

# Clinical Severity and CT Features of the COVID-19 Pneumonia: Focus on CT Score and Laboratory Parameters

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## Research

**Keywords:** SARS-CoV-2, COVID-19, Coronavirus Infections, Pneumonia, Viral, Tomography, X-ray computed.

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## Abstract

**Background:** Although CT characteristics of Coronavirus Disease 2019 (COVID-19) pneumonia between patients with mild and severe forms of the disease have already been reported in the literature, there was little attention to the correlation of imaging features and laboratory testing. We aimed to compare the laboratory and chest CT imaging features in patients with COVID-19 pneumonia between non-severe cases and severe cases, and to analyze the correlation of CT score and laboratory testing.

**Methods:** This study consecutively included 54 patients with COVID-19 pneumonia (26 males and 28 females, 26 to 92 years of age, 43 cases with non-severe and 11 cases with severe group). Clinical, laboratory and image data were collected between two subgroups. A CT score system was used to evaluate the extent of disease. Correlation between the CT score and laboratory data were estimated. Receiver operating characteristic (ROC) analysis was used to evaluate the diagnostic performance of CT score and laboratory tests.

**Results:** Compared with non-severe patients, severe patients had showed increased white blood cell count, neutrophil count, neutrophil percentage, the neutrophil-to-lymphocyte ratio (NLR) and decreased lymphocyte percentage (all  $p < 0.05$ ). Architectural distortion, pleural effusion, air bronchogram and consolidation-dominant pattern were more common in the severe group (all  $p < 0.05$ ). CT score of the severe group was higher than the non-severe group ( $p < 0.001$ ). For distribution characters of the lesions, diffuse pattern in the transverse distribution was more often seen in the severe group ( $p < 0.001$ ). CT score was positively correlated with the white blood cell counts, neutrophil counts, the percent of neutrophil, NLR, alanine aminotransferase, lactate dehydrogenase and C-reactive protein, and was inversely related to the lymphocyte, the percent of lymphocyte. ROC analysis showed that when the optimal threshold of CT score was 13, the area under the curve was the largest, which was 0.855, and the sensitivity and specificity were 100% and 60% respectively for the diagnosis of the severe patients.

**Conclusion:** CT score showed significant correlations with laboratory inflammatory markers, suggesting that chest CT and laboratory examination maybe provide a better reference for clinicians to judge the severity of diseases.

## Background

Since December 2019, a cluster of cases of pneumonia with unknown cause has reported in Wuhan, China. On Jan 7, 2020, a novel coronavirus was been identified as the causative organism by Chinese scientists (1). On February 11th, the International Committee on Taxonomy of Viruses officially named this novel coronavirus as severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2; previously known as 2019 novel coronavirus [2019-nCoV]), and World Health Organization (WHO) named the disease caused by SARS-CoV-2 as coronavirus disease 2019 (COVID-19) (2). On March 11, 2020, WHO made the assessment that COVID-19 could be characterized as a pandemic. As of April 1, 2020, it has affected 823 626 patients on a globe scale, and causing 40 598 deaths (3). However, the case fatality rate is very high in some countries, for example, the overall case fatality rate in Italy is about 7.2% (4). So far, China have effectively controlled the epidemic, but unfortunately the virus is rapidly spreading outside of China, especially in America, Italy, Spain, Germany, France, Iran, etc. (3). Typical clinical manifestations of COVID-19 pneumonia include fever, cough, dyspnea (5). In the early phase, typical pathological findings in the lungs include proteinaceous and fibrin exudates, mononuclear cells infiltration, desquamation of pneumocytes and hyaline membrane formation (6, 7). CT is important in early detection and follow-up after treatment of COVID-19 pneumonia. High resolution computed tomography (HRCT) findings mainly include peripheral unilateral or bilateral ground-glass opacities or consolidation in the early stage (8–10). In addition, different radiological patterns are observed at different time throughout the disease course (9, 11, 12). In the currently published literature, the imaging and clinical features of COVID-19 pneumonia between different clinical types have been reported (10, 13, 14). However, whether there is a correlation between some imaging findings and laboratory testing has not been reported in the literature. We aimed to describe the clinical characteristics of hospitalized patients with COVID-19 pneumonia and compare the laboratory tests and chest CT imaging features between severe cases and non-severe cases and to analyze their correlation between the imaging features and laboratory tests.

## Methods

### Patients

The Institutional Review Board granted approval for our retrospective study, waiving informed consent because of its retrospective nature. This study consecutively included 54 patients with COVID-19 from February 4, 2020 to March 23, 2020. All available clinical, laboratory and imaging data were collected for all patients. Two patients with underlying lung diseases (tuberculosis and small cell lung

cancer) were excluded, because the evaluation of the extent of the lesion may be affected. Forty-eight cases were diagnosed by real time reverse-transcription-polymerase chain-reaction (RT-PCR), six cases were clinically diagnosed, according to the guideline on COVID-19 (trial version 5) (15) issued by the China's National Health Commission. According to diagnosis and treatment of COVID-19 (trial version 5) (15), patients were classified into common, severe and critical type in our study, and common type were included in the non-severe group, while severe and critical type were included into the severe group. All patients underwent CT scan after admission.

## Chest Ct Protocol

All chest CT examinations were performed on a third-generation dual-source CT system (SOMATOM Force; Siemens Healthineers, Germany). Images were acquired in the supine position after end-inspiration and extended from the lung apices to the costophrenic angles by using the following parameters: tube voltage, 120 kVp; automated tube current modulation (Care Dose 4D); thin collimation, 0.75 mm; pitch, 0.6; rotation time, 500 ms; reconstruction matrix, 512 × 512. CT images were reconstructed into 1.0-mm section thickness by using a high spatial resolution algorithm. All CT scans were obtained with window settings that were appropriate for lung parenchyma (window width, 1300 Hounsfield units [HU]; level, -450 HU) and mediastinum (window width, 400 HU; level, 40 HU).

