Role of CT Chest in the Diagnosis and Management of SARS-Cov-2 Pneumonia Patients - Hospital Based Descriptive Study, Hyderabad

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ABSTRACT

BACKGROUND
The computerised tomography (CT) characteristics of COVID-19 are reported and compared with the CT characteristics of other viruses to familiarise radiologists with potential CT trends and to determine the effectiveness of chest CT in the diagnosis and treatment of COVID-19.

METHODS
This was a hospital based descriptive study which involved the first 324 patients with a finding of severe acute respiratory syndrome (SARS-CoV-2) infection validated by real-time reverse transcription-polymerase chain reaction (RT – PCR). Monitoring patients (198 males, 126 females with a mean age of 46.50 years ± 8.96 [SD] and age range of 21 - 76 years) from April 2020 to July 2020. We correlated the image reports from the initial CT analysis with the findings of the laboratory studies and established possible CT patterns for viral infection.

RESULTS
The initial chest CT studies of the 324 SARS-CoV-2 patients showed that the disease affected all 'five lobes' in 248 (76.54 percent) patients, both 'lower lobes' in 49 (15.12 percent) patients, the right lower lobe in 23 patients (7.10 percent), and the left lower lobe and right middle lobe in 2 patients (0.62 percent). In 303 (93.52 percent) patients, the lesions were primarily peripheral and subpleural; and there were fewer lesions along the bronchovascular bundles. Two major patterns of SARS-CoV-2 lesions on CT images are GGO (ground - glass opacity) and consolidation. In 303 of the 324 patients (93.52 percent), CT showed single or multiple abnormal GGO or consolidation, or both. In the remaining 21 (6.48 percent) cases, neither GGO nor consolidation was observed on CT. Follow-up CT showed moderate or pronounced disease worsening in 12 out of 58 (20.69 percent) cases and follow-up CT showed improvement with the appearance of fibrosis and GGO resolution.

CONCLUSIONS
In conclusion, the use of a chest CT system in SARS-CoV-2 patients can accurately evaluate pneumonia. Most notably follow-up CT scans may help assess patients with SARS-CoV-2 pneumonia in their response to treatment.

KEYWORDS
SARS-CoV-2, Pneumonia, Chest Computed Tomography, Ground-Glass Opacities

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BACKGROUND

Coronavirus disease 2019 (COVID-19) is a highly infectious pandemic disease first detected from severe acute respiratory syndrome coronavirus - 2 in Wuhan, Hubei Province, China. This disease was declared as a global public health emergency by the World Health Organisation (WHO) on 30 January 2020 and raised to an exceptionally high level on 28 February 2020.[1,2] Understanding the clinical appearance of SARS – CoV - 2 is of considerable importance. Clinical manifestations are complex and can involve fever as a primary appearance, other signs involve weakness and cough, although diarrhoea and nausea have been reported to precede fever by several works of literature.[3-5]

Few patients may be asymptomatic and elderly comorbid patients may become more vulnerable to respiratory failure. According to the Indian Council of Medical Research (ICMR) official diagnosis and treatment protocol,[6] CT is likely to become increasingly important for the diagnosis and management of COVID-19 pneumonia, given the continuing increase in global cases. The observed evolution from pneumonic injury to respiratory death in this disease suggests a pathological pathway that might be amenable to early CT detection, particularly if the patient is scanned two or more days after developing symptoms. Additionally, a negative CT, one week after the onset of symptoms is reported to have a high negative predictive value for COVID-19 pneumonia. The prognostic value of CT would be further enhanced if it was able to define early radiological abnormalities or patterns that predict a poor outcome.[7]

CT examination is a great aid in the diagnosis, follow-up, and therapy evaluation. Precise analysis of viral pneumonia based on chest CT can suggest isolation and plays an important role in managing patients with suspected SARS-CoV-2 infection, particularly when there are no medically validated therapies for SARS – CoV - 2 care. Early reports indicated that the best approach for diagnosing SARS CoV - 2 would be the CT. Moreover, SARS – CoV - 2 extensive CT features have only been published in a limited number of publications in the literature.[7,8]

Although the main hallmark of SARS – CoV - 2 was the peripheral posterior ground-glass opacities (GGO) with or without consolidation, other variable CT findings were reported.[9-11] Viral nucleic acid testing is playing an indispensable role in helping to prevent the spread of the COVID-19 epidemic. However, nucleic acid testing has rigorous laboratory specifications and requires a long time before results are available. In addition, some patients with suspected COVID-19 may have initial nucleic acid test results that are false-negative for virus infection, which is harmful for the control of infectious disease.

