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The Prevalence of Different Radiological CT Chest Finding in Patients Hospitalized for COVID 19 Pneumonia: A Retrospective Study

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Abstract

Background: Corona virus disease 2019 is a highly infectious disease, causing respiratory tract infections and resulting in acute respiratory distress syndrome in few cases. According to recommendation of WHO regarding use of chest imaging in COVID-19, all patients with confirmed COVID-19 & hospitalized with moderate to severe symptoms, chest imaging should be added to clinical and laboratory assessment to direct therapeutic management. CT chest had high sensitivity & low specificity in diagnosis of COVID 19 pneumonia, but it can also help in diagnosis of patient with pre-existing pulmonary disease.

Aim of Study: Our study assessed all possible CT chest manifestations including consolidations and ground glassing, which were the main features assessed in other studies. We also analyzed the zonal preference which proved to be diffuse or lower lobar in affection. Added to that the prevalence of peripheral parenchymal band which was detected in more than half of included patients.

Patients and Methods: This retrospective study was conducted with 207 patients who were diagnosed & admitted with positive COVID-19 infection. All patients were confirmed positive using PCR test.

Results: In all, 207 patients diagnosed with COVID-19 pneumonia, were enrolled in our study. The most prevalent finding was the presence of a ground-glass opacity (GGO), representing 87.1 % of CT findings. This was followed by peripheral parenchymal bands, as seen in 52% of patients, and consolidation patches were seen in 41.3% of patients. The least significant CT features observed in PCR-positive patients were crazy paving and reverse halo sign, seen only in 4.5% and 2.7% of patients, respectively. Overall, 81.6% of all patients showed multi-segmental affection, with 53.1 % showing diffuse zonal affection and 40.8% with lower lobe predominance.

Conclusion: The most common CT features seen in cases of COVID-19 pneumonia were GGO, consolidations, and Peripheral parenchyma bands. COVID-19 pneumonia was primarily multi-segmental in affection, showing diffuse or lower zone predominance.

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Key Words: *Real-time reverse transcription polymerase chain reaction (RT-PCR) – COVID-19 pneumonia – CT chest – Ground-glass opacity (GGO) – Multi-segmental.*

Key Points: *COVID-19 pneumonia – CT chest manifestation – Segmental and zonal distribution.*

Introduction

SINCE the first corona virus disease 2019 (COVID-19) outbreak was identified in Wuhan, China in December 2019, as identified by the first human case of this infection, the virus has rapidly spread through human-to-human transmission, despite imposed precautions. The outbreak was announced as a pandemic by the World Health Organization (WHO) on March 12, 2020 **[1]**.

Acute respiratory syndrome corona virus 2 (SARS-CoV-2), a member of the Coronaviridae family, was the cause of COVID-19. It is highly infectious, causing respiratory tract infections and resulting in acute respiratory distress syndrome in few cases. It also caused some systemic manifestations that can lead to multi-organ failure. The virus can enter the alveolar epithelial cells of the lung through angiotensin-converting enzyme 2 receptors **[2,3,4]**.

As it is a highly infectious disease, the early identification and isolation of infected patients are necessary to control its spread. Yet the clinical symptoms associated with this virus have not been helpful, as most patients are either asymptomatic or express mild, nonspecific symptoms, such as fever, cough, or dyspnea **[5]**.

List of Abbreviations:

COVID-19	: Coronavirus disease 2019.
SARS-CoV-2	: Acute respiratory syndrome corona virus 2.
RT-PCR	: Real-time reverse transcription polymerase chain reaction.
ARDS	: Acute respiratory distress syndrome.

A definitive diagnosis is achieved through a positive real-time reverse transcription polymerase chain reaction (RT-PCR) test result, according to the guidelines for the Diagnosis and Treatment of Pneumonia Caused by COVID-19 (Trial Version 3) published by the National Health Commission of the People's Republic of China (NHCPRC) [6]. However, given the limited sensitivity (71 %) and limitations associated with RT-PCR assays that were identified during the start of the outbreak, the accurate detection of COVID-19 patients and early isolations were not possible [7]. This led to the infection of a larger amount of the population due to the highly contagious nature of the virus, as well as all of the undiagnosed patients who had COVID-19, which then led this virus to infect increasing numbers of the populations.