## Image Evaluation

The thin-section CT images were assessed in totally random order by two radiologists (with 6 years and 11 years of experience in chest CT imaging, respectively) without reference to the clinical or laboratory test results. Any disagreement was resolved by discussion and consensus. We evaluated 14 imaging features, including (1) ground-glass opacities (GGO), (2) consolidation, (3) crazy-paving sign, (4) reticulation, (5) the prominent pattern of opacities (according to the extent of involvement, we divided the prominent pattern into GGO-dominant type [the extent of involvement of GGO was largest], consolidation-dominant type [the extent of involvement of consolidation was largest] and reticulation-dominant type [the extent of involvement of reticulation was largest]), (6) mixed pattern (combination of GGO, consolidation and reticular opacity) (7) mosaic attenuation, (8) nodules, (9) traction bronchiectasis, (10) architectural distortion, (11) air bronchogram, (12) tree-in-bud, (13) intrathoracic lymphadenopathy and (14) pleural effusion. The detailed descriptions of the imaging interpretation were consistent with the Fleischner guidelines (16). We defined four distributions according to the previous study, including transverse, cranio-caudal, lung region, and scattered (10). Transverse distribution included central type, lesion located in the inner one-thirds of the lung and peripheral type, located in the outer two-third of the lung. Each lung was divided into 3 zones on HRCT as follows in the cranio-caudal plane: the upper zone above the carina; the lower zone below the inferior pulmonary veins; the middle zone between the upper and lower zone. Lung region was categorized as unilateral or bilateral lung involvement. Scattered distribution was categorized as focal (one lesion), multifocal (two or more lesions, localized in two lobes), diffuse (multiple lesions, in more than two lobes). A CT score system was used to evaluate the extent of disease following the criteria defined in the previous study (11). A thin-section CT score was assigned on the basis of all abnormal areas involved. A semi-quantitative visual score system was assigned for each lobe based on the following: score 0, 0% involvement; score 1, less than 5% involvement; score 2, 5–25% involvement; score 3, 26–49% involvement; score 4, 50–75% involvement; and score 5, greater than 75% involvement. There was a score of 0–5 for each lobe, with a maximal score was 25.

## Statistical analysis

All data were expressed as mean ± standard deviation (SD), n (%) or median ± interquartile range (IQR). Continuous variables between the non-severe and the severe two subgroups were compared by using Mann-Whitney *U* test, and categorical variables were performed by  $\chi^2$  or Fisher's exact test. The correlations between CT score and laboratory tests were evaluated by Spearman correlation analysis. The performance of laboratory tests of obvious differences between the two groups and CT score were evaluated by receiver operating characteristic analysis. Then all statistical analyses were performed using a statistical software package (SPSS 23.0, Inc., Chicago, IL, USA) and MedCalc software (version 15.2.2, MedCalc Software). Two-sided *p* values < 0.05 was considered to be statistically significant.

## Results

### General description

The 54 patients included 26 males and 28 females, 26 to 92 years of age (mean age  $60 \pm 14$  years). The demographics and clinical characteristic are shown in Table 1. In the full cohort, the mean age was 60 years (SD 14; range of 26–92), including 26 (48.1%) men and 28 (51.9%) female. Epidemiological history was divided into three types. All patients were from epidemic area, 53 of them were from Wuhan, one was from Xiaogan. Four patients (7.4%) had direct exposure history to patients with confirmed disease, and 13 patients (24.1%) had a disease associated with a family outbreak. Half of patients had one or more underlying diseases, including diabetes (16[29.6%]), hypertension (21[38.9%]), chronic obstructive pulmonary disease (6[11.1%]), and cardiovascular disease (8[14.8%]). The most common symptoms in COVID-19 patients were fever (49[90.7%]), cough (45[83.3%]), sputum production (30[55.6%]), fatigue (27[50.0%]), diarrhea (26[48.1%]), chilly (22[40.7%]), dyspnea (20[37.0%]), short of breath (19[35.2%]). Less common symptoms were chest pain, sore throat and headache (Table 1). As of the end of the study, 45 patients were discharged, six remained in the hospital, three were transferred to other hospital and no patient died. The median time-interval from symptoms onset to first CT examination was 19 day. The median time-interval between first CT examination and laboratory testing was 2 day.

Table 1  
Demographics and clinical characteristics of the included 54 patients

Characteristics	All patients(n = 54)
Age(year)	60 ± 14, Range of 26 to 92
Gender	
Female	28(51.9)
Male	26(48.1)
Epidemiologic history	
Wuhan residents	53(98.1)
Close contact	4(7.4)
Family aggregation	13(24.1)
Underlying disease	
No underlying disease	27(50.0)
Diabetes	16(29.6)
Hypertension	21(38.9)
Chronic obstructive pulmonary disease	6(11.1)
Cardiovascular disease	8(14.8)
Signs and symptoms	
Fever	49(90.7)
Cough	45(83.3)
Sputum production	30(55.6)
Fatigue	27(50.0)
Diarrhea	26(48.1)
Chilly	22(40.7)
Dyspnea	20(37.0)
Short of breath	19(35.2)
Myalgia	12(22.2)
Chest tightness	11(20.4)
Inappetence	10(18.5)
Dizziness	9(16.7)
Nausea	9(16.7)
Headache	7(13.0)
Sore throat	6(11.1)
Chest pain	4(7.4)
Clinical outcomes at the end of study	
Discharged	45(83.3)
In admission	6(11.1)

Note: Numbers in parentheses are percentages. Age is mean ± standard deviation.

