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CT Quantitative Analysis and Its Relationship with Clinical Features for Assessing the Severity of Patients with COVID-19

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Objective: To investigate the value of initial CT quantitative analysis of ground-glass opacity (GGO), consolidation, and total lesion volume and its relationship with clinical features for assessing the severity of coronavirus disease 2019 (COVID-19).

Materials and Methods: A total of 84 patients with COVID-19 were retrospectively reviewed from January 23, 2020 to February 19, 2020. Patients were divided into two groups: severe group (n = 23) and non-severe group (n = 61). Clinical symptoms, laboratory data, and CT findings on admission were analyzed. CT quantitative parameters, including GGO, consolidation, total lesion score, percentage GGO, and percentage consolidation (both relative to total lesion volume) were calculated. Relationships between the CT findings and laboratory data were estimated. Finally, a discrimination model was established to assess the severity of COVID-19.

Results: Patients in the severe group had higher baseline neutrophil percentage, increased high-sensitivity C-reactive protein (hs-CRP) and procalcitonin levels, and lower baseline lymphocyte count and lymphocyte percentage ($p < 0.001$). The severe group also had higher GGO score ($p < 0.001$), consolidation score ($p < 0.001$), total lesion score ($p < 0.001$), and percentage consolidation ($p = 0.002$), but had a lower percentage GGO ($p = 0.008$). These CT quantitative parameters were significantly correlated with laboratory inflammatory marker levels, including neutrophil percentage, lymphocyte count, lymphocyte percentage, hs-CRP level, and procalcitonin level ($p < 0.05$). The total lesion score demonstrated the best performance when the data cut-off was 8.2%. Furthermore, the area under the curve, sensitivity, and specificity were 93.8% (confidence interval [CI]: 86.8–100%), 91.3% (CI: 69.6–100%), and 91.8% (CI: 23.0–98.4%), respectively.

Conclusion: CT quantitative parameters showed strong correlations with laboratory inflammatory markers, suggesting that CT quantitative analysis might be an effective and important method for assessing the severity of COVID-19, and may provide additional guidance for planning clinical treatment strategies.

Keywords: *Coronavirus disease 2019; Ground-glass opacity; Consolidation; Quantitative analysis; Severity; Computed tomography*

INTRODUCTION

A cluster of cases of pneumonia of unknown origin was reported in Wuhan, Hubei province, China, in early December 2019. It was recently confirmed to be caused by severe acute respiratory syndrome coronavirus (SARS-CoV) (1, 2). With its rapid spread, more than 80000 patients with confirmed coronavirus disease 2019 (COVID-19) have been reported in China. There are increasing numbers of cases that have also been reported worldwide. The emergence of

COVID-19 has attracted immense attention globally (3). The incidence of severe COVID-19 has been reported to range from 15.7% to 26.1% (4-7). The early identification of severe COVID-19 is of clinical importance as these patients have poor survival rates and mortality is approximately 20 times higher than that of non-severe patients (4, 5).

Computed tomography (CT) is an important and effective method for the diagnosis and evaluation of the severity of COVID-19 (6, 7). Furthermore, ground-glass opacity (GGO) and consolidation are the main CT findings in patients with COVID-19 and are associated with the course and severity of the disease. GGO on CT is more likely to be presented in patients with severe COVID-19 (7). In addition, some studies have reported that an increase in the extent of consolidations is more likely to be presented in the early- and mid-term follow-up CT, and that consolidation lesions would serve as an alert for clinicians in the management of patients (8, 9). In a study of 10 fatal cases of COVID-19 in a hospital, Yuan et al. (10) reported that there was a higher frequency of consolidation in patients who died of the disease than in those who survived.

To date, many reports have focused on the pattern and distribution of and semi-quantitative CT findings to diagnose and evaluate the severity of COVID-19 pneumonia. However, quantitative analyses of these CT features have not been reported. Recently, with the development of artificial intelligence technology, automatic lung volume segmentation has been widely applied in lung disease diagnosis and evaluation (11). In the present study, an automatic lung segmentation software was used to obtain new quantitative parameters of pneumonia, including percentage GGO, consolidation and total lesion volume in both lungs, and percentage of consolidation and GGO volume within the total lesion.

The present study aimed to analyze the initial CT quantitative parameters, including GGO, consolidation, and total lesion volume, and evaluate their relationship with clinical features of COVID-19, to promptly assess the disease severity on admission.

MATERIALS AND METHODS

The present retrospective study was approved by the Institutional Ethics Committee of the Second Affiliated Hospital of Chongqing Medical University and Chongqing Three Gorges Central Hospital. The requirement for an informed consent was waived.