According to recommendation of WHO regarding use of chest imaging in COVID-19, all patients with confirmed COVID-19 & hospitalized with moderate to severe symptoms, chest imaging should be added to clinical and laboratory assessment to inform therapeutic management [8].

Chest X-ray had lower sensitivity yet with low radiation dose & easily done repeatedly even as portable machine (which minimizes the risk of cross-infection related to patient transport). Compared to CT chest which had higher sensitivity yet less specificity & can help in diagnosis of patient with pre-existing pulmonary disease. Negative CT chest couldn't exclude positive infection [8].

Computed tomography (CT) of the chest is an easy & rapid modality that can be used for the diagnosis of pneumonia; it features a sensitivity of 98% when diagnosing patients with COVID-19 pneumonia [7]. In our study we included all patients admitted with COVID 19 infection and underwent CT chest as recommended by referring clinicians in our facility with the aim to categorize CT chest finding according to their prevalence.

Recently many researches described clinical and radiological features of COVID 19 infection, however most of these studies were mainly about the peripheral ground glassing and its bilaterality including also the crazy paving appearance, interstitial pattern and ARDS, yet only few studies investigated all CT chest manifestations that could appear during COVID 19 pneumonia, including ground glass opacity (sub-pleural, central or diffuse), Consolidations (central, sub-pleural or diffuse), Halo sign, Reverse halo sign, sub-pleural lines, Peripheral parenchymal bands & crazy paving (central or diffuse). In addition many patients were diagnosed COVID 19 pneumonia, while the CT chest features didn't include bilateral peripheral GGO This could be attributed to the less appreciated other CT chest features that could be seen in COVID 19 pneumonia.

So, the present study aims to evaluate the different CT features that could be seen in COVID 19 pneumonia and their prevalence, also including zonal & segmental affection.

Patients and Methods

This retrospective study was conducted with 207 patients who were diagnosed with COVID-19 infection, as determined by a positive PCR test, admitted during the period from March 2020 till April 2021 & underwent CT of the chest just after diagnosis. The study was approved from Ethical Committee. The research involved only CT scans from PACS Archiving system. So, waving of consent was granted from ethical committee board.

Inclusion criteria:

Patients who were admitted with positive PCR for COVID 19 infection & underwent CT chest within 24 to 48 hours after admission.

Exclusion criteria: Pediatrics below 18 years old.

Imaging protocol:

CT of the chest was done using a multi-slice 128 CT machine (Optima CT 660; GE, Boston, MA, USA). It includes:

Axial high-resolution lung tissue cuts with a slice thickness of 0.63cm with and a GAP of 4.38.

The axial lung and mediastinal window were imaged with a slice thickness of 5mm and a GAP of 0.

Coronal and sagittal reconstruction was performed for both the lung and mediastinal windows.

Image analysis:

The obtained images were assessed by two consultant chest radiologists with 5- and 10-years' experience in chest imaging. Included CT chest imaging quality was not considered in our study as most of patients had respiratory distress with difficulties in breathing which add more to motion artifacts.

Both radiologists revised the included CT chest regarding the presence/absence of the following features: Ground glass opacity (sub-pleural, central or diffuse), Consolidations (central, sub-pleural or

diffuse), Halo sign, Reverse halo sign, sub-pleural lines, Peripheral parenchymal bands & crazy paving (central or diffuse). Then they comment on lobar (multi-segmental, oligo-segmental or mono-segmental) & zonal affection (Upper, lower or diffuse).

Statistical analysis:

Data were collected, reviewed for completeness and accuracy, entered into a personal computer, and analyzed using IBM SPSS version 20 (IBM Corporation, Armonk, NY, USA). Descriptive statistics were presented as numbers and percentages; the chi-squared test was used to test the relationship between qualitative variables. If the expected count in 20% or more of the cells was less than 5, Fisher's exact test was used instead.

