmonary CT features were as follow: unilateral or bilateral pulmonary affection, the number of pulmonary lobes affected (one lobe, two or three lobes, four or five lobes affection), site of pulmonary lobe affected, site of pulmonary segment affected, the distribution of lesions in the lungs (peripheral, central, or mixed distribution), the shape of the pulmonary lesions either patchy or nodular shape, the appearance of pulmonary lesions (ground glass opacity, consolidation, or both ground glass opacity and consolidation patterns), any other associated pulmonary features like crazy paving pattern, pulmonary vascular thickening, air bronchogram sign, reversed halo sign, and signs of fibrosis), also

extra-pulmonary manifestations like mediastinal or hilar lymphadenopathy, pleural effusion or thickening were assessed.

## Results

This study included 100 patients, 54 male (54%) and 46 female (46%). All patients tested positive for COVID-19 by RT-PCR test. The patients ages ranged from 6 years to 85 years (mean age 45years) (table 1). According to CT results 10 patients (10%) showed normal pulmonary CT and 90 patients (90%) showed abnormal pulmonary CT findings. According to the site of lesions; 11 patients (11%) had unilateral pulmonary lesions and 79 patients (79%) had bilateral pulmonary lesions, According to the number of lung lobes involved there were 11 patients (11%) showed lesions in one lobe, 35 patients (35%) showed lesions in two or three lobes, and 44 patients (44%) showed lesions in four or five lobes. As regard the pulmonary lobe involved right upper lobe affected in 31patients (31%), right middle lobe affected in 37 patients (37%), right lower lobe affected in 77 patients (77%), left upper lobe affected in 33patients (33%) and left lower lobe affected in 71 patients (71%). As regard the pulmonary segments involved posterior pulmonary segments involved in 69 patients (69%) while anterior pulmonary segments involved in 44 patients (44%), as regard the lesions distribution in pulmonary lobes there were 24 patients (24%) showed mixed (peripheral and central) (figure 2,3,6), pulmonary lesions and 64 patients (64%) showed peripheral sub-pleural pulmonary lesions only (figure 1,4,5). According to the pattern of appearance of the lesions there were 44 patients (44%) showed ground glass opacities (figure 1,2,3), 13 patients (13%) showed consolidation opacities, and 33 patients (33%) showed mixed pattern of ground glass and consolidation opacities (figure 4,5,6). According to the shape of the lesions there were 40 patients (40%) appears as ill-defined patchy opacities (figure 1,4,5), 14 patients (14%) showed nodular rounded opacities and 36 patients (36%) showed both patchy and nodular opacities (figure 2,3). In our study there were 28 patients (28%) had reversed halo sign (figure 4,5,6), 39 patients (39%) showed air bronchogram sign (figure 3,4), 77 patients (77%) showed crazy paving pattern (figure 2,3,4,5,6), and 66 patients (66%) showed vascular thickening (Table 2) (figure 1,2,3,4,5,6), 7 patients (7%) showed extra-pulmonary signs in the form of pleural thickening (figure 5A).

## Discussion

By the end of May 2020 the pandemic of COVID-19 infected more than 6 million persons and killed more than 300.000 persons all over the world according to World Health Organizations (WHO) reports [8].

Early diagnosis of COVID-19 pneumonia is important to decrease the spread of COVID-19 pandemic. Early diagnosis helps in early isolation and treatment of the patients and so decreases the spread, morbidity and mortality of the disease. RT-PCR test has low sensitivity and high false negative results in diagnosis of COVID-19. Many recent studies showed that the use of high-resolution pulmonary CT helped in early detection of pulmonary lesions in COVID-19 infection [1,9].

This study included 100 patients tested positive for COVID-19 by RT-PCR.

Our study showed that COVID-19 pneumonia affected male (54%) more than female (46%), we also reported that adult are more affected with COVID-19 pneumonia than children with mean age of infection was about 45 years.

According to CT results in our study 10% of patients showed normal pulmonary CT and 90% showed abnormal pulmonary CT findings this is matched with **Bernheim, et.al. 2020** they concluded that 9% of positive COVID-19 patients showed normal pulmonary CT in the early and asymptomatic stage of the disease [10].