Patients

The health records of patients in Chongqing Three Gorges Central Hospital between January 23, 2020 and February 19, 2020, were retrospectively reviewed. Patients with confirmed COVID-19 on admission were included when they satisfied the following inclusion criteria: 1) non-contrast chest CT scan completed on admission; and 2) laboratory examinations within 1 day before or after the initial CT scan. Exclusion criteria were as follows: 1) patients with negative imaging findings on chest CT; and 2) patients with severe artifacts on CT scans. The diagnosis of COVID-19 was established according to the World Health Organization interim guidelines (12). A total of 126 patients were enrolled according to the inclusion criteria. Of these patients, 42 were excluded due to the following reasons: 1) presence of severe artifacts on CT scans (n = 15); 2) negative CT findings on admission (n = 7); and 3) no laboratory examinations within 1 day before or after the initial CT scan (n = 20). Finally, 84 patients with confirmed COVID-19 diagnosis were enrolled. Among these patients, 47 (56.0%) were male and 37 (44.0%) were female; the age range was 20–79 years.

First, clinical and laboratory data of patients were obtained. The laboratory data included neutrophil count, neutrophil percentage, lymphocyte count, lymphocyte percentage, procalcitonin level, high-sensitivity C-reactive protein (hs-CRP) level, and platelet count on admission. Clinical data included sex, age, main clinical symptoms, and presence of comorbidities.

According to the guidelines of the National Health Commission of the People's Republic of China (13), the clinical classifications of COVID-19 are as follows: 1) mild type, mild clinical symptoms, and no sign of pneumonia on imaging; 2) common type, with fever, respiratory tract symptoms, and radiological evidence of pneumonia; 3) severe type, complying with any of the following: a) respiratory distress (RR ≥ 30 beats/min), b) hypoxia (oxygen saturation ≤ 93.0% in the resting state), c) hypoxemia (arterial blood oxygen partial pressure/oxygen concentration ≤ 300 mm Hg); 4) critical type, complying with one of the following: a) respiratory failure and need for mechanical ventilation, b) shock, c) intensive care unit admission required for multiple organ failure. In the present study, the severe group broadly included patients of the severe and critical types as defined above. The 84 patients were divided into two groups: non-severe group (n = 61) and severe group (n = 23).

CT Data Acquisition

All patients with confirmed COVID-19 diagnosis underwent thin-section CT on admission. All CT examinations were performed using a 16-slice spiral CT scanner (Emotion 16 VC20B, Siemens Healthcare GmbH, Erlangen, Germany). The CT protocol was as follows: a tube voltage of 120 kV; smart mA tube current modulation; slice thickness of 1.5 mm; reconstruction matrix of 512 x 512; detector width of 1.5 mm; and breath hold at full inspiration. The reconstruction was performed with a thickness of 1 mm.

CT Image Analysis

General CT Manifestation

All CT images were independently reviewed by two senior radiologists, with each having more than 15 years of experience in thoracic radiology, who were blinded to patients' clinical information. The final finding was determined by consensus when there was a disagreement. The CT images were evaluated using the following window:

a mediastinal window with a window level of 40 HU and a window width of 350 HU; and a lung window with a window level of -600 HU and a window width of 1200 HU.

The general CT manifestation was assessed based on the definition in the Fleischner Society Recommendation (14, 15), including GGO, consolidation, crazy-paving pattern, air-bronchogram, thoracic lymphadenopathy, and pleural effusion. The distribution pattern of lesions and lobe involvement were also recorded. The outer one-third of the lung was defined as peripheral, while the remaining was defined as central.

