Original Research Article

Comprehensive evaluation of the lesion on the first positive CT of patients with COVID-19 pneumonia

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Abstract

Aims and objective: To analyse the high-resolution computed tomography (HRCT) early imaging features and the changing trend of coronavirus disease 2019 (COVID-19) pneumonia. **Materials and Methods**: A retrospective study was conducted in the Department of Radiology in Sadar Hospital, Aurangabad, Bihar, India and Netaji Subhas Medical College and hospital, Amhara, Bihta, Patna, Bihar. Total 50 patients with COVID-19 pneumonia who had an isolated lesion on the first positive CT were included in this study. The recorde for each lesion: sites, sizes, location (peripheral or central), attenuation (ground-glass opacity or consolidation), and other abnormalities (supply pulmonary artery dilation, air bronchogram, interstitial thickening, etc.) were studied. The follow-up CT images were compared with the previous CT scans, and the development of the lesions was evaluated. **Results**: The average age of the 32 male and 18female patients was 41.25 ± 11.03 years. The most common symptom was fever 44%, followed by Cough 36%, Myalgia 18% Fatigue 14%, Vomiting/Diarrhea 4%, Headache, Muscle pain, Abdominal pain. The affected segments were located in the lower lobes 56% and in the right lobe were involved more than left. .A higher proportion of medium lesions (diameter, 1 to < 3 cm) was noted 64 % and 6% had sizes less than 10 mm 12 % and 24% had size ≥3 cm. The lesions tended to be peripheral 66 % and subpleural 82 % on the first positive chest CT. 16% lesions had interlobar pleural locations and had no peripheral distribution, and 28 % of isolated lesions were located in the central region. No pure solid nodule with a well-defined boundary was observed. The main chest CT findings were pure ground glass opacity (GGO) 42%, and mixed GGO lesions with consolidations 58 %. A halo sign of ground glass around a solid nodule was observed in 12 of 50 patients (24 %). Supply pulmonary artery dilation was found in 47 of 50 patients (94%) and air bronchogram was observed in 34 of 50 patients (68%). Other findings included the thickening of intralobular interstitium 26% and interlobular septa 2%. Pleural effusion was noted in only 1 of 50 patients (2 %). **Conclusion**: The typical early CT features of COVID-19 pneumonia are ground-glass opacity, and located peripheral or subpleural location, and with supply pulmonary artery dilation. Reticulation was evident after the 2nd week and persisted in half of patients evaluated in 4 weeks after the onset. Long-term follow-up is required to determine whether the reticulation represents irreversible fibrosis.

Keywords: CT features, CT images, COVID.

Introduction

Coronavirus Disease 2019 (COVID-19) has officially been declared a pandemic by the World Health Organization (WHO), which was ultimately found to be caused by a new severe acute respiratory syndrome coronavirus 2 (SARSCov-2).[1] This virus has spread to over 200 countries, with more than 5,000,000 cases and over 300,000 deaths reported worldwide as of May, 2020. Chest CT plays a central role in monitoring the disease severity of COVID-19 pneumonia to guide clinical management.[2] Ground-glass opacities (GGO) and consolidations are two most common CT features of COVID-19 pneumonia, which are affected by the amount of exudation in the pathological process and may transform into each other over time.[3] COVID-19

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pneumonia presents as chest lesions with rapid evolution from focal unilateral to diffuse bilateral GGO that progressed to or co-existed with consolidations within several weeks.[4] Because of the co-existed different changes in the number/size and density of lung lesions5, quantitatively measuring temporal changes of COVID-19 pneumonia can be challenging. Several studies investigated the temporal changes of COVID-19 pneumonia, but these studies assessed imaging findings using CT images all by radiologists' subjective experience[2,5-9], which were unable to accurately and quantitatively evaluate the disease severity with large inter- and intra-observer variability. To date, quantitatively assessing dynamic changes of COVID-19 pneumonia over time has still not been fully elucidated Diameter measurement and volumetric measurement are two common parameters for evaluating the changes in lung lesions.[10,11] However, neither diameter measurement nor volumetric measurement can accurately and quantitatively evaluate the progression from GGO lesions to consolidation lesions. Mass is a parameter that integrates volume and density: mass increases if the volume of a lesion increases or if its density increases. Mass can be calculated by multiplying nodule volume and density because X-ray attenuation values are proportional to tissue density (i.e., mass per unit volume).[12] In fact, mass measurement has been confirmed to enable detection of growth of pulmonary ground-glass nodules earlier and is subject to less variability than are diameter or volumetric measurement.[13]

