

COVID-19: Chest Computed Tomography Imaging Patterns in Assessment of Disease Progression and Severity

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ABSTRACT

Introduction: Chest Computed Tomography (CT) plays an important role in the diagnosis and management of Corona Virus Disease (COVID-19) infection. A better understanding of the chest CT imaging findings in COVID-19 disease may help in accurate diagnosis and staging of the disease. The temporal changes in the chest CT imaging findings follows a specific pattern which helps in identification of disease progression or recovery from the illness.

Aim: To evaluate the chest CT imaging findings of COVID-19 patients during the course of disease.

Materials and Methods: This was a retrospective observational study in which 110 hospitalised patients with COVID-19 disease were evaluated for chest CT imaging findings and severity of the infection. Chest CT findings with respect to duration of symptoms onset were divided into early phase disease (<5 days of symptom onset), intermediate phase (5-12 days) and late phase disease (>12 days of symptom onset). Based on visual assessment, CT severity score was given depending on the percentage of each lobe involved in bilateral lung parenchyma. Descriptive statistics were expressed using percentage, range, means and Standard Deviation (mean±SD).

Results: A total of 110 COVID-19 positive patients (79 males and 31 females) with mean age of 48.33±9.18 years (range between 22-84 years) were included in the study. CT chest was performed during the different time periods of hospital stay ranging from 2 to 16 days. Early phase disease constituted 53 (48.18%) patients,

21 (19.09%) patients in the intermediate phase and 36 (32.72%) patients were in the late phase. Nineteen (17.27%) patients in the early phase disease (<5 days) had a normal scan. Out of 91 chest CT positive patients, 13 patients (14.28%) were asymptomatic and 78 patients were symptomatic (85.71%). Among the CT positive patients, early phase disease constituted 34 (37.36%) patients, 21 (23.07%) patients were in the intermediate phase and 36 (39.56%) patients in the late phase disease. Early phase disease was predominantly characterised by Ground Glass Opacities (GGOs) which were seen in 27 patients (79.41%), gradual conversion of these GGOs into consolidations during the intermediate phase. Consolidations with fibrotic bands were predominant imaging patterns during the late phase disease seen in 21 patients (58.33%). Mean CT severity score during the early, intermediate and late phase diseases were 4.14±2.12, 14.71±4.80 and 11.08±4.68, respectively. Along with few existing signs described in COVID-19 disease, two signs during the late phase disease were observed such as target sign in 5 patients (13.88%) and centipede sign in 13 patients (36.11%). Splenomegaly was an additional extrapulmonary finding seen in 27 patients (24.5%) which has not been described previously.

Conclusion: Specific imaging patterns during the course of COVID-19 illness provide an information regarding the stage of the illness and disease severity. Ideal timing of chest CT is found to be during the intermediate phase of disease (5-12 days of symptom onset), since most of the lesions evolve in this period and provide accurate disease severity which in turn helps in treatment planning.

Keywords: Consolidations, Computed tomography severity score, Ground glass opacities, Splenomegaly

INTRODUCTION

COVID-19 infection is an acute respiratory disease caused by Severe Acute Respiratory Syndrome Corona Virus 2 (SARS-CoV-2). COVID-19 infection is highly contagious and an exponential increase in the number of cases has been observed in the last few months [1,2]. Concerns regarding rapid identification of moderate and severe disease patients help in reducing the mortality associated with this infection. The diagnosis of COVID-19 infection is made by Reverse-Transcription Polymerase Chain Reaction (RT-PCR) technique by collection of nasopharyngeal/throat swab samples. With increase in the daily number of cases, the number of RT-PCR tests done for COVID-19 infection is limited. In the present scenario, Chest CT is found to be more sensitive and an important imaging modality for rapid identification of COVID-19 infection [3]. Considering the wide range of COVID-19 symptoms, early detection of the disease with assessment of severity is crucial. SARS-CoV-2 shares a similar genomic sequence with SARS-CoV and MERS-CoV (family of corona viruses), leading to the development of similar clinical manifestations. Diverse imaging findings ranging from focal lung lesion to extensive

interstitial inflammation and consolidations have been described [4]. Previous studies on COVID-19 pneumonia have described GGOs and consolidations as predominant CT chest findings [5,6].