Results

In all, 207 patients with ages ranging from 24.00-88.00 years (mean age: 43.85 years) and clinically diagnosed with a COVID-19 infection underwent CT chest after admission, were enrolled in our study. When examining the participants' characteristics, 55 were female (26.5%) and 152 were male (73.4%) (Table 1).

Table (1): Characteristics of the studied Patients (n=207).

Variables	No.	%
Age:		
Less than or equal 30Y	24	11.59
31-40Y	73	35.26
41-50Y	48	23.18
51-60Y	38	18.35
More than 60Y	24	11.59
Sex:		
Male	152	73.4
Female	55	26.6

In our study, the majority of patients showed positive finding on chest CT (86.47%), while the rest 13.52% had a negative chest CT.

In our study, we observed that the most common finding was ground-glass opacities (GGOs), which were found in 87.1 % of patients with positive CT findings. About 44.7% of patients showed a diffuse distribution and 38.5% had a peripheral sub-pleural distribution (Fig. 1), yet only 3.9% showed a central peri-bronchial distribution (Table 2).

The next most common finding was the presence of peripheral parenchymal bands, as seen in 52% of patients, which was followed by consolidation patches seen in 41.3% of patients; 21.2% of patients showed a sub-pleural distribution and 17.9% showed a diffuse distribution. Interstitial thickening was also noted in 28.5% of patients, followed by sub-pleural lines, which were seen in 26.8% of patients. Pulmonary nodules were found in 19.6% of patients, followed by the halo sign, present in 15.6% of cases.

Table (2): Radiological Findings among PCR +ve patients (n=179) 34.

Variables	No.	%
Reverse halo:		
Negative	174	97.2
Positive	5	2.7
Ground glass opacity:		
Negative	23	12.8
Diffuse	80	44.7
Central	7	3.9
Subpleural	69	38.5
Consolidation:		
Negative	105	58.7
Diffuse	32	17.9
Central	4	2.2
Subpleural	38	21.2
Halo sign:		
Negative	151	84.4
Positive	28	15.6
Crazy paving:		
Negative	171	95.6
Positive	8	4.5
Interstitial thickening:		
Negative	128	71.5
Positive	51	28.5
Subpleural lines:		
Negative	131	73.1
Positive	48	26.8
Peripheral parenchymal bands:		
Negative	86	58
Positive	93	52
Nodules:		
Negative	144	80.4
Positive	35	19.6
Lobar affection:		
Multilobar	146	81.6
Oligosegmental	24	13.4
Monosegmental	9	5
Diffuse	95	53.1
Zonal affection:		
Lower	73	40.8
Upper	11	6.1
Other pulmonary manifestations:		
ARDS	2	1.1
Sub-pleural cysts	1	0.6
Pneumothorax and Pneumomediastinum	1	0.6
Calcific nodules	2	1.1
Pleural findings:		
Pleural thickening	4	2.2
Pleural Effusion	8	4.5

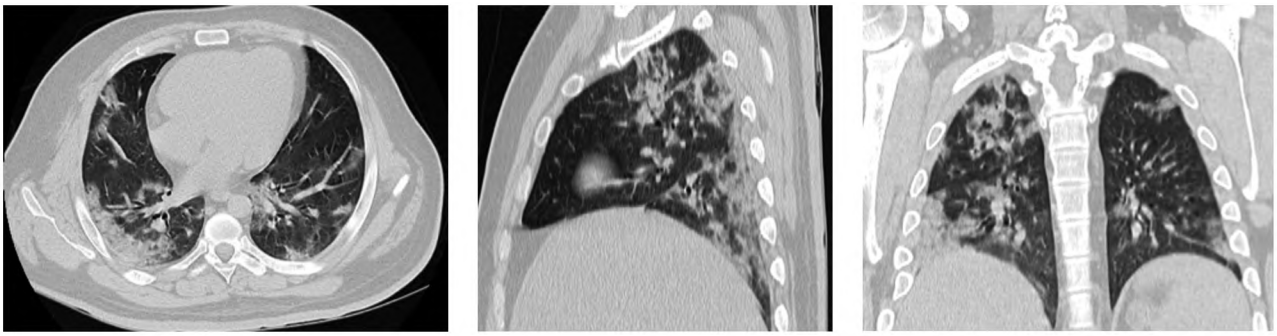
The least common CT features observed in PCR-positive patients were crazy paving and reverse halo sign, seen only in 4.5% and 2.7% of patients, respectively.

