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## FULL PAPER

# Chest CT features and progression of patients with coronavirus disease 2019

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**Objectives:** Coronavirus disease 2019 (COVID-19) is a major public health emergency. It poses a grave threat to human life and health. The purpose of the study is to investigate the chest CT findings and progression of the disease observed in COVID-19 patients.

**Methods:** Forty-nine confirmed cases of adult COVID-19 patients with common type, severe and critically severe type were included in this retrospective single-center study. The thin-section chest CT features and progress of the disease were evaluated. The clinical and chest imaging findings of COVID-19 patients with different severity types were compared. The CT severity score and MuLBSTA score (a prediction of mortality risk) were calculated in those patients.

**Results:** Among the 49 patients, 35 patients (71%) were common type and 14 patients (28%) were severe and critically severe type. Nearly all patients (98%) had pure ground-glass opacities (GGO) in CT imaging. Of the severe and critically severe type patients, 86% exhibited GGO with consolidation, in comparison with 54% of the patients with common type. Fibrosis presented in 79% of the severe and critically severe type patients and 43% of the common type patients. The severe and critically severe type patients were significantly more prone

to experience five-lobe involvement compared to the common type patients ( $p = 0.002$ ). The severe and critically severe type patients also had higher CT severity and MuLBSTA scores than the common type patients ( $5.43 \pm 2.38$  vs  $3.37 \pm 2.40$ ,  $p < 0.001$ ; and  $10.21 \pm 3.83$  vs  $4.63 \pm 3.43$ ,  $p < 0.001$ , respectively). MuLBSTA score was positively correlated with admittance to the intensive care unit ( $p = 0.005$ ,  $r = 0.351$ ). Nineteen patients underwent three times CT scan. The interval between first and second CT scan was 4[4,8] days, second and third was 3[2,4] days. There were greater improvements in the third CT follow-up findings compared to the second ( $p = 0.002$ ).

**Conclusions:** The severe and critically severe type patients often experienced more severe lung lesions, including GGO with consolidation. The CT severity score and MuLBSTA score may be helpful for the assessment of COVID-19 severity and progression.

**Advances in knowledge:** Chest CT has the value of evaluated radiographical features of COVID-19 and allow for dynamic observation of the disease progression. Considering coagulation disorder of COVID-19, MuLBSTA score may need to be updated to increase new understanding of COVID-19.

## INTRODUCTION

Coronavirus disease 2019 (COVID-19) is a major public health emergency. It poses a grave threat to human life and health. COVID-19 can cause multiple system infections; mainly respiratory tract infections in humans.<sup>1</sup> The pneumonitis caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) is much less severe than that caused by SARS-CoV,<sup>2</sup> but it has stronger infectivity. At present, the clinical and imaging features of COVID-19 have been recognized. However, the clinical manifestations of the COVID-19 are complex and diverse, and the imaging features are difficult to identify, especially in severe and critically severe type patients.

The National Health Committee of the People's Republic of China published guidelines for the diagnosis and treatment of pneumonitis caused by COVID-19 infection (trial sixth version).<sup>3</sup> As awareness and understanding of this disease improve, the guidelines have been revised for the recognition, treatment, and prevention of the disease, including the use of imaging examinations. The pharyngeal and nasal test papers have been reported to produce false-negatives and may require multiple tests because the result can depend on the concentration of the virus as well as the skill of the operator. A multicenter study reported that abnormalities were present in 86.2% of the 975 case report with CT exam, while 59.1% of the 274 X-rays were abnormal.<sup>4</sup> Imaging plays a very important role in the diagnosis and treatment of COVID-19, especially chest CT. The purpose of this study was to review the thin-section chest CT features and changes as the disease progresses in COVID-19 patients. We also compared the chest CT findings of the different severity types.

## METHODS AND MATERIALS

### Population characteristics

For this retrospective single-center study, we recruited adult patients from January 6 to February 22, 2020, at our institution. The ethics boards of our institution approved this research (No.2020.43). The epidemiological data, history of exposure, symptoms, laboratory and CT features were obtained with data collection forms from electronic medical records. The medical data were collected from admission to discharge for all patients.

All the recorded data were independently reviewed by two researchers. The medical records of patients were analyzed by the research team. To ascertain any incomplete data that were

not available from the electronic medical records, the researchers communicated directly with patients or their families.