Characteristics	All patients(n = 54)
Transferred to other hospitals	3(5.6)
Died	0(0)
Note: Numbers in parentheses are percentages. Age is mean ± standard deviation.	

## Comparison of basic clinical characteristics, laboratory tests and CT findings in the non-severe and the severe groups

Among the 54 included patients, 43 (20 men, 23 women) were non-severe group, and 11 (six men, five women) were severe group. No significant differences in age ( $p = 0.186$ ), gender ( $p = 0.634$ ), and underlying disease ( $p = 0.735$ ) were found between the two groups. Patients of severe group showed increased white blood cell (WBC) count ( $9.1 \times 10^9/L$ ), neutrophil count ( $7.9 \times 10^9/L$ ), neutrophil percentage (82.9%), the neutrophil-to-lymphocyte ratio (NLR) (median[IQR] 8.2 [4.7–14.3]) and decreased lymphocyte percentage (9.7%) (all  $p$  value  $< 0.05$ , Table 2). There was no obvious difference in levels of lymphocyte count, the percent of monocyte, aspartate aminotransferase (AST) and CRP between the two groups (all  $p > 0.05$ ), while levels of LDH had the tendency for increase in severe group.

Table 2  
Demographic, laboratory findings and HRCT features for the 54 Patients between two groups

Parameters	All patients(n = 54)	Non-severe Group (n = 43)	Severe Group (n = 11)	<i>p</i>
Age, years	62.0(50.5–69.3)	64.0(52.0–72.0)	57.0(42.0–69.0)	0.186
Sex				0.634
Female	28(51.9)	23(53.5)	5(45.5)	
Male	26(48.1)	20(46.5)	6(54.5)	
Underlying disease	27(50)	22(51.2)	5(45.5)	0.735
Diabetes	16(29.6)	14(32.6)	2(18.2)	0.474
Hypertension	21(38.9)	17(39.5)	4(36.4)	1.000
Chronic obstructive pulmonary disease	6(11.1)	3(7.0)	3(27.3)	0.091
Cardiovascular disease	8(14.8)	5(11.6)	3(27.3)	0.337
White blood cell count, × 10 <sup>9</sup> /L	5.8(4.2–7.7)	5.4(4.0-7.2)	9.1(5.0-13.1)	0.004
Neutrophil count, × 10 <sup>9</sup> /L	3.9(2.9–5.9)	3.6(2.7–5.4)	7.9(3.9–11.7)	0.001
The percent of neutrophil granulocyte (%)	72.5(59.5–80.6)	70.4(57.2–78.2)	82.9(73.5–89.7)	0.003
Lymphocyte count, × 10 <sup>9</sup> /L	1.0(0.8–1.5)	1.0(0.8–1.5)	0.9(0.6-2.0)	0.452
The percent of Lymphocyte (%)	17.8(11.0-28.4)	20.4(14.1–30.7)	9.7(5.9–15.7)	0.001
The neutrophil-to-lymphocyte ratio (NLR)	4.1(2.0-7.4)	3.5(1.9–5.7)	8.2(4.7–14.3)	0.001
Monocyte count, × 10 <sup>9</sup> /L	0.5(0.3–0.6)	0.5(0.4–0.5)	0.8(0.3–1.2)	0.109
The percent of monocyte (%)	8.2(6.4–10.6)	8.3(6.4–10.8)	7.9(6.0-10.4)	0.519
Alanine aminotransferase, U/L	23.0(14.8–44.5)	22.0(16.0–46.0)	31.0(13.0–40.0)	0.838
Aspartate aminotransferase, U/L	25.5(19.0–45.0)	31.0(19.0–45.0)	23.0(17.0–39.0)	0.273
Lactate dehydrogenase, U/L	290.5(213.3-362.5)	288.0(211.0-317.0)	361.0(265.0-416.0)	0.201
C-reactive protein, mg/L	29.0(7.8–62.7)	29.8(7.2–64.9)	14.6(8.4–57.5)	0.747
Ground-glass opacities	54(100)	43(100)	11(100)	NA
Consolidation	50(92.6)	39(90.7)	11(100)	0.571
Crazy-paving sign	5(9.3)	3(7.0)	2(18.2)	0.266
Reticulation	36(66.7)	28(65.1)	8(72.7)	0.733
Mixed pattern	31(57.4)	23(53.5)	8(72.7)	0.319
Prominent CT pattern of opacities				0.033*
GGO-dominant	33(61.1)	28(65.1)	5(45.5)	
Consolidation-dominant	10(18.5)	5(11.6)	5(45.5)	
Reticulation-dominant	11(20.4)	10(23.3)	1(9.1)	
Mosaic attenuation	7(13.0)	4(9.3)	3(27.2)	0.140
Nodules	18(33.3)	15(34.9)	3(27.2)	0.733

Note: Data are n (%) or median (IQR). NA = not applicable. Non-severe group and severe group are compared by  $\chi^2$ , Fisher's exact test, or Mann-Whitney *U* test. \* $\chi^2$  test comparing all subcategories