A better understanding about the imaging finding of COVID-19 pneumonia will help to identify the stage of the disease. Initiation of antiviral therapies in the early stages of the disease decreases the duration of illness and prompts early recovery [7]. In the present study, imaging findings were analysed during different phases of COVID-19 infection and severity using CT severity score was assessed.

MATERIALS AND METHODS

This was a retrospective observational study conducted at Hassan Institute of Medical Sciences, Hassan, Karnataka, India from July-August 2020 for a period of two months. The study was approved by the Institutional Ethical Committee (IEC/HIMS/RR171) and the need for informed consent was waived. The study included 110 patients who were positive for COVID-19 infection by RT-PCR test and were admitted in the hospital. The duration of hospital stay during which the CT chest was performed ranged from 2 to 16 days.

Inclusion Criteria

RT-PCR positive patients with COVID-19 disease who had undergone at least one chest CT during the hospital stay. CT chest was performed as per the clinician decision (based on clinical assessment) and suspicion for COVID-19 infection on chest x-ray which was performed for all hospitalised patients in their respective COVID wards.

Exclusion Criteria

Patients with pre-existing lung disorders were excluded. Based on the duration of onset of symptoms to the time of CT scan, the sample population was divided into. Early phase (<5 days), Intermediate phase (5-12 days duration), Late phase (>12 days after the date of symptom onset). The CT imaging characteristics in these different phases were evaluated. CT was performed using 16-slice Multi Detector Computed Tomography (MDCT) scanner (Philips MX-16). All patients underwent non-contrast CT scan of the thorax in supine position and during end inspiration. The following parameters were used: Tube voltage of 100-120 kV; tube current-exposure time product of 200-300 mAs; and section thickness of 1.25 mm. The CT imaging patterns were described according to the internationally standard nomenclature defined by the Fleischner Society and peer-reviewed literature on viral pneumonia [8,9]. The CT images were evaluated for the presence of GGO, consolidation, reticular pattern, mixed pattern (combination of GGO and consolidation), fibrotic bands, and other findings. Various chest CT signs described in COVID-19 infection were also observed in the present study [10]. Target sign is seen as a ring like peripheral opacity with central small ground glass attenuation [11]. Centipede sign is seen in late phase of the disease represents resolving subpleural curvilinear consolidation of varying length with small reticular shadows on either side which has not been described previously.

CT severity score: A semi-quantitative scoring system was used to assess the percentage of lung involvement in each of the five lobes [12]. Depending on the percentage of lung parenchymal involvement, each of the five lung lobes will be visually scored on a scale of 0 to 5, with score 0 indicating no involvement; 1 for <5% involvement; 2 indicating 5%-25% involvement; 3 for 26%-49% involvement; 4 signifies 50%-75% involvement; and 5 indicating more than 75% involvement. The total CT score was determined as the sum of lung involvement, ranging from 0 (no involvement) to 25 (maximum involvement). The severity of lung parenchymal involvement on CT scan was classified on a three-point ordinal scale: grade one with score of 1-8, grade two with score of 9-15 and grade three with score of 16-25 [13].

STATISTICAL ANALYSIS

Quantitative and Qualitative data were recorded using Microsoft Excel Spread Sheet (2010). Descriptive statistics for quantitative data were expressed using percentage, range, means and standard deviation (mean±SD).

RESULTS

A total of 110 COVID-19 positive patients with mean age of 48.33±9.18 years (range between 22-84 years) were included in the study. Thirty one of the 110 patients (28.18%) were females and 79 patients (71.81%) were males. Thirteen patients (11.8%) were found to be asymptomatic. Among symptomatic patients, the most common presentations were fever (46.36%) and cough (40.90%) followed by breathlessness (32.72%) [Table/Fig-1].

Nineteen (17.27%) patients in the early phase disease had no chest CT findings. Out of 91 chest CT positive patients, 13 patients (14.28%) were asymptomatic and 78 patients were symptomatic (85.71%). The imaging findings observed in CT positive patients is depicted in [Table/Fig-2]. Among the CT positive patients, early phase disease constituted 34 (37.36%) patients, 21 (23.07%) patients were in the intermediate phase and 36 (39.56%) patients in the late phase