Fifty-one patients were enrolled with a diagnosis of COVID-19 according to the diagnostic criteria of the guideline. All patients were positive for SARS-CoV-2 at laboratory testing of respiratory secretions obtained by means of bronchoalveolar lavage, endotracheal aspirate, nasopharyngeal swab, or oropharyngeal swab. Patients who did not have a thin-section chest CT exam were excluded from the study. Two patients were deemed too ill to undergo CT exam. And they underwent bedside X-ray exam. A total of 49 patients remained, including 26 males and 23 females (mean age: 41 years, ranging from 19 to 77 years). We recorded sex, heart rate, respiratory rate, and underlying disease and reviewed the clinical features. The underlying diseases include hypertension, diabetes, COPD, cardiovascular disease, cerebrovascular disease, CKD and chronic liver disease. According to the diagnostic criteria of the guideline, COVID-19 patients were divided into common, severe and critically severe groups.<sup>5</sup> In common type, symptoms such as fever and respiratory tract are present, and pneumonia can be seen on imaging. Severe type meet any of the following: 1. Respiratory distress, RR  $\geq$ 30 times/min; 2. In the resting state, oxygen saturation  $\leq$ 93%; 3. arterial partial pressure of oxygen (PaO<sub>2</sub>)/oxygen concentration (FiO<sub>2</sub>)  $\leq$ 300 mm Hg (1 mm Hg = 0.133 kPa). In critically severe type, one of the following conditions is met: 1. Respiratory failure occurs and mechanical ventilation is required; 2. Shock; 3. ICU monitoring and treatment are required for patients with other organ failure.

### CT protocol

All patients underwent thin-section chest CT exam on GE-Bright Speed spiral CT with the following acquisition parameters: detector row number 16;120 kVtube voltage; automatic adjustment tube current; noise factor 11; 1.75:1 screw pitch; 17.5 mm/rotation bed speed; the scan thickness was 1.25 mm and the reconstructed thickness was 0.625 mm. All scans were obtained with the patient in the supine position. At the end of deep inhalation, the patient was then scanned using the breath-hold technique. The acquisition range was from the thoracic inlet to 2 cm below the diaphragm level. Standard lung window (window level 430-550HU, window width 1150-1350HU) and mediastinal window (window level 35-40HU, window width 350-400HU) were used for reconstruction.