CT Quantitative Analysis

The entire lung and lung lesions were automatically segmented using the Pulmonary Infection Assisted Diagnosis (V1.7.0.1) software on the FACT Medical Imaging System (Dexin Medical Imaging Technology Co., Ltd., Shanxi, China) (11, 16). Based on this automatic segmentation, the boundaries of each lesion were further precisely adjusted by the senior radiologist, according to
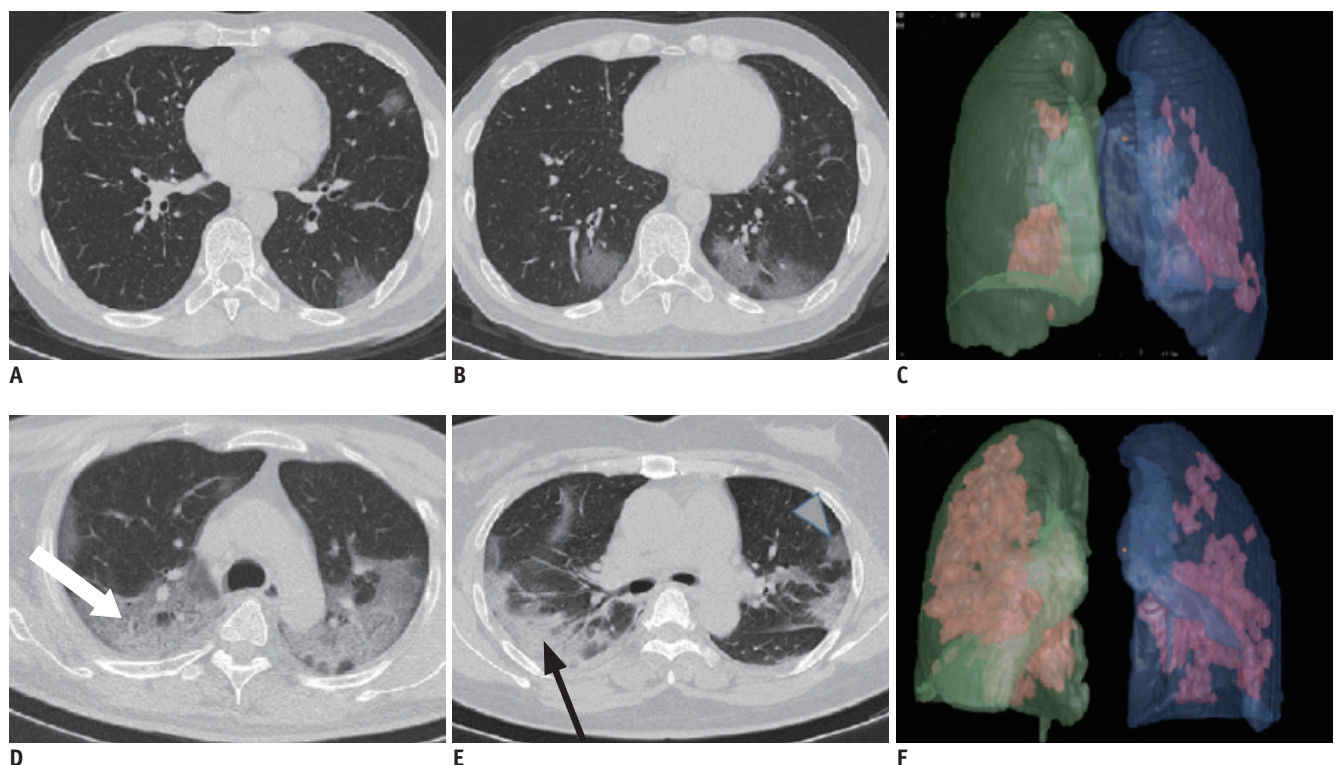

Fig. 1. CT manifestation in patients with COVID-19 pneumonia.
A-C. Chest CT scan of 38-year-old man confirmed with non-severe COVID-19. GGO and mixed peripheral and central distributions are seen and four lobes are involved. GGO score, consolidation score, and total lesion score are 1.5%, 0, and 1.5%, respectively; GGO/total lesion and consolidation/total lesion ratios are 1 and 0, respectively. **D-F.** Chest CT scan of 54-year-old man confirmed with severe COVID-19. GGO (arrowhead), consolidation (thin arrow), crazy-paving sign (thick arrow), and mixed peripheral and central distributions are seen and four lobes are involved. GGO score, consolidation score, and total lesion score are 15.5%, 4.2%, 19.7%, respectively; GGO/total lesion and consolidation/total lesion ratios are 0.8 and 0.2, respectively. COVID-19 = coronavirus disease 2019, GGO = ground-glass opacity

manual tools, to avoid the influence of non-pulmonary conditions, such as large blood vessels, pleural effusion, and pleural thickening. The GGO and consolidation volume were further measured according to the semi-automatic segmentation, based on the following two steps: 1) the GGO and consolidation components inside the infection region were segmented based on adaptive region growing and thresholds (17); and 2) the results of the segmentation were reviewed by a senior radiologist with more than 15 years of experience in thoracic radiology. False positives were deleted, and false negatives were manually added based on the definition of GGO and consolidation in the Fleischner Society Recommendations (15). Finally, the volume of the total lesion, GGO, consolidation and both lungs, as well as

the total lesion score, GGO score and consolidation score were automatically calculated (Fig. 1). The percentage of GGO, consolidation, and total lesion volume in both lungs were defined as the GGO score, consolidation score, and total lesion score, respectively.

