# "Characteristic imaging signs of COVID-19 infection in high resolution pulmonary CT"

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## Abstract

**Aim of the work**

This study aimed to detect the characteristic imagingsigns  of  COVID-19  infection  that  appeared  in  the  high  resolution pulmonary CT of COVID-19 positive patients.

**Methods**

150 patients included in this study (mean age 43 years, 48% female and 52%  male).  All  included  individuals  were  positive  for  COVID-19  virus. High  resolution  pulmonary  CT  were  done  for  all  patients  included  in  the study.

**Results**

Pulmonary  CT  was  abnormal  in  126  patients  (84%).  Bilateral  lung affection  was  in  105  patients  (70%).  14 %  had  single  lobar  affection  and 70 %  had  multi-lobar  affection.  The  commonest  affected  lung  lobes  were the  lower  lung  lobes  (76%  and  70%  for  right  and  left  lung  respectively). Posterior  lung  segment  (72%)  were  affected  more  than  anterior  lung segments  (42%).  Peripheral  lung  zone  was  the  most  affected  part  by COVID 19 infection. The commonest CT pattern for COVID-19 was ground glass opacities (44%), and mixed pattern of both consolidative

and ground glass opacities (34%). As regard other pulmonary and extra pulmonary signs (peri-bronchovascular thickening, crazy paving pattern, airbronchogram sign, reversed halo sign and pleural thickening were seen in 68%, 64%, 32%, 30% and 8% respectively.

**Conclusion**

The characteristic pulmonary imaging signs of COVID- 19 infection in HRCT were bilateral, multiple, peripheral ground glass with or without consolidation patches in basal and posterior pulmonary predominance in association with peri-bronchovascular thickening, crazy paving pattern, air bronchogram or reversed halo sign without any extra- pulmonary affection except for some irregular pleural thickening.

**Keywords**: pulmonary CT signs, COVID-19, crazy paving, ground glass.

## Introduction:

Coronavirus disease is highly infectious disease that proved to be transmitted rapidly by droplets infection. The disease caused by corona virus is called severe acute respiratory syndrome coronavirus 2 or (SARS-CoV-2) (Han et.al. 2020).

The beginning of COVID epidemic was in Wuhan city China and started by the end of 2019 (Li et.al. 2020).

The incubation period of COVID-19 ranges from one day up to two weeks. COVID-19 infection symptoms appear between three days to one week after exposure to infection (Jin et.al. 2020).

COVID-19 symptoms are varying greatly from completely non-symptomatic to more severe symptoms that may cause death (Li et.al. 2020).

COVID 19 infection can classified according to their symptoms into five stages; the first stage is a stage of asymptomatic infection, the second stage is the stage of upper respiratory tract infection, the third stage is the stage of mild pneumonia, and the fourth stage is the stage of severe pneumonia, and finally the fifth stage and it considers as the most severe stage of acute severe respiratory distress symptoms (Jin et.al. 2020).

COVID-19 infection diagnosis depends mainly in real time PCR test. Although the high specificity of this test, its sensitivity is low due to its high false negative results (Guan et.al. 2020).

High resolution CT of the lung together with laboratory investigations and clinical manifestation all consider as valuable modalities that can help in COVID-19 infection diagnosis (Xiang et.al. 2020).

The sensitivity of high resolution pulmonary CT in COVID-19 infection diagnosis is high reaching up to 97%-98% (Ai et.al. 2020). The high resolution pulmonary CT scans has a higher sensitivity for COVID-19 infection diagnosis than RT-PCR results (Kolta et.al. 2020).

About 25% of COVID-19 PCR positive individuals showed normal CT lung. This usually occurs in mild cases and in an early stage of corona virus infection (Guan et.al. 2020).

Characteristic high resolution Pulmonary CT signs observed in COVID-19 infected patients were unilateral or bilateral, single lobar or multi-lobar pulmonary ground glass opacities may be associated with consolidation opacities (Xiang et.al. 2020).

