

High-resolution chest computed tomography findings of coronavirus disease 2019 (COVID-19) – A retrospective single center study of 152 patients

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ABSTRACT

Introduction: Coronavirus disease 2019 (COVID-19) pandemic has engulfed the world, within a short span of time crippling many health systems. The disease in its ever-evolving course is exhibiting a myriad of symptoms and imaging manifestations. This retrospective study was conducted to generate evidence from the chest computed tomography (CT) findings of patients with COVID-19 pneumonia to aid in the diagnosis and disease management. **Methods:** This retrospective study included all patients with reverse transcriptase polymerase chain reaction confirmed COVID-19 disease who underwent chest CT between 1st June to 31st December 2020 at a tertiary care institute of North India. Anonymized data of 152 COVID-19 positive patients was used for the evaluation of the clinical profile and imaging findings. **Results:** The common presenting clinical symptoms were fever, cough, myalgia and sore throat. The most frequent CT imaging feature consisted of ground-glass opacities (GGOs), consolidation and crazy paving distributed bilaterally, peripherally in subpleural location with a predilection for the posterior parts of lungs. Reverse halo sign was observed in 12 patients and halo sign in 3 patients. Dilated pulmonary vessels with mild bronchiolectasis were observed in the involved lung parenchyma. Less common findings included pleural effusion, mediastinal lymphadenopathy, and pericardial effusion. The mean CT severity score gradually increased with increasing age. **Conclusion:** The predominant imaging finding of COVID-19 pneumonia was peripheral GGO's distributed bilaterally in peripheral subpleural region and having predilection for the posterior parts of the lungs which gradually evolve into organizing pneumonia patterns. Although COVID-19 shares imaging findings with other viral pneumonias, however in the context of the current pandemic, we must keep COVID-19 a differential diagnosis, in all patients with fever and respiratory symptoms.

Keywords: Chest computed tomography, Coronavirus, COVID-19, pneumonia

Introduction

In December 2019, an atypical viral infection, coronavirus disease 2019 (COVID-19) was first reported in Wuhan, Hubei Province

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of China, caused by a novel Corona virus named SARS CoV-2.^[1,2] Since then, the disease has made rapid strides across the globe coercing the World Health Organization to declare it a global health emergency on January 30,2020.^[3] Spread by respiratory droplets and direct contact are the most common modes of transmission of the disease.^[4,5] With no major pharmacological breakthrough, till date early detection and isolation remains the most viable option to control the spread of disease. Till date

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reverse transcriptase polymerase chain reaction (RT-PCR) is considered as the gold standard to confirm the diagnosis of COVID-19 infection, but an increasing number of false-negative rates are being reported with RT-PCR, especially when viral load is low, or the sample is inadequate.^[6,7] Due to increasing number of false negative RT-PCR reports, computed tomography (CT) imaging is preferred alternative to evaluate patients presenting with COVID-19 infection for early diagnosis and isolation. With more mutant strains of the virus being increasingly reported, changes in the viral nucleic acid and protein sequences jeopardize the utility of some of the diagnostic assays if the mutation occurs in a portion relevant for primer or antibody binding in RT-PCR and immunoassays.^[8] Since COVID -19 is a rapidly evolving disease with a multitude of symptoms, primary care physicians need to be well acquainted with rapidly evolving imaging patterns of this emerging infection. With this background, we characterize the chest CT findings in 152 patients to establish the typical CT imaging findings of COVID-19 pneumonia.

Methods

This retrospective study included patients who were confirmed positive for COVID-19 by RT-PCR nasopharyngeal sample and underwent chest CT imaging at a single center of North India. Consecutive sampling was used and patients were enrolled from 1st June to 31st December 2020. The purpose of the study was explained to the study participants and written consent was obtained before the procedure. CT was chosen as the diagnostic modality over chest radiography as it is more sensitive to detect lung opacities. Moreover, CT findings may be present early in the disease before the onset of symptoms.

