HIGH-RESOLUTION CT FEATURES OF THE COVID-19 INFECTION, INITIAL AND FOLLOW-UP CHANGES AMONG DIFFERENT CLINICAL TYPES

Radiodiagnosis

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ABSTRACT

Background: To discuss the high resolution computed tomography (HRCT) manifestations of corona virus disease 2019 (COVID-19) patients among different clinical types on initial and follow-up CT. **Methods:** Seventy COVID-19 patients admitted to the Affiliated Hospital of SP Medical Collage Bikaner were enrolled. All patients underwent initial and follow-up chest HRCT. The main CT features and semi-quantitative score which represent disease severity among different clinical types were evaluated. **Result:** On initial CT, the main abnormalities observed in common and severe cases respectively were pure ground glass opacities (GGOs) and patchy consolidation surrounded by GGOs. Critical cases had multiple consolidation surrounded by wide range of GGOs distributed in the whole lung fields. The CT severity score and density score in mild (up to 8 and 5), moderate (>8 to 15 and 9) and severe (>15 and 12) cases were increased by gradient. On follow-up CT, mild and moderate types manifested as decreasing density of lesion, absorbed consolidation and GGOs. Severe cases showed progression of the disease. The extent and progression scores in mild and moderate patients were significantly decreased, while the range score of patients with severe disease reached the highest points, accompanied with an increase in the density score. **Conclusion:** CT scanning can accurately assess the severity of COVID-19, and help to monitor disease transformation during follow-up among different clinical conditions.

KEYWORDS

anterior hip dislocation, fracture femoral head, fracture acetabulum

1. Introduction

In late December 2019, a pneumonia of unknown cause occurred as an outbreak in Wuhan City, Hubei Province, China, with clinical symptoms similar to viral pneumonia including fever, cough, and dyspnea [1]. A previously unknown novel virus named as severe acute respiratory syndrome corona virus 2 (SARS-CoV-2) with a characteristic crown morphology at electron microscopy scanning was identified as the source of this disease [2]. Subsequently, the pneumonia caused by SARS-CoV-2 was official termed as corona virus disease 2019 (COVID-19) on 11 February 2020 [3]. As of March 13, 2020, a total of 81,003 patients with confirmed COVID-19, including 3181 deaths, have been reported in China [4]. From current knowledge of the cases, most patients with mild and common symptoms have a relatively good prognosis while cases of death are more frequently seen in severe and critical patients, which could progress to severe pneumonia, ARDS and multiple organ failures leading to higher mortality [5-7]. Early diagnosis and accurate staging, therefore, are essential in COVID-19 patients.

The COVID-19 pandemic in India is part of the worldwide pandemic of corona virus disease 2019 (COVID-19) caused by severe acute respiratory syndrome corona virus 2 (SARS-CoV-2). The first case of COVID-19 in India was reported on 30 January 2020. India currently has the largest number of confirmed cases in Asia, and has the second-highest number of confirmed cases in the world after the United States, with the number of total confirmed cases breaching the 100,000 mark on 19 May, and 1,000,000 confirmed cases on 17 July 2020. On 29 August 2020, India recorded the global highest single-day spike in COVID-19 cases with 78,761 cases, surpassing the previous record of 77,368 cases recorded in the US on 17 July 2020. India currently holds the single day record for largest increase in cases, set on September 17, with an additional 97,894.

India's case fatality rate is among the lowest in the world at 2.41% as of 23 July and is steadily declining. By mid-May 2020, six cities accounted for around half of all reported cases in the country- Mumbai, Delhi, Ahmadabad, Chennai, Pune and Kolkata. As of 10 September 2020, Lakshadweep is the only region which has not reported a case. On 10 June, India's recoveries exceeded active cases for the first time.

Viral nucleic acid detection remains the golden standard in diagnosis of COVID-19 regardless of clinical signs and symptoms, and is also the effective method to screening asymptomatic infection patients. Throat swabs tested by real-time reverse transcription polymerase-chain-reaction (RT-PCR) is the most commonly used method [8]. However, previous studies have shown that several defects may limit the clinical application of laboratory tests, including immaturity of the nucleic acid detection technology, variation in detection rate from different manufacturers, disagreements in inter-laboratory consultation caused by low patient viral load or improper clinical sampling [8,9]. In addition, nucleic acid detection cannot accurately