Figure 1. A: common type patient; B: severe and critically severe type patient

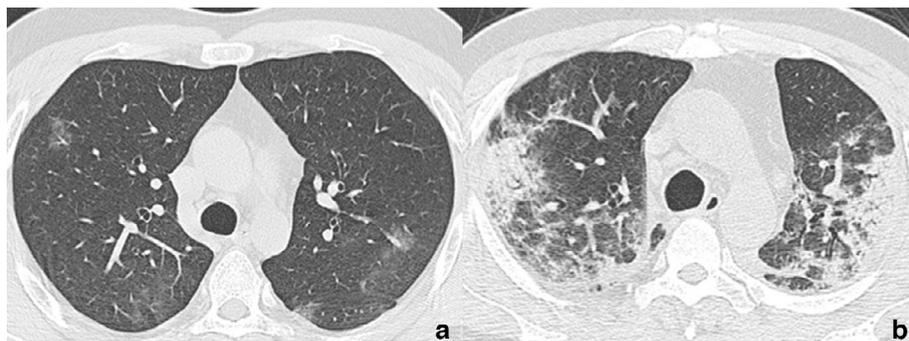


Table 1. Baseline characteristics of COVID-19 patients

|                              | <b>Total<br/>(n = 49)</b> | <b>Common type<br/>(n = 35)</b> | <b>Severe and critically<br/>severe type (n = 14)</b> | <b>P</b>     |
|------------------------------|---------------------------|---------------------------------|---|--------------|
| Age, median(IQR)             | 41(33-56)                 | 37(30-54)                       | 48.5 (36.75–65)                                       | <b>0.041</b> |
| Male(%)                      | 26 (53%)                  | 15 (43%)                        | 11 (79%)  | <b>0.024</b> |
| <b>Exposure history</b>      |                           |                                 |   |              |
| Living in Wuhan              | 12 (24%)                  | 8 (23%)                         | 4 (29%)   | 0.958        |
| Recent travel to Wuhan       | 14 (28%)                  | 7 (20%)                         | 7 (50%)   | 0.080        |
| Exposure to infected patient | 19 (39%)                  | 16 (46%)                        | 3 (21%)   | 0.115        |
| Unknown exposure             | 10 (20%)                  | 8 (23%)                         | 2 (14%)   | 0.779        |
| <b>Pathogenetic process</b>  |                           |                                 |   |              |
| Time from onset to admission | 5 (3–8)                   | 5 (3–8)                         | 6.5 (5–8.75)  | 0.430        |
| Hospital stays               | 11(9-14)                  | 11(9-14)                        | 12 (9.5–15)   | 0.698        |
| <b>Signs and Symptoms</b>    |                           |                                 |   |              |
| Fever                        | 42 (86%)                  | 28 (80%)                        | 14 (100%)   | 0.175        |
| Fatigue                      | 11 (22%)                  | 7 (20%)                         | 4 (29%)   | 0.787        |
| Headache                     | 4 (8%)                    | 3 (9%)                          | 1 (7%)  | 1.000        |
| Cough                        | 33 (67%)                  | 21 (60%)                        | 12 (86%)  | 0.162        |
| Expectoration                | 21 (43%)                  | 13 (37%)                        | 8 (57%)   | 0.209        |
| Myalgia                      | 8 (16%)                   | 5 (14%)                         | 3 (21%)   | 0.855        |
| Nausea                       | 1 (2%)                    | 1 (3%)                          | 0 (0%)  | 1.000        |
| Chest pain                   | 3 (6%)                    | 1 (3%)                          | 2 (14%)   | 0.396        |
| Chest distress               | 4 (8%)                    | 3 (9%)                          | 1 (7%)  | 1.000        |
| Runny nose                   | 2 (4%)                    | 2 (6%)                          | 0 (0%)  | 0.909        |
| Dyspnea                      | 12 (24%)                  | 7 (20%)                         | 5 (36%)   | 0.431        |
| Diarrhea                     | 8 (16%)                   | 7 (20%)                         | 1 (7%)  | 0.501        |
| Abdominal pain               | 1 (2%)                    | 1 (3%)                          | 0 (0%)  | 1.000        |
| Chill                        | 9 (18%)                   | 5 (14%)                         | 4 (29%)   | 0.448        |
| <b>Underlying disease</b>    |                           |                                 |   |              |
| Hypertension                 | 7 (14%)                   | 2 (6%)                          | 5 (36%)   | <b>0.024</b> |
| Diabetes                     | 4 (8%)                    | 2 (6%)                          | 2 (14%)   | 0.680        |
| COPD                         | 1 (2%)                    | 1 (3%)                          | 0 (0%)  | 1.000        |
| Cardiovascular disease       | 3 (6%)                    | 1 (3%)                          | 2 (14%)   | 0.396        |
| Cerebrovascular              | 2 (4%)                    | 1 (3%)                          | 1 (7%)  | 1.000        |
| Chronic kidney disease       | 2 (4%)                    | 0 (0%)                          | 2 (14%)   | 0.138        |
| Chronic liver disease        | 3 (6%)                    | 3 (9%)                          | 0 (0%)  | 0.638        |
| <b>Heart rate, bpm</b>       | 88(81-99)                 | 86(80-96)                       | 92 (87.75–115)  | 0.123        |
| <b>Respiratory rate</b>      | 20(20-21)                 | 20(20-20)                       | 20.5 (20–24)  | 0.125        |

IQR: interquartile ranges

### CT imaging analysis

Two experienced radiologists with approximately 5 years of experience in chest CT analyzed all chest CT images. All images were processed and read using a viewing console. The chest radiologists independently reviewed and analyzed all images, and final decisions were reached by consensus. The radiologists

using thin-section axial images and sagittal and coronal reformations. For disagreement between the two primary radiologist interpretations, a third chest radiologist with 10 years of experience adjudicated the findings and made a final decision.

