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ORIGINAL ARTICLE

HRCT Manifestations of COVID-19 Infection: Clinico-Radiological Correlation

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Abstract

Background: Coronavirus disease 2019 (COVID-19) is an infectious disease caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). HRCT plays an essential role in the evaluation and clinical management of COVID-19. ***Purpose:*** To characterize the spectrum of HRCT findings in symptomatic COVID 19 patients and to correlate HRCT findings with clinical symptoms of the disease. ***Material and Methods:*** The study includes 100 symptomatic patients with COVID-19 disease. The patients were divided into two groups according to the duration of symptoms. The first group has been scanned within the first week of presentation while the second group has been scanned in the second week. ***Results:*** The HRCT findings include ground glass opacity (GGO), consolidation, bronchovascular thickening, crazy paving appearance, pulmonary nodules, subpleural bands/fibrosis and bronchiectasis. Pleural effusion, tree in bud appearance and cavitation were less commonly seen only in few of the patients. The distribution of CT changes amongst the two groups were as follows: bilateral changes were 78.5% vs 86.6%, central distribution was 10% vs 10%, peripheral distribution was 58.5% vs 36.6 % and diffuse (central and peripheral) distribution were 21.4% vs 40% while multilobar distribution were 64.2% vs 70 %. ***Conclusion:*** The spectrum of HRCT findings in COVID-19 infection include ground glass opacities, consolidations, bronchovascular thickening, crazy paving pattern, pulmonary nodule, pleural effusion, subpleural bands/fibrosis and bronchiectasis. The type, extent and distributions of pulmonary manifestations are significantly different between the two groups who have been scanned in the different stages of disease. Ground glass opacities and crazy paving pattern were more common in first week while the consolidations, subpleural bands and diffuse lung involvement were more common in the second week of illness.

Key Words

HRCT, COVID-19, CT, RT-PCR

Introduction

COVID-19 infection is a disease caused by a virus named severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). The diagnosis of COVID-19 requires the detection of the specific viral genetic material in the specimens collected from nose, blood, faeces or respiratory secretions. Lung injury caused by the COVID-19 infection in the form of acute respiratory distress has been seen in about 30% cases (1).

Older adults and people of any age who have underlying medical conditions, such as hypertension and diabetes, are more likely to develop a more severe course and progression of the disease and have shown worse prognosis (2). Diabetic patients have increased morbidity and mortality rates and have been linked to more

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hospitalization and intensive care unit admissions (2). People with chronic obstructive pulmonary disease (COPD) or any respiratory illness are also at higher risk for severe illness from COVID-19 (3).

HRCT plays an essential role in the evaluation of COVID-19 even, sometimes before the clinical symptoms become apparent (4). There is evidence of prognostic value of chest CT where a specific CT Score could predict the mortality of patients with COVID-19 (5). This study was thus done to characterize the spectrum of HRCT findings in symptomatic COVID 19 patients and to correlate the CT severity score with the clinical picture of patients who were confirmed to have COVID 19 disease using the 25-point visual quantitative assessment.

Material and Methods

The patients data was collected from Government Medical College, Jammu and Chest Disease & TB Hospital, Jammu. Hundred symptomatic patients with proven COVID-19 infection were enrolled in this study. The Institutional ethics committee of GMC, Jammu has approved this study.

High Resolution Computed Tomography of chest was carried out on dual slice Siemens Somatom Spirit machine with slice thickness of 1 mm and slice interval of 10 mm, pitch 1.2 mm, collimation 1-2 mm at 130 kvp and 45 mAs. Images were subjected to various post-processing such as multiplanar reconstruction (MPR), maximum intensity projection (MIP), minimum intensity projection (MinIP) and Volume Rendered Images.

Study Design: Cross-sectional Prospective Observational Study.

Inclusion Criteria: Laboratory confirmed (RTPCR proven) symptomatic cases of COVID-19 infection.

Exclusion Criteria: Asymptomatic COVID-19 patients and paediatric patients of less than 18 years.