determine the severity of disease in COVID-19 patients. As a promising method recommended the diagnosis and treatment program by govt. of India high resolution computed tomography (HRCT) plays an essential role in the diagnosis and monitoring prognosis in COVID-19 patients. The main CT appearances of COVID-19 include ground glass opacities (GGOs) and patchy consolidations, which have respectively been regarded as a marker of early and progression stage of disease [11]. Based on the above-mentioned image abnormalities, HRCT could provide supplementary information to improve the planning of treatment, and evaluate the variations of image. To the best of our knowledge, little literature focuses on the change of CT appearances among different clinical types during the course of medical treatment. Therefore, the purpose of this study was to evaluate the discrepancy of series CT manifestations in COVID-19 among different clinical types within the short-term follow-up periods, aiming to help clinicians monitor and predict outcome and to make more accurate and effective clinical decisions.

2. Materials and methods

Patients

From 12 April to 20 Sep. 2020. Affiliated Hospital of SP Medical Collage Bikaner, were enrolled into our study. All patients tested positive for 2019-nCoV in the laboratory testing of respiratory secretions obtained by bronchoalveolar lavage, endotracheal aspirate, nasopharyngeal swab, or oropharyngeal swab. The patients were subsequently sub-divided into common, severe and critical groups based on clinical criteria [10]. The baseline data are recorded in Table 1.

Table 1 Baseline Characteristics in COVID-19 patients.

Characteristics	Patient (n = 70)
Age (y)	53.86 ± 12.48
Female	30
Clinical type	
Common	20
Severe	40
Critical	10
Signs and symptoms	
Fever	60
Cough	40
Fatigue	30
Headache and dizziness	10
Dyspnea	10
Nausea	20
Asymptomatic	10
Exposure history	
Exposure to Bikaner	20
No exposure to Bikaner	40
Unknown exposure	10

All patients underwent an initial and at least 2 follow-up thoracic CT

during the study period. The interval between onset of disease and initial CT scanning was 3 days (range, 1-9 days), and the mean time between initial CT and first follow-up CT, and between first and second follow-up was 3 days (range, 2-4 days) and 2.5 days (range, 1-4 days), respectively.

Image acquisition

All CT examinations were performed with a 128-row multidetector CT system (REVOLUTION EVO). Scanning coverage was from the thoracic inlet to the level of middle of the left kidney. The CT scanning protocol was as follows: tube voltage of 140 KV, tube current of 250 mA (automatic exposure control employed), rotation time of 0.35 s, pitch of 1.5 mm, detector collimation of 0.6 mm, slice thickness/reconstruction thickness of 5 mm/1 mm. All scans were performed in the supine position during end-inspiration. Data were transferred to the image processing workstation (AW SERVER 3.2)

Imaging analysis

All CT images were reviewed on the above-mentioned workstation at lung window (width of 1000 HU and window level of 700 HU). In order to ensure accuracy of analysis, all images were independently evaluated by an experienced radiologist, blinded to clinical information.

According to expert consensus [11], the initial and follow-up CT abnormalities among groups were assessed mainly based on the following features: presence of ground-glass opacities (GGO) or consolidation; presence of other abnormalities (e.g. air-bronchogram, reticulation, interlobular septal thickening, and bronchiectasis); lesion shape (e.g. patchy, nodular, etc.); Additional, we devised a semi-quantitative scoring system to evaluate the extent and progression of disease in order to assess the severity of the disease more accurately.

As illustrated in Tables 2 and 3, the CT lesion extent and density scores were determined based on the anatomic distribution and density of lung lesions with reference to the reported semi-quantitative score system [12,13]. The extent score was assessed according to the extent of lesion distributed on the five lung lobes, and the density score was evaluated based on the percentages of GGO and consolidation in each COVID-19 lesion. Thus, the score range for both lungs in each patient is from 0 (no detectable abnormality) to 20 (more than 75% of each lung lobe involved by COVID-19 lesion and 100% of consolidation in each lesion).

To assess the intra-observer variability of the above semi quantitative measurements, the first author repeated the image data analysis three days later. The intra-observer variability was obtained through comparison of the two sets of measurements by the first author. The inter-observer variability was accessed by comparison of the respective measurements of the first and corresponding authors.

Statistical analysis

All data were statistically analyzed using IBM SPSS statistics software (version 25.0). Both intra-observer and inter-observer variability were tested for CT scores using the inter-class correlation coefficient (ICC). The semi-quantitative extent and density scores of COVID-19 lesions on initial CT were considered to be reproducible when the ICC was greater than 0.75 [14]. Statistical difference was defined as $P < 0.05$ for all tests.