Parameters	All patients(n = 54)	Non-severe Group (n = 43)	Severe Group (n = 11)	<i>p</i>
Traction bronchiectasis	40(74.1)	22(51.2)	9(81.8)	0.092
Architectural distortion	29(53.7)	9(20.9)	9(81.8)	< 0.001
Air bronchogram	16(29.6)	9(20.9)	7(63.6)	0.010
Tree-in-bud	1(1.9)	0(0)	1(9.1)	0.204
Intrathoracic lymphadenopathy	6(11.1)	6(14.0)	0(0)	0.327
Pleural effusion	12(22.2)	6(14.0)	6(54.5)	0.009
Transverse distribution				< 0.001
Peripheral	35(64.8)	34(79.1)	1(9.1)	
Diffuse	19(35.2)	9(20.9)	10(90.9)	
Craniocaudal distribution				0.086*
Upper lung zone	1(1.9)	1(2.3)	0(0)	
Middle lung zone	11(20.3)	8(18.6)	3(27.3)	
Lower lung zone	14(25.9)	14(32.6)	0(0)	
Diffuse	28(51.9)	20(46.5)	8(72.7)	
Lung region distribution				
Unilateral	1(1.9)	1(2.3)	0(0)	1.000
Bilateral	53(98.1)	42(97.7)	11(100)	
Scattered distribution				1.000*
Focal	1(1.9)	1(2.3)	0(0)	
Multifocal	2(3.7)	2(4.7)	0(0)	
Diffuse	51(94.4)	40(93.0)	11(100)	
CT scores	14.0(9.8–20.0)	13.0(9.0–17.0)	22.0(15.0–25.0)	< 0.001
Time-interval from symptom onset to CT scan (days)	19.0(15.8–25.0)	18.0(15.0–22.0)	25.0(18.0–44.0)	0.027
Note: Data are n (%) or median (IQR). NA = not applicable. Non-severe group and severe group are compared by $\chi^2$ , Fisher's exact test, or Mann-Whitney <i>U</i> test. * $\chi^2$ test comparing all subcategories				

Most patients with COVID-19 pneumonia had typical imaging features, such as GGO (54 [100%]), consolidation (50 [92.6%]), reticulation (36[66.7%]), traction bronchiectasis (31[57.4%]), mixed pattern (31[57.4%]), and architectural distortion (29[53.7%]) in the lesion (**Figures 1 and 2**). Only one patient had tree-in-bud sign and pneumothorax in our study (Fig. 2B). Four of the 14 imaging features – architectural distortion (Fig. 2A), pleural effusion (Fig. 2A), air bronchogram (Fig. 3A) and the prominent pattern of opacities – were statistically significant between the two groups (all  $p < 0.05$ ) (Table 2). There was no obvious difference in reticulation, traction bronchiectasis, GGO, consolidation, crazy-paving sign, mixed pattern, mosaic attenuation, nodules, tree-in-bud, and intrathoracic lymphadenopathy between the two groups (all  $p > 0.05$ ). The distribution pattern lesions in two groups are also shown in Table 2. Lesions were more likely to have a diffuse distribution in transverse and craniocaudal plane (10 [90.9%] and eight [72.7%], respectively), to have bilateral involvement (11 [100%]), and be diffuse (11 [100%]) in scattered distribution in the severe group, but only the transverse distribution pattern between two groups had significant differences ( $p < 0.001$ ). The result showed that the CT score of the severe group was higher than the non-severe group (median score [IQR] 22.0 [15.0–25.0] vs. 13.0 [9.0–17.0],  $p < 0.001$ ). There was a longer time-interval from symptom onset to first chest CT scan in the severe group (the median time [IQR] 25.0 [18.0–44.0] vs. 18.0 [15.0–22.0],  $p = 0.027$ ).

# Correlation between CT score and laboratory tests and their performances for severe patients of COVID-19 pneumonia

CT score was positively correlated with the cell counts of WBC, neutrophil, the percent of neutrophil, NLR, ALT, LDH and CRP, and inversely related to the lymphocyte, the percent of lymphocyte. CT score was not correlated with monocyte count, monocyte percentage and AST (Table 3). The performance of CT score and laboratory tests for severe patients of COVID-19 pneumonia are also shown in Table 4. The area under the curve of CT score, the percent of lymphocyte, neutrophil count, NLR, the percent of neutrophil and WBC were 0.855, 0.828, 0.827, 0.820, 0.789 and 0.786 respectively. The CT score demonstrated the best performance when the cut-off value of CT score was 13.

Table 3  
Results of Spearman correlation of laboratory variables with CT score

Variables	Correlation to CT score	
	Coefficient( $\rho$ )	<i>P</i>
WBC count, $\times 10^9/L$	0.380	0.005
Neutrophil count, $\times 10^9/L$	0.511	< 0.001
The percent of neutrophil	0.608	< 0.001
Lymphocyte count, $\times 10^9/L$	-0.322	0.017
The percent of Lymphocyte	-0.617	< 0.001
NLR	0.613	< 0.001
CRP, mg/L	0.309	0.023
Monocyte count, $\times 10^9/L$	0.057	0.682
The percent of monocyte (%)	-0.265	0.053
ALT, U/L	0.317	0.019
AST, U/L	0.228	0.097
LDH, U/L	0.625	< 0.001

Table 4  
The performance of CT score and laboratory tests for severe patients of COVID-19 pneumonia

	Results (n)				Test performance (%)					
	TP	TN	FP	FN	Sensitivity [95%CI]	Specificity [95%CI]	PPV [95%CI]	NPV [95%CI]	Accuracy [95%CI]	Cut-Off
CT score	11	26	17	0	100(11/11) [72–100]	60(26/43) [44–75]	39(11/28) [22–59]	100(26/26) [87–100]	69(37/54) [54–80]	13
WBC	8	41	2	3	73(8/11) [39–94]	95(41/43) [84–99]	80(8/10) [44–97]	93(41/44) [81–99]	91(49/54) [80–97]	8.3
Neutrophil count	7	42	1	4	64(7/11) [31–89]	98(42/43) [88–100]	88(7/8) [47–100]	91(42/46) [79–98]	91(49/54) [80–97]	6.6
The percent of neutrophil	8	32	11	3	73(8/11) [39–94]	77(32/43) [61–88]	42(8/19) [20–67]	91(32/35) [77–98]	74(40/54) [60–85]	78.2%
The percent of lymphocyte	8	36	7	3	73(8/11) [39–94]	84(36/43) [69–93]	53(8/15) [27–79]	92(36/39) [79–98]	81(44/54) [69–91]	11.4%
NLR	7	39	4	4	64(7/11) [31–89]	91(39/43) [78–97]	64(7/11) [31–89]	91(39/43) [78–97]	85(46/54) [73–93]	7.5