HRCT Image Evaluation: Two radiologists have evaluated the CT images separately to identify the pulmonary changes and to determine the disease severity score in each patient. The scans were first assessed whether negative or positive for typical findings of COVID-19 pneumonia (bilateral, multilobar, posterior peripheral ground glass opacities) as defined by the RSNA Consensus statement (6,7). Severity was then assessed using the following scoring system which depends on the visual assessment of each lobe involved (8,9,10). Each lobe was assigned a score that was based on the percentage of lobar involvement: score 0, 0% involvement; score 1, less than 5 % involvement; score 2, 5%-25% involvement; score 3, 26%-49% involvement; score 4, 50% -75 % involvement; and score 5, greater than 75% involvement. There is a score of 0 to 5 for each lobe with a total possible score of 0 to 25. The sum of the lobar scores indicates the overall severity. The patients were categorized as mild COVID-19 disease (score 7 or less), moderate COVID-19 disease (score 8-17) and severe COVID-19 disease (score 18 or more).

Pulmonary changes identified included ground glass opacity, consolidation, crazy paving, tree in bud, bronchovascular thickening, bronchiectasis, pulmonary nodules, cavitation, pleural effusion, subpleural bands, fibrosis. The distribution of pulmonary changes was identified as unilateral vs bilateral and central vs peripheral distribution. Lung changes were identified as peripheral if limited to the outer one- third and central when confined to the inner two- thirds of the lung. Diffuse changes when both peripheral and central zones were affected simultaneously.

All patients were evaluated for the clinical symptoms and were also subjected to other routine investigations. They were followed from date of admission to date of discharge.

Results

Hundred symptomatic patients with proven COVID-19 were enrolled in this study, amongst which 66 were males and 34 females. The age of patients varied from 18-92 years with mean age of 47.6 years and more than half of patients were within age group of 40-60 years and more than 70% patients being aged >40 years.

The symptoms of patients included cough (59%), fever (55%), myalgia (40%), headache (38%), dyspnea (49%), sore throat (24%), diarrhea (15%), nausea vomiting (14%), loss of smell or taste (38%) and abdominal pain (16%). While 33% patients had spO2 value between 90-94%; 8% patients had spO2 less than 90%. Whereas 32% patients had respiratory rate greater than 24 breaths per minute; 7% patients had respiratory rate greater than 30 breaths per minute.

Scan negative patients had cough (18.1%), fever (27.2%), myalgia (36.3%), headache (63.6%), dyspnea (18.1%), sore throat (63.6%), diarrhea (45.4%), nausea vomiting (54.5%), loss of smell or taste (72.7%) and abdominal pain (54.5%). Patients with mild CT severity had cough (30.9%), fever (11.9%), myalgia (66.6%), headache (64.2%), dyspnea (11.9%), sore throat (30.9%), diarrhea (11.9%), nausea vomiting (11.9%), loss of smell or taste (47.6%) and abdominal pain (11.9%) (*Table 1*).

Table 1: Correlation of CT Severity with Symptoms/Signs of COVID-19 Infection

Symptoms	Scan Negative (n=11)	Mild (n=42)	Moderate (n=38)	Severe (n=9)	Total No. of Patients (n=100)
Cough	2(18.1%)	13(30.9%)	35(92.1%)	9(100%)	59
Fever (>38° C)	3(27.2%)	5(11.9%)	38(100%)	9(100%)	55
Myalgia	4(36.3%)	28(66.6%)	7(18.4%)	1(11.1%)	40
Headache	7 63.6%)	27(64.2%)	3(7.8%)	1(11.1%)	38
Dyspnea	2(18.1%)	5(11.9%)	33(86.8%)	9(100%)	49
Sore Throat	7(63.6%)	13(30.9%)	3(7.8%)	1(11.1%)	24
Loss of Smell or Taste	8(72.7%)	20(47.6%)	8(21%)	2(22.2%)	38
Nausea/Vomiting	6(54.5%)	5(11.9%)	2(5.2%)	1(11.1%)	14
Diarrhea	5(45.4%)	5(11.9%)	3(7.8%)	2(22.2%)	15
Abdominal Pain	6(54.5%)	5(11.9%)	3(7.8%)	2(22.2%)	16
SpO2 90-94% <90%	0(0%) 0(0%)	0(0%) 0(0%)	32(84.2%) 0(0%)	1(11.1%) 8(88.8%)	33 8
Respiratory Rate >24 bpm >30 bpm	 0(0%) 0(0%)	 0(0%) 0(0%)	 30(78.9%) 0(0%)	 2(22.2%) 7(77.7%)	 32 7

