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Combined clinical and imaging features better predict the critical outcomes of patients with SARS-COV-2

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Abstract

The purpose of this study was to investigate the predictive value of combined clinical and imaging features, compared with the clinical or radiological risk factors only. Moreover, the expected results aimed to improve the identification of severe acute respiratory syndrome coronavirus-2 (SARS-COV-2) patients who may have critical outcomes.

This retrospective study included laboratory-confirmed SARS-COV-2 cases between January 18, 2020, and February 16, 2020. The patients were divided into 2 groups with noncritical illness and critical illness regarding severity status within the hospitalization. Univariable and multivariable logistic regression models were used to explore the risk factors associated with clinical and radiological outcomes in patients with SARS-COV-2. The ROC curves were performed to compare the prediction performance of different factors.

A total of 180 adult patients in this study included 20 critical patients and 160 noncritical patients. In univariate logistic regression analysis, 15 risk factors were significantly associated with critical outcomes. Of importance, C-reactive protein (1.051, 95% confidence interval 1.024-1.078), D-dimer (1.911, 95% CI, 1.050–3.478), and CT score (1.29, 95% CI, 1.053–1.529) on admission were independent risk factors in multivariate analysis. The combined model achieved a better performance in disease severity prediction ($P = .05$).

CRP, D-dimer, and CT score on admission were independent risk factors for critical illness in adults with SARS-COV-2. The combined clinical and radiological model achieved better predictive performance than clinical or radiological factors alone.

Abbreviations: ARDS = acute respiratory distress syndrome, AUC = Area under the curve, CI = confidence interval, CK-MB = creatine kinase isoenzyme, CRP = C-reactive protein, GGO = ground glass opacity, ICC = Intragroup correlation coefficient, ICU = intensive care unit, LDH = lactate dehydrogenase, MERS = Middle East respiratory syndrome, OR = odds ratio, SARS-CoV-2 = severe acute respiratory syndrome coronavirus-2, WHO = World Health Organization.

Keywords: CT score, risk factor, SARS-COV-2

1. Introduction

In December 2019, a cluster of novel coronavirus pneumonia occurred in Wuhan, Hubei Province, China,[1] which is characterized as having fever and cough, and less commonly other nonspecific symptoms, such as dyspnea, myalgia, and fatigue.[2] On February 11th, 2020, the World Health Organization (WHO) officially had declared this disease as 2019 coronavirus disease provisionally,[3] which has been renamed as severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2) by the International Committee on Taxonomy of Viruses later.[4] Although most SARS-COV-2 infected patients have mild or moderate disease, a few may rapidly develop worse outcomes such as acute respiratory distress syndrome (ARDS) or even die. SARS-COV-2 has been rapidly spreading in other countries around the world. It has become a global pandemic. As of September 19, over 30,369,778 confirmed SARS-COV-2 cases have been reported with 948,795 deaths globally, according to the WHO website.[5] Therefore, how to detect high-risk patients to avoid disease progression was an important issue.

To date, several clinical biomarkers have been found to predict prognosis in patients with SARS-COV-2. Male gender, lymphopenia, elevated C-reactive protein (CRP), and comorbidity were

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the potential risk factors for the poor outcome in SARS-COV-2 patients.[6] A recent study including 201 patients with SARS-COV-2 pneumonia reported that the risk factors, such as older age, neutrophilia, and higher lactate dehydrogenase (LDH) and D-dimer, could predict the development of ARDS and death.[7] Besides, the crucial role of CT as an efficient screening and fast diagnostic tool for SARS-COV-2 patients has been recognized due to its convenience and high sensitivity.[8,9] Computed tomographic (CT) findings were found to link to the severity of SARS-COV-2 infection.[10] Besides, the CT score as a quantitative evaluation has already shown great results in research on SARS and H1N1 influenza pneumonia.[11,12] Either clinical or radiological features can demonstrate the inflammatory severity. However, the combined clinical and radiological characteristics in predicting disease progression on admission have not yet been well described.

Therefore, the purpose of this study was to investigate the predictive value of combined clinical and radiological findings in predicting critical clinical outcomes of patients with SARS-COV-2, and compared its prediction performance to radiological or clinical features alone. The study aimed to identify high-risk SARS-COV-2 patients before critical outcomes occurrence and therefore guide treatment implementation timely.