Regarding segmental affection, we found that 81.6% of patients showed multi-segmental affection. With respect to zonal affection, 53.1% of patients showed diffuse zonal affection with no lobe predominance, while 40.8% of patients showed lower lobe predominance (Figs. 2,3), and only about 6.1% showed upper lobe predominance.

Other pulmonary manifestations found in our study, one patient with pulmonary embolism, one showed pneumothorax and pneumomediastinum, was intubation related complication, not from COVID chest presentation, and two patients progressed to acute respiratory distress syndrome (Fig. 4). Furthermore, one patient had a subpleural cyst, eight patients developed pleural effusion, and four patients developed pleural thickening. We also recorded few extra pulmonary complications in 5 patients that developed during our study, which included pericardial effusion (1 patient), multiorgan failure (1 patient), hemorrhagic encephalitis (1 patient), hemorrhagic pancreatitis (1 patient), and 1 patient with pontine infarction that had died (Table 3).

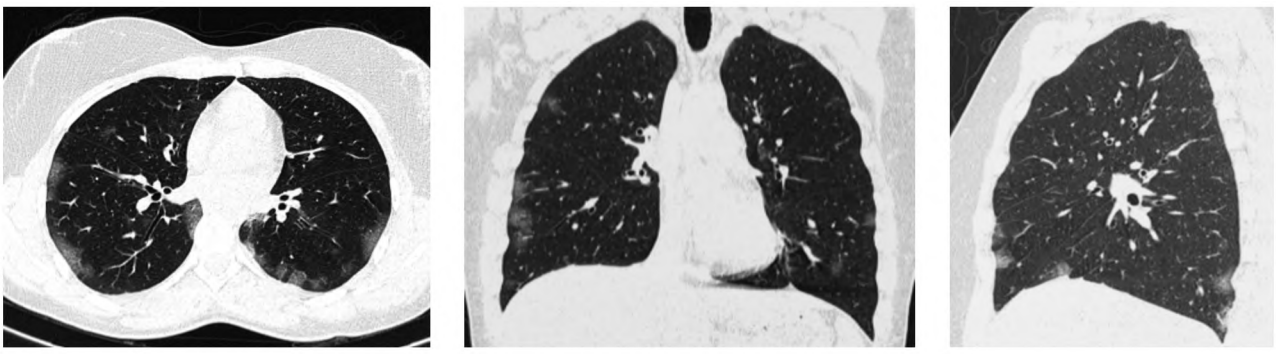
Table (3): Extrathorathic Complications among PCR +ve patients (n=179).

Variables	No.	%
Extrathorathic Complications:		
Negative	174	97
Pericardial effusion	1	0.6
Liver failure, renal failure, Ascites with edema	1	0.6
Bifrontal Hemorrhagic encephalitis	1	0.6
Hemorrhagic pancreatitis with ARDS	1	0.6
Infractions pontine	1	0.6