In our study most of abnormal pulmonary CT showed bilateral pulmonary affection 79% of the patients and only 11% showed unilateral pulmonary affection. In our study numbers of patients with multiple pulmonary lobar affection were dramatically higher (79%) than the numbers of patients with single lobar affection (11%) this matched with **Han et.al. 2020** they concluded that 65% of patients showed more than one pulmonary lobe affection [1].

In our study we reported that the lower pulmonary lobes were more affected by COVID-19 pneumonia than the upper pulmonary lobes, the right lower lobe affected in 77% of patients and left lower lobe affected in 71% of patients this was in agreement with **Bernheim, et.al. 2020** who concluded that the lower lobes were more affected than upper lobes [10]. This may be due to the thicker and shorter anatomy of the right lower bronchus that accelerates its invasion by the virus [1].

In our study we reported that the posterior pulmonary segments were much more affected (69%) by COVID-19 pneumonia lesions than anterior pulmonary segments (44%). This was in agreement with **Yang et.al. 2020** they concluded the posterior pulmonary segments affected more than anterior pulmonary segments by COVID-19 lesions [11].

In our study according to the distribution of the lesions in the pulmonary lobes 64% of patients showed peripheral sub-pleural pulmonary lesions and 24% showed mixed peripheral and central (peri-broncho-vascular) pulmonary lesions this was in agreement with **Han et.al. 2020 and Bernheim, et.al. 2020** they concluded that the COVID-19 pneumonia lesions affected peripheral sub-plural lung zones more than central zones [1,10].

Many studies **Han et.al. 2020, Bernheim et.al 2020 and Li et.al 2020**, concluded that the most common pattern of COVID-19 pneumonia in pulmonary CT scan was presence of ground glass opacities with or without consolidation opacities [1,10,12]. This was in match with our study we concluded that the most common pattern of COVID-19 pneumonia in pulmonary CT scan was ground glass pattern (44%) followed by mixed pattern of both ground glass and consolidation opacities (33%) and the least pulmonary CT pattern was consolidation opacity alone (13%).

**Huang et.al. 2020** reported that the pathophysiologic mechanism of coronavirus infections may be the same as SARS-CoV and MERS-CoV infections that cause diffuse alveolar damage due to inflammatory cytokine storm and this explained the ground glass opacities in early pulmonary CT [13].

In our study we reported that the most common shape of COVID-19 pneumonia opacities were ill defined patchy opacities (76%) either alone or mixed with nodular pattern and this matched with **Han et.al. 2020** that concluded that 86% of the lesions showed patchy shape [1].

In our study we reported many characteristic pulmonary CT signs for COVID -19 pneumonia as reversed halo sign (28%) , air bronchogram sign (39%), crazy paving pattern (77%), and vascular thickening (66%) and all these signs were reported in many researches [1,10,12].

Many researchers **Han et.al. 2020, Bernheim et.al 2020 and Li et.al 2020** reported that pulmonary fibrosis and extra-pulmonary manifestations, like pleural effusion, mediastinal, and hilar lymphadenopathy, were not detected in pulmonary CT scan of early COVID-19 pneumonia and they explained that as these findings may appear in the later and severe stage of the disease [1,10,12]. This was matched with our study as we didn't detect signs of pulmonary fibrosis or extra-pulmonary manifestations in our study for few pleural thickening (7%).

In our study we concluded that the main pulmonary CT signs in COVID-19 infection are bilateral, peripheral, sub-pleural multi-lobar ground glass opacification with or without consolidation in patchy distribution with or without nodular pattern more on posterior and basal pulmonary segments. Other pulmonary signs may also present include crazy paving pattern, reversed halo sign vascular thickening, and air bronchogram sign with no extra-pulmonary signs except for few pleural thickening and these were in agreement with Many researchers [1,10,12].

In our study we had a limitation as there was no follow-up CT to evaluate the treatment effect and the prognosis of the disease as all positive RT-PCR patients were transferred to quarantine hospitals and isolation centers.