We aimed to describe the early CT characteristics of COVID-19 pneumonia based on an isolated lesion on initial CT scans. Thus far, this information has not been previously reported. In this study, we conducted a comprehensive evaluation of the isolated lesion on the first positive CT of patients with COVID-19 pneumonia. Additionally, we presented temporal lung changes in the follow-up chest CT scans.

Material and Methods

A retrospective study was conducted in the Department of Radiology in Paras HMRI, Patna, Bihar, India and Netaji Subhas Medical College and hospital, Amhara, Bihta, Patna, Bihar.

Methodology

The patients who had an isolated lesion on the first positive chest CT and who underwent the follow-up chest CT for one month include in this study. Some patients had recent travel history, certain patients had contact with other patients with a diagnosis of COVID-19 pneumonia. The patients underwent CT for fever or other symptoms including cough, myalgia, fatigue, vomiting or diarrhoea. All cases were later confirmed with a positive result to real-time fluorescence polymerase chain reaction (RTPCR) assay for SARS-CoV-2 nucleic acid, with throat or nasopharyngeal swab specimens. 100 patients were included in the study. All patients underwent non-contrast CT scanning (GE Healthcare, Philips, or Toshiba Medical Systems) of the thorax in the supine position during end-inspiration (80–120 kVp, automated tube current modulation, mA ranges from 60 to 300,rotate time 0.5 s, pitch 0.984:1,a slice thickness of 1.25 mm.

All CT images were reviewed by radiologist. The lesions were analysed based on sites and sizes, and the lesion size was described as small (diameter, < 1 cm), medium (diameter, 1 to < 3 cm), or large (diameter, ≥3 cm). The CT images were also analysed for peripheral or central location, subpleural, ground-glass opacity (GGO) or consolidation, a halo sign of ground glass around a solid nodule, supply pulmonary artery dilation, air bronchogram, interstitial thickening, and other abnormalities (pleural effusion, cavitation, lymphadenopathy, etc). The location of the lesion was defined as peripheral if it was located in the outer one-third of the lung, and otherwise, it was defined as central. Supply pulmonary artery of the lesion area was compared supply pulmonary artery of the lesion area with other pulmonary artery at the same or similar normal segment. The intervals of the follow-up CT ranged from 3 days to 30 days after the onset of initial symptoms. The CT images were compared with previous CT scans and were evaluated for lesion development.

Statistical Analysis

The recorded data was compiled and entered in a spreadsheet computer program (Microsoft Excel 2010) and then exported to data editor page of SPSS version 19 (SPSS Inc., Chicago, Illinois, USA). Descriptive statistics included computation of percentages.

Results

The average age of the 64 male and 36 female patients was 41.25 ± 11.03 years old (range, 20−62 years). The most common symptom was fever 88(88 %), followed by Cough 36%, Myalgia 19% Fatigue 14%, Vomiting/Diarrhea 8%, Headache, Muscle pain, Abdominal pain. (Table 1).

In all, 36 of 50 patients (72 %) had assigned to common type, and 13 of 50 patients (26%) had progressed to severe type. None of the patients had died at the time of this writing.

Table 1: Demographics and clinical characteristics of patients with COVID-19 Pneumonia (N = 100)

Demographic profile	Number of patients	%
Ages(years)	41.25 ± 11.03	
Gender		
Male	32	64
Female	18	36
Sign and symptoms		
Fever	44	88
Cough	18	36
Myalgia	9	18
Fatigue	7	14
Vomiting /diarrhea	4	8
Headache	2	4
Muscle pain	2	4
Abdominal pain	1	2

The first chest CT scan was performed 1–7days (3.8 ± 1.5) after the onset of symptoms.