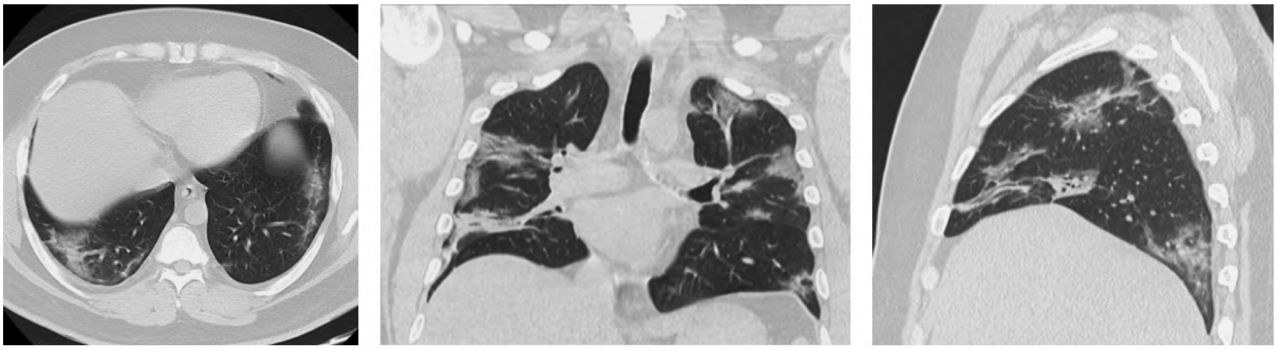
(A) (B) (C)

Fig. (1): 33 years old male patients confirmed positive for COVID 19, 1 day CT after diagnosis showed. (A): Axial CT chest cuts showed the sub-pleural distribution of consolidations associated with sub-pleural lines (B &C): Sagittal and coronal reformate showed the multi-segmental involvement of both lung parenchyma with mainly sub-pleural distribution and lower lobe predominance.



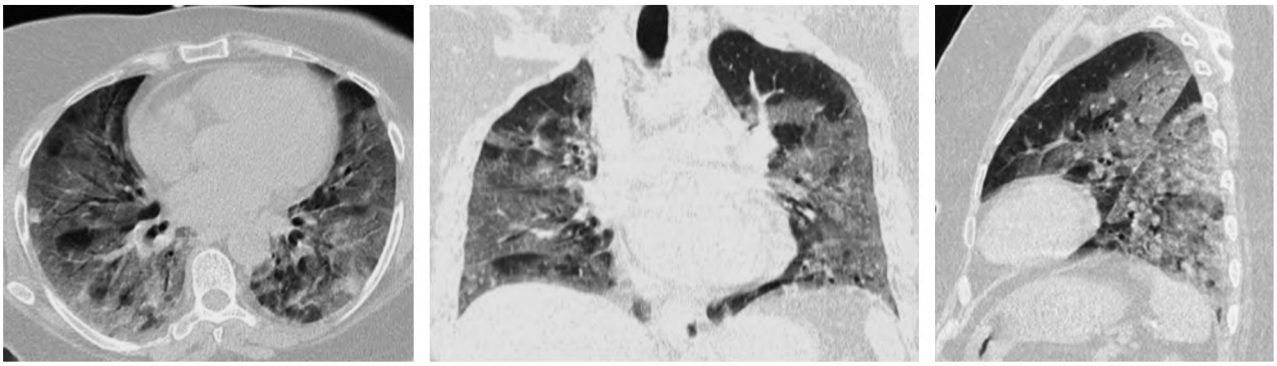
(A) (B) (C)

Fig. (2): 29 years old female patient confirmed positive for COVID 19. (A): Axial CT chest cuts showed sub-pleural areas of ground glassing. (B&C): Coronal and sagittal cuts confirmed multi-segmental involvement of both lung parenchyma with lower lobes predominance.