2. Participants and methods

2.1. Study design and participants

A single-center, retrospective study was performed on SARS-COV-2 patients confirmed by real-time polymerase chain reaction from the First Peoples Hospital of Jingmen (Hubei province, China), from January 18, 2020, to February 16, 2020. The composite end-point consisted of the admission intensive care unit (ICU), ARDS, or death. The confirmed patients were divided into 2 groups, noncritical and critical based on the presence and absence of end-point events, linking to the clinical profiles and imaging characteristics. On the basis of the CT features, the severity of SARS-COV-2 would be assessed by CT score. Patients younger than 18 years or those who had suboptimal image quality were excluded.

This study was approved by the ethics committee of the Sir Run Run Shaw Hospital of Zhejiang University School of Medicine. The need for informed consent was waived for this retrospective study due to no potential risk to patients.

2.2. Data collection

Demographic, clinical, and laboratory data were extracted from electronic medical records. Laboratory data mainly consisted of a complete blood count, serum biochemical tests, liver and renal function, CRP, procalcitonin, LDH, creatine kinase isoenzyme (CK-MB), and D-dimer. All laboratory tests were conducted according to the clinical care needs of patients. We analyzed the initial laboratory data on admission in this study.

2.3. Chest CT imaging

2.3.1. CT image acquisition. All patients were scanned in the supine position during end-inspiration with one of two 64-multidetector CT scanners (GE Healthcare Optima 660 or GE Light Speed VCT). The parameter settings for the scanning protocol were as follows: tube voltage, 120 kV; tube current, 350 mAs; pitch, 0.984; matrix, 512 mm x 512 mm, reconstructed slice thickness, 0.625 mm. Unenhanced CT scans were obtained for all patients. Follow-up CT scans were obtained according to clinical needs, and only the baseline chest CT on admission was evaluated.

2.3.2. CT features assessment. All CT images were reviewed with multiplanar reconstruction tools by 2 radiologists (T.Y. and J.H.) with 3 and 7 years of experience in imaging who assessed the images blindly and independently. Final decisions were reached by consensus. In the case of disagreement between the 2 primary radiologists, a third thoracic radiologist (HJ. H) with 25 years of experience made the final decision.

For each of the included patients, the following features of the CT images were evaluated: distribution: peripheral or peripheral + central (peripheral was defined as involving mainly the peripheral one-third of the lung region, otherwise as central distribution); density: ground-glass opacities (GGO), GGO + consolidation, nodules with halo, and fibrotic lesions; location of the lobes affected; number of lobes affected; unilateral or bilateral lung affected; pleural effusion or mediastinal lymphadenopathy: lymphadenopathy was defined as the short-axis diameter of a lymph node ≥10 mm; and CT score: Each of the 5 lung lobes was assessed by visual quantitative evaluation. Each lobe CT score was calculated based on the infection lobe volume/entire lobe volume. The score of 0 indicated none (no involvement), 1 indicated minimal (1–25% involvement), 2 indicated mild (26–50% involvement), 3 indicated moderate (51–75% involvement), and 4 indicated severe (76–100% involvement). The overall lung total CT score was recorded by summing the five lobe scores (ranging from 0 to 20), as previously reported by Chung et al.[10]

2.4. Statistical analysis

Continuous variables were expressed as the means ± standard deviations or medians with interquartile ranges. Categorical variables were expressed as numbers and percentages N (%) in each category. The Mann–Whitney U test, χ^2 test, and Fisher exact test were used to compare the differences between noncritical and critical illness groups. Univariable and multivariable logistic regression models were performed to identify potential risk factors associated with SARS-COV-2 severity. Variables with P values $< .05$ in univariate analysis were selected into the multivariate regression model. The intragroup correlation coefficient (ICC) was used to test the consistency of the CT score of the 2 radiologists. The areas under the ROC curves (AUC) of risk factors were completed to evaluate the prediction performance. The P value of less than .05 was considered statistically significant. Data were analyzed using SPSS statistical software (version 24, IBM) and MedCalc software (version 15.2.2).

3. Results

3.1. Demographic and clinical characteristics

Total of 184 patients during the study timespan were confirmed with SARS-CoV-2 at the First People's Hospital of Jingmen. Finally, 180 cases, which included 20 critical illness cases and 160 noncritical cases, were collected in the final analysis after excluding 4 patients who had suboptimal image quality. Among critical patients, 14 of them died and others had been discharged from the hospital. All noncritical patients had a definite outcome,

Table 1

Clinical and radiographic findings in patients with COVID-19.