## Methods

The study was done in quarantine hospitals in Port-Said, Egypt. This study was done in 2020 from April to July.

We approved this study by Research Ethic Committee of faculty of medicine Port Said University.

All patients performed real time PCR nasopharyngeal swab test. According to the real time PCR test results, we included in this study all patients who were proved to be positive for COVID-19 virus and excluded non infected negative individuals.

### High resolution pulmonary CT scanning

High resolution pulmonary CT (HRCT) was performed for all patients included in this study with 16 slice computed tomography machine (Alexion Toshiba, Japan). At first patients were lying down in supine position on the CT table. Chest scanning began from apices of both lungs down to lungs bases with full inspiration. Slice thickness was 1mm. No contrast media was used. For all patients we obtained both pulmonary and mediastinal widows

All the images were sent for processing and manipulation in a separate workstation for multi-planner reconstruction (MPR) (axial, coronal and sagittal planes).

**High resolution pulmonary CT Analysis**

All high resolution pulmonary CT images were evaluated by two expert radiologists. They recorded independently pulmonary and extra pulmonary CT signs for all patients included in the study.

The two radiologists searching for the following:

- Unilateral or bilateral lung affection.
- Number and site of pulmonary lobes affected.
- Site of pulmonary segments affected (anterior and posterior segments).
- Presence of ground glass or pulmonary consolidation opacities and their distribution in the lung lobes.
- Presence of other pulmonary or extra-pulmonary signs.

## Results

This study included 150 patients proved to be infected with COVID-19 virus by real time PCR test. The patient's age ranged from 8 to 78 years (mean age 43 years). From 150 patients included in the study there were 78 male (52%) and 72 female (48%).

In this study 99 patients (66%) presented with fever, 84 patients (56%) presented with dry cough and 66 patients (44%) presented with dyspnea (Table 1).

According to the high resolution pulmonary CT results 24 patients (16%) had normal pulmonary CT report while 126 patients (84%) had abnormal pulmonary CT report.

One lung affected in 21 patients (14%) and both lungs affected in 105 patients (70%). One pulmonary lobe involved in 21 patients (14%), two or three pulmonary lobes involved in 48 patients (32%) and four or five pulmonary lobes involved in 57 patients (38%) (Table 2).

In the right lung the upper lobe involved in 45 patients (30%), the middle lobe involved in 54 patients (36%), lower lobe involved in 114 patients

(76%). In the left lung the upper lobe involved in 51 patients (34%) and the lower lobe involved in 105 patients (70%) (Table 2).

In this study the posterior segments of the lung were affected by covid-19 lesions in 108 patients (72%) and anterior segments of the lung were affected in 63 patients (42%) (Table 2).

Peripherally located pulmonary lesions seen in 84 patients (56%) while pulmonary lesions with mixed distribution (peripheral and central) seen in 42 patients (28%) (Table 2).

Ground glass opacities were seen in 66 patients (44%), consolidation opacities were seen in 9 patients (6%) and mixed pattern were seen in 51 patients (34%) (Table 3).

Patchy opacities were seen in 57 patients (38%), nodular opacities were seen in 18 patients (12%) and mixed patchy and nodular opacities were seen in 51 patients (34%).

As regard other pulmonary signs peri-bronchovascular thickening was seen in 102 patients (68%) (Table 3) (Figure 1,2,3,4,5,6), Crazy paving pattern was seen in 96 patients (64%) (Figure 2,3,4,5,6), air bronchogram sign was seen in 48 patients (32%) (Figure 3,4), and reversed halo sign was seen in 45 patients (30%) (Figure 4,5,6).