2 cases were negative according to the first CT and were positive on the second/follow-up CT. A total of 50 lesions were analysed on the initial positive chest CT. All lobes of the lung can be involved, and the affected segments were located located in the lower lobes 56% and in the right lobe were involved more than left. (Table 2, Fig. 1).

Table 2: Number of patients with affected segments in particular lung regions.

Location	Number of patients	%
Right upper lobe	11	22
Right middle	6	12
Right lower lobe	16	32
Left upper lobe	13	26
Left lower lobe	12	24

A difference was observed between the sizes of the lesions (7−65 mm). A higher proportion of medium lesions (diameter, 1 to < 3 cm) was noted 64 % (32/50), and 12 lesions had sizes less than 10 mm 12 % (6/50) and 24% (12/50) had size ≥3 cm. (Table 3, Fig. 2a).

Table 3: Number of sizes of Lesions on the first positive CT

Lesion Diameter Number	Number of patients	%
< 1 cm	6	12
1 to < 3 cm	32	64
≥3 cm	12	24

Characteristics of Lesions on the initial positive chest CT In terms of location within a lung segment, the lesions tended to be peripheral (66 % [33/50]) and subpleural (82 % 41/50]) on the first positive chest CT. 16% lesions had interlobar pleural locations and had no peripheral distribution, and 28 % of isolated lesions (14/50) were located in the central region (Table 4). No pure solid nodule with a well-defined boundary was observed. The main chest CT findings were pure ground glass opacity (GGO) 42 % (Fig. 2b), and mixed GGO lesions with consolidations 58 % (Fig. 3). A halo sign of ground glass around a solid nodule was observed in 12 of 50 patients (24 %). Supply pulmonary artery dilation was found in 47of 50 patients (94%) and air bronchogram was observed in 34 of 50 patients (68%). Other findings included the thickening of intralobular interstitium 26 % and interlobular septa 2%. Pleural effusion was noted in only 1 of 50 patients 2 %.

Table 4: Number of patients with particular characteristics on the first positive CT

Location	Number of patients	%
Peripheral	33	66
Subpleural	41	82
Opacification		
Pure ground-glass opacification	21	42

Mixed ground-glass and consolidation	29	58
Pure well-defined solid nodule	nil	nil
A halo sign of ground glass around a solid nodule	12	24
Supply pulmonary artery dilation	47	94
Air bronchogram	34	68
Intralobular interstitium thickening	13	26
Interlobular septal thickening	1	2
Pleural effusion	1	2

A total of 125 pulmonary CT scans were performed and each patient underwent an average of 4 ± 1 CT scans (range: 2–6). The average CTDIs were 2.59 ± 1.34 mGy, DLPs were 94.17 ± 46.34 mGy.cm, and the effective dose after ICRP guideline was 2.11 ± 0.47 mSv for each CT scan. Longitudinal changes in specific abnormalities were documented in 18 patients with serial scans obtained in the 2nd week, in 12patients with serial scans obtained in the 3rd weeks and in 10 patients in the 4th weeks or later after the onset. At 2–14 days after the onset of initial symptoms, the lesions were larger and expanding, and new lesions were observed at 7–14 days after onset of all patients, which might indicate a progressive stage. Diffuse lesions in most lobes (white lung) were observed at 10 days after onset in one patient. In 7–30 days after onset, the lesions were gradually absorbed and became irregularly linear and reticular structure, and were even completely absorbed in 2 patients. However, the absorbed lesions were accompanied by new lesions at 10–20 days. After 9 day (the 2nd week), 10 (62.5 %) of 18 patients had irregular linear opacities with or without associated ground-glass opacity or consolidation. Mixed and predominantly reticular patterns were noted from the 14th day in 7 of 18 patients (38.88 %). At 22–30 days after the onset of initial symptoms, the lesions were completely absorbed in only 4 of 10 patients (40 %,). Of 14 in whom the isolated lesion was located the central region on the first CT, 12 cases (85.71 %) showed involvement of the central and perihilar regions by expanding on the follow-up chest CT (Fig. 3).