## Discussion

It has been reported that about 70%-85% of COVID-19 patients have a mild form of disease, a self-limiting disease, while approximately 15%-30% of patients have a severe form of disease [17–19]. Most of mild patients can heal themselves, while severe patients need medical intervention. If some clinical or imaging indicators can differentiate them, it will help clinicians choose more beneficial treatment regimens. In this study, 20.4% of patients were severe after admission to the hospital, receiving ICU care, while 79.6% of patients were non-severe, receiving general therapy (i.e. supportive therapy, oxygen therapy, antiviral and antibiotic therapy). Our results indicated that some laboratory and imaging indicators of COVID-19 patients in severe group can be distinguished from those in non-severe group. And we semi-quantitatively evaluated the extent of involvement of the lesion and found that it was related to many indicators of laboratory testing.

In our study, most hospitalized patients with COVID-19 pneumonia were elderly. There was no obvious predilection for sex and underlying disease in full cohort, consistent with previous reports (17). The epidemiological history showed that patients with a close contact accounted for only 7.4%, while patients with familial aggregation accounted for 24.1%. It suggested that the confirmed patients should be strictly isolated from their families, and the isolation measures similar to the shelter hospital may curb the spread of the epidemic. Patients with underlying diseases accounted for half of the cases, higher than reported literatures (5, 18), which may be related to the fact that most of the patients in our cohort were elderly. Fever, cough, sputum production, dyspnea and short of breath were the most common symptoms in patients with COVID19 pneumonia, indicating that the receptor of target cells of might be primarily located in the lower airway, consistent with reported literature (5, 17, 18, 20). However, the intestinal symptoms such as diarrhea seemed more prominent in our cohort than previously reported, which may be related to the difference in the route of infection and the course of disease.

Our results showed that there was no obvious difference in age, gender and underlying diseases between the two groups, but previous studies showed that patients with severe disease were generally older, and had a greater number of underlying diseases than those with non-severe disease [17, 18]. These results may be related to the insufficient sample size. Compared with non-severe group, some laboratory indicators such as the leukocyte count, neutrophil count, NLR and the percentage of neutrophils were higher in severe patients, which may indicate that severe patients may be associated with other microbial infections, such as bacterial infection. In addition, neutrophilia may be related to cytokine storm induced by virus invasion. The percentage of lymphocytes was lower in severe patients, which may be due to the increased proportion of neutrophils. The lymphocyte count of the two groups decreased, but there

was no significant difference between two groups. In general, the lymphocyte count of viral infection increased, but SARS-CoV-2 infection, similar to severe acute respiratory syndrome (SARS) (21, 22) and the Middle East respiratory syndrome (MERS) (23, 24), also caused the lymphopenia of peripheral blood. In the published literature, most patients had the normal ALT and AST and increased LDH in the whole cohort, consistent with previous reports (17, 18). However, the levels of ALT, AST and LDH of severe patients were higher than those of mild patients, which were inconsistent with our studies. Some researchers believed that virally induced cytotoxic T cells and the induction of a dysregulated innate immune response were a more probable explanation for the association between deranged liver markers and COVID-19 disease severity (25).

Chest CT has a high sensitivity for diagnosis of COVID-19 pneumonia (25). It can be used in the early screening of highly suspected cases, especially for the patients whose PCR are negative for the first time. Our study showed ground-glass opacities (100%), consolidation (92.6%), reticulation (66.7%), traction bronchiectasis (57.4%), mixed pattern (57.4%) and architectural distortion (53.7%) are the most common imaging findings. These features may correspond to the alveolar exudation combined with fibroblasts proliferated in the alveolar cavity and interstitium. It suggests that the inflammatory process of injury and repair occur simultaneously in the lesions. However, unlike other published studies (13, 14, 27), our study showed that the frequency of consolidation and reticulation is higher. This may be related to the long course of infection leading to organic pneumonia. That is, with the increase of time course, the frequency of reticulation and consolidation increase in our study. This study showed that architectural distortion was more likely to be seen in severe patients, and traction bronchiectasis has a high frequency in severe patients. These findings may indicate pulmonary fibrosis. A follow-up study of patients recovering from SARS showed that traction bronchiectasis was recoverable at 114 days after symptom onset and did not certainly represent irreversible fibrosis (28). It is not known whether these signs in severe patients with COVID-19 represent irreversible fibrosis and further follow-up research is needed. Tree-in-bud sign may be due to infectious bronchiolitis in our study. The frequency of tree-in-bud sign is very low, different from H1N1 influenza A pneumonia (29), which may serve to distinguish SARS-CoV-2 from other types of viral pneumonia. Our research showed that consolidation-dominant pattern and air bronchogram are more common in severe patients, suggesting alveolar exudation is still predominant. There was a high virus load in the body at this time, then alveolar macrophages engulf the virus in large quantities, and lung tissue damage is dominant. Pleural effusion suggested poor prognosis in many studies about COVID-19 (10, 14), consistent with our study. Previous studies also showed that the presence of pleural effusion in patients infected with MERS was a poor prognostic indicator (30). For lesion distribution, patients with COVID-19 tended to have peripheral distribution (64.8%), bilateral involvement (98.1%), diffuse distribution in craniocaudal plane (51.9%), and be diffuse in numbers (94.4%), which were consistent with results of previous studies except for lower lung zone distribution (10). The severe patients were usually more diffuse in axial distribution, that is, inferior one-thirds of the lung zone was also affected, indicating that inflammation spreads from the periphery to the central lung. CT score was higher in severe patients, suggesting that the affected lungs are more extensive in severe patients, consistent with many studies (10, 14). Our study revealed CT score was associated with a number of laboratory indicators, it's probably because they're all related to the severity of the disease. The significance of this result is that if the laboratory indicators change during the follow-up after treatment, it seems that the laboratory indicators can be used instead of frequent CT examination to assess the severity of the disease. The laboratory indicators are more convenient to obtain, and the radiation dose of CT can be reduced correspondingly.