Table 2. The CT features in different COVID-19 groups

|  | Total( <i>n</i> = 49) | Common type<br>( <i>n</i> = 35) | Severe and<br>critically severe<br>type ( <i>n</i> = 14) | <i>P</i>     |
|--|-----------------------|---------------------------------|--|--------------|
| <b>CT scan</b>                             |                       |                                 |  |              |
| Interval from onset of symptoms to CT scan | 10 (5.5–13.5)         | 9 (5–11)                        | 10.5 (5.75–15.25)  | 0.430        |
| Interval from formal treatment to CT scan  | 3 (1–6)               | 4 (1–6)                         | 2 (1–4.5)  | 0.698        |
| <b>CT features</b>                         |                       |                                 |  |              |
| Pure ground-glass opacities                | 48 (98%)              | 34 (97%)                        | 14 (100%)  | 1.000        |
| Consolidation                              | 13 (27%)              | 9 (26%)                         | 4 (29%)  | 1.000        |
| Ground-glass opacities with consolidation  | 31 (63%)              | 19 (54%)                        | 12 (86%)   | <b>0.039</b> |
| Nodule                                     | 17 (35%)              | 12 (34%)                        | 5 (36%)  | 1.000        |
| Fibrosis                                   | 26 (53%)              | 15 (43%)                        | 11 (79%)   | <b>0.024</b> |
| Vascular enlargement                       | 25 (51%)              | 16 (46%)                        | 9 (64%)  | 0.240        |
| Interlobular septa thickened               | 24 (49%)              | 17 (49%)                        | 7 (50%)  | 0.928        |
| Emphysema                                  | 2 (4%)                | 2 (6%)                          | 0 (0%)   | 0.909        |
| Pulmonary bullae                           | 8 (16%)               | 4 (11%)                         | 4 (29%)  | 0.299        |
| Pleural effusion                           | 5 (10%)               | 2 (6%)                          | 3 (21%)  | 0.263        |
| Pleural thickening                         | 7 (14%)               | 4 (11%)                         | 3 (21%)  | 0.651        |
| Grid shadow                                | 8 (16%)               | 5 (14%)                         | 3 (21%)  | 0.855        |
| <b>Frequency of lobe involvement</b>       |                       |                                 |  |              |
| Right upper lobe                           | 31 (63%)              | 19 (54%)                        | 12 (86%)   | <b>0.039</b> |
| Right middle lobe                          | 33 (67%)              | 20 (57%)                        | 12 (86%)   | 0.117        |
| Right lower lobe                           | 29 (59%)              | 17 (35%)                        | 12 (86%)   | <b>0.017</b> |
| Left upper lobe                            | 29 (59%)              | 17 (35%)                        | 12 (86%)   | <b>0.017</b> |
| Left lower lobe                            | 43 (88%)              | 29 (59%)                        | 14 (100%)  | 0.241        |
| <b>No. of lobes affects</b>                |                       |                                 |  |              |
| 1  | 10 (20%)              | 9 (18%)                         | 1 (7%)   | 0.287        |
| 2  | 5 (10%)               | 6 (17%)                         | 0 (0%)   | 0.241        |
| 3  | 8 (16%)               | 6 (17%)                         | 1 (7%)   | 0.651        |
| 4  | 9 (18%)               | 7 (20%)                         | 2 (14%)  | 0.953        |
| 5  | 17 (35%)              | 7 (20%)                         | 10 (71%)   | <b>0.002</b> |
| <b>Bilateral lung disease</b>              | 37 (76%)              | 24 (69%)                        | 13 (93%)   | 0.156        |

COVID-19: Coronavirus Disease 2019.

For each of the 49 patients, the initial CT scans were evaluated for the following characteristics: (1) presence of pure ground-glass opacities (GGO), consolidation, GGO with consolidation, nodule, fibrosis, vascular enlargement, interlobular septa thickened, emphysema, pulmonary bullae, pleural effusion, pleural thickening and grid shadow; (2) number of lobes affected; (3) degree of lobe involvement in addition to overall lung “total CT severity score.”

Each of the five lung lobes was assessed for degree of involvement and classified as 0 (none0%), 1 (minimal1%–25%), 2 (mild 26–50%), 3 (moderate 51–75%), or 4 (severe 76–100%). The overall lung “total CT severity score” was obtained by

summing up the scores of five-lobe (range of possible scores 0–20). Patients underwent follow-up chest CT during the hospitalization. These scans were also examined to assess for lung lesions change or progression over time, which was evaluated qualitatively with a consensus approach by two of the chest radiologists.

Nineteen patient received two follow-up chest CTs. The lesions of each lobe were evaluated for progression. If the lesions increased in scope or changed from GGO to consolidation, the lesions were considered to be aggravated, and if not, the lesions were considered to be improved. Finally, the overall assessment of all lobes was performed.

Figure 2. Male, 63 years with fever, cough and fatigue for two days, common type. Axial chest CT shows the progressional changes of the right lower lobe lesions. There is no consolidation or fibrosis.