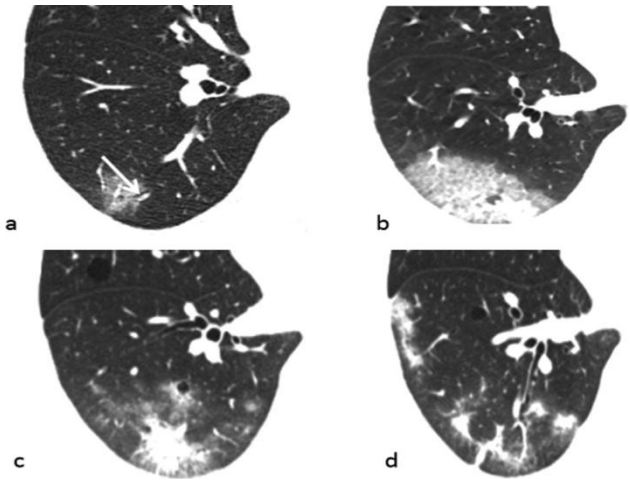

Fig 1: 47-year old male presenting with fever, cough, myalgia, and fatigue. (a) At present (day 4) ground-glass opacity lesion locates peripheral and subpleural region, in the posterior basal segment of right lower lobe. Air bronchogram (a, arrow) and Intralobular interstitium is clearly visible. (b) day 9, progressive ground glass opacity in the posterior basal segment of right lower lobe was seen. (c) day 14 and (d) day 21 the lesion was gradually absorbed.

Fig. 2: 35-year old male presenting with cough. (a) shows normal lung on first CT. (b) showed a new ground-glass opacity lesion in the right lower lobe (arrow) after 2 days. (c) follow-up image obtained 6 days later showed the lesion was larger and expanding in the posterior segment of right lower lobe and a new small lesions appeared in left lower lobe. (d) follow-up image ob- tained 14 days later showed the lesions were gradually absorbed.

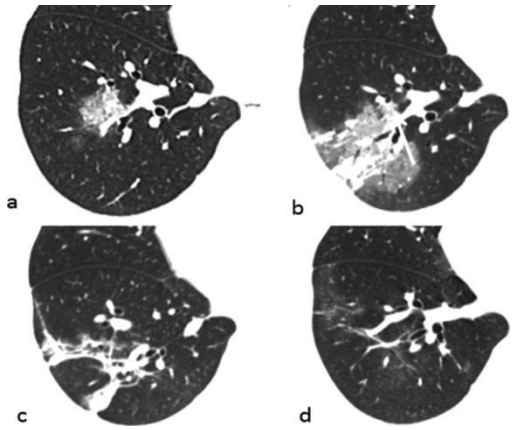

Fig. 3: 41-year old male presenting with fever. (a) At present (day 3) A mixed ground-glass opacity and small consolidation lesion was showed, located in central region of lateral basal segment of right lower lobe. Air bronchogram, supply pulmonary artery dilation (a, arrow), and intralobular interstitium were seen. (b) day 6, image showed expanding lesion with involvement of the perihilar regions, and ground glass changed to be consolidation. (c) day 13 and (d) day 30, the lesion is absorbed. Ground-glass opacities with superimposed irregular linear opacities were seen in 30 day after the onset of initial symptoms.

Discussion

In this study the early CT features of patients diagnosed with COVID-19 pneumonia. We assessed the isolated lesion on the initial positive CT and had progression on the follow-up CT. We explained the CT findings on the initial positive CT in details, when patients are suggested to be in an earlier stage of the disease. Additionally, we study the temporal lung changes on the follow-up chest CT. Lei et al.[14] introduced the CT findings of COVID-19 pneumonia as a case report, which showed multiple ground-glass opacities in the bilateral upper lobe lungs. Our initial experience has shown that the typical findings from chest CT images of COVID-19 pneumonia were bilateral multiple lobular consolidations and ground-glass opacity, predominantly in the lower lobes, similar to previous reports.[15-17] We found that the typical early pulmonary CT images of COVID-19 pneumonia were ground-glass opacity with or without consolidation, predominantly located peripheral or subpleural location with pulmonary artery dilation and air bronchogram. However, the early image performance of some cases of the COVID-19 infection