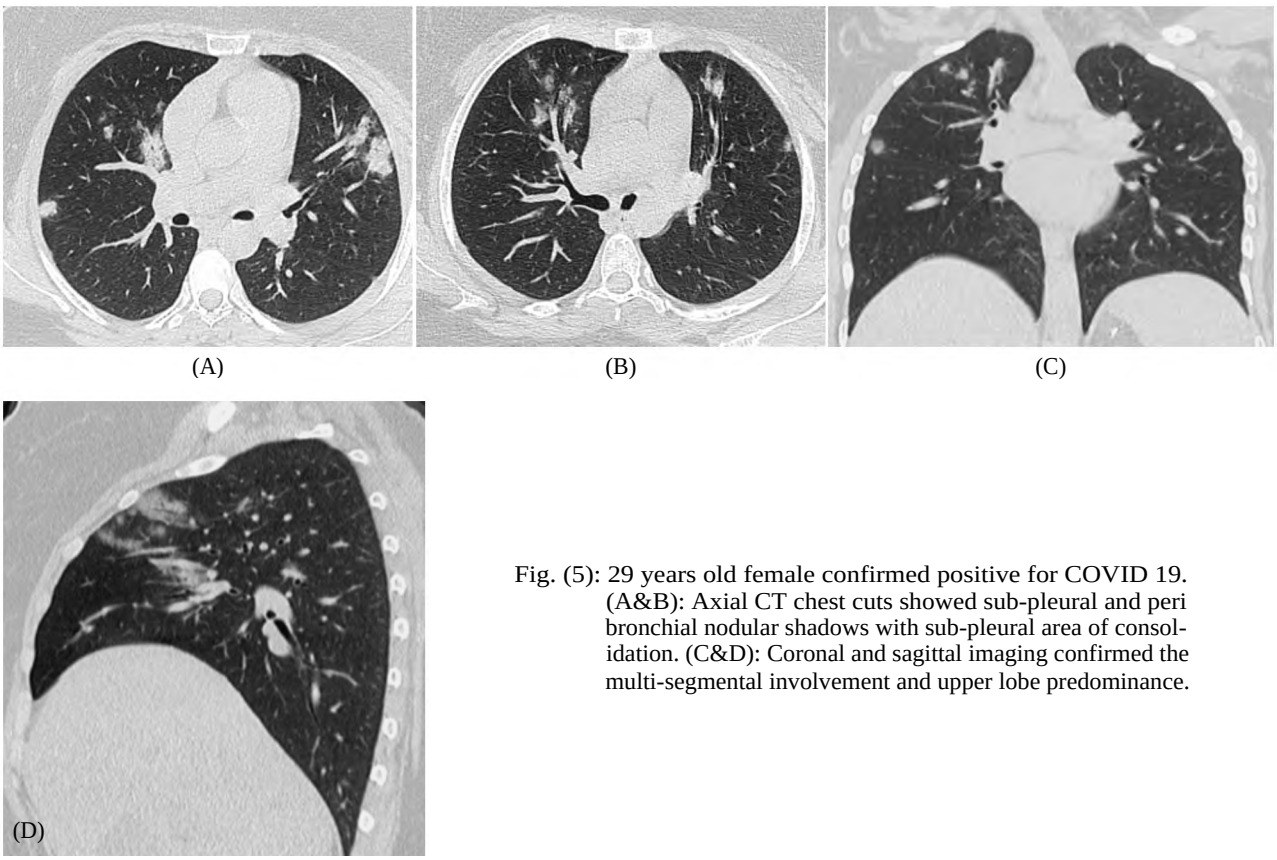
(A) (B) (C)

Fig. (3): 38 years old male confirmed positive for COVID 19 infection. (A): Axial CT chest cuts showed sub-pleural line, peripheral parenchyma bands with sub-pleural ground glassing & consolidations. (B&C): Coronal and sagittal images confirmed the multi-segmental involvement with no lobar predilection.



(A) (B) (C)