The extra-pulmonary signs were not present except for 12 patients (8%) showed some irregular pleural thickening (figure5A) (table3)

Table 1: clinical picture:

| Clinical picture | No. (%) of patients |
|---|---|
| Fever | 99 (66%) |
| Dry cough | 84 (56%) |
| Dyspnea | 66 (44%) |

## Table 2: COVID-19 pneumonia distribution

| *lung involvement* | |
|---|---|
| • *Unilateral affection*<br>• *Bilateral affection* | *21 (14%)*<br>*105 (70%)* |
| *lobar involvement* | |
| *Right lung*<br>• *upper lobe*<br>• *middle lobe*<br>• *lower lobe*<br><br>*Left lung*<br>• *upper lobe*<br>• *lower lobe* | <br>*45 (30%)*<br>*54 (36%)*<br>*114(76%)*<br><br><br>*51 (34%)*<br>*105 (70%)* |
| *segmental involvement* | |
| • *Posterior segments*<br>• *Anterior segments* | *108 (72%)*<br>*63 (42%)* |
| *lobar distribution* | |
| • *Peripheral*<br>• *Mixed* | *84 (56%)*<br>*42 (28%)* |

## Table 3: Pulmonary and extra-pulmonary CT signs

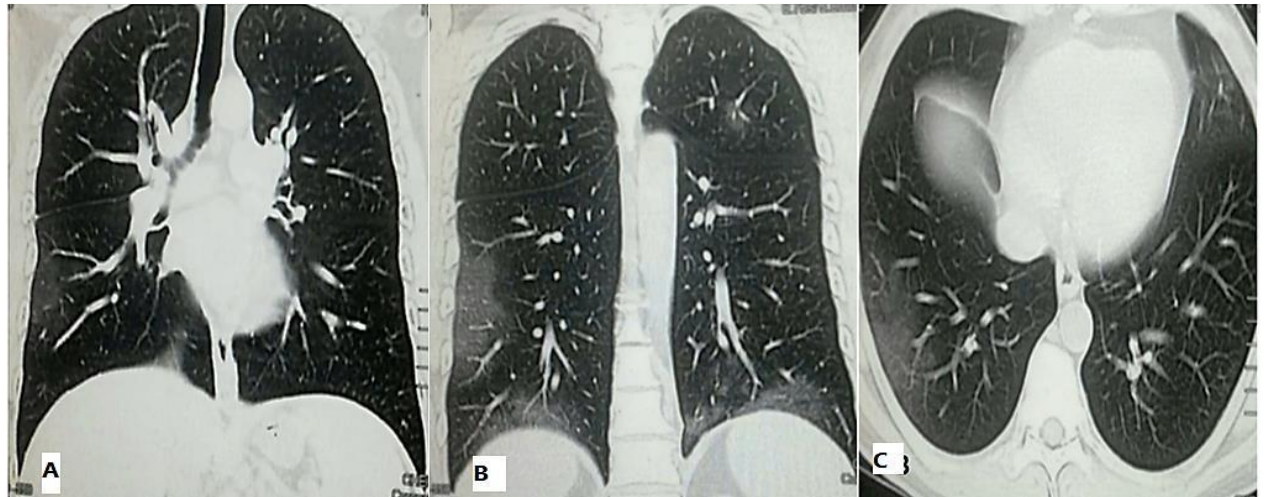| *Pulmonary lesions* | No (%) |
|---|---|
| • *Ground glass opacity.* | *66 (44%)* |
| • *Mixed pattern*<br>• *Consolidation* | *51 (34%)*<br>*9 (6%)* |
| • *Peri-bronchovascular thickening* | *102 (68%)* |
| • *Crazy paving pattern*<br>• *Air bronchogram sign*<br>• *reversed halo sign* | *96 (64%)*<br>*48 (32%)*<br>45 (30%) |
| *Extra pulmonary lesions* | |
| • *Pleural thickening* | *12 (8%)* |
| • *others* | *0 (0%)* |