is not typical. 14 of 50 isolated lesions (28 %) were located in the central region. In total, 12 of 14 cases (85.7 %) showed involvement of the central and perihilar regions by expanding on the follow-up chest CT. A halo sign of ground glass around a solid nodule was observed in 12 of 50 patients. Pleural effusion was uncommon. No cavitation, calcification or lymphadenopathy was found in this study. In our cases, 6 lesions had sizes less than 10 mm. We advised that the small lesions, and especially new lesions, that contained an area of ground-glass opacity required follow-up to eliminate the possibility of COVID-19 pneumonia in these high-risk groups. Particularly, it should be noted that 2 cases in this study were negative on the first CT and positive on the follow-up CT. Therefore, CT re-examination might be recommended for the high-risk population with a history of epidemic condition exposure. We hope that our study findings can help to ensure triage and early recognition of the COVID-19 pneumonia. The dynamic changes in lesion manifestation were closely monitored by analyzing multiple follow-up CT scans. Although lesion development progressed in a time-dependent manner, we observed that at 3–14 days after disease onset, patients exhibited increased lung involvement accompanied by lesion enlargement and expansion, or new lesions were observed, indicating a potential progressive stage of the infection. This stage might be critical for treatment intervention and requires close clinical observations. During the reconstruction stage, which occurred at 7–30 days after disease onset in our studies, the lesions were absorbed and formed irregular linear opacities. In further analysis, we found that the lesions were absorbed but that patients developed new lesions at 10–20 days. Additionally, Mixed and predominantly reticular patterns were noted from the 14th day in 13 of 32 patients (40.62 %). At 22–30 days after the onset of initial symptoms, the lesions were completely absorbed in only 8 of 21 patients (38.1 %,). Long-term follow-up with CT and concomitant functional studies are required to determine the long-term pulmonary squeal of COVID19 pneumonia. Several studies have suggested that COVID-19 enters into host cells via cell receptor angiotensin converting enzyme II (ACE2)[18-20], and excessive activation of immune cells leads to the production of a large number of inflammatory cytokines, such as IL-6, causing diffuse damage to pulmonary capillary endothelial cells and alveolar epithelium. Though with meticulous treatments, it takes a time for the immune response to build and produce antibodies to suppress virus replication. A large sample study is needed to establish the evolution mechanism of CT characteristics during the disease.

Limitations

The limitations of this study include its retrospective nature. Secondly, the full range of COVID-19 pneumonia appearance and distribution might not have been reflected. To further elucidate the early CT imaging features and changes in the images associated with COVID-19 pneumonia, a larger sample size is needed in our next study. Besides, we evaluated the reticulation in 4 weeks after the onset. Long-term follow-up is required in future to determine whether the reticulation represents irreversible fibrosis. In summary, the typical early CT image features of COVID-19 pneumonia were ground-glass opacity, predominantly located peripheral or subpleural location and pulmonary artery dilation. Additionally, a new small lesion that contained an area of ground-glass opacity might require follow-up CT to eliminate the possibility of COVID-19 infection in high-risk groups. Reticulation is evident after the 2nd week and persists in half of patients evaluated after 4 weeks. Long-term follow-up is required to determine whether the reticulation represents irreversible fibrosis. We hope that our study findings can facilitate early identification and management of cases of suspected COVID-19 pneumonia.

Conclusion

The typical early CT features of COVID-19 pneumonia are ground-glass opacity, and located peripheral or subpleural location, and with supply pulmonary artery dilation. Reticulation was evident after the 2nd week and persisted in half of patients evaluated in 4 weeks after the onset. Long-term follow-up is required to determine whether the reticulation represents irreversible fibrosis.