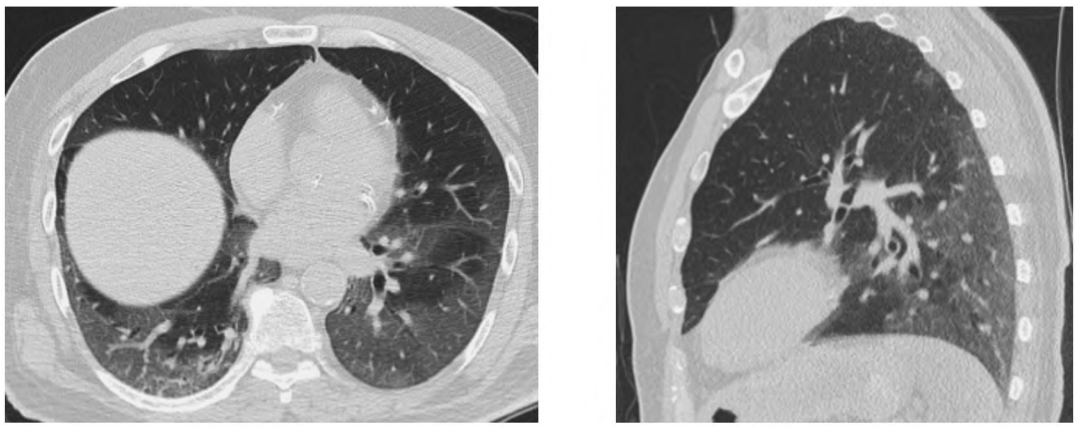
Fig. (4): 63 years old male patient confirmed positive for COVID 19 infection. (A): Axial cuts showed diffuse lung parenchyma involvement by areas of ground glassing giving crazy paving appearance. (B&C): Coronal and sagittal imaging confirmed multi-segmental involvement of both lung parenchyma with lower lobes predominance.



(A) (B) (C)

(D)

Fig. (5): 29 years old female confirmed positive for COVID 19. (A&B): Axial CT chest cuts showed sub-pleural and peri bronchial nodular shadows with sub-pleural area of consolidation. (C&D): Coronal and sagittal imaging confirmed the multi-segmental involvement and upper lobe predominance.



(A) (B)

Fig. (6): 72 years old man confirmed positive for COVID 19. (A): Axial CT chest cuts showed sub-pleural ground glassing with sub-pleural lines. (B): Sagittal CT chest reconstruction illustrating the lower lobe predominance.

Discussion

The COVID-19 pandemic, caused by severe acute respiratory syndrome corona virus 2 (SARS-CoV-2) evolved in March 2020. A wide variety of imaging finding and CT features were noted in COVID-19-related pneumonia. Chest CT findings showed that this modality is sensitive, yet less specific, in the diagnosis of COVID-19 infection (9). When differentiating between COVID-19-related pneumonia from other pneumonia causes, a CT of the chest will add more to the early diagnosis of the disease. However, it should be known that it is still hard to differentiate between COVID-19-related pneumonia and other causes of viral pneumonia that also showed GGO and consolidations **[9]**.

Viral pneumonia showed main five characteristics on chest CT, including GGO and consolidation, nodules and tree-in-bud opacities, interlobular septal thickening, bronchial and/or bronchiolar wall thickening and, finally, a mosaic attenuation pattern **[10]**.

In our study, we analyzed the whole CT features that were present in 207 PCR-positive COVID-19 patients, of whom 179 showed positive chest CT findings and 28 of had negative findings. all patients with confirmed COVID-19 & hospitalized experienced moderate to severe symptoms and CT chest imaging added to clinical and laboratory assessment to direct therapeutic management.

The most common changes identified in our study included bilateral areas of GGO and, to a lesser extent, peripheral parenchymal bands and peripheral consolidation (Figs. 5,6).

We also showed that COVID-19-related pneumonia is more commonly multi-segmented, with either lower lobe predominance or a diffuse distribution. Chen et al., with their study of 99 patients, found that bilateral affection was seen in 75% of patients **[2]**, compared to our study which had 81.6% bilateral multi-segmental affection.

We found that most common features, as identified on chest CT, were GGOs and consolidations, seen in 87.1% and 41.3% of our patients, respectively. The consolidations were mainly peripherally sub-pleural in distribution, while GGOs could be either diffuse or peripherally sub-pleural with no preference. Our results were nearly similar to those of Chung et al. **[12]**, who studied 21 patients with COVID-19 pneumonia. The authors also noted areas of GGO and consolidation on chest CT that were distributed in the peripheral pulmonary areas.