The diagnosis and treatment program (6th version) published by the National Health Commission of the People's Republic of China[6] had defined the diagnosis of viral pneumonia based on radiologic features by radiologists as one of the diagnostic criteria for COVID-19. The accurate diagnosis of viral pneumonia based on chest CT may indicate isolation and plays an important role in the management of patients with suspected SARS CoV - 2 infection, especially when there are no scientifically proven therapies for the treatment of COVID-19. Early discussions suggested that CT should be the preferred modality for diagnosis of COVID-19. However, the use of CT for COVID-19 diagnosis is controversial. In addition, the detailed CT features of COVID-19 have been reported in only a small number of articles in the literature.[7,8]

We retrospectively analyzed the initial and follow-up chest CT images of patients with SARS – CoV - 2 infection and two patients with adenovirus infection. To evaluate the misdiagnosis rates of the radiologists, we compared the image reports of initial chest CT studies with the laboratory test results. In addition, we evaluated the initial and follow-up CT studies to identify the CT features of COVID-19 to familiarize radiologists with possible CT patterns of COVID-19 and enable more effective response.

Objectives

The goal of the current research was to examine the SARS –CoV - 2 CT findings in a pictorial analysis to help radiologists familiarize themselves with SARS – CoV - 2 findings.

METHODS

This was a hospital based descriptive study conducted at Care hospital, Hyderabad from April 2020 to August 2020 on adults above 20 years of age who were confirmed positive by tests of RT - PCR. Cases were compiled from picture achieving and communication system (PACS) at Care hospital in Hyderabad. The inclusion criteria were as follows : 1) patients with laboratory-confirmed SARS – CoV - 2 ; 2) patients underwent CT scan more than one time.[12,13] Diagnosis of SARS – CoV - 2 was calculated using the following three methods: isolation of SARS – CoV - 2 on at least two positive tests by real-time reverse transcription-polymerase chain reaction assay for SARS – CoV - 2 or a genetic sequence matching SARS – CoV - 2 assay. Finally, it involved a total of 324 consecutive laboratory-confirmed patients with SARS – CoV - 2 (198 males, 126 females; mean age, 46.50 years ± 8.96 [SD]; age span, 20-76 years), who underwent serial CT scans, were included. All available clinical and epidemic characteristics were collected. As the treatment methods were different for different categories, we split the patients involved into two groups: Non-emergency group (mild) and emergency group (severe or fatal).

Imaging Technique

All patients involved were screened using one scanner, the Optima platform with GE 128 - slice. The selection requirements were 120 kV; 100 - 200 mAs; 0.75 – 1.5 in pitch; and 0.625 – 5 mm in collimation. Both image data is replicated using a medium straight reconstruction algorithm with a thickness of 0.625 - 5 mm. At full inspiration in co - operative patients, CT scans were obtained in the supine position.

Image Interpretation

Two consenting radiologists with 10 and 13 years of experience sincerely and independently reviewed all the chest CT scans. All studies were presented on both the lung settings (1500 HU width; 700 HU level) and the mediastinal (350 HU width; 40 HU level). Imaging characteristics like GGO, consolidation, mixed GGO and consolidation, centrilobular nodules, bronchial distortion, cavitation, tree-in-bud, bronchial wall thickening, reticulation, subpleural lines, traction bronchiectasis, intrathoracic lymph node enlargement, intra lesional vascular enlargement and pleural effusions were examined for 14 image characteristics. The detailed explanations of the above characteristics were well known in the preceding analysis.[14,15]

Four distribution types were evaluated - craniocaudal distribution (predominant in the upper lung, predominant in the lower lung, or no craniocaudal predilection), transverse distribution (central, peripheral or non-transverse predilection), lung distribution (unilateral or bilateral) and distribution (focal, multifocal or diffuse). Focal was described as a single abnormality lesion, multifocal as multiple lesions, and diffuse as involving more than the distribution of one lung lobe. To calculate the severity of the illness, a CT - score system was used.[16] We identified follow up of CT imaging (between 7 to 14 days) and evaluated craniocaudal distribution, transverse distribution, lung distribution and distribution. No change, progression, and improvement. No change referred to no obvious changes in chest CT. Progression referred to the presence of new lesions or the presence of increased extent of involvement during the treatment. Improvement referred to the resolving abnormities. We also evaluated the duration of imaging progress, which was calculated from the time of baseline CT or the time of CT showing new lesions to that of the CT showing abnormal imaging findings.