Table 2: Co-morbidities Associated with COVID-19 Patients and Mortality

Co-morbidities	No. of Patients	Mortality (n=6)
Diabetes	33	4
Hypertension	22	3[#]
COPD	5	1
Others[*]	10	1

[*]Others including CKD, CLD, cardiac abnormalities, cancer patients;
[#]3 patients had co-existing diabetes and hypertension

Table 3: HRCT Manifestations of COVID-19 Infection

HRCT Finding	Group I (<1 Week of Disease) (n=70)	Group II (>1 Week of Disease) (n=30)
GGO	63(90%)	26(86.6%)
Consolidation	20(28.5%)	12(40%)
Bronchovascular Thickening	13(18.5%)	3(10%)
Crazy Paving	11(15.7%)	1(3.3%)
Tree in Bud	3(4.2%)	1(3.3%)
Bronchiectasis	4(5.7%)	8(26.6%)
Nodule	3(4.2%)	3(10%)
Pleural Effusion	2(2.8%)	0(0%)
Cavitation	1(1.4%)	1(3.3%)
Fibrosis/ Subpleural Bands	1(1.4%)	16(53.3%)

Patients with moderate CT severity had cough (92.1%), fever (100%), myalgia (18.4%), headache (7.8%), dyspnea (86.8%), sore throat (7.8%), diarrhea (7.8%), nausea vomiting (5.2%), loss of smell or taste (21%) and abdominal pain (7.8%). 84.2% patients had spO2 between 90-94%. Respiratory rate of 78.9% patients was greater than 24 bpm. Patients with severe CT severity had cough (100%), fever (100%), myalgia (11.1%), headache (11.1%), dyspnea (100%), sore throat (11.1%), diarrhea (22.2%), nausea vomiting (11.1%), loss of smell or taste (22.2%) and abdominal pain (22.2%). While 88.8% patients had spO2 less than 90%; 11.1% patients had spO2 between 90-94%. Respiratory rate of 77.7% patients was greater than 30 bpm; and 22.2% was greater than 24bpm (*Table 1*).

Co-morbidities associated with COVID-19 patients included diabetes (33% patients), hypertension (22%), COPD (5%) and others including underlying heart, liver, kidney disease and coexisting cancers in 10% patients. Diabetes was the leading co- morbidity amongst COVID-19 deaths (four out of six expired patients had diabetes) (*Table 2*).

Patients were divided into two groups according to the duration of symptoms as follows: the first group

Table 4: Distribution of Pulmonary CT Changes Among COVID-19 Patients

CT Characteristics	Group I (n=70)	Group II (n=30)
Unilateral	8(11.4%)	0(0%)
Bilateral	55(78.5%)	26(86.6%)
Central	7(10%)	3(10%)
Peripheral	41(58.5%)	11(36.6%)
Diffuse	15(21.4%)	12(40%)
Upper	3(4.2%)	0(0%)
Middle	5(7.1%)	0(0%)
Lower	10(14.2%)	5(16.6%)
Multilobar	45(64.2%)	21(70%)

Table 5: Correlation of CT Severity on HRCT with Oxygen Requirement (n=100)

CT Severity	Oxygen Required	Oxygen Not Required	Total
Scan Negative	2(18.2%)	9(81.8%)	11
Mild	4(9.5%)	38(90.5%)	42
Moderate	33(86.8%)	5(13.2%)	38
Severe	9(100%)	0(0%)	9
Total	48	52	100

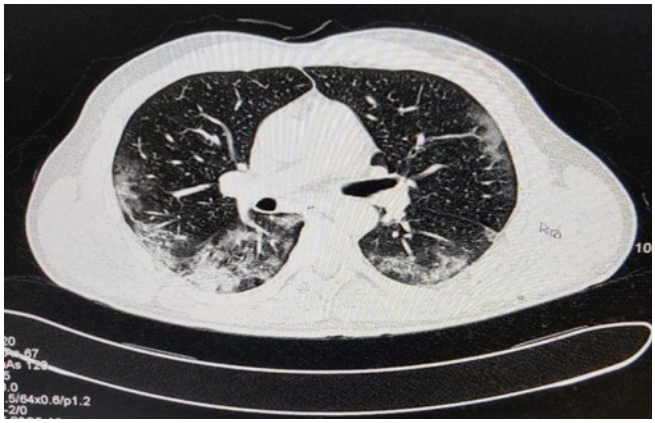

Figure 1: CT Image Shows Peripheral Multifocal Ground Glass Opacities and Consolidation in RTPCR Proven Case of COVID-19 Infection

included the patients who were scanned within the first week after onset of symptoms and second group included the patients who were scanned within the second week after onset of symptoms.