### MuLBSTA score

MuLBSTA score was used as a method to predict the risk of mortality. The score included the following parameters: multi-lobular infiltrates (five points), lymphocyte  $\leq 0.8 \times 10^9/L$  (four points), bacterial coinfection (four points), acute-smoker (three points), quit-smoker (two points), hypertension (two points) and age  $\geq 60$  years (two points). A score of 12 points was used as a cut-off value for mortality risk stratification. A MuLBSTA score of 0–11 is considered as “low-risk” for mortality and a score from 12 to 22 is considered as “high-risk” for mortality.<sup>6</sup>

### Statistical analysis

All data were analyzed using the Kolmogorov–Smirnov test. Values are presented as the median (IQR). The homogeneity of variance assumption was assessed using Levene’s test. Continuous variables were compared using the independent Student’s t-test of variance. The Mann–Whitney U-test was used to compare data that were did not normally distributed. The proportions for categorical variables were compared using the  $\chi^2$  test, but the Fisher exact test was used instead when the data were limited. All statistical analyses were performed using SPSS (v.24.0; IBM Corp., Armonk, NY, USA), and GraphPad Prism (v.7.0; GraphPad Software, San Diego, CA, USA). A *P*-value  $< 0.05$  was considered to indicate a statistically significant difference.

## RESULTS

### Clinical features

The clinical features of the COVID-19 patients are presented in Table 1. Of the 49 patients hospitalized with COVID-19, the median age was 41 years (IQR, 33–56 years). Thirty-five patients (71%) were diagnosed with common type and 14 (28%) patients were diagnosed with severe and critically severe type COVID-19. The severe and critically severe type patients were older than the common type patients ( $p = 0.041$ ). Thirty-nine of 49

patients (80%) had a history of epidemiological exposure. Fever (42, 86%), cough (33, 67%) and expectoration (21, 43%) were the most common symptoms. There were no differences in the signs and symptoms exhibited between the two types (all  $p > 0.05$ ). The median time from the first symptom to admission was five days, and the median hospital stay was 11 days. The severe and critically severe type patients were more likely to have hypertension than the common type patients (5, 36% vs 2, 6%;  $p = 0.024$ ). There was no significant difference in other underlying diseases between the two groups.

### CT findings

There was no significant difference in the interval from the onset of symptoms to the first CT scan between the common type and the severe and critically severe type patients (9[5–11] vs 10.5 [5.75–15.25] days). The chest CT findings of all participants were obtained and compared (Table 2, Figures 1–4). Among the 49 patients, 48 (98%) of the CT images revealed the presence of pure GGO. There were no significant differences between the common type and the severe and critically severe types in the presence of pure GGO ( $p = 1.000$ ). Twelve (12/14, 86%) severe and critically severe type patients had more GGO with consolidation than common type (19/35, 54%). Compared with common type (15/35, 43%), severe and critically severe type patients (11/14, 79%) had more fibrosis features. Right upper lobe, right lower lobe and left upper lobe in the severe and critically severe type patients (86%, 86%, 86%) involved higher fibrosis than common type (54%, 35%, 35%). The severe and critically severe type patients were more prone to five-lobe infection compared to the common type patients (10, 71% vs 7, 20%;  $p = 0.002$ ). The total CT severity scores are presented in Figure 5. The severe and critically severe type patients had higher CT severity scores than common type patients ( $5.43 \pm 2.38$  vs  $3.37 \pm 2.40$ ,  $p < 0.001$ ) (Figure 5). Nineteen patients underwent three times CT scan.

Figure 3. Male, 47 years with fever for 11 days, severe and critically severe type. Axial chest CT shows the progressional changes of right lower lobe lesions. The lesions of GGO with consolidation absorbed gradually.

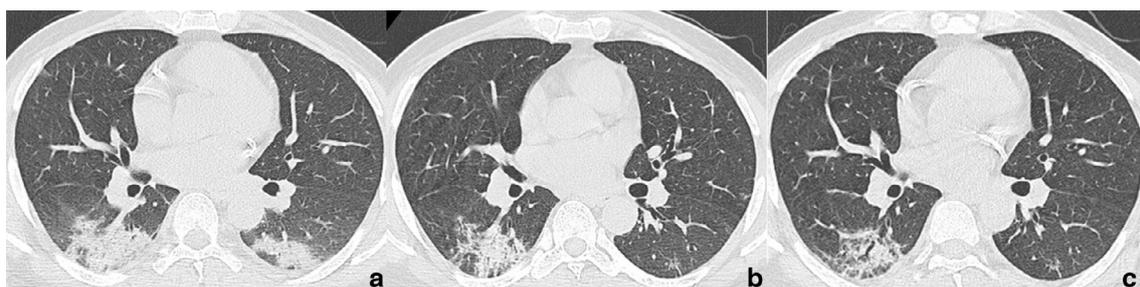


Figure 4. Male, 37 years with fever for 5 days, severe and critically severe type. The lesions are accompanied by extensive fibrosis.