References

1. Huang C, Wang Y, Li X, et al. Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. Lancet 2020;395:497-506.
2. Pan F, Ye T, Sun P, et al. Time Course of Lung Changes at Chest CT During Recovery From Coronavirus Disease 2019 (COVID-19). Radiology 2020;295:715-21.
3. Jin YH, Cai L, Cheng ZS, et al. A rapid advice guideline for the diagnosis and treatment of 2019 novel coronavirus (2019-nCoV) infected pneumonia (standard version). Mil Med Res 2020;7:4.
4. Shi H, Han X, Jiang N, et al. Radiological findings from 81 patients with COVID-19

pneumonia in Wuhan, China: a descriptive study. Lancet Infect Dis 2020;20:425-34.
5. Pan Y, Guan H, Zhou S, et al. Initial CT findings and temporal changes in patients with the novel coronavirus pneumonia (2019-nCoV): a study of 63 patients in Wuhan, China. Eur Radiol 2020;30:3306-9.
6. Wang Y, Dong C, Hu Y, et al. Temporal Changes of CT Findings in 90 Patients with COVID-19 Pneumonia: A Longitudinal Study. Radiology 2020:200843.
7. Fang Y, Zhang H, Xu Y, et al. CT Manifestations of Two Cases of 2019 Novel Coronavirus (2019-nCoV) Pneumonia. Radiology 2020;295:208-9.
8. Lei J, Li J, Li X, et al. CT Imaging of the 2019 Novel Coronavirus (2019-nCoV) Pneumonia. Radiology 2020;295:18.
9. Shi H, Han X, Zheng C. Evolution of CT Manifestations in a Patient Recovered from 2019 Novel Coronavirus (2019-nCoV) Pneumonia in Wuhan, China. Radiology 2020;295:20.
10. Lee HJ, Goo JM, Lee CH, et al. Nodular groundglass opacities on thin-section CT: size change during follow-up and pathological results. Korean J Radiol 2007;8:22-31.
11. Marten K, Auer F, Schmidt S, et al. Inadequacy of manual measurements compared to automated CT volumetry in assessment of treatment response of pulmonary metastases using RECIST criteria. Eur Radiol 2006;16:781-90.
12. Mull RT. Mass estimates by computed tomography: physical density from CT numbers. AJR Am J Roentgenol 1984;143:1101-4.
13. de Hoop B, Gietema H, van de Vorst S, et al. Pulmonary ground-glass nodules: increase in mass as an early indicator of growth. Radiology 2010;255:199-206.
14. J. Lei, J. Li, X. Li, X. Qi, CT imaging of the 2019 novel coronavirus (2019-nCoV) pneumonia, Radiology 2020 (January (31)) (2020) 200236
15. Q. Li, X. Guan, P. Wu, et al., Early transmission dynamics in Wuhan, China, of novel coronavirus-infected pneumonia, N Engl J Med. (January (29)) (2020)
16. M. Chung, A. Bernheim, X.Y. Mei, et al., CT imaging features of 2019 novel coronavirus(2019-nCoV), Radiology (February (4)) (2020) 200230,
17. Y. Pan, H. Guan, S. Zhou, et al., Initial CT findings and temporal changes in patients with the novel coronavirus pneumonia (2019-nCoV): a study of 63 patients in Wuhan, China, Eur. Radiol. (February (13)) (2020.
18. R. Channappanavar, J. Zhao, S. Perlman, T cell-mediated immune response to respiratory coronaviruses, Immunol. Res. 59 (1–3) (2014) 118–128,
19. Hao Zhang, Zijian Kang, Haiyi Gong, et al., The Digestive System Is a Potential Route of 2019-nCov Infection: A Bioinformatics Analysis Based on Single-cell Transcriptomes, https://www.biorxiv.org/content/10.1101/2020.01.30. 927806v1.full.pdf+html.
20. N. Chen, M. Zhou, X. Dong, et al., Epidemiological and clinical characteristics of 99 cases of 2019 novel coronavirus pneumonia in Wuhan, China: a descriptive study, Lancet 395 (10223) (2020) 507–513.

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