Characteristics	Number (n=110)
Age (years)	
Mean±SD	48.33±9.18
Range	22-84 years
Sex	
Male	79 (71.81%)
Female	31 (28.18%)
Symptoms*	
Asymptomatic	13 (11.8%)
Fever	51 (46.36%)
Cough	45 (40.90%)
Breathlessness	36 (32.72%)
Others (myalgia, sore throat and diarrhea)	18 (16.36%)
Phase of illness (Based on the duration of symptom onset)	
Early phase <5 days	53 (48.18%)
Intermediate phase (5-12 days)	21 (19.09%)
Late phase (>12 days)	36 (32.72%)

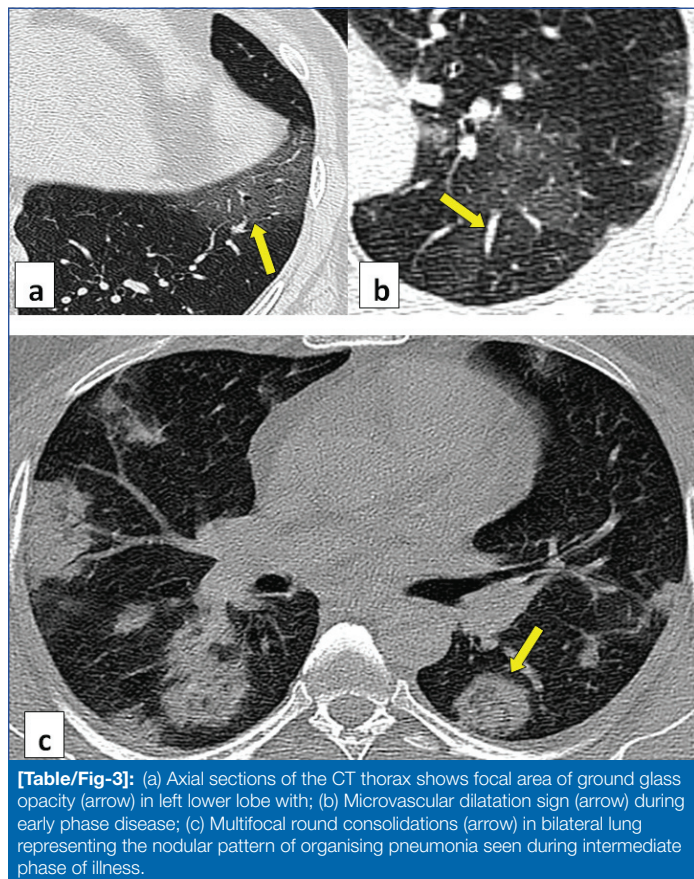
[Table/Fig-1]: Demographic and clinical characteristics of the study group.
*more than one symptom present

Characteristics (CT positive patients)	Number
Pattern of lesion distribution (n=91)	
Peripheral	57 (62.63%)
Both central and peripheral	34 (37.36%)
Lesions observed in each phase	
Early phase (n=34)	
Peripheral	28 (82.35%)
Both central and peripheral	6 (17.64%)
Ground glass opacities alone	27 (79.41%)
Ground glass opacities + Consolidations	7 (20.58%)
Intermediate phase (n=21)	
Ground glass opacities alone	2 (9.52%)
Ground glass opacities + Consolidations	10 (47.61%)
Consolidations alone	7 (33.33%)
Consolidations + Fibrotic bands	2 (9.52%)
Late phase (n=36)	
Ground glass opacities alone	5 (13.88%)
Ground glass opacities + Consolidations	10 (27.77%)
Consolidations + Fibrotic bands	21 (58.33%)
Signs during the early phase (n=34)	
Microvascular dilatation	15 (44.11%)
No sign	19 (55.88%)
Signs during the Intermediate phase (n=21)	
Organising pneumonia	9 (42.85%)
No sign	12 (57.14%)
Signs during the late phase (n=36)	
Subpleural transparent line	18 (50%)
Target sign	5 (13.88%)
Centipede sign	13 (36.11%)
Mean CT severity score	
Early phase (<5 days)	4.14±2.12
Intermediate phase (5-12 days)	14.71±4.80
Late phase (>12 days)	11.08±4.68

[Table/Fig-2]: Chest CT imaging characteristics of the study group.

disease. Early phase disease was predominantly characterised by GGO which was seen in 27 patients (79.41%), gradual conversion of these GGOs into consolidations during the intermediate phase [Table/Fig-3]. Microvascular dilatation sign was observed during the early

phase disease in 15 patients (44.11%) [Table/Fig-3]. Consolidations with well-defined rounded margins representing nodular pattern of organising pneumonia were observed during the intermediate phase [Table/Fig-3]. Consolidations with fibrotic bands were predominant imaging patterns during the late phase disease seen in 21 patients (58.33%) [Table/Fig-4]. Along with subpleural transparent line seen in 18 patients (50%) and two new signs were observed during the late phase disease such as target sign in 5 patients (13.88%) and centipede sign in 13 patients (36.11%) [Table/Fig-4].