Figure (1) female patients aged 34 diagnosed with COVID-19 infection (A&B) coronal, (C) axial pulmonary HRCT images shows bilateral, multiple patchy ground-glass opacities scattered in peripheral zone, with peri-bronchovascular thickening
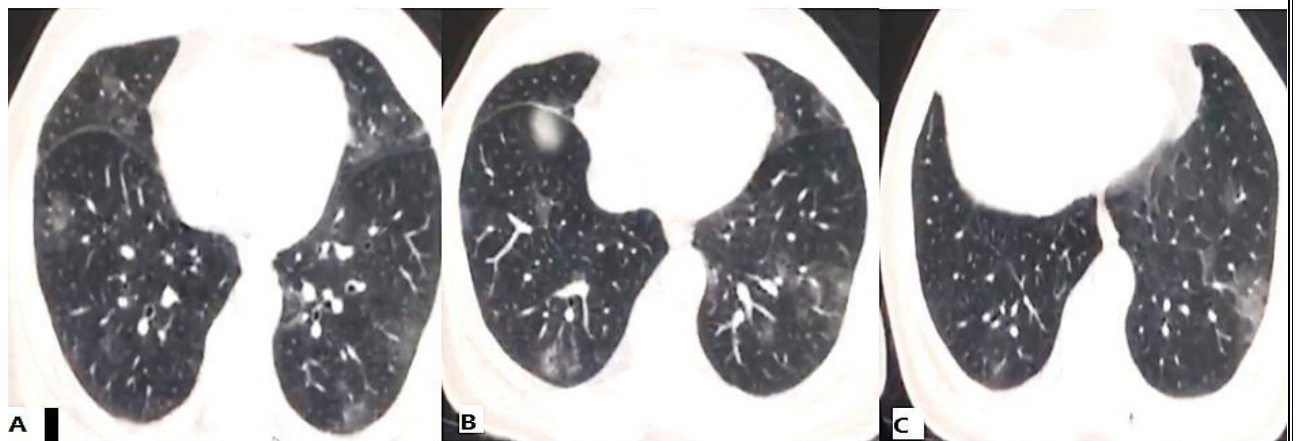


Figure (2) male patient aged 62 years old diagnosed with COVID-19infection (A, B &C) axial pulmonary HRCT images shows multiple, bilateral, patchy and nodular ground-glass opacities scattered in both central andperipheral lung zones, with crazy paving and peri-bronchovascular thickening
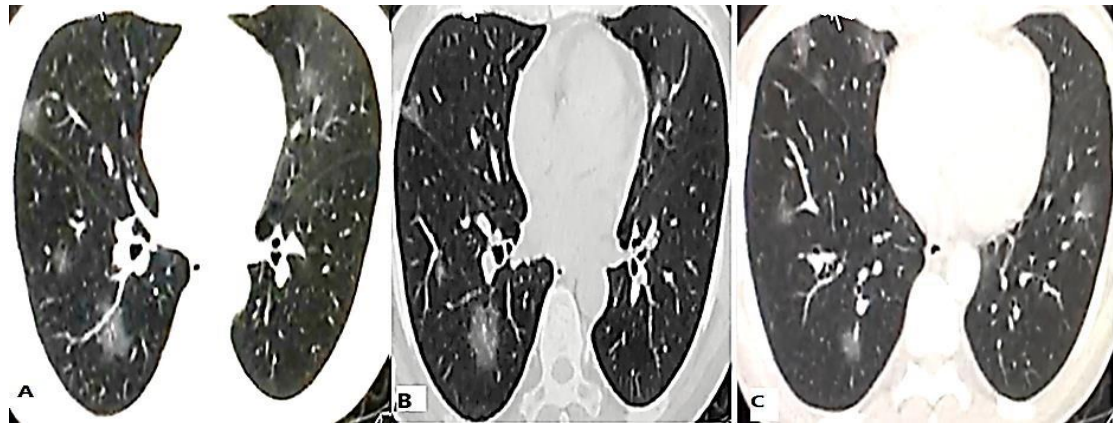
Figure (3) female patient aged 45 years diagnosed with COVID-19 infection (A, B &C) axial pulmonary HRCT images shows multiple, bilateral, patchy and nodular ground-glass opacities scattered in both central and peripheral lung zones, with crazy paving and peri-bronchovascular thickening
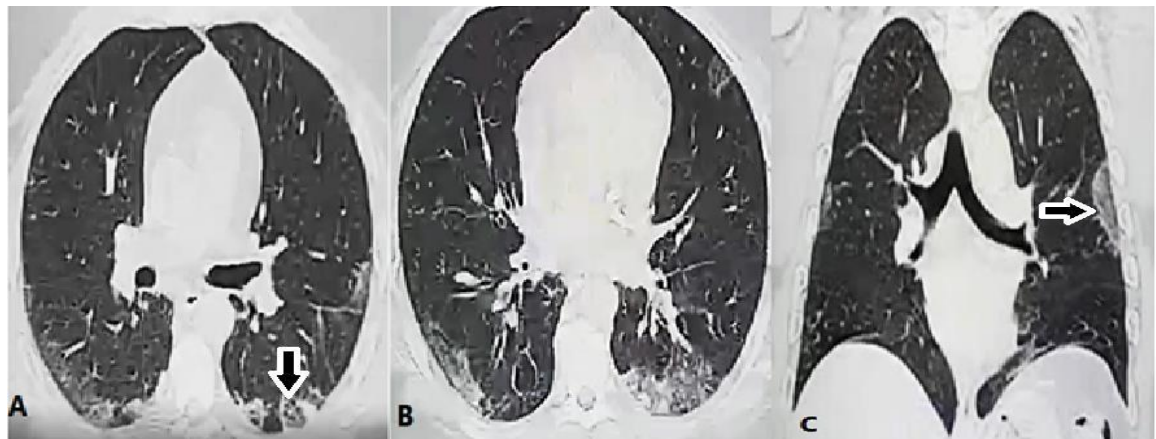