## Conclusion

The main pulmonary CT signs in patients with COVID-19 infection are bilateral, peripheral, sub-pleural, multi-lobar Ground glass opacification with or without consolidation in patchy distribution with or without nodular pattern more frequent in posterior and basal lung segments. Other pulmonary signs may also present include crazy paving pattern, reversed halo sign vascular thickening, and air bronchogram sign with no extra-pulmonary signs except for few pleural thickening.

## Declarations

- This study involved human subjects.
- The author confirmed that all appropriate ethical guidelines for the use of human subjects have been followed, any necessary IRB and/or ethics committee review has been obtained, and information about the IRB/ethics committee is included in the manuscript.

- The author has confirmed that all necessary patient/participant consent or assent has been obtained and the appropriate institutional forms have been archived. If the IRB/ethics committee waived the requirement for patient/participant consent or assent, an explanation for the waiver is included in the text.
- The author has confirmed that a statement listing potential conflicts of interest or lack thereof is included in the text.

## Abbreviations

CT: Computed Tomography.

COVID-19: coronavirus disease 2019.

RT-PCR: Reverse transcriptase polymerase chain reaction.

SARS-CoV-2: severe acute respiratory syndrome coronavirus 2

WHO: World Health Organizations.

MERS-CoV: Middle east respiratory syndrome coronavirus

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## Tables

**Table 1: Characteristics of patients (n 100)**

Age (y)	
• Mean	45
• Range	6-85
Sex: no. (%) of patients	
• Male	54 (54%)
• Female	46 (46%)

**Table 2. Pulmonary CT findings**



<b>CT findings</b>	<b>No (%)</b>
<i>Normal pulmonary CT</i>	10 (10%)
<i>Abnormal pulmonary CT</i>	90 (90%)
<b><i>Number of lungs affected</i></b>	
<ul style="list-style-type: none"> <li>• One lung ( unilateral)</li> <li>• Two lungs (bilateral)</li> </ul>	11 (11%) 79 (79%)
<b><i>Pulmonary lobe affected</i></b>	
<ul style="list-style-type: none"> <li>• Right upper lobe</li> <li>• Right middle lobe</li> <li>• Right lower lobe</li> <li>• Left upper lobe</li> <li>• Left lower lobe</li> </ul>	31 (31%) 37 (37%) 77(77%) 33 (33%) 71 (71%)
<b><i>Pulmonary segments affected</i></b>	
<ul style="list-style-type: none"> <li>• Anterior pulmonary segments</li> <li>• Posterior pulmonary segments</li> </ul>	44 (44%) 69 (69%)
<b><i>Lesion distribution</i></b>	
<ul style="list-style-type: none"> <li>• Central (peri-broncho-vascular)</li> <li>• Peripheral (sub-plural)</li> <li>• Mixed (central and peripheral)</li> </ul>	0 (0%) 64 (64%) 24 (24%)
<b><i>Number of pulmonary lobes involved</i></b>	
<ul style="list-style-type: none"> <li>• One pulmonary lobe</li> <li>• 2-3 pulmonary lobes</li> <li>• 4-5 pulmonary lobes</li> </ul>	11 (11%) 35 (35%) 44 (44%)
<b><i>Pattern of lesions</i></b>	
<ul style="list-style-type: none"> <li>• Ground glass opacity.</li> <li>• Consolidation</li> <li>• Mixed pattern</li> </ul>	44 (44%) 13 (13%) 33 (33%)
<b><i>Shape of lesions</i></b>	
<ul style="list-style-type: none"> <li>• Patchy opacity</li> <li>• Nodular opacity</li> <li>• Mixed</li> </ul>	36 (36%) 14 (14%) 40 (40%)
<b><i>Other pulmonary signs</i></b>	