Computed tomography acquisition

Patients underwent non-contrast chest CT scans on Philips Ingenuity 128 slice CT machine. Adhering to the protocols, axial 5 mm sections were taken from supraclavicular region to costophrenic angle in supine position at end inspiratory phase. Thin planner reconstruction with 1 mm thin sections was done. The reconstructed images were transferred to workstation and picture archiving and communication systems for multiplanar reconstruction post-processing and reporting.

Image interpretation

Two experienced thoracic radiologists (with 6-8 years of experience) blinded to the clinical data examined and reviewed the CT images independently. Discrepancy, if any was resolved by mutual discussion and consensus as per the academic guidelines. CT images of each patient were assessed for the presence of ground-glass opacities, crazy paving, and consolidations. When present, related features such as fibrosis, subpleural lines, halo sign, reversed halo sign, pleural effusion, and lymphadenopathy were also documented.

A semi-quantitative CT severity scoring proposed by Pan *et al.*^[9] was calculated for each of the five lobes considering the extent

of anatomic involvement, as follows: 0, no involvement; 1, <5% involvement; 2, 5–25% involvement; 3, 26–50% involvement; 4, 51–75% involvement; and 5, >75% involvement. The resulting global CT score was the sum of each lobar score (0 to 25).

Statistical analysis

Data were recorded in Microsoft Excel Sheet. Data were analyzed using SPSS software (Version 19.0. Armonk, NY: IBM Corp). Frequency was expressed using proportion and percentages. Normally distributed data were presented as mean (\pm SD), and categorical variables as frequency (%).

Ethical approval

This retrospective study was approved by the Institute Ethics Committee vide letter number IEC/AIIMS/BTI/081. All necessary protocols were adhered to before the procedure and confidentiality was maintained.

Results

In this study, we evaluated 152 patients with COVID -19 pneumonia. The majority of patients were between 51 and 60 years with mean age distribution of 54 + 14 years. Out of 152 patients, 115 were males, and 37 were females [Table 1].

The most common presenting symptom was fever in 148 patients (97.4%). The other common symptoms were cough in 78 (51.3%), myalgia in 41 (27%), sore throat in 36 (23.7%), dyspnea and chest discomfort in 31 (20.4%). Some patients reported diarrhea 10 (6.6%) as one of the symptoms [Figure 1].

Imaging findings at initial chest CT scan are highlighted in Table 2. Most common pattern on imaging was GGO's and consolidation [Figure 2]. Reverse halo sign was observed in 12 patients and halo sign in 3 patients. Majority of patients (79.6%) had both the lungs involved while 10% of patients had unilateral lung involvement. The right lung was more frequently involved than the left lung and posterior segments were more frequently involved. The disease was peripheral subpleural in distribution. The lobe most frequently involved was the right lower in 84.2%, followed by the left lower lobe in

Table 1: Demographic characteristics of the study population

	Number of patients
Age group (in years)	
<30	10
30-40	18
40-50	24
50-60	48
60-70	37
>70	15
Gender	
Male	115
Female	37

77.6%. The right middle lobe was least involved in only 58.5% of patients. Mean CT severity score gradually increased with an increasing age group and was maximum for patients above 70 years (P value = 0.048) [Figure 3]. Among airway abnormalities, peri-bronchial wall thickening was present in 55 patients (36.2%) and mild bronchiectasis in 14 (9%) of patients. Mild pleural effusion was seen in five patients, mediastinal lymphadenopathy in five, and pericardial effusion in one patient. Atelectatic bands were seen in 5 patients and subpleural lines in 31 patients.

