Diagnostic performance of chest computed tomography in coronavirus disease 2019 infection and its correlation with disease severity

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Introduction

Coronavirus disease 2019 (COVID-19) pneumonia is a recently diagnosed rapidly spreading acute respiratory syndrome. Real-time reverse-transcription (RT-PCR) testing for COVID-19 pneumonia is the standard for diagnostic confirmation. Because of low sensitivity rates of RT-PCR and the need for rapid diagnosis, noncontrast computed tomography (CT) of the chest has been regularly used in the current pandemic situation.

Aim

The aim of this study was to assess the diagnostic performance of CT chest and to grade the severity of lung involvement in COVID-19 infection.

Results

With RT-PCR serving as a reference standard, sensitivity, specificity, and accuracy of chest CT in COVID-19 pneumonia were 98.8, 58, and 72%, respectively. According to CT severity score, 66.7% of patients were mild cases, whereas 33.3% were severe. The most frequent CT chest finding was ground-glass opacities (98.9%). Most of the cases presented with bilateral and lower lobe involvement with peripheral distribution (88.9%). However, both peripheral and central distributions showed significant correlation with disease severity ($P<0.1$). Moreover, a significant correlation was found between CT severity score and crazy paving pattern, as it was present in 76.7% of severe cases ($P<0.1$).

Conclusion

CT of the chest is a valid imaging method for assessing the extent and severity of COVID-19 pneumonia and can be used as a standard method in early management of patients.

Keywords:
coronavirus disease 2019, computed tomography, diagnostic performance

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Introduction

Coronavirus disease 2019 (COVID-19) pneumonia is a recently diagnosed rapidly spreading acute respiratory syndrome [1]. Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), a novel coronavirus, was found to be associated with an outbreak of unexplained viral pneumonia initially started in Wuhan, China, in December 2019. The disease later called COVID-19 has affected a lot of people all over the world and was declared as a pandemic by the WHO on March 11, 2020 [2].

The mode of transmission of COVID-19 is in the form of respiratory droplets. One of the common manifestations of the disease is lower respiratory tract infection with clinical progression to acute respiratory distress syndrome in 17–29% of cases [3,4].

Real-time reverse-transcription (RT-PCR) testing for COVID-19 pneumonia is the standard for diagnostic confirmation. The specificity of RT-PCR is ~95%, but the sensitivity at initial presentation is 60–71% because of kit performance, sampling, and transportation limitations [5]. Because of these low sensitivity rates of RT-PCR and the need for rapid diagnosis, noncontrast computed tomography (CT) of the chest has been regularly used in the current pandemic situation [6].

The sensitivity of a diagnostic test in a communicable disease is very important because a false-negative finding may result in large outbreaks among future contacts [7]. Therefore, CT of the chest is progressively recognized as a valid method for early diagnosis, because the pulmonary changes in chest imaging sometimes may be detected earlier than the clinical symptoms [8].

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CT chest shows different pathological changes in the lung such as ground-glass opacities (GGO), consolidations, crazy paving, vascular dilatations, traction bronchiectasis, subpleural bands, and architectural distortion; different radiological patterns are observed at different times throughout the disease course [9,10]. Multilobar lung involvement is seen in the majority of cases, and the right lower lobe is the most commonly affected lobe [11].

Patients with COVID-19 pneumonia may present with different disease severity, from mild to critical forms. As severe cases can progress to acute respiratory distress syndrome or death, their identification is very important to promptly start the right treatment [12]. Computed tomography severity score (CT-SS) can provide an objective approach in rapidly identifying patients in need of hospital admission. The CT-SS is an adjustment of a method previously used in patients with SARS to describe the extent of the disease in the lungs, which was correlated with clinical and laboratory parameters [13]. The median CT score of patients with severe disease is significantly higher compared with patients with mild symptoms [14].

The aim of this study was to assess the diagnostic performance of CT chest and to grade the severity of lung involvement in cases with COVID-19 infection.

Patients and methods

The local institutional review board approved this retrospective study and waived the need for written informed consent.

Study population

We retrospectively studied the CT chest of patients diagnosed with COVID-19 from November 10, 2020 to May 30, 2021. This study involved 205 patients, and among them, 90 patients had COVID-19, confirmed by positive RT-PCR test results. All cases were referred from the COVID clinic to the Radiology Department for noncontrast CT chest.

Inclusion criteria were as follows:

(1) Clinically suspected SARS-CoV-2 infection.
(2) Having performed a chest CT scan in the emergency department.
(3) Having undergone RT-PCR assays within 7 days of the CT scan.

Exclusion criteria were as follows

(1) Severe motion artifacts in the CT scan.
(2) Unknown RT-PCR.
(3) Having undergone a chest CT and an RT-PCR test with a time interval of more than 7 days.