In our study, peripheral parenchymal bands were seen in about half of all patients (52%), yet interstitial thickening and subpleural lines were seen in about a quarter of patients (28.5% and 26.8%, respectively). Nodules could be seen in 19.6% of patients, followed by the halo sign, which was found in 15.6%. The least common CT features were reverse halo sign and crazy paving, seen in 2.7% and 4.5% of patients, respectively. When compared to the findings of Bai **[11]**, who compared the CT features of COVID-19- and non-COVID-19-related pneumonia, the author found that GGOs were found in 91% of cases of COVID-19 pneumonia, while peripheral distribution was found in 80% of patients. In that study, interstitial thickening was found in 56% of patients, and reverse halo sign was seen in only 5% of patients.

In Chung et al.'s **[12]** study of 21 patients, GGOs were found in 57% of patients, while 29% had consolidations. A peripheral distribution was noted in 33% of patients. Reticulation and crazy paving were also less common and seen in 14% and 19% of patients, respectively. Also, the authors noted that about 76% of patients showed bilateral involvement.

Song et al., **[13]** with their study done on 51 patients, the CT chest images found high prevalence of ground glassing which was seen in 39 of 51 (77%) patients followed by consolidations which could be detected in 28 of 51 (55%) patients. 86% patients showed bilateral lung affection with 44 of 51 (86%) showed peripheral distribution.

Meta analysis done by Awulache, et al., on 5041 COVID 19 patients was comparable to our results as it also showed that 98% of patients had positive finding compared to 87.1 % in our study. Patients with positive CT chest had, bilateral involvement of chest in 80% of patients compared to 81.6% in our study. Ground-glass opacity was observed in 65% patients, compared to 87% in our study & consolidations were seen in 22% patients, compared to 41.3% in this our patients diagnosed with COVID-19 pneumonia. Interstitial thickening was detected in about 27% patients, nearly same as our study which showed 28.5% of patients with interstitial thickening **[14]**.

We found other pulmonary complications in our study, such as pneumothorax and pneumomediastinum, yet those were complications associated with intubation. Furthermore, ARDS was noted in two patients, and a few patients developed pleural effusion and thickening, which were secondary to superadded pulmonary bacterial infection.

All patients who developed additional thoracic complications during our study period, such as pericardial effusion, multiorgan failure, hemorrhagic encephalitis and pancreatitis, and pontine infarctions, had died.

Our study confirmed and agreed with most of the research work done on CT chest finding in patients diagnosed positive for COVID 19 infection, yet still need to be applied on larger centers distributed in different areas of the country. As the main drawbacks was doing our research in local center.

Conclusions:

In conclusion, our study was performed on a COVID-19-positive patients admitted in our facility & underwent CT chest according to clinical recommendation. The main CT features seen in COV ID-19-related pneumonia were GGO, consolidations, and peripheral parenchymal bands. COVID-19-related pneumonia was mainly multi-segmental in affection, and it had mainly diffused zonal predominance. Other features, which were also seen in about a quarter of patients, were sub-pleural lines and interstitial thickening. Negative CT chest was seen in non-small proportion of positive patients denoting that negative CT chest doesn't exclude positive clinically significant disease.

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مظاهر الأشعة المقطعية للصدر فى المرضى الذين يعانون من الالتهاب الرئوى COVID-19

منذ بدء فاشية COVID-19 فى ووهان، الصين، فى ديسمبر ٢٠١٩، انتشر الفيروس بسرعة من إنسان إلى آخر وأعلنت منظمة الصحة العالمية أنه وباء فى ١٢ مارس ٢٠٢٠.

كان يتم التشخيص عن طريق إيجابية تفاعل البوليميراز المتسلسل (RT-PCR). ومع ذلك، فإن حساسية التحليل محدودة (٧١٪). كان التصوير المقطعى الصدرى طريقة سهلة وسريعة ولتشخيص الالتهاب الرئوى مع حساسية ٩٨٪ فى تشخيص المرضى الذين يعانون من الالتهاب الرئوى COVID-19.

الهدف من دراستنا هو تحليل مختلف ميزات التصوير المقطعى المحوسب فى المرضى الذين يعانون من COVID-19 الإيجابية للوصول إلى أهم سمة الصدر فى المرضى الذين يعانون من التهاب رئوى COVID-19.