Treatment

All suspected and confirmed cases were transferred to SARS – CoV - 2 designated hospitals in the initial days of study and managed at our hospital eventually. We also adopted the clinical criteria based on the SARS-CoV- 2 recommendations provided by the ICMR.[6] The basic therapy included the use of symptomatic medication, recombinant human interferon *α 2 b* (inhalation of aerosols), antiviral drugs, corticosteroid therapy and where necessary, antibiotic treatment. Severe cases were treated with intrusive artificial ventilation. ECMO (Extracorporeal membrane oxygenation) was used for life support.

Statistical Analysis

Both statistical analyses were conducted using SPSS (IBM Corp., Armonk, NY, US). It represents the mean ± SD of the continuous variables. Categorical considerations and counts are expressed as percentages. The distribution of CT features related to age and sex has been measured using the chi-square scale. For evaluating the proportion of infection through multiple segments of the lung, the generalized linear mixed model was used. The lung segment, age, and gender were used as fixed effects in this experiment, and the patients were used as random effects.

RESULTS

The clinical characteristics of the patients are summarized in Table 1. Typical hospital comorbidities included hypertension, diabetes, coronary atherosclerotic heart disease, liver disease, nervous system disease, chronic lung disease, chronic kidney disease, and tumour. The usual self-reported sickness symptoms were fever (91.98 %), cough (64.19 %), exhaustion (56 %), and no symptoms (0.32); as of July 10, 318 patients (98.15 %) had recovered, and 6 (1.85 %) had died.

	Characteristic	No. (%) of Patients (N = 324)
Age (y)	Mean	46.5 ± 8.96
	Range	21 - 76
Sex	Male	198 (61.11)
	Female	126 (38.89)
Comorbidities	Hypertension	93 (28.70)
	Diabetes	39 (12.03)
	Cardiovascular disease	22 (6.80)
	Liver disease	14 (4.32)
	Nervous system disease	9 (2.78)
	Chronic lung disease	8 (2.46)
	Chronic kidney disease	8 (2.46)
	Tumour	4 (1.23)
Symptoms at presentation	Fever	298 (91.98)
	Fatigue and poor appetite	16 (4.94)
	Cough	208 (64.19)
	No symptoms	2 (0.32)
Outcome	Recovery	318 (98.15)
	Death	6 (1.85)

Table 1. Demographic and Clinical Features in the Study

Note—Percentages may not add up to 100 because of rounding

		No. (%) of Patients (N = 324)
CT findings	Vascular enlargement	241 (74.38)
	Interlobular septal thickening in a crazy-paving pattern	198 (61.11)
	Air bronchogram sign	192 (59.26)
	Air trapping	35 (10.80)
	"Reversed halo" sign	16 (4.94)
GGOs and consolidation	Absence of both GGOs and consolidation	21(6.48)
	Presence of GGOs with consolidation	179 (55.24)
	Presence of GGOs without consolidation	98 (30.24)
	Presence of consolidation without GGOs	26 (6.48)
	Bronchus deformation due to fibrosis and bandlike lesions	61 (18.83)
	Pleural effusion	6 (1.85)
	Mediastinal lymphadenopathy	2 (0.62)
Discrete pulmonary nodules	Nodules with halo sign	56 (17.28)
	Nodules without a halo sign	13 (4.01)

Table 2. Initial CT Findings of 324 Patients with SARS-CoV-2

GGOs = ground-glass opacities.
Note—Percentages may not add up to 100 because of rounding