	All patients (n = 180)	Noncritical illness (n = 160)	Critical illness (n = 20)	*P*
Clinical characteristics				
Age, yr	4 7 ± 15	46 ± 14	57 ± 16	.003
Sex				.874
Female	93 (52%)	83 (52%)	10 (50%)	
Male	87 (48%)	77 (48%)	10 (50%)	
Exposure to confirmed patient	47 (26%)	41 (26%)	6 (30%)	.243
Current smoker	6 (4%)	5 (3%)	1 (5%)	.512
Comorbidity				
Diabetes	14 (8%)	9 (6%)	5 (25%)	.001
Cardiovascular disease	36 (20%)	24 (15%)	12 (60%)	< .0001
Chronic kidney disease	10 (6%)	2 (1%)	8 (40%)	< .0001
Chronic obstructive lung disease	2 (1%)	2 (1%)	0 (0%)	1.000
Clinical symptoms				
Fever (temperature ≥37.3°C)	138 (77%)	120 (75%)	18 (90%)	.224
Cough	93 (52%)	85 (53%)	8 (40%)	.268
Myalgia	5 (3%)	4 (3%)	1 (5%)	.449
Fatigue	15 (8%)	13 (8%)	2 (10%)	1.000
Diarrhea	5 (3%)	5 (3%)	0 (0%)	1.000
Nasal congestion and runny nose	1 (0.5%)	1 (0.6%)	0 (0%)	.210
Dyspnea	2 (1%)	1 (0.6%)	1 (5%)	.149
Laboratory findings				
White blood cell count, $\times 10^9$ per L	4.5 (3.7–5.8)	4.5 (3.7–5.7)	5.6 (3.5–8.1)	.287
Neutrophil count, $\times 10^9$ per L	2.8 (1.9–4.0)	2.7 (1.9–3.9)	3.7 (2.3–6.5)	.022
Lymphocyte count, $\times 10^9$ per L	1.2 (0.9–1.5)	1.3 (1.0–1.6)	0.6 (0.4–1.0)	< .0001
AST, U/L	21 (17–27)	21 (17–27)	24 (20–45)	.105
ALT, U/L	23 (16–35)	23 (16–35)	22 (15–37)	.877
LDH, U/L	186 (161–235)	183 (159–222)	300 (230–360)	<.0001
CK-MB, U/L	9 (7–11)	9 (7–11)	11 (7–17)	.147
CRP, mg/L	8.8 (2.9–18.2)	7.6 (2.6–13.7)	52.1 (18.8–90.4)	< .0001
D-dimer, μg/mL	0.3 (0.2–0.7)	0.3 (0.2–0.6)	1 (0.7–1.8)	< .0001
Procalcitonin, ng/mL	0.05 (0.03–0.08)	0.04 (0.03–0.06)	0.15 (0.07–2.12)	< .0001
Radiographic findings				
Normal appearance	3 (2%)	3 (2%)	0 (0%)	
Distribution				
Peripheral	79 (44%)	76 (48%)	3 (15%)	.006
Peripheral and central	98 (55%)	80 (50%)	18 (90%)	.001
Density				
Ground-glass opacity	64 (36%)	62 (39%)	2 (10%)	.011
Ground glass with consolidation	87 (48%)	73 (46%)	14 (70%)	.040
Fibrotic streaks	23 (13%)	20 (13%)	3 (15%)	1.000
Nodules with halo	3 (2%)	3 (2%)	0 (0%)	1.000
Lobes affected				
Right upper lobe	112 (62%)	95 (59%)	16 (80%)	.074
Right middle lobe	104 (58%)	86 (54%)	18 (90%)	.002
Right lower lobe	150 (83%)	130 (81%)	19 (95%)	.061
Left upper lobe	121 (67%)	103 (64%)	17 (85%)	.065
Left lower lobe	137 (76%)	117 (73%)	19 (95%)	.061
Number of lobes affected				
1 lobe	24 (13%)	24 (15%)	0 (0%)	.131
2 lobes	32 (18%)	31 (19%)	1 (5%)	.202
3 lobes	19 (11%)	18 (11%)	1 (5%)	.637
4 lobes	24 (13%)	22 (14%)	2 (10%)	.907
5 lobes	78 (43%)	62 (39%)	16 (80%)	< .0001
Unilateral pulmonary involvement	35 (19%)	35 (23%)	1 (5%)	.138
Bilateral pulmonary involvement	141 (78%)	121 (76%)	19 (95%)	.093
Mediastinal lymphadenopathy	5 (2.8%)	4 (2.5%)	1 (5%)	.449
Pleural effusion	1 (0.6%)	1 (0.6%)	0 (0%)	1.000
CT score	5.6 ± 3.9	5.0 ± 3.1	11.5 ± 5.3	<.0001

Continuous variables were expressed as the means ± standard deviations or medians with interquartile ranges. Categorical variables were expressed as numbers and percentages N (%).
ALT = alanine aminotransferase, AST = aspartate aminotransferase, CK-MB = Creatine kinase isoenzyme, CRP = C-reactive protein, LDH = Lactate dehydrogenase.