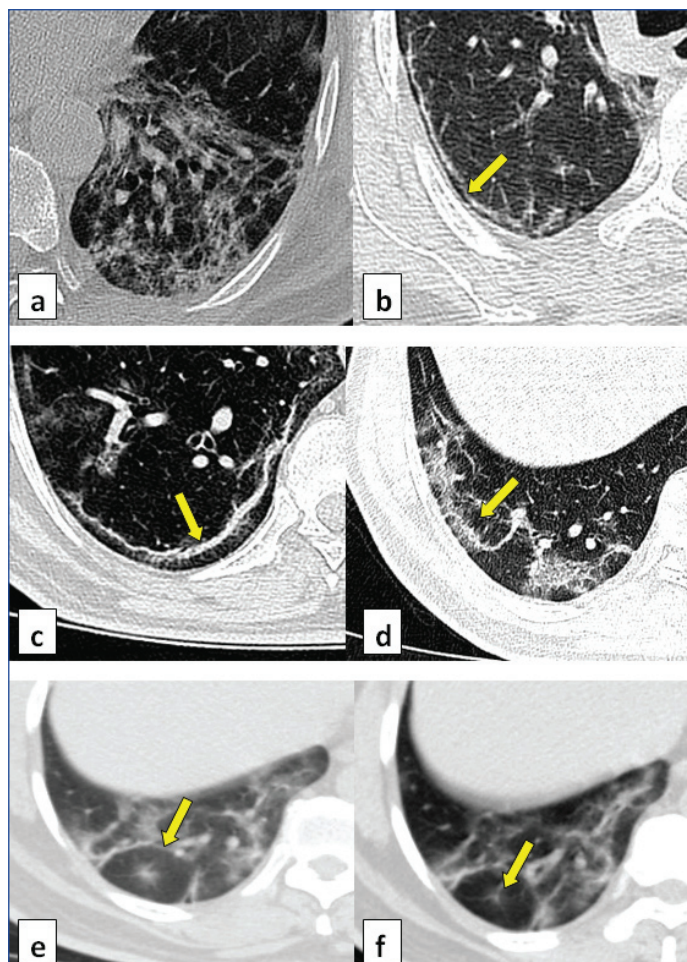
[Table/Fig-3]: (a) Axial sections of the CT thorax shows focal area of ground glass opacity (arrow) in left lower lobe with; (b) Microvascular dilatation sign (arrow) during early phase disease; (c) Multifocal round consolidations (arrow) in bilateral lung representing the nodular pattern of organising pneumonia seen during intermediate phase of illness.

Out of total 91 CT chest positive patients, 31 patients (91.17%) in the early phase had a CT severity score of less than 8 indicating mild disease and three patients (8.82%) had CT scores in the range of 8-15. Eleven patients (52.38 %) in the intermediate phase had severe disease with a severity score of more than 15, seven patients (33.33%) had scores in the range of 8-15 and three patients (14.28%) had a score of less than 8. Seventeen patients (47.22%) in the late phase had moderate disease with signs of absorptive phase. Eleven patients (30.55%) in the late phase had a score of less than 8 and severe disease with score of more than 15 was seen in eight patients (22.22%). The mean CT severity score was more during the intermediate and late phases of disease as summarised in [Table/Fig-2].