CT Features of SARS-CoV-2 Disease Initial CT Scans

The original chest CT analyses of the 324 SARS-CoV-2 patients found that the condition affected all five lobes in 248 patients (76.54 percent), both lung 'lower lobes' in 49 patients (15.12 percent), right lung lower lobe in 23 patients (7.10 percent), left upper lobe and right lower lobe in 2 patients (0.62 percent), and left lung upper lobe and right lung middle lobe in 2 patients (0.62 percent). The lesions were mainly peripheral and subpleural in 303 (93.52

percent) cases and there were fewer lesions associated with the bronchovascular bundles. Two main patterns of SARS – CoV - 2 lesions on CT images are GGO and consolidation. In 303 of 324 patients (93.52 %), CT indicated single or multiple abnormal GGO or consolidation zones or both. In the remaining 21 (6.48 %) patients, neither GGO nor consolidation was found on CT (Table 2)

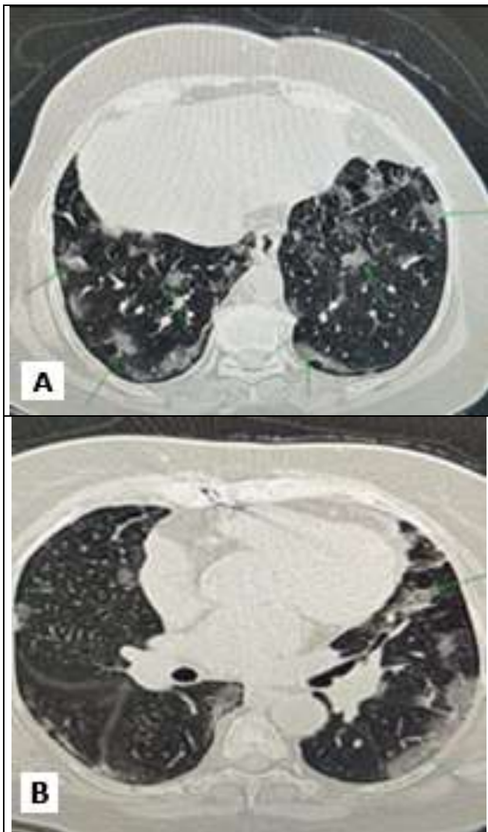

***Figure 1.* A and B 62-Year-Old Woman with SARS-CoV-2 Disease. A Transverse CT scan Shows Multiple Predominantly Peripheral Ground-Glass Densities**

***Figure 1C.* Coronal CT Sections in Another Patient Showing Air Bronchogram Sign (Arrow)**

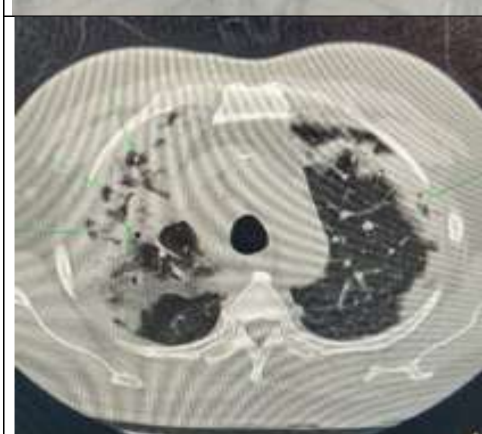

***Figure 1D.* Air Trapping-Hypodense Areas Shown by Arrows**

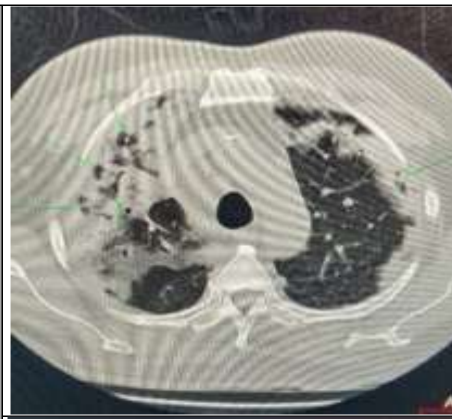

***Figure 1E.* Air Trapping-Hypodense Areas Shown by Arrows**

***Figure 2.* 52-year-old Man with SARS-CoV-2 disease. The Transverse CT Image shows Consolidation with Enlarged Vessels (Arrow)**