Statistical Analysis

Categorical variables are presented as the frequency and percentage, and quantitative variables as the median and interquartile range. For quantitative variables, the Student's *t* test or Mann-Whitney U-test was used to analyze the differences between groups, according to the normal distribution, and chi-square test or Fisher's exact test was used for categorical variables. The normality of continuous

Table 1. Clinical Characteristics of 84 Patients with COVID-19 on Admission

Clinical Characteristics	Total (n = 84)	Severe Group (n = 23)	Non-Severe Group (n = 61)	*P*
Age (years), Median (IQR)	46.0 (37.0–53.0)	54.0 (45.0–68.0)	44.0 (34.0–50.0)	< 0.001
Male gender, no. (%)	37 (44.0)	10 (43.4)	27 (44.3)	0.570
Comorbidity, no. (%)				
Diabetes	8 (9.5)	4 (17.4)	4 (6.6)	0.206
Hypertension	9 (10.7)	1 (4.3)	8 (13.1)	0.433
Cardiovascular disease	2 (2.3)	1 (4.3)	1 (1.6)	0.475
COPD	2 (2.3)	1 (4.3)	1 (1.6)	0.475
Cerebrovascular disease	2 (2.3)	1 (4.3)	1 (1.6)	0.475
Hepatitis B infection	3 (3.6)	1 (4.3)	2 (3.3)	1.000
Initial symptom, no. (%)				
Fever (> 37.3°)	47 (56.0)	12 (52.2)	35 (57.4)	0.668
Cough	53 (63.0)	17 (73.9)	36 (59.0)	0.311
Sputum production	13 (15.5)	5 (21.7)	8 (13.1)	0.330
Myalgia or fatigue	16 (19.0)	3 (13.0)	13 (21.3)	0.538
Headache	12 (14.3)	1 (4.3)	11 (18.0)	0.166
Stuffy and runny nose	2 (2.4)	1 (4.3)	1 (1.6)	0.475
Sore throat	3 (3.6)	1 (4.3)	2 (3.3)	1.000
Nausea and vomit	2 (2.3)	1 (4.3)	1 (1.6)	0.475
Anorexia	5 (6.0)	1 (4.3)	4 (6.6)	1.000
Diarrhea	2 (2.4)	1 (4.3)	1 (1.6)	0.475
Mild dyspnea or chest pain	3 (3.6)	1 (4.3)	2 (3.3)	1.000
Laboratory findings, median (IQR)				
Platelet count (x 10^9)	178.0 (130.0–271.0)	265.0 (127.0–319.0)	176.0 (138.7–241.0)	0.630
White blood cell count (x 10^9)	5.3 (4.2–7.8)	5.7 (4.5–8.5)	5.2 (4.1–6.6)	0.160
Neutrophil percentage (%)	71.0 (64.1–81.2)	84.2 (73.7–89.0)	68.2 (62.9–74.6)	< 0.001
Neutrophil count (x 10^9/L)	3.5 (2.6–5.0)	3.4 (2.9–5.8)	3.5 (2.5–4.5)	0.620
Lymphocyte percentage (%)	0.2 (0.1–0.3)	9.7 (7.8–15.1)	23.4 (16.9–28.6)	< 0.001
Lymphocyte count (x 10^9/L)	1.1 (0.7–1.4)	0.7 (0.4–1.1)	1.2 (0.9–1.5)	< 0.001
hs-CRP (mg/L)	16.1 (5.2–58.9)	83.9 (36.8–133.1)	12.5 (3.4–29.9)	< 0.001
Procalcitonin (ng/mL)	0.046 (0.032–0.077)	0.080 (0.045–0.120)	0.040 (0.029–0.067)	< 0.001

Quantitative variables were presented as median and IQR (in parentheses); categorical variables were presented as number of patients and percentage (in parentheses). COPD = chronic obstructive pulmonary disease, COVID-19 = coronavirus disease 2019, hs-CRP = high-sensitivity C-reactive protein, IQR = interquartile range, no. = number

variables was assessed using the Kolmogorov–Smirnov test. The correlation between laboratory examination results and CT quantitative parameters were analyzed using Spearman's correlation test. Receiver operating characteristic analysis was performed to evaluate the discriminative performance of these CT quantitative parameters for assessing the severity of the disease. SPSS statistics software (version 22.0, IBM Corp., Armonk, NY, USA) and R software (version 3.6.1, R Core Team, Vienna, Austria) were used for statistical analyses. $P < 0.05$ was considered statistically significant.