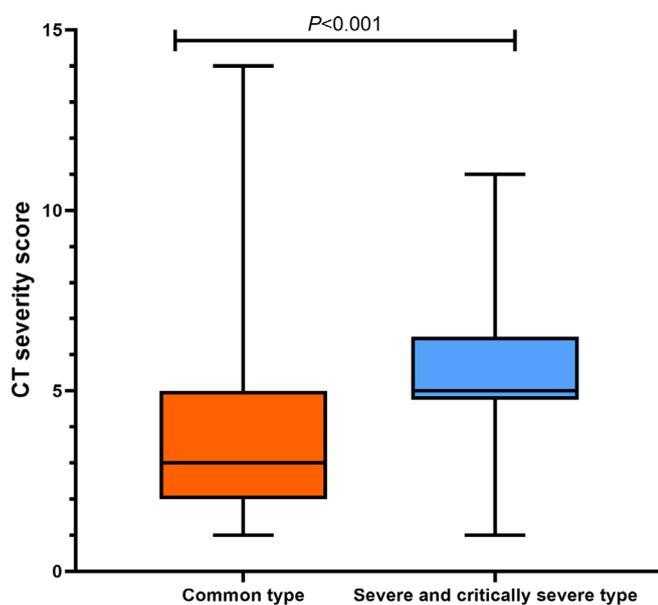


The interval between first and second CT scan was 4[4,8] days, second and third was 3[2,4] days. The follow-up chest CT images showed that 50% of patients' lung lesions were reduced and 45% had increased. When compared with the second CT images, the lung lesions in the third CT images were significantly reduced ( $p = 0.002$ ) (Figure 6).

#### MuLBSTA score

Forty-eight patients were treated and discharged and one patient died. Five (36%) of the severe and critically severe type patients required ICU care. All of the common type patients did not require ICU care. The severe and critically severe type patients presented more multilobular infiltrates than the common type patients ( $p = 0.038$ ). The severe and critically severe type patients also presented with more bacterial infections ( $p < 0.001$ ) and histories of hypertension ( $p = 0.024$ ). (Table 3) The MuLBSTA scores of the severe and critically severe type patients were higher than the scores of the common type patients (10.5 vs 5,  $p < 0.001$ ) (Figure 7). MuLBSTA score was positively correlated with ICU admittance ( $p = 0.005$ ,  $r = 0.351$ ). Eight patients had MuLBSTA scores higher than 12, seven patients were in the severe and critically severe group, and one patient died.

Figure 5. CT severity score



## DISCUSSION

We investigated the clinical, thin-section chest CT features and the progression of COVID-19 in patients with different severity types. The severe and critically severe type patients were older than the common type patients, which suggests that older people are at higher risk for developing severe infections. We observed a greater number of males than females in the severe and critically severe type. In addition, the severe and critically severe type patients were more likely to have hypertension. Previous study have reported that COVID-19 is more likely to affect older males with comorbidities, which can result in severe and even fatal respiratory diseases such as acute respiratory distress syndrome.<sup>5,7</sup> This is consistent with the results of our research. Thirty-nine of 49 patients (80%) had a history of epidemiological exposure, which was very important for diagnosis. Fever, cough and expectoration were the most common clinical symptoms, which is consistent with the results of previous studies.<sup>8,9</sup> The signs and symptoms were the same between the common and severe type groups. In some mild cases, there are no obvious clinical symptoms, suggesting that symptoms alone are not an accurate way to diagnose and judge the severity of COVID-19.