The HRCT findings in the first and second group were as follows: ground glass opacity was 90 % vs 86.6%,

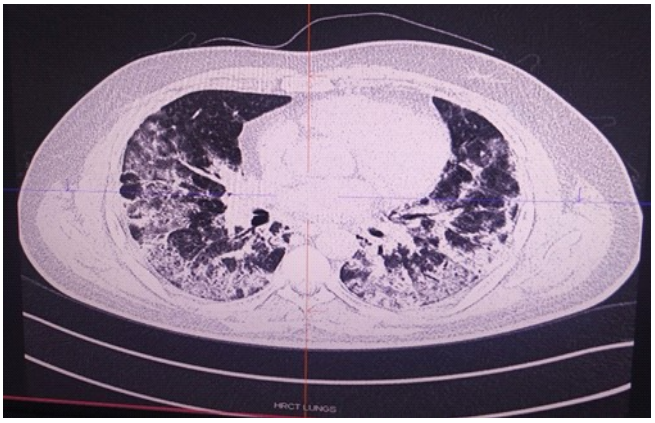

Figure 2: CT Image in Patient Showing Diffuse Lung Involvement with Areas of Ground Glass Opacity and Interlobular Septal Thickening Suggestive of Crazy Paving Pattern

Figure 3: CT Image Showing Unilateral Lung Involvement Evident by Crazy Paving Pattern of Combined Ground Glass Opacity and Interlobular Septal Thickening

consolidation was 28.5% vs 40%, bronchovascular thickening were 18.5 % vs 10%, crazy paving appearance were 15.7% vs 3.3 %, tree in bud appearance were 4.2% vs 3.3 %, pulmonary nodules were 4.2% vs 10% and bronchiectasis were 5.7% vs 26.6%. Pleural effusion was seen only in the first group (2.8 %). Cavitation was seen in 1.4% in first group and 3.3% in second group of patients. Fibrosis /subpleural bands were mainly seen only in the second group in 53.3% patients and only 1.4% patients in first group (*Table 3*) (*Figure 1-3*).

The distribution of CT changes across the two groups were as follows: bilateral changes were 78.5% vs 86.6%, central distribution was 10 % vs 10%, peripheral distribution was 58.5% vs 36.6 % and diffuse (central

and peripheral) distribution were 21.4% vs 40% while multilobar distribution were 64.2% vs 70 % (*Table 4*).

11 patients showed no findings on HRCT and were categorized as scan negative patients.42 patients had mild disease, 38 patients had moderate disease and 9 patients had severe disease based on CT severity scoring (*Table 1)*.

Out of hundred patients, 52 patients didn't require any oxygen support while remaining 48 patients required oxygen support in various forms like nasal cannula, venturi mask, high flow mask, bilevel positive airway pressure and invasive support in the form of intubation (*Table 5*).

Regarding hospital stay, 35 patients were discharged within 7-10 days, 38 patients were discharged in 10-15 days while 21 patients with moderate and severe disease required hospitalization for >15 days. Six patients expired in hospital.

Discussion

The clinical symptoms of COVID 19 disease varied with the CT severity of disease with dyspnea, fever and cough being more common in moderate and severe patients. These findings were consistent with study by Killerby *et al*. (11) and Tenforde *et al.* (12). Headache, myalgia, sore throat, loss of smell/taste, diarrhea, nausea/ vomiting and abdominal pain were more common in scan negative and milder form of disease. This agreed well with study by Pan *et al.* (13). Patients with moderate and severe CT severity index on HRCT chest correlated well with the clinical severity of disease as evident by fall in their spO2 levels and increase in respiratory rates. These findings were consistent with study by Francone *et al.* (14).