Figure (4) male patient aged 56 years old diagnosed with COVID-19 infection (A&B) axial, (C) coronal HRCT images of the both lungs showed multiple ground-glass patches with consolidation scattered in peripheral lung zones, with crazy paving, reversed halo sign (arrows in A&C), air bronchogram sign and peri-bronchovascular thickening
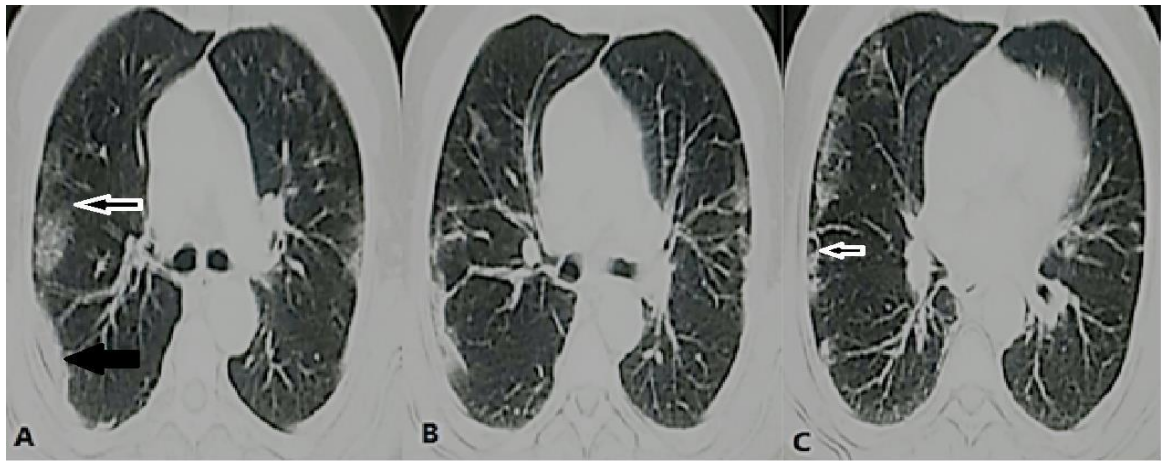
Figure (5) female patient aged 66 years old diagnosed with COVID- 19 infection (A,B& C) axial high HRCT images of the both lungs showed multiple ground glass opacities with consolidation patches scattered in sub-plural peripheral zones of both lungs, with reversed halo sign (empty arrows in figure A&C), crazy paving, , peri-bronchovascular thickening and pleural thickening (black arrow in A)
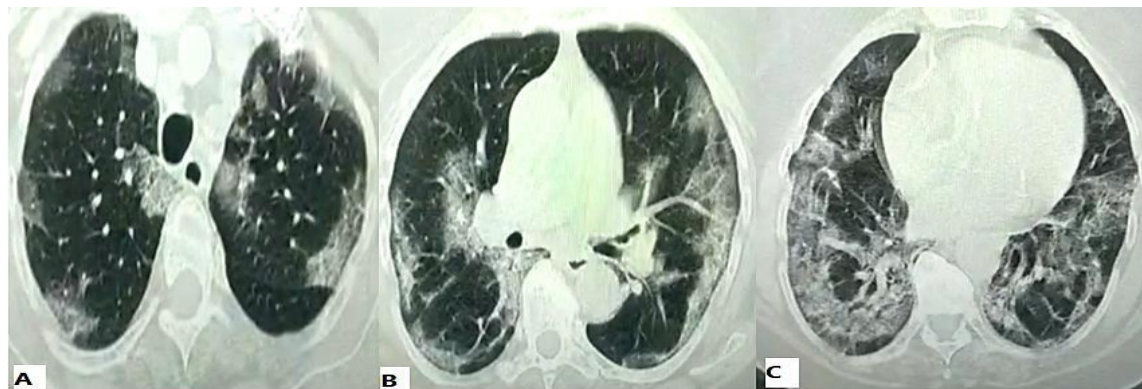