There are some limitations in our study. First, due to the small sample size of severe patients, it may cause selection bias. Second, the time-interval between laboratory testing and the CT examination was variable, which may limit the ability to determine the relationship between laboratory tests and CT score. However, the median time-interval between laboratory testing and the CT scan was 4 day, during this time interval, it may not cause major changes in indicators. Third, because the diagnosis standard of severe pneumonia is not uniform, it can cause reference test bias. Finally, CT scoring is a semi-quantitative scoring system, which still has some subjectivity. Artificial intelligence is expected to play a more important role in future research.

## Conclusion

In conclusion, CT score showed significant correlations with laboratory inflammatory markers, suggesting that chest CT and laboratory examination maybe provide a better reference for clinicians to judge the severity of diseases.

## Abbreviations

COVID-19: coronavirus disease 2019; SARS-CoV-2: severe acute respiratory syndrome coronavirus 2; ICU: intensive care unit; ROC: Receiver operating characteristic; 2019-nCoV = 2019 novel coronavirus; WHO: World Health Organization; HRCT: High resolution computed tomography; RT-PCR: real time reverse-transcription-polymerase chain-reaction; SD: standard deviation; IQR: interquartile

range; GGO: ground-glass opacities; WBC: White blood cell; NLR: The neutrophil-to-lymphocyte ratio; ALT: Alanine aminotransferase; AST: Aspartate aminotransferase; LDH: Lactate dehydrogenase; CRP: C-reactive protein; SARS: Severe Acute Respiratory Syndrome; MERS: Middle East respiratory syndrome; CI: confidence intervals

## Declarations

## Ethics approval and consent to participate

For this retrospective study written informed consent was waived by the Institutional Review Board.

## Consent for publication

Not applicable.

## Competing interests

We declare that we have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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None.

## Authors' contributions

All authors meet the author requirements according to ICMJE guidelines. All authors read and approved the final manuscript.

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## Availability of data and materials

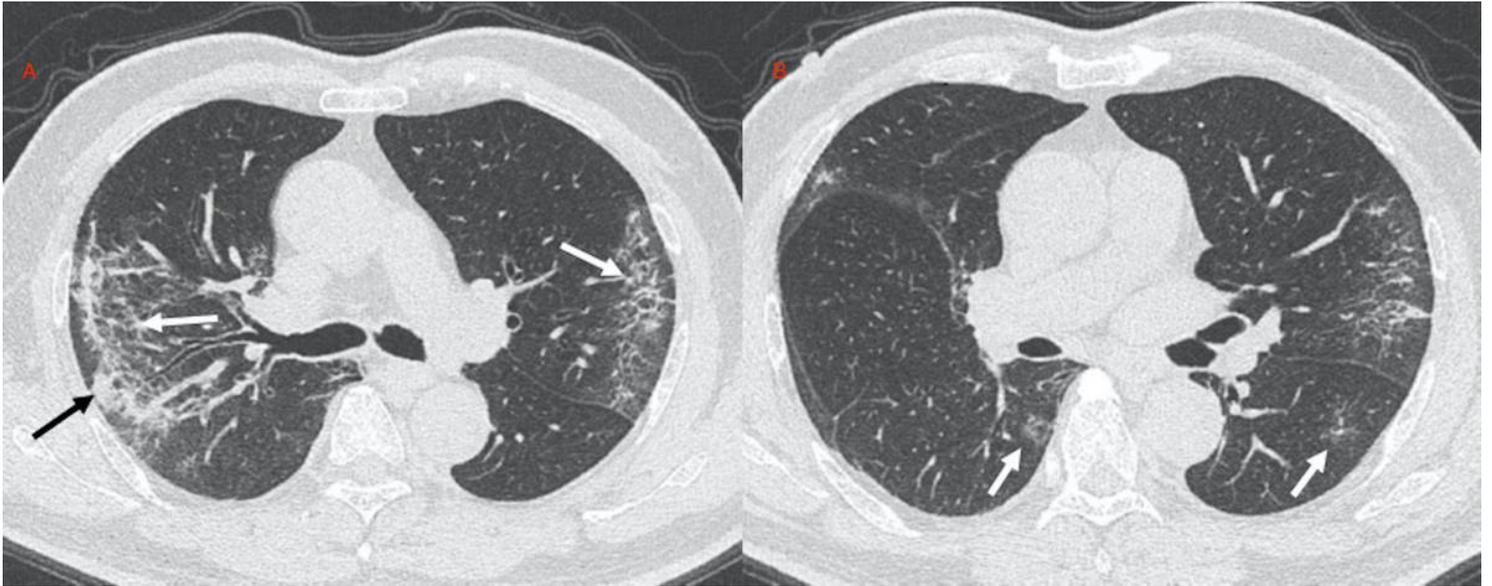
The datasets analysed during the current study are available from the corresponding author on reasonable request.