Methods

All patients completed a prescreening questionnaire about COVID-19 symptoms to collect specific clinical information pertaining to fever, cough, and dyspnea. Specific blood tests (COVID-19 panel) and nasopharyngeal or oropharyngeal swabs were obtained for each patient. To confirm a positive SARS-CoV-2, RT-PCR was used.

CT of the chest was performed using a Siemens Healthineers 16-detector CT scanner. CT images were taken at the end of full inspiration from the apex of the lung to the costophrenic angle in the supine position. Reconstruction was performed with thin slice thickness for axial and coronal images in lung and mediastinal window. Complementary minimum intensity projection (MinIP) images were also reconstructed to detect faint GGO.

Image analysis

Each study was reviewed by two radiologists with 10–15 years of experience, and findings were reached in consensus. The radiologists recorded the presence of any of the following findings: GGO, consolidation, crazy paving, halo sign, reversed halo sign, septal thickening, parenchymal bands, vascular dilatation, spider-web, bronchiectasis, pleural thickening or effusion, and lymphadenopathy. The lesions' distribution was also recorded. Then, the CT-SS was calculated independently by the two radiologist and averaged between them.

A semiquantitative scoring system was used to quantitatively estimate the pulmonary involvement of all these abnormalities based on the region involved. The CT-SS was calculated based on the extent of lobar involvement. Each of the five lung lobes was visually scored on a scale of 0–5, with 0 indicates no involvement, 1 indicates less than 5% involvement, 2 indicates 5–25% involvement, 3 indicates 26–49% involvement, 4 indicates 50–75% involvement, and 5 indicates more than 75% involvement. The total CT score was the sum of each lobar scores and ranged from 0 (no involvement) to 25 (maximum involvement) [15,16].

Statistical analysis

Statistical analysis was performed by using STATA/IC11 software [Timberlake Consultants (Middle East) (Dubai, UAE)]. Continuous data were expressed as mean or median, whereas categorical data were expressed as counts with percentages. Statistical correlation was assessed by Pearson χ^2 or Bonferroni test.

The diagnostic performance of CT was assessed by measuring sensitivity, specificity, positive predictive value, negative predictive value, and diagnostic accuracy, considering RT-PCR as the reference standard.

Results

The study population included 205 consecutive participants, including 123 (60%) males and 82 (40%) females. Their age ranged from 25 to 87 years, with a mean age of 55.37±12.679 years.

Of the 205 participants, 143 (70%) patients presented with fever, whereas only four (2%) patients presented with diarrhea. The presenting symptoms in our study and their frequency are recorded in Table 1.

Of the 205 patients, 90 (43.9%) had positive RT-PCR results and 137 (66.8%) had positive CT findings. To understand the CT features of patients with COVID-19 pneumonia, a subanalysis was performed considering only study participants with positive RT-PCR test results and chest CT findings, which were 89 patients. With RT-PCR serving as the reference standard, sensitivity, specificity, positive predictive value, negative predictive value, and accuracy of CT for COVID-19 diagnosis were 98.8, 58, 65, 98, and 72%, respectively.

Average CT-SS in our study was found to be 13.68, ranging from 3 to 24. The mild group (CT-SS of 1–17) consisted of 59 (66.7%) patients, whereas the severe group (CT-SS of 18–25) consisted of 30 (33.3 %) patients.

According to disease distribution, all of the cases presented with bilateral findings, and most of them had lower lobe involvement with peripheral distribution as presented in Table 2.

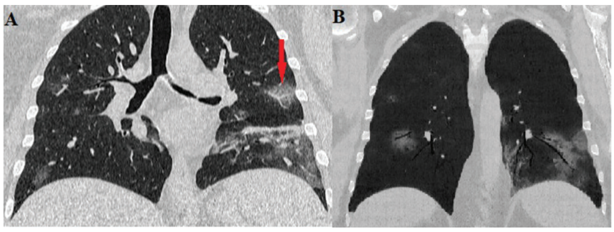
A significant correlation was found between CT-SS and peripheral distribution, both peripheral and central, and both upper and lower lung lobe disease distribution, yet no significant correlation was found between CT-SS and central distribution, upper lung lobe predilection, or lower lung lobe predilection.

The most frequent CT abnormalities observed were GGO in 89 (98.9%) patients followed by vascular dilatation in 83 (92.22%) patients (Fig. 1), and parenchymal bands in 71 (78.89%) patients (Fig. 2).