Discussion

Symptoms of COVID-19 are variable and non-specific with an evolving course. Dyspnea may occur in severe cases and may progress to acute respiratory distress syndrome, septic shock,

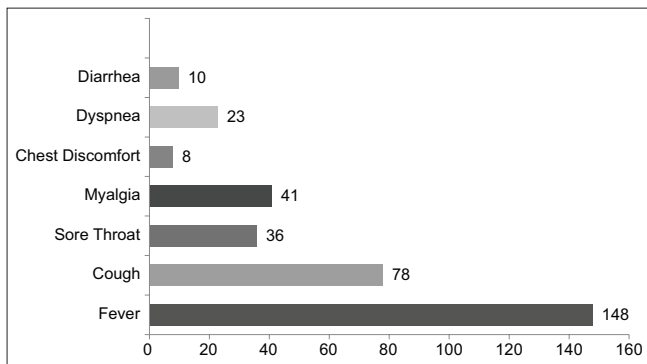


Figure 1: Distribution of cases as per symptoms

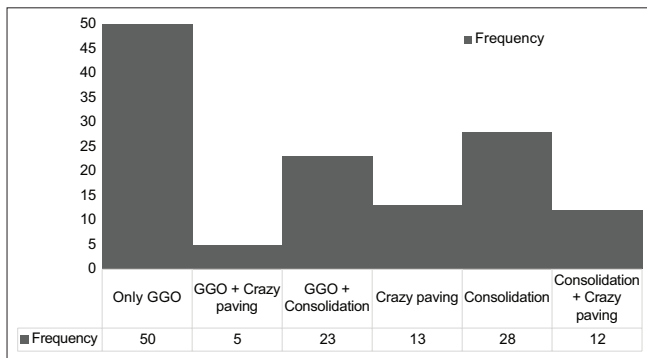


Figure 2: Pattern of lesions on high resolution computed tomography (HRCT)

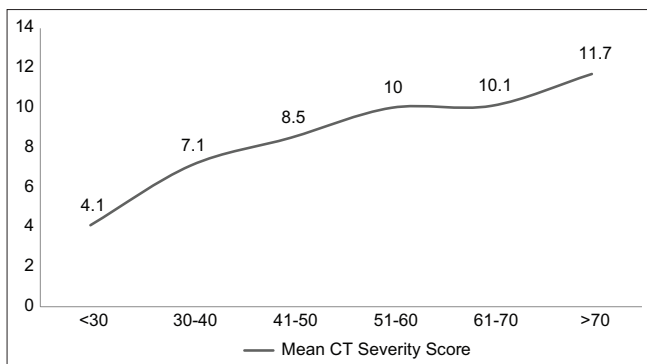


Figure 3: Relation of mean CT severity score with age

Table 2: Imaging findings of patients with SARS-CoV-2 at presentation

Variables	Presentation	Number	
Pattern of lesion	Only GGO	50	
	GGO + Crazy paving	05	
	GGO + Consolidation	23	
	Crazy paving	13	
	Consolidation	28	
	Consolidation + Crazy paving	12	
	Other findings	Subpleural line	31
		Atelectatic bands	05
		Halo Sign	03
		Reverse halo sign	12
White out lung		03	
Pleural effusion		05	
Pericardial effusion		01	
Mediastinal lymphadenopathy		05	
Airway changes	Bronchiectasis	14	
	Bronchial wall thickening	55	
	Mucus plugging	00	
	None	94	
Distribution	Peripheral subpleural	106	
	Diffuse	29	
	Peri-bronchovascular	00	
	Anterior	2	
	Posterior	72	
	Anterior + Posterior	62	
Lung involved	Bilateral	121	
	Unilateral	15	
Frequency of lobe involvement	Right upper lobe	111	
	Right middle lobe	89	
	Right lower lobe	128	
	Left upper lobe	108	
	Left lower lobe	118	
	CT severity score for each lobe	Right upper lobe	41
		33	
		42	
		12	
		14	
		10	
	Right middle lobe	63	
		45	
		19	
		10	
		06	
		09	
	Right lower lobe	24	
		19	
		36	
		21	
		22	
		30	
	Left upper lobe	44	
		31	
		45	
		14	
		11	
		07	

Contd...

Table 2: Contd...

Variables	Presentation	Number
	Left lower lobe	34
		20
		39
		18
		14
		27

refractory metabolic acidosis, and coagulation dysfunction.^[10] Majority of the patients in the present study presented with fever (97.4%) followed by cough (51.3%) and myalgia (27%). Due to non-specificity of the presenting complaints, imaging is vital to establish the diagnosis of COVID-19 pneumonia and assess the disease severity.