## References

1. Zhu N, Zhang D, Wang W, et al. A novel coronavirus from patients with pneumonia in China, 2019. *N Engl J Med.* 2020;382:727–33.
2. World Health Organization. Novel coronavirus (2019-nCoV) situation report-22. Available at: [https://www.who.int/docs/default-source/coronaviruse/situation-reports/20200211-sitrep-22-ncov.pdf?sfvrsn=fb6d49b1\\_2](https://www.who.int/docs/default-source/coronaviruse/situation-reports/20200211-sitrep-22-ncov.pdf?sfvrsn=fb6d49b1_2). Accessed 11 February 2020.
3. World Health Organization. Novel coronavirus (2019-nCoV) situation report-72. Available at: [https://www.who.int/docs/default-source/coronaviruse/situation-reports/20200401-sitrep-72-covid-19.pdf?sfvrsn=3dd8971b\\_2](https://www.who.int/docs/default-source/coronaviruse/situation-reports/20200401-sitrep-72-covid-19.pdf?sfvrsn=3dd8971b_2). Accessed 1 April 2020.
4. Onder G, Rezza G, Brusaferro S. Case-fatality rate and characteristics of patients dying in relation to COVID-19 in Italy. *JAMA.* 2020.
5. 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.
6. Xu Z, Shi L, Wang Y, et al. Pathological findings of COVID-19 associated with acute respiratory distress syndrome. *Lancet Respir Med.* 2020.
7. Tian S, Hu W, Niu L, Liu H, Xu H, Xiao SY. Pulmonary pathology of early-phase 2019 novel coronavirus (COVID-19) pneumonia in two patients with lung cancer. *J Thorac Oncol.* 2020.

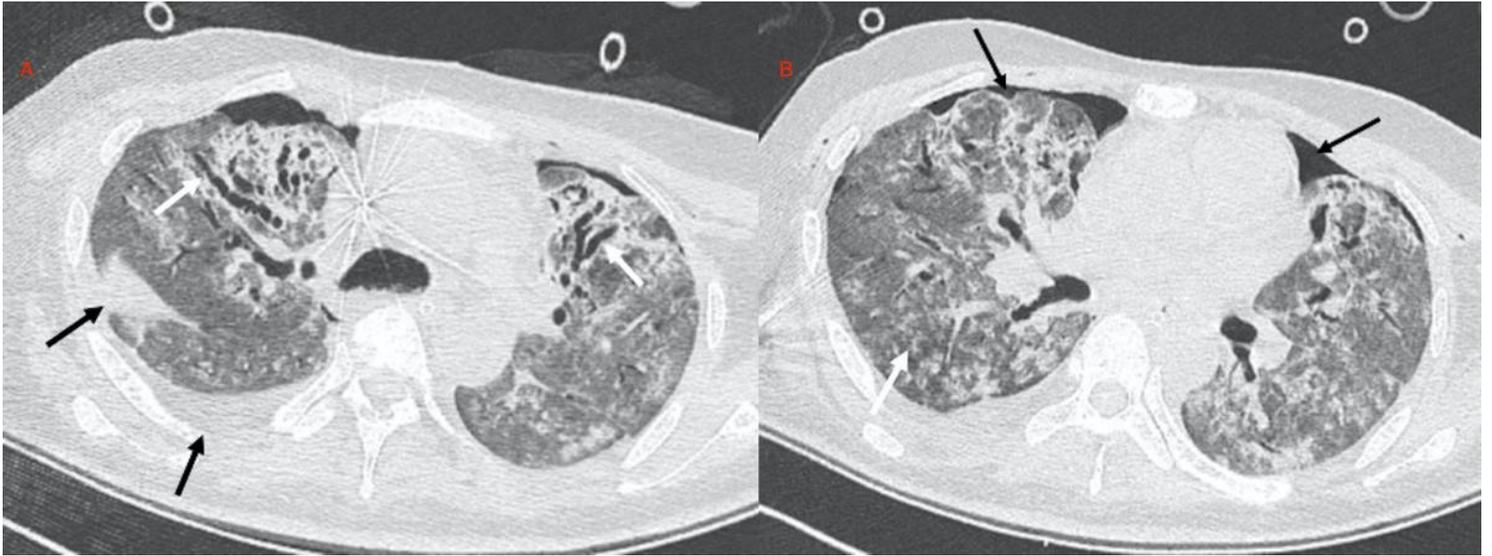
8. Chung M, Bernheim A, Mei X, et al. CT Imaging Features of 2019 Novel Coronavirus (2019-nCoV). *Radiology*. 2020;295:202–7.
9. Shi H, Han X, Jiang N, et al. Radiological findings from 81 patients with COVID-19 pneumonia in Wuhan, China: a descriptive study. *Lancet Infect Dis*. 2020.
10. Zhao W, Zhong Z, Xie X, Yu Q, Liu J. Relation between chest CT findings and clinical conditions of coronavirus disease (COVID-19) pneumonia: a multicenter study. *AJR Am J Roentgenol*. 2020:1–6.
11. Pan F, Ye T, Sun P, et al. Time course of lung changes on chest CT during recovery from 2019 novel coronavirus (COVID-19) pneumonia. *Radiology*. 2020.
12. Bernheim A, Mei X, Huang M, et al. Chest CT findings in coronavirus disease-19 (COVID-19): relationship to duration of infection. *Radiology*. 2020.
13. Xu YH, Dong JH, An WM, et al. Clinical and computed tomographic imaging features of novel coronavirus pneumonia caused by SARS-CoV-2. *J Infect*. 2020;80:394–400.
14. Li K, Wu J, Wu F, et al. The clinical and chest CT features associated with severe and critical COVID-19 pneumonia. *Investigative Radiology*. 2020.
15. China National Health Commission website. Notice on issuing a new coronavirus infected pneumonia diagnosis and treatment plan (trial version 5). [bgs.satcm.gov.cn/zhengcewenjian/2020-02-06/12847.html](http://bgs.satcm.gov.cn/zhengcewenjian/2020-02-06/12847.html). Published February 4, 2020.
16. Hansell DM, Bankier AA, MacMahon H, McLoud TC, Müller NL, Remy J. Fleischner Society: glossary of terms for thoracic imaging. *Radiology*. 2008;246:697–722.
17. Wang D, Hu B, Hu C, et al. Clinical characteristics of 138 hospitalized patients with 2019 novel coronavirus-infected pneumonia in Wuhan, China. *JAMA*. 2020.
18. Guan WJ, Ni ZY, Hu Y, et al. Clinical characteristics of coronavirus disease 2019 in China. *N Engl J Med*. 2020.
19. Wu Z, McGoogan JM. Characteristics of and important lessons from the coronavirus disease 2019 (COVID-19) outbreak in China summary of a report of 72 314 cases from the Chinese Center for Disease Control and Prevention. *JAMA*. 2020.
20. Chen N, Zhou M, Dong X, et al. Epidemiological and clinical characteristics of 99 cases of 2019 novel coronavirus pneumonia in Wuhan, China: a descriptive study. *Lancet*. 2020;395:507–13.
21. Booth CM, Matukas LM, Tomlinson GA, et al. Clinical features and short-term outcomes of 144 patients with SARS in the greater Toronto area. *JAMA*. 2003;289:2801–9.
22. Peiris JS, Chu CM, Cheng VC, et al. Clinical progression and viral load in a community outbreak of coronavirus-associated SARS pneumonia: a prospective study. *Lancet*. 2003;361:1767–72.
23. Assiri A, Al-Tawfiq JA, Al-Rabeeh AA, et al. Epidemiological, demographic, and clinical characteristics of 47 cases of Middle East respiratory syndrome coronavirus disease from Saudi Arabia: a descriptive study. *Lancet Infect Dis*. 2013;13:752–61.
24. Arabi YM, Arifi AA, Balkhy HH, et al. Clinical course and outcomes of critically ill patients with Middle East respiratory syndrome coronavirus infection. *Ann Intern Med*. 2014;18:160:389–97.
25. Bangash MN, Patel J, Parekh D. COVID-19 and the liver: little cause for concern. *Lancet Gastroenterol Hepatol*. 2020.
26. Ai T, Yang Z, Hou H, et al. Correlation of chest CT and RT-PCR testing in coronavirus disease 2019 (COVID-19) in China: a report of 1014 cases. *Radiology*. 2020.
27. Song F, Shi N, Shan F, et al. Emerging 2019 Novel Coronavirus (2019-nCoV) Pneumonia. *Radiology*. 2020;295:210–7.
28. Chang YC, Yu CJ, Chang SC, et al. Pulmonary sequelae in convalescent patients after severe acute respiratory syndrome: evaluation with thin-section CT. *Radiology*. 2005;236:1067–75.
29. Kang H, Lee KS, Jeong YJ, Lee HY, Kim KI, Nam KJ. Computed tomography findings of influenza A (H1N1) pneumonia in adults: pattern analysis and prognostic comparisons. *J Comput Assist Tomogr*. 2012;36:285–90.
30. Das KM, Lee EY, Al Jawder SE, et al. Acute Middle East respiratory syndrome coronavirus: temporal lung changes observed on the chest radiographs of 55 patients. *AJR Am J Roentgenol*. 2015;205:W267–74.