***Figure 3.* 65-Year-Old Man with SARS-CoV-2 Disease. A Transverse CT Scan Shows "Reversed Halo" Sign in the Left Lower Lobe (Arrow)**

***Figure 4.* 64-Year-Old Man with SARS-CoV-2 Disease. The Minimum-Intensity-Projection CT Image Shows Bronchus Deformation Due to Fibrosis (Arrows)**

On CT images, we observed additional indicators of lesions with SARS-CoV-2. CT demonstrated GGO or consolidation (Fig. 1a, b); consolidation with air bronchogram in 192 patients; (Fig. 1c) air trapping in 35 (10.80 %) patients (Fig. 1d) with consolidation / ground glass density vascular enlargement in 241 (74.38) patients (Fig. 2); and "reversed halo" in 16 (4.94) patients (Fig. 3). CT revealed 69 (21.30 percent) patients had distinct pulmonary nodules: 56 patients had halo-surrounding the nodules and 4.01 percent had strong halo-surrounded nodules. 61 (18.83 percent) patients with fibrosis and band like lesions had bronchial deformation (Fig. 4). In 198 (61.11 percent) patients, interlobular septal thickening occurring in a crazy-paving fashion (Fig 5e, f); 6 (1.85 percent) patients displayed pleural effusion is which adjacent to crazy- paving fashion. Two patients had lymphadenopathy.

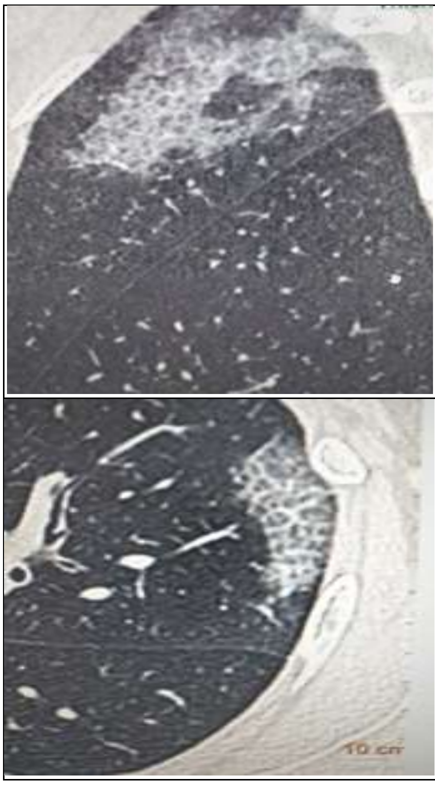

Figure 5D. 5E. 55-Year-Old Man with SARS Co V 2 Diseases. Axial CT Scan Images Show Interlobular Septal Thickening within Ground Glass Densities

Follow-Up CT Scans

As of June 28, 58 patients with an initial chest CT test indicating possible lesions of a viral infection had received follow-up CT. The mean period between the original and the follow-up CT studies was 7.0 days (range, 2 – 14 days). CT showed increased consolidation density in the follow-up tests. However, the number of GGOs observed in the follow-up CT analysis indicated mild disease. Follow-up CT showed moderate to marked disease progression in 12 out of 58 patients (20. 69 percent) and in some cases, the upper lobes showed new lesions now affecting the five lobes of both lungs as the disease progresses. In 6 patients with the presence of fibrosis and GGO resolution follow-up, CT demonstrated improvement.

DISCUSSION

The CT patterns of viral pneumonia are related to the pathogenesis of the viral infection. Viruses of the same family (e.g., Coronaviridae) have a similar pathogenesis.[9] Therefore, viral pneumonia caused by different viruses from the same virus family exhibit a similar pattern on chest CT images. SARS CoV - 2 belongs to the genus Beta coronavirus according to genome analysis.[10] Beyond diagnostic challenges, the first wave of COVID-19 also introduced patient management issues related to workflow, isolation, personal protective equipment, and treatment decisions. During initial risk estimation in the emergency department, RT-PCR results were usually not immediately available and, even when they become available, negative RT - PCR does not exclude COVID-19, especially when the pre-test probability of COVID-19 is high.[20]