Figure (6) male patient aged 45 years old diagnosed with COVID-19 infection (A,B& C) axial HRCT images of the both lungs showed multiple ground-glass patches with consolidation scattered in both peripheral and central lung zones with reversed halo sign, vascular thickening and crazy paving.

## Discussion

World Health Organizations (WHO) reported that 7 million persons were infected and killed by COVID- 19 infection all over the world by the end of June 2020 (WHO website).

Early diagnosis of COVID-19 infection permits early isolation of the patients and decrease the spread of COVID-19 pandemic. Also early diagnosis allows early treatment of infected patients in order to decrease and prevent the subsequent morbidity and mortality of the disease (Kolta et.al. 2020).

The high false negative results of real time PCR test leads to decrease the test sensitivity for diagnosis of corona virus infection (Chung et.al. 2020).

Many studies reported that HRCT of the lungs helps in early diagnosis of COVID-19 infection due to its great ability in diagnosis of early and small pulmonary lesions. High resolution pulmonary CT proved to have a great value in diagnosis and follow up of the COVID-19 infection progression (Ali et.al. 2020).

This study included 150 patients all of them were proved to be infected with COVID -19 viruse by real time PCR test.

In our study COVID-19 infection was more predominant in male (52%) than female (48%). In this study we noted that children were less affected with COVID 19 pneumonia than adult patients. In this study the mean age was about 43 years.

The most presented symptom in our study was fever (66%) followed by dry cough (56%) while dyspnea was the least presented symptoms 44%. These results were matched with Lovato et al. they reported that fever was the commonest symptoms in COVID-19 positive patients 58.6% followed by dry cough 68.7% (Lovato et.al. 2020).

From 150 patients involved in our study there were 24 patients (16%) showed normal CT results with no detected HRCT abnormality. The remaining 126 patients (84%) showed HRCT abnormality. This was in agreement with Bernheim and their colleagues, they reported in their research that nine percentages of asymptomatic corona virus positive patients showed normal lung in high resolution pulmonary CT in asymptomatic or early stages of the infection (Bernheim et.al. 2020).

In this study we noted that the bilateral lung affection by COVID 19 pneumonia was more common (70%) than single lung affection (14%). In our study the multi lobar pulmonary affection by COVID-19 pneumonia (70%) was higher than single lobar affection (14%). These results were matched with Han and their colleagues; they found that 65% of COVID-19 infection involved more than one pulmonary lobe (Han et.al. 2020).