<ul style="list-style-type: none"> <li>• <i>reversed halo sign</i></li> <li>• <i>Air bronchogram sign</i></li> <li>• <i>Crazy paving pattern</i></li> <li>• <i>Vascular thickening</i></li> </ul>	28 (28%) 39 (39%) 77 (77%) 66 (66%)
<b><i>Extra pulmonary signs</i></b>	
<ul style="list-style-type: none"> <li>• <i>Pleural thickening</i></li> <li>• <i>Pleural effusion</i></li> <li>• <i>Mediastinal and hilar lymphadenopathy</i></li> </ul>	7 (7%) 0 (0%) 0 (0%)

## Figures

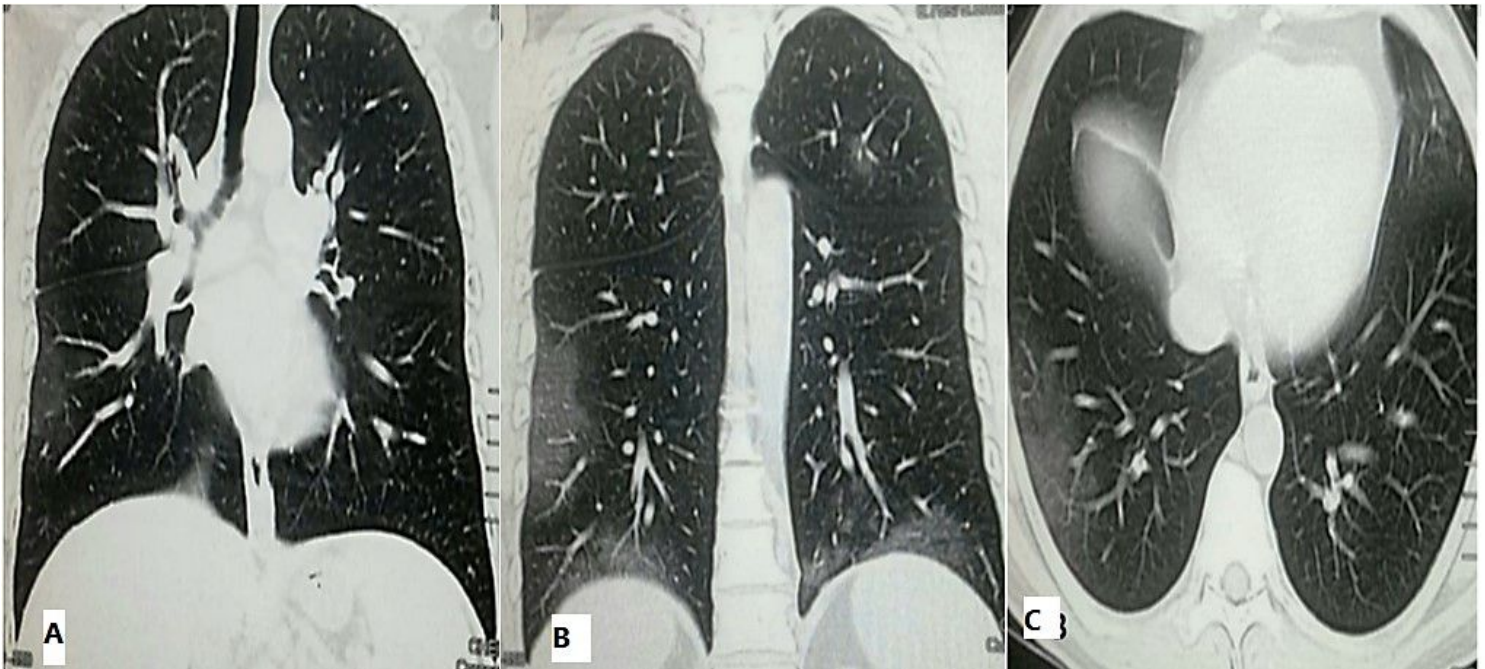


Figure 1

34 years old female with COVID-19 infection A-C (A&B) coronal, (C) axial pulmonary CT images (pulmonary window) shows multiple patchy ground-glass opacities scattered in sub-pleural peripheral zone of both lungs, with vascular thickening