RESULTS

Clinical and Laboratory Analyses

The clinical and laboratory results of all 84 patients are presented in Table 1. There was a significant difference in age between the non-severe group and severe group, with patients in the severe group being older ($p < 0.001$). However, there was no significant difference between severity groups in terms of sex, presence of comorbidities, or main initial symptoms on admission. Regarding laboratory examination markers, patients in the severe group had higher neutrophil percentage, hs-CRP level, and procalcitonin level, but lower lymphocyte count and

lymphocyte percentage than those of the non-severe group (all, $p < 0.01$). However, there were no significant differences in the blood leukocyte count, neutrophil count, and platelet count between the groups.

Chest CT Quantitative Analysis

The chest CT findings of patients are presented in Table 2. There was no significant difference in lobe involvement between the two severity groups. However, with regard to distribution pattern and CT imaging signs, mixed peripheral and central distribution, crazy-paving sign, and air bronchogram more commonly occurred in the severe group ($p < 0.05$) (Fig. 1). Furthermore, the severe group had one patient with lymphadenopathy and five patients with pleural effusion.

The results for the GGO, consolidation, and total lesion scores, and the ratio of consolidation to the total lesion volume and ratio of GGO to the total lesion volume for these two groups are presented in Figure 2 and Table 2. There were significant differences between the severe group and non-severe group ($p < 0.05$) for all measures. The severe group had significantly higher GGO scores, consolidation scores, and total lesion scores and percentage consolidation (relative to total lesion volume) but had lower percentage GGO (relative to total lesion volume).

Table 2. CT Characteristics of 84 Patients with COVID-19 on Admission

CT Characteristics	Total (n = 84)	Severe Group (n = 23)	Non-Severe Group (n = 61)	P
Number of lobes involved, no. (%)				0.111
1	2 (2.3)	0 (0)	2 (2.3)	
2	6 (7.1)	1 (4.3)	5 (8.2)	
3	10 (1.2)	1 (4.3)	9 (14.8)	
4	14 (16.7)	4 (17.4)	10 (16.4)	
5	52 (61.9)	17 (73.9)	35 (57.4)	
Distribution pattern, no. (%)				0.009
Peripheral	24 (28.5)	3 (13.0)	21 (34.4)	
Central	1 (1.2)	0 (0)	1 (1.6)	
Mixed peripheral and central distribution	59 (70.2)	20 (87.0)	39 (63.9)	
Crazy-paving, no. (%)	22 (26.2)	10 (43.5)	12 (19.7)	0.027
Air-bronchogram, no. (%)	17 (20.2)	9 (39.1)	8 (13.1)	0.014
Lymphadenopathy, no. (%)	1 (1.2)	1 (4.3)	0 (0)	
Pleural effusion, no. (%)	5 (6.0)	5 (21.7)	0 (0)	
Total lesion CT score, median (IQR)	4.0 (1.4–11.6)	20.5 (12.5–29.8)	2.8 (0.9–4.9)	< 0.001
GGO CT score, median (IQR)	3.1 (1.2–8.1)	13.3 (8.3–18.6)	1.7 (0.9–4.3)	< 0.001
Consolidation CT score, median (IQR)	0.5 (0–2.4)	4.4 (1.5–10.4)	0.2 (0–0.9)	< 0.001
GGO/ total lesion, median (IQR)	0.9 (0.7–1.0)	0.7 (0.5–0.9)	0.9 (0.7–1.0)	0.002
Consolidation/total lesion, median (IQR)	0.1 (0–0.3)	0.2 (0.1–0.4)	0.1 (0–0.3)	0.008

Quantitative variables were presented as median and IQR (in parentheses); categorical variables were presented as number of patients and percentage (in parentheses). CT = computed tomography, GGO = ground-glass opacity