3. Results

CT manifestations

On initial CT, the common type mainly appeared as single or scattered focal GGOs and nodules located in central lobule, separated by a grid-like thickening of interlobular septa which was dominant in the middle and lower pleura (Fig. 1A). Severe patients had focal consolidation or patchy opacity in middle and lower lobules of bilateral pulmonary surrounded by GGOs (Fig. 2A). In critical cases, meanwhile, HRCT showed multiple patchy consolidation surrounded by a wide range of GGO with air-bronchogram inside distributing bilateral lungs from hila regions to the whole lung fields (Fig. 3A). In general, GGO was the main finding in common type whereas consolidation was the most common pattern observed in severe and critical cases, all abovementioned lesions were distributed in peripheral and sub pleural areas of bilateral lung tissue.

Table 2 Severity scoring system of COVID-19 on computed tomography.

Extent of lobe involved	Percentage (%)	Score
	0	0
	<5	1
	5-25	2
	26-49	3
	50-75	4
	76-100	5

Severity	Total Score
none	0
mild	1-8
moderate	9-15
severe	16-25

Table 3 Density scoring system of the COVID-19 on computed tomography

Category of lesions in a lobe based on the density	Score
No abnormal findings	0
Pure GGO	1
GGO with <50% consolidation and/or other abnormalities	2
GGO with ≤50% consolidation and/or other abnormalities	3
Consolidation with other abnormalities without GGO	4

Note: GGO, Ground glass opacity.

During follow up, most common and severe cases saw improvements in their lesions, manifested as the decreasing of GGO density, partial absorbing of consolidation and changing into strand-like opacity, reducing lesion volume, and the thickened interlobular septum returned to normal (Fig. 1B and C, Fig. 2B-C). However, aggravation of the lesion was noted in critical patients, as the consolidations and GGOs progressed to the increased density and enlargement volume (Fig. 3B and C).

Quantification of CT appearance

The mean intra-observer and inter-observer intra class correlation coefficients were 0.92 (95% CI: 0.83-0.96) and 0.91 (95% CI: 0.81-0.96) for extent score, and 0.95 (95% CI: 0.88-0.98) and 0.92 (95% CI: 0.81-0.97) for density score, respectively. Therefore, the average of the extent score and density score from the two set of measurements was used for the subsequent statistical analysis.

As shown in Figs. 4 and 5, the scope and density score in common (4.5 and 5, respectively), severe (9.5 and 9.5, respectively) and critical (19 and 12, respectively) cases were increased, which was consistent with clinical manifestations. During follow-up, the extent and progression score in common and severe patients was significantly decreased. However, the severity score of critical case reached the highest point on follow-up CT, accompanied with gradually increased density score, indicated patient undergoing progressed disease course.

4. Discussion

The emergence and spread of COVID-19 have caused the large global outbreak to become a major public health issue [15]. Were deaths which mainly progressed from severe and critical patients, and who tended to develop to serious complications including ARDS and multiple organ failures leading to insufficient curative efforts. Therefore, it is important to accurately assess the clinical type of patient and the effect of treatment for each type.

According to the guideline of diagnosis and treatment program on COVID-19 issued by govt. of India, patients infected with SARS-CoV-2 can be divided into common, severe and critical clinic types based on symptoms, laboratory examination and imaging. As one of the reference standards for clinical staging, the abnormal thoracic CT appearance could help in early diagnosis of disease and efficiently evaluate the extent and progress of COVID-19.

Our study found that the initial CT appearances vary according to the clinical type; this is consistent with previous reports [16-18]. The discrepancies of CT finding among different clinical types could be explained as the CT abnormalities might respectively reflect the potential pathological abnormalities in different stages of the disease. Seen mainly in the early and decaying stages of the disease, GGOs might be associated with the pathological small amount of exudation of fluid in alveolar cavity and interlobular interstitial edema [19]. As a marker of more severe phase, consolidation could reflect the pathological features of a large amount of cell-rich or fibrous

exudation accumulated in the alveolar cavity and pulmonary interstitium [20]. Additionally, the extent of GGO and consolidation in severe and critical were greater than that of common cases. Similarly, severe and critical cases tend to have higher extent and density scores compared with common type patients by semi-quantitative score system. Therefore, CT findings could accurately evaluate the severity of disease with different clinical types, and provide evidence for the further management.