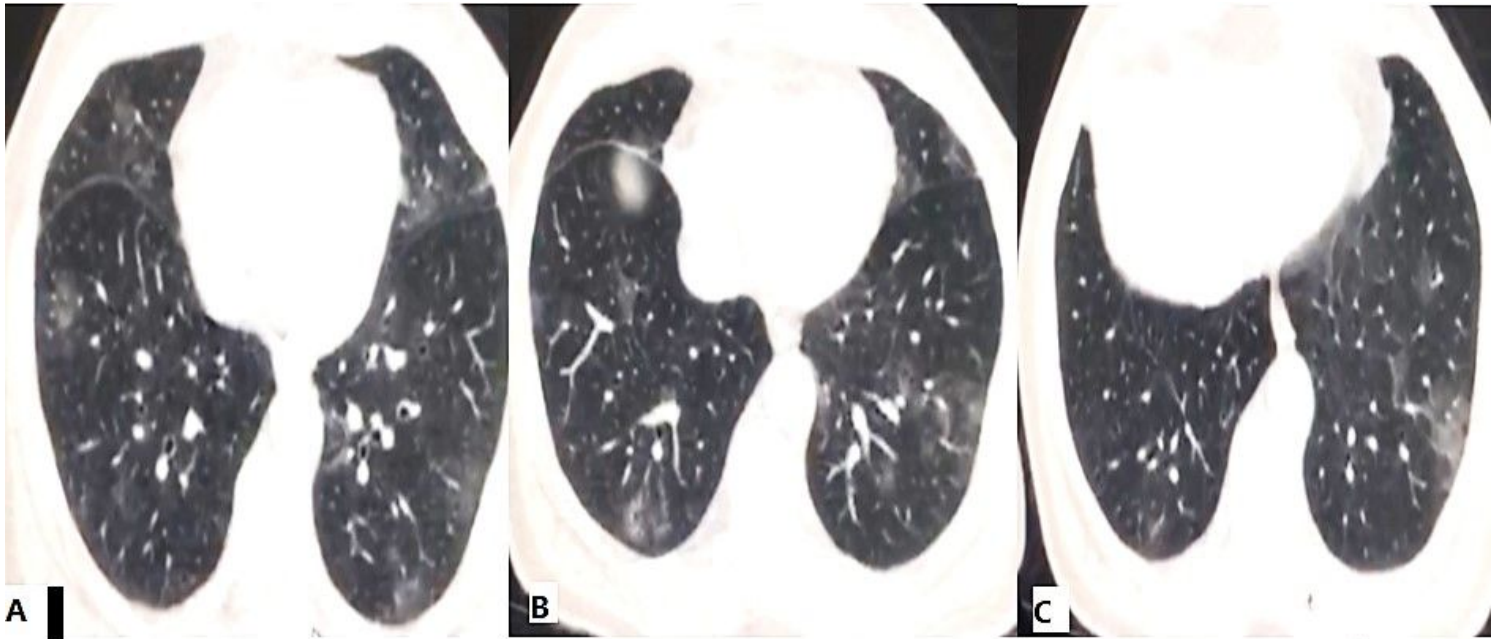


Figure 2

62 years old male with COVID-19 infection A-C (A, B &C) axial pulmonary CT images (pulmonary window) shows multiple patchy and nodular ground-glass opacities scattered in both central and sub-pleural peripheral zone of both lungs, with crazy paving and vascular thickening