Figure 6. CT progress score

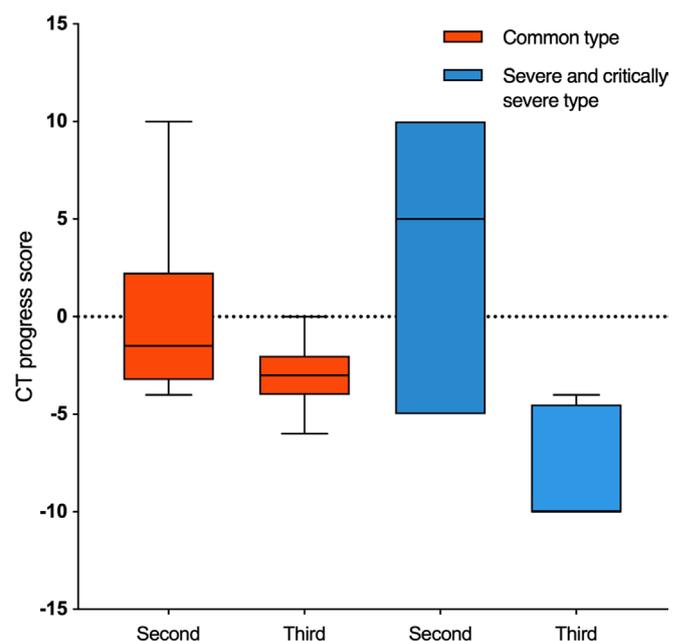


Table 3. The assessment of prognosis of COVID-19 patients

|                                     | Total<br>(n = 49) | Common type (n = 35) | Severe and critically<br>severe type (n = 14) | P            |
|-------------------------------------|-------------------|----------------------|---|--------------|
| Hospital discharge                  | 48 (98%)          | 35 (100%)            | 13 (93%)                                      | 0.632        |
| ICU                                 | 5 (10%)           | 0 (0%)               | 5 (36%)                                       | <b>0.000</b> |
| Death                               | 1 (2%)            | 0 (0%)               | 1 (7%)  | 0.632        |
| <b>MuLBSTA scale</b>                |                   |                      |   |              |
| Multilobular infiltrates            | 34 (69%)          | 20 (57%)             | 13 (93%)                                      | <b>0.038</b> |
| Lymphocyte $\leq 0.8 \times 10^9/L$ | 15 (31%)          | 8 (23%)              | 7 (50%)                                       | 0.129        |
| Bacterial coinfection               | 10 (20%)          | 2 (6%)               | 8 (57%)*                                      | <b>0.000</b> |
| Smoker                              | 4 (8%)            | 2 (6%)               | 2 (14%)                                       | 0.680        |
| Age $\geq 60$ years                 | 10 (20%)          | 6 (17%)              | 4 (29%)                                       | 0.614        |
| Hypertension                        | 7 (14%)           | 2 (6%)               | 5 (36%)                                       | <b>0.024</b> |

COVID-19: Coronavirus Disease 2019; ICU: Intensive Care Unit.

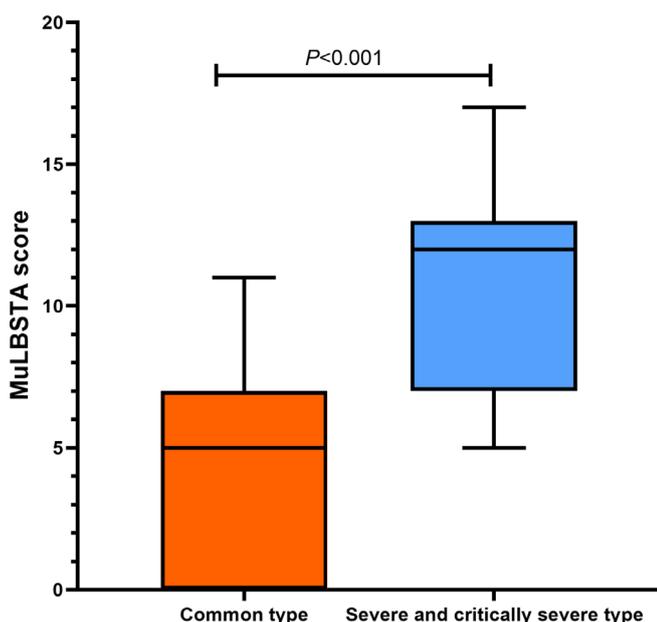
Our results revealed a high prevalence of bacterial coinfection in severe and critically severe type patients. This suggests that the severe and critically severe type patients may have low immunity and be susceptible to infection.

The pharyngeal and nasal test papers have been reported to produce false-negatives and may require multiple tests because the result can depend on the concentration of the virus as well as the skill of the operator. Chest CT can be used as an important complement for the diagnosis of COVID-19 pneumonia in the current epidemic context. With the development of imaging technology, CT can be used to obtain high-quality images at a lower radiation dose in less time. AiT et al reported that RT-PCR and chest CT in the 1014 case cohort study were 59 and 88% accurate for the diagnosis of suspected patients with

COVID-19, respectively.<sup>10</sup> In their research, with RT-PCR as a reference, the sensitivity of chest CT imaging for COVID-19 was 97%.<sup>10</sup> The thin-section chest CT exam plays a vital role in the diagnosis and treatment of COVID-19.