Correlations between Laboratory Data and CT Quantitative Parameters

The correlations between laboratory findings and CT quantitative parameters are presented in Table 3. The total lesion score, GGO score, and consolidation score were strongly correlated with neutrophil percentage, lymphocyte count, lymphocyte percentage, and hs-CRP level ($p < 0.001$). The total lesion score and GGO score were also positively correlated with procalcitonin level ($p = 0.001$). The percentage GGO and percentage consolidation (both relative to total lesion volume) were correlated with neutrophil percentage, lymphocyte count, and lymphocyte percentage ($p < 0.05$). Among these quantitative parameters, the total lesion score had the highest absolute correlation with the laboratory examination measures.
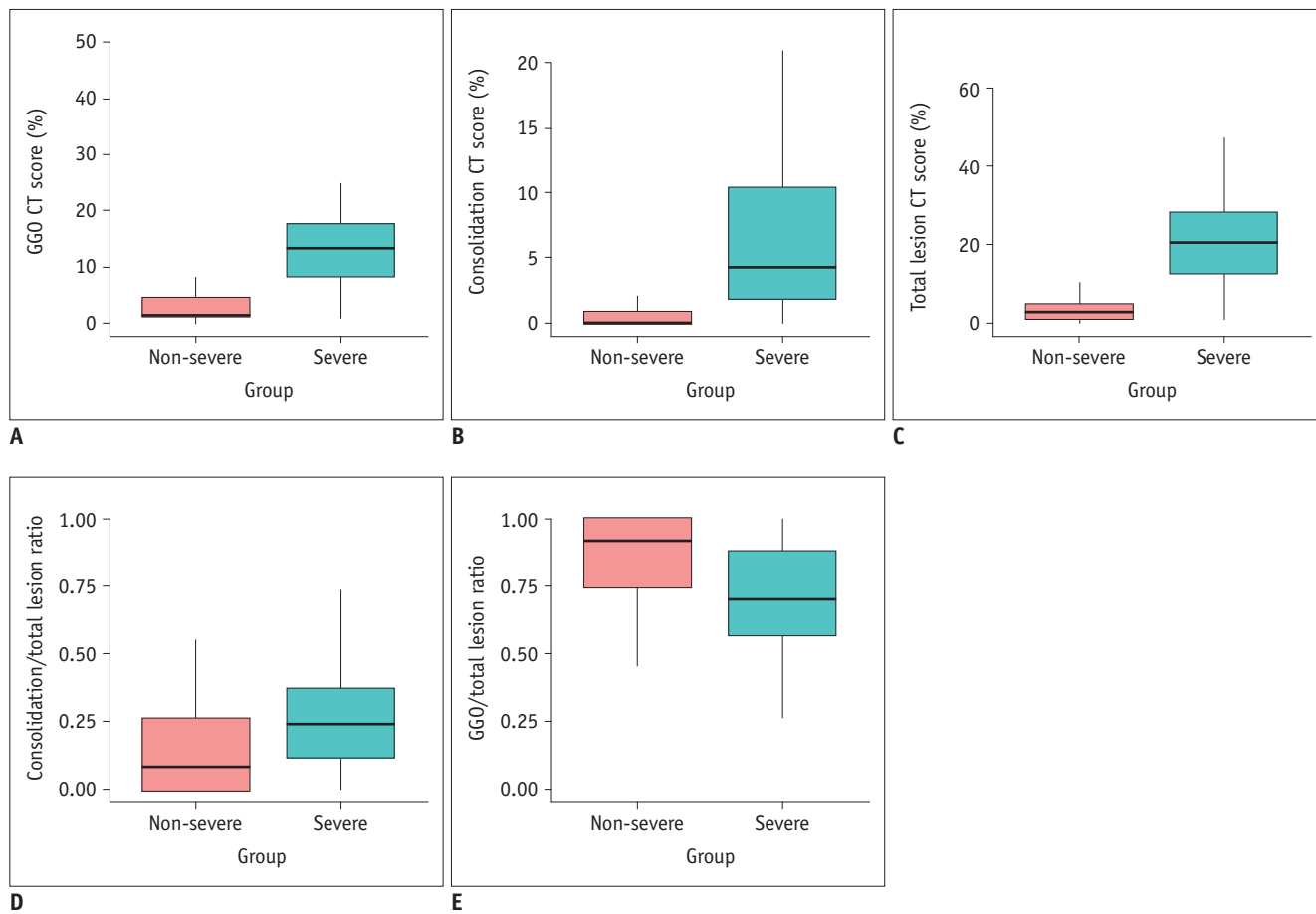

Fig. 2. Results of GGO score (A), consolidation score (B), total lesion score (C), consolidation/total lesion ratio (D), and GGO/ total lesion ratio (E) in severe and non-severe groups. CT = computed tomography

Table 3. Correlation between Laboratory Examination Results and CT Quantitative Parameters in 84 Patients with COVID-19