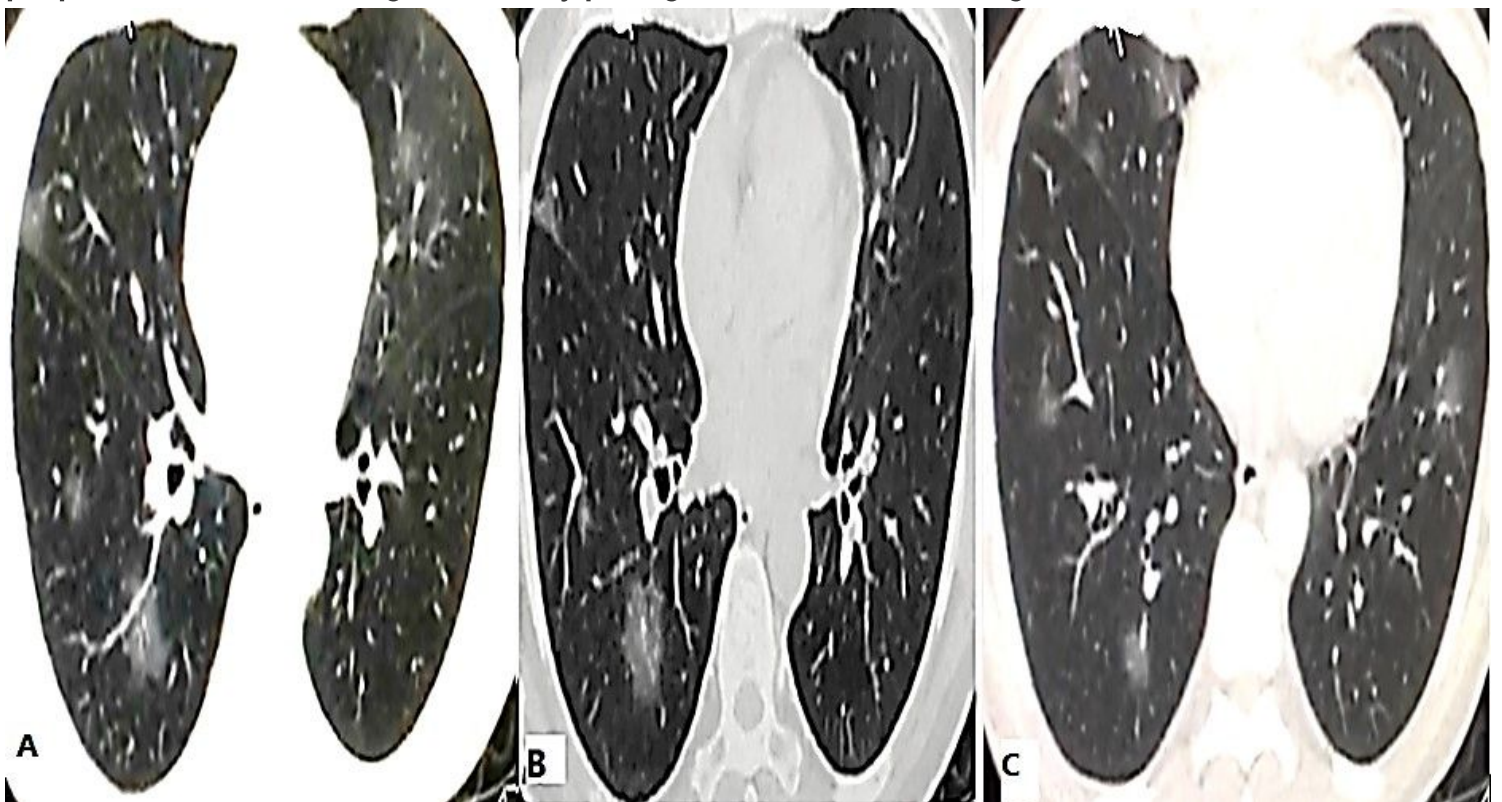


Figure 3



45 years old female with COVID-19 infection A-C (A, B & C) axial pulmonary CT images (pulmonary window) shows multiple patchy and nodular ground-glass opacities scattered in both central and sub-plural peripheral zone of both lungs, with crazy paving, air bronchogram and vascular thickening