Chest CT can accurately evaluate the feature and extent of lung lesions. A systematic review of COVID-19 CT findings showed that typical CT signs were GGO, GGO with mixed consolidation, adjacent pleura thickening, interlobular septal thickening, and air bronchograms.<sup>11</sup> Our results are roughly in the same range as this reported. We demonstrated that most common chest CT imaging finds were pure GGO, GGO with consolidation, fibrosis and vascular enlargement. These four lesions often occur simultaneously in same patients. Nodules were relatively less common in COVID-19 patients. Compared with pure GGO, GGO with consolidation represented the progression of the disease. With RT-PCR results as reference in 1014 patients study, the sensitivity, specificity, accuracy of chest CT in indicating COVID-19 infection were 97%, 25 and 68%, respectively.<sup>10</sup> Actually, COVID-19 does not have a characteristic image feature to distinguish it from other viral pneumonitis. Meanwhile, the imaging findings of viral pneumonia are diverse and overlap with those of other non-viral infections and inflammatory conditions. Through literature review, we found that although a definite diagnosis cannot be achieved on the basis of imaging features alone, recognition of viral pneumonia patterns may aid in differentiating which virus are present. Koo HJ's review indicates that there are specific imaging features that indicate the possibility of viral infections.<sup>12</sup> Previous studies reported that in severe acute respiratory syndrome (SARS) coronavirus infection CT images, GGO with consolidations were the main findings and reticulation is typically noted after the second week.<sup>13</sup> Cavitation and pleural effusions were not common findings.<sup>14</sup> These findings are consistent with our results. In our study, pure GGO (98%) and GGO with consolidations (63%) were the main findings in CT images. This may be because viruses of the same viridae present similar pathogenesis. In Middle East respiratory syndrome (MERS) coronavirus infection, pleural effusions were more common in

Figure 7. MuLBSTA score



the patients who died than in those who recovered.<sup>15</sup> Pleural effusion was less common in our study and may be associated with less severe cases and better prognoses.

Previous studies reported that the COVID-19 patients with the highest CT severity score were admitted to the intensive care unit.<sup>9</sup> Our study results were consistent with this finding. The CT severity score of severe and critically severe type patients was higher than the scores of the common type patients consistent with earlier study.<sup>5</sup> Thus, the CT score may be a more intuitive indicator of COVID-19 severity. CT examination plays an important auxiliary role in subsequent management of COVID-19 patients. The follow-up chest CT images revealed that some patients' lung lesions were reduced while some increased. Compared with the second CT images, the lung lesions size and density of third CT images were greatly reduced. Guo et al.'s retrospective clinical research proposed the MuLBSTA score (age  $\geq 60$  years, a history of smoking, hypertension history, multilobular infiltrates and lymphocyte  $\leq 0.8 \times 10^9/L$  and combined bacterial infections) as an early warning model for predicting mortality of viral pneumonia.<sup>6</sup> The MuLBSTA scores greater than 12 indicated a high viral pneumonia death risk. The author also confirmed that the characteristics of COVID-19 patients who died were in line with the early warning model for predicting mortality in viral pneumonia using the MuLBSTA score.<sup>7</sup> A higher MuLBSTA score might be used as a good predictor of prognosis.<sup>7</sup> In our study, the disease progressed rapidly in the patient who died; he developed multiple organ failure in a short time. This patient had a MuLBSTA score greater than 12. The MuLBSTA score was also associated with ICU admittance.

The COVID-19 patients with severe and critically severe type often develop multiple organ dysfunction or failure in later stages. Previous studies and anatomical pathology suggested that systemic coagulation disorder was an important cause of multiple organ dysfunction and disease progression in COVID-19 patients.<sup>16-18</sup> Autopsy report showed that the pulmonary vascular lesions of COVID-19 patients showed hyaline thrombus and hemorrhagic infarction of lung tissue.<sup>19</sup> These changes were not limited to the lungs, but could also occur in the spleen and

brain. In fact, patients presented with varying degrees of coagulation disorder in our study. But the MuLBSTA score did not consider coagulation disorder. In this study, we did not evaluate the coagulation disorder, which is a shortcoming of this study.

The present study has some limitations. First, this is a retrospective single-center study and we had a relatively small number of patients. Less than half of the patients had two CT follow-ups. Second, individual critically severe patients who could not complete CT exams were excluded. Those patients often received bedside X-rays imaging. Finally, we have no histopathological results.

In summary, the chest CT has the value of evaluating the radiographical features of COVID-19 and allow for dynamic observation of the disease progression. The severe and critically severe type patients more commonly experienced severe lung lesions. The CT severity score and MuLBSTA score may be useful for the assessment of COVID-19 severity and progression. Considering coagulation disorder of COVID-19, MuLBSTA score may need to be updated to increase new understanding of COVID-19. Whether the inclusion of coagulation disorder in future studies will have an impact on MuLBSTA score needs to be confirmed by further large-sample studies.

## CONFLICT OF INTEREST

The authors declare that they have no competing interests.

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