Chest X-ray, being portable, simple and cheap, is the initial imaging modality of choice for investigating patients with COVID-19 pneumonia.^[11] However, its sensitivity remains low as the ground glass opacities found during the initial stages of COVID-19 pneumonia may not be visible on chest X-ray. Also, the predominant distribution of these opacities is peripheral subpleural and in posterior parts of the lungs, which may be obscured by the overlying anatomical structures. Chest X-rays can be used for close quantitative evaluation of disease in very sick patients who are too sick to be shifted for imaging or when a CT scan facility is not available.^[12]

Present literature assessing COVID-19 findings suggest that CT is more sensitive than other radiological investigations (i.e., X ray) especially in the initial assessment of the patients.^[13] Shi *et al.*^[14] demonstrated the presence of ground-glass opacities in 15 asymptomatic patients of COVID-19. They proved CT scan to be a highly sensitive modality in diagnosing patients with high clinical suspicion and false-negative RT-PCR results. CT scan can be considered an essential step in the diagnostic algorithm of COVID-19 pneumonia.

In present study common CT imaging features of COVID-19 include GGO's (ground glass opacities) distributed peripherally in posterior parts of lungs in subpleural location followed by consolidation and crazy paving. The GGO's had rounded or wedge-shaped configuration with ill-defined margins. It is proposed that Chest CT findings depend on the disease course and disease severity.^[6,15] In retrospective study of CT images of 21 patients, Pan *et al.*^[9] demonstrated GGO's during the early course of the disease, followed by the development of crazy paving and consolidation in later stages. In the present study, the most common presentation was pure GGO's in 33% of patients followed by consolidation in 18.4% and GGO with consolidation in 15%. Twenty-one patients with positive RT-PCR status had no imaging findings on CT scans. Imaging at an earlier stage of disease might be one of the reasons. In the study of 121 patients with confirmed COVID-19 status, 56% (20 of the 36) of patients had a normal CT scan when imaged in early phase i.e., 0-2 days after symptom onset contrary

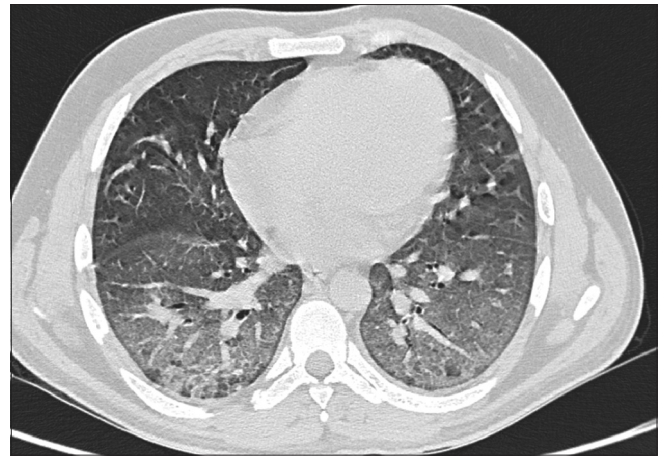


Image 1: Axial non-contrast CT chest of 31-year-old male showing GGO's distributed posteriorly in both the lungs. Multiple air-bronchograms and dilated vessels are seen in the involved lobes

to imaging findings in patients imaged during intermediate and late phase.^[16]

The majority of patients had bilateral multifocal distribution with a predilection for posterior parts of the lung. Similar characteristics were found in another study, which proved that most pulmonary lesions were mainly distributed in the posterior and peripheral part of the lungs bilaterally involving multiple lobes.^[17] In current study, anterior segments of lungs were involved in only in severe cases and later in the disease.