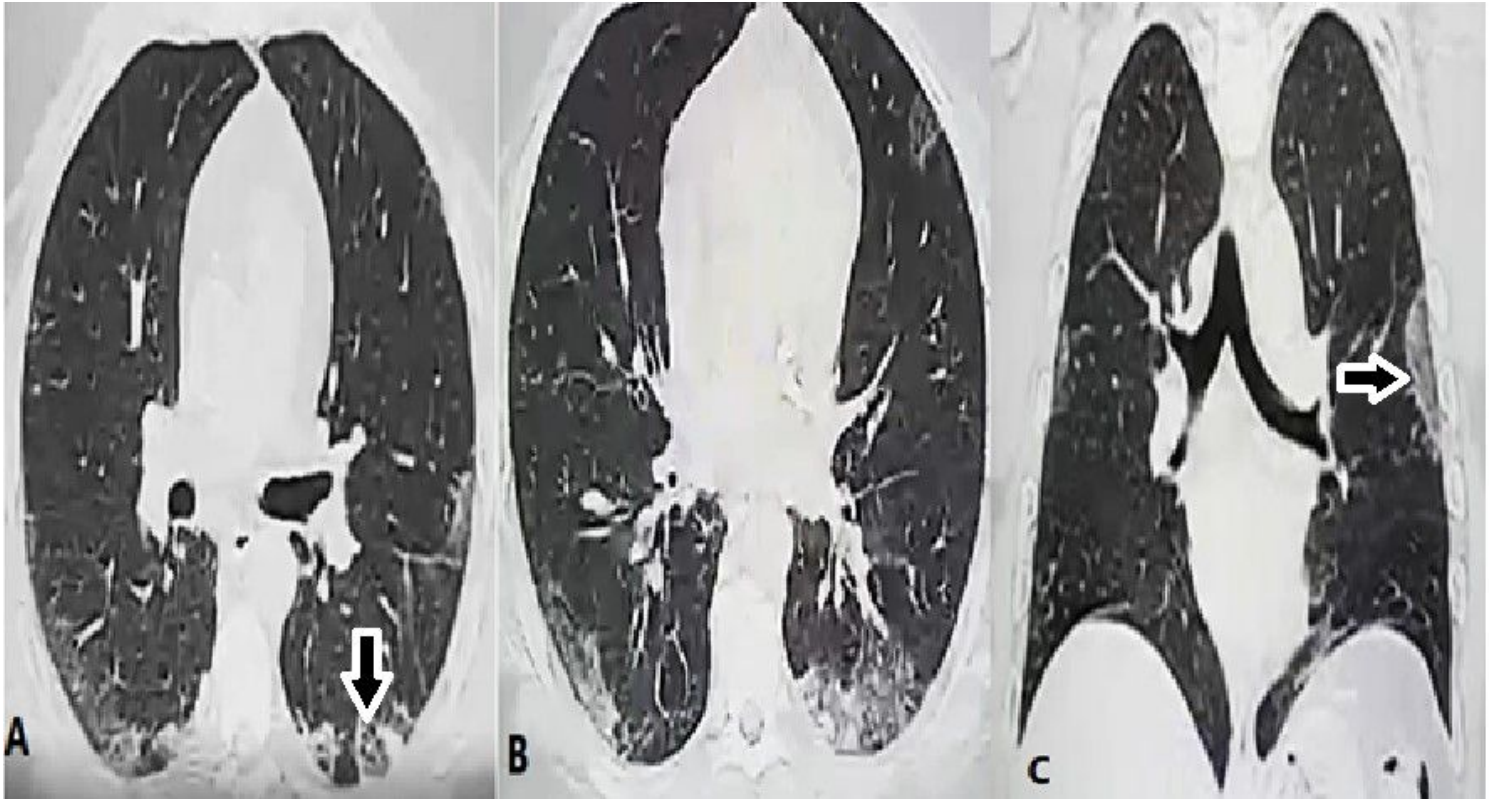


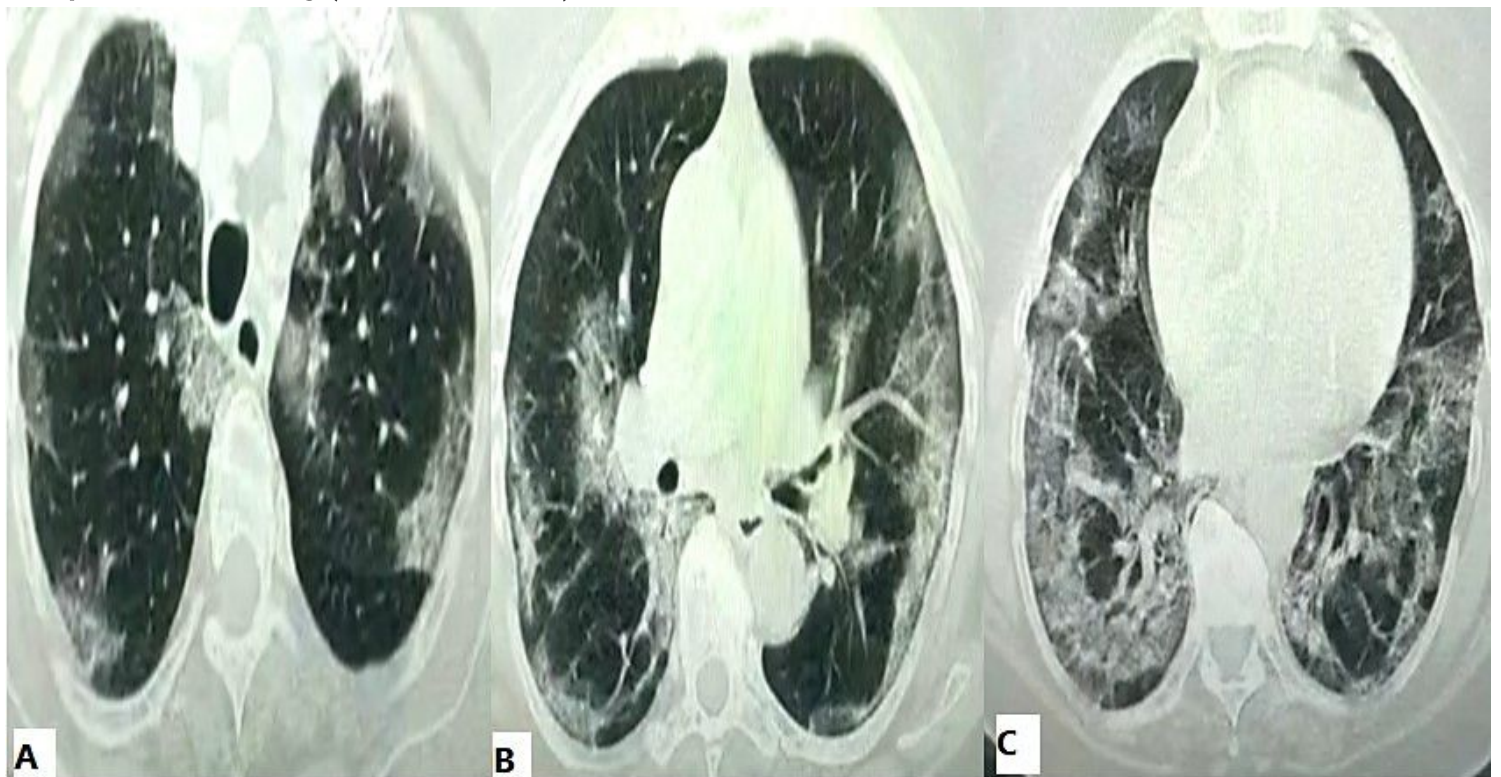
Figure 4

56 years old male with COVID-19 infection A-C (A&B) axial, (C) coronal CT images of the lungs (pulmonary window) multiple patchy ground-glass opacities with consolidation scattered in peripheral sub-plural zones of both lungs, with reversed halo sign (arrows in A&C), crazy paving, air bronchogram sign, and vascular thickening



Figure 5

66 years old female with COVID-19 infection A-C (A,B& C) axial CT images of the both lungs (pulmonary window) multiple patchy ground-glass opacities with consolidation scattered in peripheral sub-plural zones of both lungs, with reversed halo sign (white arrows in A&C), crazy paving, , vascular thickening and pleural thickening (black arrow in A)



## Figure 6

45 years old male with COVID-19 infection A-C (A,B& C) axial CT images of the both lungs (pulmonary window) multiple patchy ground-glass opacities with consolidation scattered in both peripheral sub-plural and central zones of both lungs, with reversed halo sign, crazy paving, and vascular thickening