Table 1 The common presenting symptoms in our study and their frequency

Clinical manifestations	*n* (%)
No complain	16 (7.8)
Fever	143 (70)
Cough	138 (67.3)
Dyspnea	72 (36.6)
Tachypnea	9 (4.4)
Sore throat	27 (13.3)
Fatigue	43 (21)
Pleuritic pain	9 (4.4)
Abdominal pain	9 (4.40)
Diarrhea	4 (2)
Chronic lung disease	57 (27.80)

Figure 1



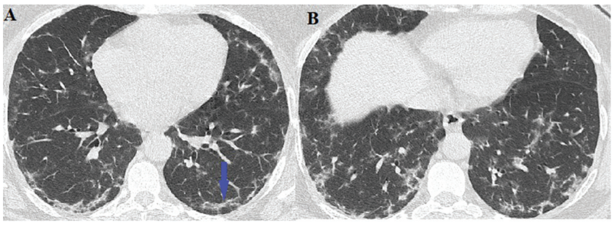
CT of the chest in (a) coronal lung window image and (b) coronal MinIP image showing bilateral predominantly peripheral patchy GGOs, with vascular dilatation (red arrow). CT-SS: 11/25. CT, computed tomography; CT-SS, computed tomography severity score; GGO, ground-glass opacities; MinIP, minimum intensity projection.

Table 2 The frequency of lesion distribution and their correlation with computed tomography severity score

Site affected	Frequency	Percentage	*P* value	Pearson correlation	Significance (2-tailed)
Peripheral	80	88.9	0.003*	−0.350**	0.001
Central	1	1.1	0.155	0.150	0.158
Both	9	10.0	0.006*	0.314**	0.003
Upper lung lobe	8	8.9	0.714	−0.055	0.605
Lower lung lobe	58	64.4	0.119	−0.164	0.122
Both upper and lower lung lobes	24	26.7	0.043*	0.213*	0.044

Correlation is significant at the 0.01 level (2-tailed). Correspondence to Correlation is significant at the 0.05 level (2-tailed). *P* value less than 0.1: significant.

Figure 2



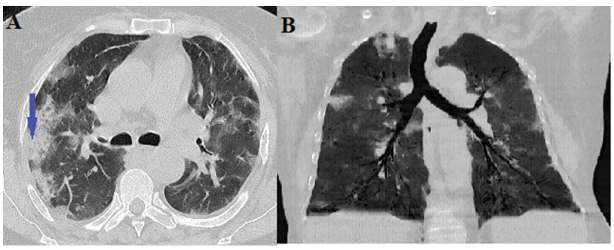
CT of the chest in (a and b) axial lung window images bilateral predominantly peripheral patchy ground-glass opacities with bilateral subpleural peri-lobular densities and fibrotic stripes forming the spider web sign (blue arrow). CT-SS: 15/25. CT, computed tomography; CT-SS, computed tomography severity score.

Table 3 The frequency of the main computed tomography chest imaging findings and their correlation with computed tomography severity score

CT chest finding	*n* (Percentage)	*P* value	Pearson correlation	Significance (2-tailed)
GGO	89 (98.9)	1	0.075	0.483
Consolidation	39 (43.3)	0.071	0.190	0.072
Crazy paving	32 (35.55)	0.000#	0.607**	0.000
Reverse halo sign	12 (13.33)	0.048#	–0.208*	0.049
Interlobular septal thickening	68 (75.55)	0.001#	0.347**	0.001
Traction bronchiectasis	63 (70)	0.027#	0.257*	0.014

GGO, ground-glass opacities. **Correlation is significant at the 0.01 level (2-tailed). *Correlation is significant at the 0.05 level (2-tailed). #*P* value less than 0.1: significant.

Figure 3

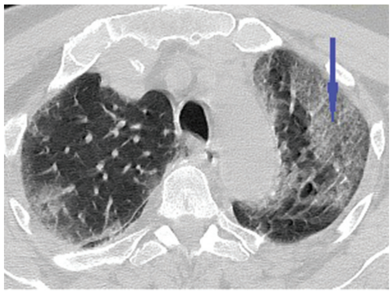


CT of the chest in (a) axial lung window image and (b) coronal MinIP image showing bilateral peripheral GGOs and consolidation (blue arrow). CT-SS: 12/25. CT, computed tomography; CT-SS, computed tomography severity score; GGO, ground-glass opacities; MinIP, minimum intensity projection.

The main CT chest findings and their frequency are displayed in Table 3.

No significant correlation was found between GGO or consolidation and CT-SS (Fig. 3). However, a significant correlation was found between CT-SS and crazy paving sign (Fig. 4), as it was present in 76.7% of severe cases and in 15.25% of mild cases; reverse halo sign, as it was present in 18.6% of mild cases and in 3.3% of severe cases; interlobular septal thickening, as it was present in 66.0% of mild cases and in 96.7% of severe cases; and traction bronchiectasis, which was present in 62.7% of mild cases and in 86.7% of severe cases.