In our study, 303 of the 324 (93. 52 percent) patients with SARS-CoV-2 were diagnosed with viral pneumonia based on CT findings; the remaining patients with SARS – CoV - 2 were bedridden in-patients with underlying diseases. In an attempt for these 318 patients to improve, the clinician recommended isolation and supportive treatment in time. Positive CT diagnostic findings of viral pneumonia were available in our study group of 324 patients. CT-diagnosis of viral pneumonia was available three days earlier than expected diagnosis on the nucleic acid test findings. However, when a clinician wants to order nucleic acid test for monitoring in terms of disease progression, we are certain that CT is highly accurate and can be used as a standard tool for monitoring SARS – CoV - 2. Using CT to diagnose viral pneumonia helps to classify and monitor patients with suspected SARS-CoV- 2 infection for rapid treatment and thereby improve patient safety.[17] Some of the CT features of patients with reported SARS –CoV - 2 that were commonly observed in patients in our study are identical to SARS CT features. SARS – CoV - 2 causes immediate lung injury by affecting the angiotensin conversion enzyme which results in diffuse alveolar damage.[18] This may explain the pathologic mechanism of GGO and consolidation as well as the rapid changes in CT findings. Our results support the observed trend that bilateral GGOs or consolidations on chest imaging should prompt the radiologist to suggest COVID-19 as a possible diagnosis.[12] However, we observed that some patients had difficulty breathing during CT, so obtaining perfect CT images during end-inspiration may be difficult in this population. Therefore, when reviewing CT examinations, radiologists should pay attention to differentiating GGO or consolidation from motion artefact. Furthermore, we found that all the CT features seen on the initial chest CT examinations of patients with COVID-19 GGO, consolidation, vascular enlargement, interlobular septal thickening, air bronchogram sign, and air trapping are similar to the CT features of SARS and Middle East respiratory syndrome (MERS). These CT features are caused by alveolar and interstitial pulmonary injury and oedema.

This will clarify the process of GGO's pathology and consolidation, as well as the significant changes in CT findings. Our results reflect the trend observed that bilateral GGOs or consolidations of chest imaging would lead the radiologist to prescribe SARS CoV - 2 as a possible diagnosis.[19,20] However, we found that certain patients had difficulty in breathing during CT, and in this group, flawless CT images can be difficult to obtain during end-inspiration. Radiologists should also pay attention when performing CT studies to distinguish GGO from motion artefacts. We also found that all of the CT characteristics were used in SARS – CoV - 2 patient's initial CT exams. The CT characteristics of SARS are equivalent to GGO, vascular enlargement, interlobular septal thickening, air bronchogram signs, and air trapping. Multifocal involvement was more common in our study than unifocal involvement. This observation is supported by Chung et al. analysis.[18] The severe infectious diseases of SARS, lung parenchymal abnormalities eventually spread to the central area and bilateral upper lobes.[21,22] The progression of SARS – CoV - 2 on CT images was following the progression pattern of CT in our study. In our cohort of SARS – CoV - 2 patients, disease distribution was predominantly peripheral (subpleural) and restricted to the middle and lower lung areas of the original chest CT scan.

Follow-up CT revealed that inflammation and coalescence infiltrations entered the lungs as the disease progressed and affected the upper lobes. Indeed, all five lobes of both lungs were impaired in several situations, with CT showing white lungs. The growing number of GGOs and consolidation densities in our research group suggested disease development, while the presence of fibrosis and GGO resolution or consolidation indicated improvement. Bronchus deformation due to fibrosis and band like lesions can cause permanent damage and can impair the patient's respiratory function.

In 20. 69 percent (12 of 58) of patients seeking follow-up CT, CT showed progression. One patient who was exposed to three CT follow-up tests was in unstable condition and showed modest progress on the third follow-up test despite initial substantial growth on the first and second follow-up trials and improvement on the third and fourth follow-up studies. For more in-depth analysis into evaluating the possible effect of CT in SARS-CoV- 2 patient care, further study may be required.

CONCLUSIONS

Pneumonia can be accurately assessed in SARS-CoV-2 patients by using a chest CT study. Several patients in our sample had no type of emergency and had a good clinical response. Most notably, improvements in CT follow-up during recovery will help to assess the response of SARS-CoV-2 pneumonia patients. More pathological correlation studies will help to better understand the findings of the imaging and its value in evaluating prognosis.

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