Laboratory Examination	Total Lesion CT Score	Consolidation CT Score	GGO CT Score	GGO/ Total Lesion	Consolidation/ Total Lesion
Neutrophil percentage (%)	0.436[†]	0.433[†]	0.404[†]	0.296[†]	0.264*
Neutrophil count (x 10⁹/L)	0.083	0.147	0.050	-0.128	0.130
Procalcitonin (ng/mL)	0.322[†]	0.198	0.299[†]	0.061	0.086
hs-CRP (mg/L)	0.489[†]	0.349[†]	0.442[†]	-0.202	0.184
Lymphocyte count (x 10⁹/L)	-0.331[†]	-0.370[†]	-0.317[†]	0.286[†]	-0.259*
Platelet count (x 10⁹/L)	0.028	-0.019	0.022	0.061	-0.086
White blood cell count (x 10⁹/L)	0.119	0.174	0.098	-0.087	0.100
Lymphocyte percentage (%)	-0.457[†]	-0.471[†]	-0.481[†]	0.345[†]	-0.316[†]

*$p < 0.05$, [†]$p = 0.001$.

Discriminative Performance of CT Quantitative Parameters

A discrimination model was established according to the GGO, consolidation, and total lesion scores as well as percentage consolidation (relative to total lesion volume), and percentage GGO (relative to total lesion volume). The discriminative performance of these five parameters is presented in Figure 3 and Table 4. Regarding the area under the curve (AUC), the total lesion score on CT demonstrated the best performance in assessing the severity of COVID-19 when the data cut-off was 8.2%, and the AUC, sensitivity, and specificity were 93.8%, 91.3% and 91.8%, respectively.

DISCUSSION

In the present study, GGO and consolidation components within the infection region of patients diagnosed with COVID-19 were quantitatively assessed according to lesion density, to evaluate the severity of COVID-19. While this
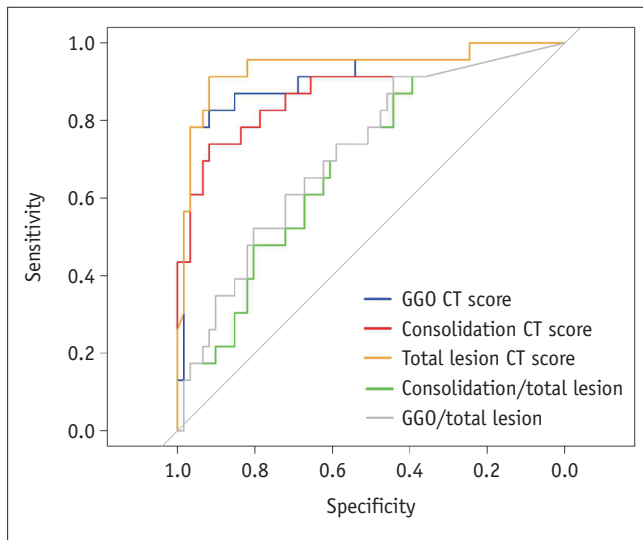

Fig. 3. Receiver operating characteristic curves analysis of GGO score, consolidation score, total lesion score, consolidation/total lesion ratio, and GGO/total lesion ratio for assessing severity of COVID-19.

method was similar to that reported previously (18) which was based on visual, semi-quantitative, evaluation of the disease (19-21), the current quantitative analysis of GGO, consolidation, and total lesion volume can more accurately assess pulmonary inflammation. Based on the retrospective assessment of initial CT and clinical characteristics, it was found that the quantitative parameters of lung CT were significantly different for patients with severe COVID-19, and that these parameters were significantly correlated with laboratory inflammatory markers. The results of the present study suggest that CT quantitative analysis can be helpful in assessing the severity of COVID-19 and may provide further guidance for planning clinical treatment strategies.

The average age of the severe group was greater than that of the non-severe group, which was consistent with the findings of previous research (6, 22). However, there was no significant difference between the groups in terms of the presence of comorbidities or main initial symptoms on admission, which is in contrast to previous findings (22). This may be due to the sample selection bias. Inflammation of the deep airways and alveoli was significantly heavier in the severe group, as demonstrated by higher baseline neutrophil percentage, hs-CRP level, and procalcitonin level, and lower lymphocyte count and lymphocyte percentage. This finding was in line with that of a study conducted on the clinical course and outcomes of critical patients with COVID-19 (23). In this study, 80% of critical patients had lymphopenia, and lymphocytopenia was a prominent feature of critical patients with SARS-CoV infection due to damage to the cytoplasmic component of the lymphocytes by SARS-CoV viral particles, causing their destruction (24).