Out of 152, 121 patients had bilateral lung involvement, whereas 15 patients had unilateral lung involvement. In unilateral lung disease, the right lung was more frequently involved than the left lung. The right lower lobe was the first lobe to be involved and was more severely affected than other lung lobes. Similar findings have been reported in a study on 81 patients in Wuhan, which proposed that short and straight right bronchus might be causing the virus to favor this location.^[14] In a systematic review of imaging findings of COVID-19 pneumonia, GGO's were seen mainly in the lower lobe and less frequently in the middle lobe.^[18] The mean CT severity score gradually increased with increasing age and was maximum for age group >70 years.

Reverse halo sign was seen in 8% of patients and halo sign in 2%, which was slightly higher than that reported in the literature. The studies had reported its presence in 2% and 3% of COVID-19 patients.^[16,19] Reverse halo sign can be due to organizing pneumonitis in viral or fungal infection, and halo sign can also represent organizing pneumonia and viral infection such as COVID-19.^[17,20] Halo sign has been described as a chest CT finding in various case reports.^[21-23]

Mild bronchiectasis was seen in the involved lung segments in 14 patients, and peri-bronchial wall thickening was present in 55 patients. Other less common findings in present study included mediastinal lymphadenopathy in one patients, pleural effusion

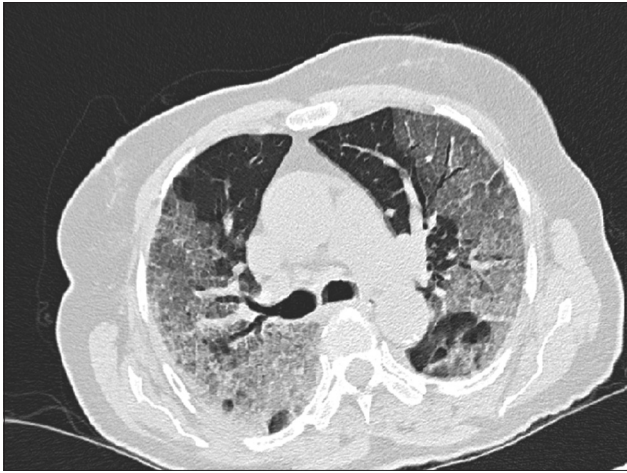


Image 2: Axial non-contrast CT chest of 73-year-old female with COVID-19 pneumonia showing crazy paving manifesting as GGO's along with interlobular septal thickening and air bronchograms in both lungs

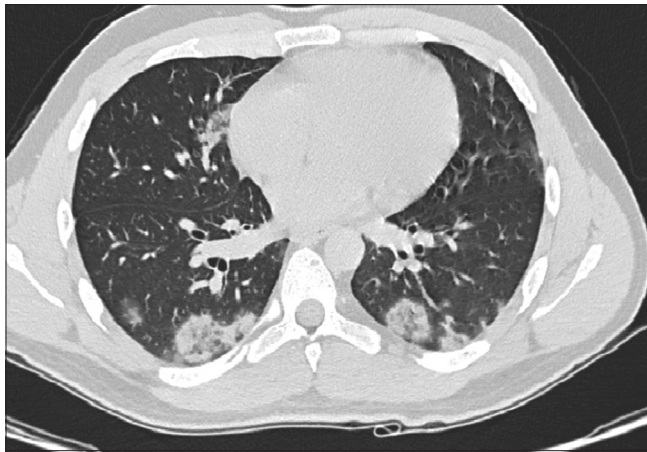


Image 3: Axial non-contrast CT chest of 27-year-old male showing consolidations with rounded configuration in subpleural areas of both lower lobes as well as in right middle lobe