Fig. 1. Initial and follow-up HRCT in a common case. A 49-year old male, who was asymptomatic and had no exposure history. Initial CT(A) illustrated multiple patchy GGOs distributed mainly in the peripheral and posterior of the lungs. The CT severity score and density score was 3 and 5, respectively. On first follow-up CT (B), the GGOs were in slighter density and smaller range, with the respective CT score and density scores being 3 and 3. Second follow-up CT(C) 7 days after admission demonstrated an improvement in absorption with fewer GGOs. Second follow-up CT extent and density scores were 2 and 2 respectively.

Fig. 2. Initial and follow-up HRCT of severe case. A 55-year old female with fever and cough symptoms A, Initial CT showed bilateral GGOs and consolidations, with the extent and density score of 7 and 10, respectively B, First follow-up CT illustrated decreasing size of consolidation surround by slight GGOs. The extent and density scores were 6 and 9 respectively C, Second follow-up CT 8 days after admission showed previous opacifications being dissipated into irregular linear opacities. Respective second follow-up CT extent and density scores were 5 and 7

Fig. 3. Initial and follow-up HRCT of critical case. A 60-year old man with a history of long-term residence in bikaner presented with fever and dyspnea, ultimately requiring intensive care unit admission. Initial CT (A) showed multiple patchy consolidation surrounded by a wide range of GGO in bilateral pulmonary, initial CT score and density scores were 19 and 12 respectively. First follow-up CT (B) illustrated the density and the volume of consolidation were significantly increased. Respective first follow-up CT extent and density scores were 20 and 16. Second follow-up CT (C) showed a progression with enlargement of GGOs, and increasing volume and attenuation of

consolidation. Second follow-up CT extent and density scores were 20 and 19 respectively.

Fig. 4. The extent scores among common, severe and critical cases. On initial CT, the critical type exhibited a greater severity score and showed slight elevation during follow-up CT scanning. In common and severe cases, the lesion extent significant decreased after treatment.

Fig. 5. Density scores among common, severe and critical cases. On series CT scanning, critical/common cases had gradient increased/decreased density scores in series CT scanning. Severe cases reached the maximum density scores at the first follow-up while decreased significantly on second follow-up.

Moreover, CT could also monitor lesion status among different clinical types of COVID-19 during the same treatment periods. We found that the variation of extent and progression obtained on the follow-up CT could exist among patients with different clinical conditions. In detail, the improvement of disease could be observed in common and severe type, exhibited as total or partial resolution of GGO or consolidation, result in decreasing of score and density scores. These changes may relate to the underlying pathological features of fibrous exudation of the alveolar cavity and the disappearance of capillary congestion in the alveolar wall, which may represent a dissipation phase of COVID-19 pneumonia [-]. In contrast, critical case could progress to the more severe phase of disease during the same period of follow-up CT, represented by enlargement of GGOs, and increasing volume and attenuation of consolidation [-]. Numerous GGOs might be associated with the invasion of adjacent lung tissues and spread in lung []. As the pathologic feature mainly including infiltration of alveolar by inflammatory cells and deposition of exudation in the airway wall accompanied by destroyed and incomplete alveolar structures, change in consolidation could indicate the continuous progress of the disease, which has been reported by previously studies [27,28].

This study had several limitations. Firstly, the sample size was very small especially in the critical type. A larger sample size of COVID-19 patients is thus required for further investigation to compared imaging feature among different groups of different clinical types. Secondly, the semi-quantitative scoring system of disease severity in our study was based on the typical CT manifestations applied in the expert consensus [], other abnormal findings such as reticulation and interlobular septal thickening were not particularly evaluated, and further modification is required. Finally, the follow up CT had a short time interval, it would be still inconclusive with CT follow up findings to evaluate treatment efficacy.

CONCLUSION

In conclusion, the initial and short-term follow-up chest CT findings of COVID-19 pneumonia vary according to the clinical type. The common and severe types tend to have relatively less severe disease courses which improve after treatment while the CT manifestations were serious in critical patient, and the condition had aggravated during follow-up. CT scanning could accurately assess the severity of COVID-19 pneumonia, and help to monitor diseases transformation during follow-up among different clinical condition.

Ethic statement

The Ethic Committee in our hospital approved this research. All enrolled subjects agreed to participate in this research and written informed consent was obtained from the enrolled subjects prior to investigation.

Conflict of interest

None.

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Not applicable.

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