Initial CT revealed that lesions commonly involved multiple lobes with peripheral or mixed peripheral and central distribution, crazy-paving sign, and air bronchogram, and these markers were more common in the severe group. This indicates that the diversity of the initial lesions in severe patients was not solely due to GGO lesion caused by exudation, but also due to a large number of consolidations. This present study finding was consistent

Table 4. Value of Cut-Off, AUC, 95% CI, Sensitivity, Specificity of Five CT Quantitative Parameters

CT Quantitative Parameters (%)	AUC (95% CI)	Sensitivity (95% CI)	Specificity (95% CI)	Cut-Off (%)
GGO CT score	90.7 (82.6–98.9)	78.3 (65.2–95.7)	96.7 (77.0–100)	8.2
Consolidation CT score	87.0 (76.9–97.2)	73.9 (47.8–91.3)	91.8 (67.2–100)	2.1
Total lesion CT score	93.8 (86.8–100)	91.3 (69.6–100)	91.8 (23.0–98.4)	8.2
GGO/total lesion	68.7 (56.5–81.0)	91.3 (69.6–100)	44.3 (15.1–62.3)	0.9
Consolidation/total lesion	71.5 (59.4–83.6)	73.9 (56.5–95.7)	59.0 (34.4–77.0)	0.1

AUC = area under curve, CI = confidence interval

with that of a previous report, in which severe patients had a larger lung lesion involvement (i.e., total lesion CT score) than that in non-severe patients (25). The total lesion score on CT quantitatively represents the percentage of lung parenchyma, demonstrating evidence of abnormalities as a whole and assesses of the total extent of the disease. A significant correlation was found between the extent of disease assessed on chest CT and the impairment in gas exchange as well as the severity of dyspnea (18). In addition, patients in the severe group demonstrated an increase in the consolidation component of lesions, indicating extension of the disease course and deterioration of the lesion, which were correlated to the pathological characteristics of severe patients. A recent pathological study revealed that patients with severe COVID-19 had total lung injury (26), including alveolar edema with bleeding, alveolar inflammation with epithelial inflammatory damage, and bronchiolitis, which was similar to that in patients with SARS.

The present study revealed that the total lesion score, GGO score, consolidation score, percentage GGO (relative to total lesion volume), and percentage consolidation (relative to total lesion volume) were negatively correlated with the lymphocyte count and lymphocyte percentage. Lymphopenia is the common abnormal laboratory result that occurs due to the progression of COVID-19 (6, 27). The damage to lymphocytes may be an important factor leading to symptom exacerbations in patients with COVID-19. A previous study suggested that a decrease in T-lymphocyte count indicates that the 2019 novel coronavirus (2019-nCov) virus has consumed many immune cells (28), inhibited the cellular immune function, and reduced these even further in patients with severe COVID-19. In addition, the present study also revealed significant positive correlations between CT quantitative parameters and neutrophil percentage, hs-CRP levels, and procalcitonin levels. These results were consistent with those of another report (25). Neutrophil percentage and C-reactive protein levels may be correlated to the cytokine storm induced by viral infection (6) and increased procalcitonin level may be due to secondary bacterial infection (27). These results revealed that the extent of inflammatory involvement on lung CT was consistent with the changes in laboratory inflammatory markers, which further indicates that CT could have the potential to assess the severity of pulmonary inflammation and lung damage due to COVID-19.

The early identification of patients and assessment of

the severity of COVID-19 may guide clinical treatment options and reduce the mortality rate. In the present study, a discrimination model was established to diagnose and evaluate the severity of COVID-19 according to CT quantitative parameters. The total lesion score demonstrated the best performance, and the AUC was 0.94 when the data cut-off was 8.2%. The results revealed that a total lesion score of 8.2% indicated disease course extension and lesion deterioration.

Although the investigators initially investigated the value of CT quantitative parameters and their correlation with laboratory examination results for assessing the severity of COVID-19, there were several limitations. First, the sample size was too small, especially in the severe group, and sample selection bias may have occurred. Second, there was a lack of histopathological support in all cases, and the correlation between CT features and histopathological manifestations requires further study. Third, since this study was completed within approximately 40 days since the outbreak occurred, more observations are required to understand the pathophysiological changes of the disease. Finally, there was no further analysis of the longitudinal pattern of the disease; however, this will be covered in our future research.

In summary, this study revealed that CT quantitative parameters were correlated with laboratory inflammatory markers, and that the total lesion score on CT demonstrated the best performance for assessing the severity of COVID-19. These results suggest that CT quantitative analysis could play a significant role in assessing the severity of COVID-19, which could be used as an important disease indicator, and help in guiding the clinical treatment and contribute to disease prognosis.

Conflicts of Interest

The authors have no potential conflicts of interest to disclose.

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