With the continuing COVID-19 pandemic and the increasing number of patients suspected or confirmed with the disease, the radiologists are facing more and more cases because of the paramount role of imaging, particularly chest CT in the workup algorithm. In current study we have compared the pulmonary radiological features associated with COVID-19 infection between two groups of patients, who underwent chest CT scans after different durations from initial clinical presentations. In both groups, the most common observed changes were the bilateral, peripheral and multilobar areas of ground glass opacity and lesser extent consolidation in a patchy form. The early CT scans within the first week showed more GGO (90% vs 86.5%) and lesser consolidation (28.5% vs 40%). Our findings were similar to study by Sultan *et al.* (15). Subpleural bands, fibrosis and bronchiectasis was mainly seen in second week as compared to the first week (53.3% vs 1% for subpleural bands/fibrosis and 26.6 % vs 5.7 % for bronchiectasis). These findings were consistent with study by Sultan *et al*. (15).

Bronchiectasis, cavitation and nodules may suggest more aggressive or superimposed infection. The distribution of pulmonary changes was also different between the groups. The increasing bilateral pulmonary changes were seen in the second week (86.6% vs 78.5% in the first week). More diffuse involvement was seen in the second week. This agreed well with the recent studies by Bernheim *et al.* (7), Pan *et al.* (10) and Li *et al.* (16). Moreover, multilobar involvement increased from 64.2% in first week to 70 % in second week which is also consistent with other studies (7,10).

It has been concluded in our study that older patients are more likely to contract and succumb to the COVID-19 disease. A retrospective study of middle-aged and elderly patients with COVID-19 found that the elderly population is more susceptible to this illness and is more likely to be admitted to the ICU with a higher mortality rate (17). In the USA, the Centers for Disease Control and Prevention (CDC) uses COVID- NET in 14 states to monitor the demographics of COVID-19 patients who are being hospitalized and found that 89.3 % patients had an underlying comorbidity and the most common comorbidities found were obesity, hypertension and diabetes mellitus (18).

Multiple comorbidities are associated with the severity of COVID-19 disease progression (19). Patients with Type II diabetes were more likely to have increased severity of COVID-19. In a cohort study of 7337 patients with Covid-19 with and without diabetes, it was shown that those with type 2 diabetes required increased interventions for their hospital stay versus those that were nondiabetic (20). A meta-analysis of multiple studies in China found that there was a four-fold increase in mortality in patients with preexisting COPD that were diagnosed with COVID-19 (3). In our study we also found same results with diabetes being the leading comorbidity among COVID-19 deaths. These results are also consistent with the study by Guan *et al.* (21). A study by Sanyaolu *et al.* (22) also concluded that COVID-19 patients with history of hypertension, obesity, chronic lung disease, diabetes and cardiovascular disease have the worst prognosis and most often end up with deteriorating outcomes such as ARDS and pneumonia. Also, elderly patients in long-term care facilities, chronic kidney disease

patients, and cancer patients are not only at risk for contracting the virus, but there is a significantly increased risk of death among these groups of patients.

In our data, oxygen requirement increased with increase in CT severity. These findings were consistent with study by Saeed *et al.* (23). Regarding the length of hospital stay, it also increased with the increase in CT severity. This matched well with study by Saeed *et al.* (23). Death rate in our study also increased among patients with severe CT findings as noted in other study by Li *et al.* (24).

Limitations: The study excluded the pediatric population and it does not include the COVID-19 patients who were negative on RTPCR but show finding on HRCT. Thirdly, it does not differentiate the HRCT findings of COVID-19 disease from underlying interstitial lung disease in those presenting in second week of illness. The study also excluded asymptomatic patients.

Conclusion

The spectrum of HRCT findings in COVID-19 infection include ground glass opacities, consolidations, bronchovascular thickening, crazy paving pattern, pulmonary nodules, pleural effusion, subpleural bands, fibrosis and bronchiectasis. The type, extent and distributions of pulmonary manifestations are significantly different between the two groups who have been scanned in the different stages of disease. Ground glass opacities and crazy paving pattern were more common in first week while the consolidations, subpleural bands, fibrosis, bronchiectasis and diffuse lung involvement were more common in the second week of illness.

It has been concluded in our study that older patients are more likely to contract and succumb to the COVID-19 disease. Multiple comorbidities are associated with the severity of COVID-19 disease progression and thus require oxygen support and longer hospitalization. In our study, diabetes was the most leading comorbidity associated with COVID-19 deaths.

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Conflicts of Interest

There are no conflicts of interest.

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