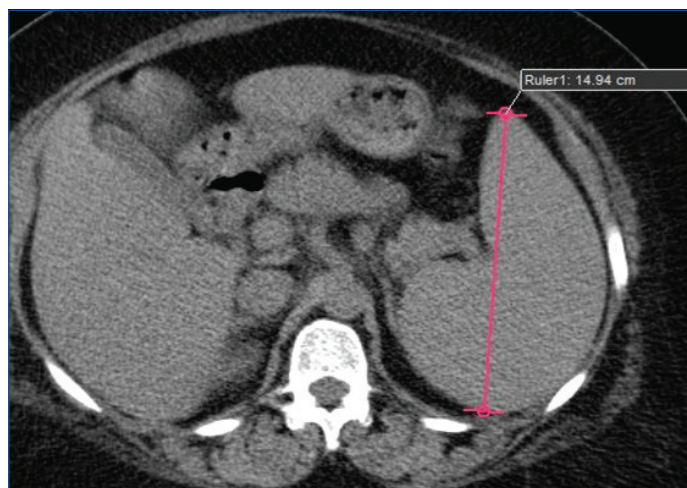
Splenomegaly was an additional extrapulmonary finding seen in the upper abdominal sections of 27 patients (24.5%) which has not been described previously [Table/Fig-5].

DISCUSSION

In this study, chest CT findings were retrospectively evaluated to determine the stage and severity of COVID-19 disease. Present study results suggest that the infection was less severe during the early phase and progresses during the intermediate and late phase of disease. Specific signs have been described to accurately identify the stage of the disease. Nineteen patients (17.27%) in the early phase disease (<5 days) had no chest CT findings. Similar negative chest CT findings were seen in other studies during the early phase of illness [Table/Fig-6] [14-16]. Ideal timing of chest CT appears to be after 5 days of symptom onset since all the patients in intermediate



[Table/Fig-4]: (a) Axial sections of the CT thorax shows mixed resolving consolidations and fibrotic changes in left lower lobe; (b) Subpleural transparent line (arrow) just adjacent to linear consolidation band; (c) Subpleural curvilinear consolidation (arrow); (d) Reticular shadows (arrow) on either side representing centipede sign; (e) Target sign seen as a peripheral ring like opacity (arrow); (f) Central small ground glass attenuation representing a dilated microvasculature (arrow).



[Table/Fig-5]: Visualised upper abdominal section of the CT thorax shows mildly enlarged spleen.

Early phase CT findings	Bhandari S et al., [14]	Hu Q et al., [15]	Pan F et al., [16]	Present study
No CT findings	36.25%	4.34%	16.66%	17.27%
Peripheral location	52.94%	65.22%	54.16%	82.35%
Ground Glass Opacities (GGO)	49.01%	39.13%	75%	79.41%

[Table/Fig-6]: Comparison of early phase CT findings with previous studies [14-16].

phase shows lung involvement. Semi-quantitative CT scoring helps to know the severity of different phases of COVID-19 disease. A previously validated CT severity scoring system was used which is based on the extent of lobar involvement as reported by Pan F et al.,

[16]. A three-point ordinal scale was derived to grade the CT severity score based on the results given by Francone M et al., [13]. Mean CT severity score in mild, severe and critical categories were 8.7 ± 4 , 17.4 ± 3.1 and 20.3 ± 3 , respectively [13]. Two grades were used by Bhandari S et al., to classify patients into mild and severe group with scores less than 15 indicating mild infection and severe disease with scores more than 15 [14]. The intermediate phase between 5-12 days of symptom onset is crucial and is characterised by expansion of the GGOs with consolidations and increasing severity score. The typical findings in this stage include nodular pattern of organising pneumonia. This stage in particular is important for initiation of antiviral therapies and close monitoring [15].

Patients who had recovered from COVID-19 pneumonia presented with severe disease on CT at approximately 10 days after initial onset of symptoms indicating peak stage. Absorptive stage with improvement in chest CT signs began at approximately 14 days after the onset of initial symptoms [16]. Signs in the each of these three different phases has been described indicating the evolution of the lesions from early to late stage. Along with subpleural transparent line, target sign and centipede sign are indicative of late phase of infection. The temporal changes of the radiological manifestations followed a specific pattern, which might indicate the progression and recovery of the illness [17]. A long term follow-up of moderate and severe disease patients is required to know the duration of radiological recovery and whether there is persistence of fibrotic changes.

Limitation(s)

Relatively small sample size in different phases of COVID-19 disease, warrants further study with larger study group. Only hospitalised patients were included resulting in possible selection bias. Follow-up of the patients was not included.

CONCLUSION(S)

Being familiarised with the chest CT findings of COVID-19 pneumonia will help to identify the stage of the disease and assess severity. Chest CT imaging is found to be useful in identification of disease progression or signs of improvement. Patients can be categorised based on the CT severity score and patients with severe disease can be started on early antiviral therapy.

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