## Figures



**Figure 1**

COVID-19 pneumonia in a 61-year-old man with fever, cough and sputum for 14 days before CT scan. Chest CT scan confirmed with non-severe COVID-19. A. Axial thin-section unenhanced CT scan shows in the lung window showed multiple reticulation (white arrow) in the bilateral upper lobe and subpleural consolidation (black arrow) in right upper lobe. B. Axial unenhanced image reveals patchy of ground-glass opacities (arrows) in the lower lobes of both lungs, and shows peripheral ground-glass opacities and linear opacities in upper lobe of left lung. CT extent score is 6.



**Figure 2**

COVID-19 pneumonia in a 42-year-old man who presented with fever, cough for 47 days and dyspnea for 39 days before CT scan ultimately requiring the treatment of extracorporeal membrane oxygenation (ECMO). Chest CT scan confirmed with severe COVID-19. A. Axial thin-section unenhanced CT scan demonstrates diffuse ground-glass opacities, patchy consolidation, prominent traction bronchiectasis and architectural distortion (white arrows) in bilateral upper lobes and superior segments of bilateral lower lobes, and demonstrates a small amount of right pleural effusion and interlobular effusion (black arrows). B. Axial unenhanced image at the bifurcation level of intermediate bronchus shows that diffuse ground-glass opacities, patchy consolidation and tree-in-bud sign (white arrow), and shows bilateral pneumothorax (black arrows). CT extent score is 25.



**Figure 3**

COVID-19 pneumonia in a 62-year-old woman who presented with fever, cough for 26 days and dyspnea for 16 days before CT scan. Chest CT scan confirmed with severe COVID-19. On unenhanced CT scan, subpleural consolidation and air bronchogram (arrow) can be seen in the superior segment of the bilateral lower lobes, and scattered consolidation and GGO are distributed along the bronchovascular bundle or subpleural area of both lungs. The prominent pattern of opacities is consolidation.