We noted that lower lobes of the lung more liable for affection with corona virus than upper lobes of the lung (76% and 70% right and left lung lobe respectively). These results were matched with Yang et.al. they reported that the lower lobes of the lung were more affected with corona virus infection than upper lung lobes (Yang et.al 2020). This was explained by Han et.al. as the right lower bronchus is thicker and shorter than other bronchi and this may accelerates its infection by the COVID

19 virus (Han et.al. 2020).

We noted that posterior located lung segments were more affected by COVID 19 pneumonia (72%) more than anterior located lung segments (42%). These results were matched with Kolta research they noted that posterior located lung segments were more affected with corona virus pneumonia than anteriorly located lung segments (Kolta et.al. 2020).

In our study the majority of lesions of corona virus pneumonia located peripherally in sub-pleural location within the lung lobes. These results were matched with Yang research they noted that peripheral zone of the lung were more affected than central lung zones by COVID-19 pneumonia lesions (Yang et.al. 2020).

In our study we noted that the commonest high resolution CT pattern of COVID-19 pneumonia was ground glass opacities. In our study the ground glass pattern was seen in 66 patients (44%). The second most common pattern of COVID 19 infection was mixed pattern that include both ground glass pattern and consolidation pattern. Mixed pattern was seen in 51 patients (34%) the least pattern of COVID-19 pneumonia in HRCT was consolidation opacities that was seen in 9 patients (6%). These results were matched with many researchers they noted that the commonest COVID-19 pneumonic pattern in high resolution pulmonary CT scan was ground glass opacities with or without presence of consolidation opacities (Kolta et.al. 2020) (Li et.al.2020)

Huang et.al. recommended that the pathophysiologic behavior of COVID- 19 virus infections may be the identical to those of severe acute respiratory syndrome coronavirus 2 (SARS-CoV2) and Middle east respiratory syndrome coronavirus (MERS-CoV) infections. All these viruses may cause diffuse damage of the alveoli, this damage caused by inflammatory cytokine storm that explained the ground glass opacities pattern in early high resolution pulmonary CT (Huang et.al. 2020).

In our study we noted that the commonest shape of COVID-19 opacities was patchy opacities that was seen in 57 patients (38%) followed by mixed patchy and nodular opacities that was seen in 51 patients (34%) while nodular opacities was seen only in 18 patients (12%). These results were in agreement with Han research who reported that 86% of the COVID -19 lesions were appeared as patchy opacities (Han et.al. 2020).

In our study we noted that many other characteristic pulmonary signs

may appear in high resolution pulmonary CT of patient diagnosed with COVID-19 infection. These signs included peri-bronchovascular thickening that was seen in 102 patients (68%), Crazy paving pattern that was seen in 96 patients (64%), air bronchogram sign that was seen in 48 patients (32%), and reversed halo sign that was seen in 45 patients (30%). All these pulmonary HRCT signs were reported in many researches (Ali et.al.2020) (Kolta et.al.2020).

The extra-pulmonary HRCT signs were not present in our study except for 12 patients (8%) showed some irregular pleural thickening these were in agreement with many researchers they reported that extra-pulmonary HRCT signs, like pleural effusion, pericardial effusion, hilar and mediastinal, lymph node enlargement or cavitation were not seen in high resolution pulmonary CT scan of patient with early COVID-19 infection and they recommended that these extra-pulmonary signs may appear later in the late stage of the corona virus infection (Ali et.al. 2020) (Kolta et.al.2020).

Finally, our study concluded that the characteristic pulmonary imaging signs of COVID-19 infection in HRCT were bilateral, multiple, peripheral ground glass with or without consolidation patches in basal and posterior pulmonary predominance in association with peri-bronchovascular thickening, crazy paving pattern, air bronchogram or reversed halo sign without any extra-pulmonary affection except for some irregular pleural thickening.

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