Figure 4



CT of the chest in axial lung window image showing bilateral predominantly peripheral GGOs with crazy paving pattern (blue arrows). CT-SS: 12/25. CT, computed tomography; CT-SS, computed tomography severity score; GGO, ground-glass opacities.

Table 4 The frequency of other computed tomography chest imaging findings and their correlation with computed tomography severity score

CT chest findings	*n* (%)	Correlations	
Halo sign	7 (7.77)	Pearson correlation	–0.205
		Significance (2-tailed)	0.052
Parenchymal bands	71 (78.89)	Pearson correlation	0.135
		Significance (2-tailed)	0.205
Spider web	8 (8.89)	Pearson correlation	0.110
		Significance (2-tailed)	0.300
Vascular thickening	83 (92.22)	Pearson correlation	0.205
		Significance (2-tailed)	0.052
Pleural thickening	70 (77.78)	Pearson correlation	0.094
		Significance (2-tailed)	0.376
Pleural effusion	1 (1.1)	Pearson correlation	0.150
		Significance (2-tailed)	0.158
Lymphadenopathy	33 (36.67)	Pearson correlation	0.098
		Significance (2-tailed)	0.359

Correlation is significant at the 0.01 level (2-tailed). Correlation is significant at the 0.05 level (2-tailed).

There was no significant correlation with any of the other CT chest findings as illustrated in Table 4.

Discussion

COVID-19 was first discovered in Wuhan, China, in early December 2019 [17]. CT chest plays a pivotal role for early detection of COVID-19, as well as in managing and monitoring the course of disease [18]. The CT-SS of COVID-19 pneumonia had a great significance in assessing the extent of disease and in predicting the dynamic changes by CT follow-up examinations [19].

We studied the chest CTs of 205 participants and found a greater number of male patients than female patients, which was consistent with the study done by Fang *et al.* [10] The reduced susceptibility of females to viral infections might be attributed to the protection from X chromosome and sex hormones, which play an important role in innate and adaptive immunity [20].

In accordance with the previous study by Yang *et al.* [13], we found fever, cough, and dyspnea to be the most common manifestations in COVID-19.

Correlation of chest CT and RT-PCR testing in COVID-19 proved that CT of the chest had a sensitivity of 98.9%, specificity of 58%, and accuracy of 72%. These results were consistent with a previous study by Ai *et al.* [5], which reported that CT has 97% sensitivity, specificity of 25%, and accuracy of 68% in diagnosing COVID-19.

In concordance with our study, all other studies reported that COVID-19 had typical peripheral distribution, and most patients presented with multiple lobes involvement, particularly the lower lobes [21–24].

Moreover, in agreement with our study, all previous studies reported that the main CT chest feature of COVID-19 pneumonia is the presence of multifocal bilateral patchy GGOs with interlobular septal and vascular thickening with or without consolidation [21,23,25–28].

Although crazy paving pattern in our study was encountered in 35.6% of cases, the study by Wu *et al.* [27] reported crazy paving pattern in 76.9% of cases.In our study, we found only one case of pleural effusion, similar to the studies by Wen *et al.* [22] and Caruso *et al.* [29]. Thus, we can say that pleural effusion is a rare finding in COVID-19.

Lymphadenopathy was observed in 36.6% of patients in our study, and it showed no significant correlation with disease severity. However, a study by Valette *et al.* [30] reported high incidence of lymphadenopathy (66%) in patients admitted to ICU, and they considered it a sign of critically ill patients.

In this study, the lobar involvement scoring system (0–25) was used as it was practical and time saving with such a high flow of cases [15,16].

We found a significant correlation between CT-SS and crazy paving sign, reverse halo sign, and traction bronchiectasis. Likewise, the study by Pan *et al.* [16] reported that crazy paving sign indicates that the disease is in the severe stage. Other studies by Farias *et al.* [31] and Wu *et al.* [32]found that the reverse halo signs were more common in advanced disease than early disease. Moreover, the study by Li *et al.* [33] reported that the frequency of bronchiectasis was more common in patients with severe disease.

There were some limitations in this study. First, these observations were restricted only to the patients presenting to a tertiary hospital and most of them admitted for treatment and isolation. Second, we included in CT chest assessment patients without laboratory confirmation of COVID-19 pneumonia based on their typical CT imaging features.

In conclusion, CT of the chest is a valid imaging method for assessing the extent and severity of the COVID-19 pneumonia and can be used as a standard method in early management of patients.

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Authors' contributions: S.F.T. and M.A.F.H. reviewed the images. S.F.T., Y.H.E.H., D.M.N., and M.A.F.H. analyzed and interpreted the patient data. S.F.T. wrote the manuscript, and M.A.F.H. reviewed it.

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Conflicts of interest
There are no conflicts of interest.

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