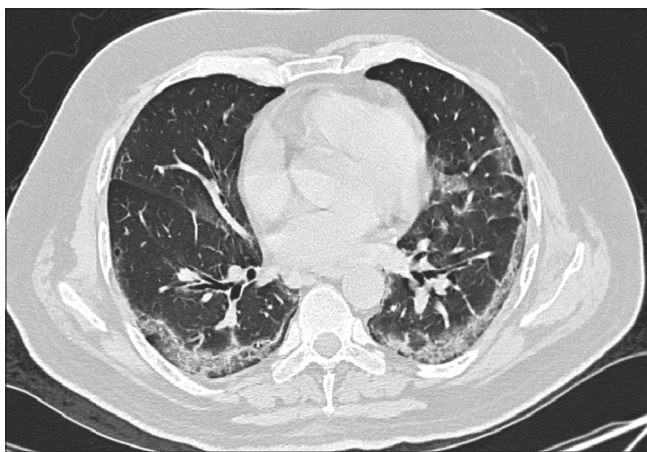


Image 4: Axial non-contrast CT Chest of 31-year-old male showing consolidation in both lungs with striking peripheral subpleural distribution. Mild bronchiectasis with peri-bronchial wall thickening seen in both the lower lobes

in one, and pericardial effusion in one patient. Atelectatic bands were found in five patients. There was no case of any cavitation, nodular lesions, tree in bud pattern, or mucus plugging in the airway.

Most of the patients in present study were above the age of 50 years (65.78%), probably due to a more severe course of the disease in this age group due to associated comorbidities. So, the older age group is more likely to undergo imaging evaluation. In our study, 115 patients out of 152 were men. However, no preference for any particular gender has been reported so far. This discrepancy might be due to different demographic characteristics of our cohort studied.

At times it may be difficult to distinguish COVID-19 pneumonia from other viral pneumonias, which manifest as diffuse large patches of GGO's with thickening of interlobular septum. However, COVID-19 pneumonia more frequently shows a peripheral predominance with paucity of pleural effusion and lymphadenopathy.^[24]

The imaging features of COVID -19 bear a resemblance to severe acute respiratory syndrome and Middle East respiratory syndrome. They all belong to the coronavirus family and show similar pathogenic mechanism. Avian influenza virus also shows large patches of GGO's and consolidation in the lungs. So, it is difficult to distinguish them based on imaging alone, and the use of pathogenic tests may aid in their discrimination.^[10]

Mycoplasma pneumonia patient's manifest with paroxysmal and irritant dry cough, and CT scans show centrilobular nodules and consolidations and mediastinal lymphadenopathy. Centrilobular nodules and mediastinal lymphadenopathy are not known in COVID-19 pneumonia. Bacterial pneumonia shows leukocytosis and neutrophilia and shows patches of consolidation in the peri-bronchial location on imaging.^[10]

There are some limitations to our study. First, it was a retrospective study, and anonymized data was used. This study could be affected by choice of patients who underwent imaging at these hospitals. Second, the disease has varied presentations at different stages of the disease. Review follow-up was not feasible of the patients, which could better equip us the pathophysiology of the disease and its evolution.

Conclusions

CT is a highly sensitive modality for diagnosing COVID-19 pneumonia. Typical imaging features include bilateral multifocal subpleural wedge-shaped or rounded GGO's with a predilection for the lower lobes and posterior parts of lungs. Knowledge about the novel clinical manifestations and chest imaging findings of COVID-19 needs to be disseminated among the primary care physicians so as to aid in early diagnosis, patient isolation, and patient management.

Abbreviations

CT – Computed Tomography
 COVID-19 – Coronavirus Disease 2019
 RT-PCR – Reverse Transcriptase Polymerase Chain Reaction
 GGO – Ground glass opacities
 WHO – World Health Organisation
 PACS – Picture Archiving and Communication System
 ARDS – Adult Respiratory Distress Syndrome
 SARS – Severe Acute Respiratory Syndrome
 MERS - Middle East Respiratory Syndrome
 SD – Standard Deviation

Key-points

- Chest CT is a highly sensitive modality for evaluating COVID-19 pneumonia
- It may not be possible to distinguish COVID-19 pneumonia from other viral pneumonias based on imaging alone due to overlapping imaging features
- Typical imaging features of COVID-19 pneumonia consists of bilateral multifocal subpleural wedge-shaped or rounded GGO's with or without areas of consolidation and interlobular septal thickening having predilection for the lower lobes and posterior parts of lungs.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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