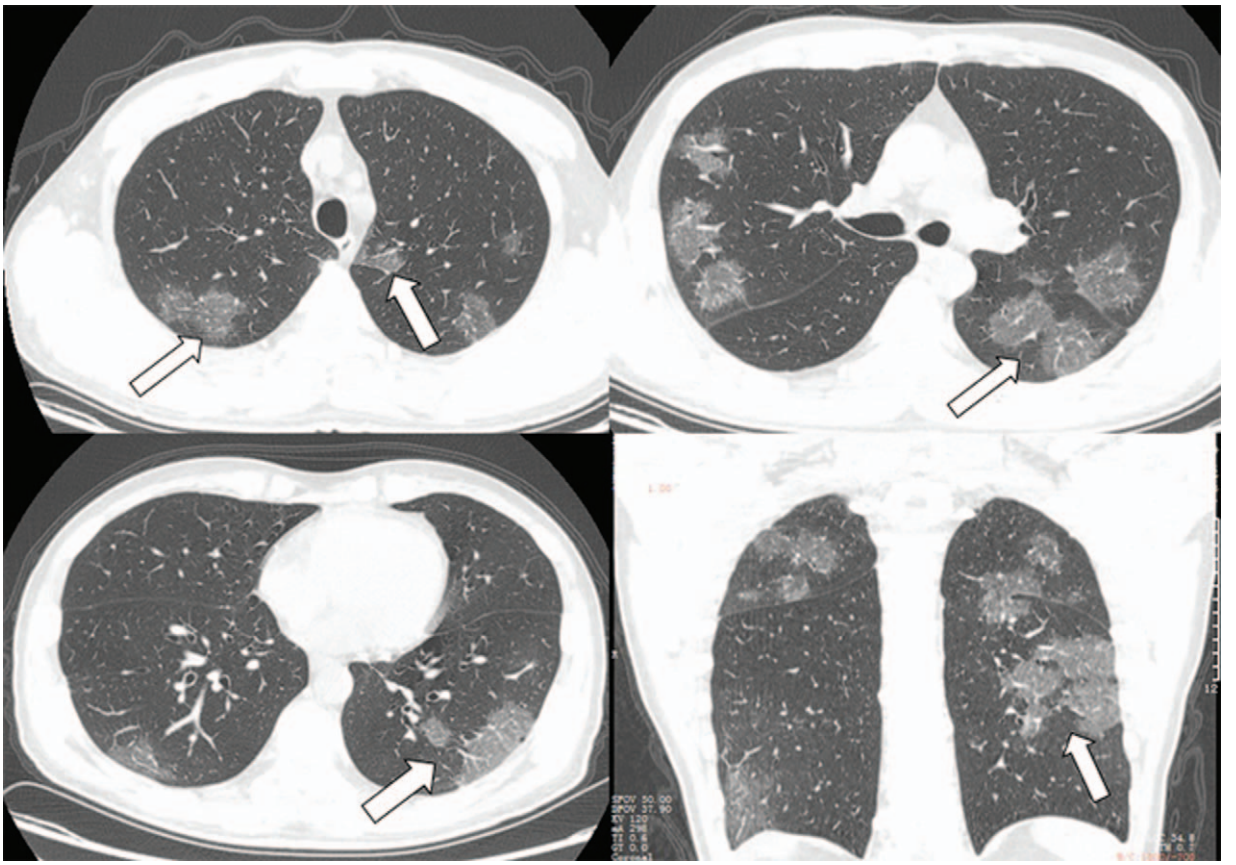

Figure 1. A 49-year-old man with fever was in noncritical group. Axial thin-section unenhanced CT images showed multiple ground glass opacities (white arrows), predominantly subpleural distribution, involvement of 5 lobes, and the CT score of 8. The value of CRP and D-dimer were 3.8 mg/L, 0.23 μg/mL respectively.

discharged. According to the official diagnosis and treatment protocol (6th edition) declared by the National Health Commission of China,[13] the discharge criteria were as follows: no fever for at least 3 days, significant improvement on chest CT, relieved clinical respiratory symptoms, and 2 nasopharyngeal specimens negative for SARS-CoV-2 RNA obtained (the interval at least 24 hours). As summarized in Table 1, the mean age of all patients was 47 ± 15 years, ranging from 18 to 90 years. The mean age of critical patients was 57 ± 16 years, which was significantly higher than that of noncritical patients (46 ± 14). A similar ratio of males and females with SARS-COV-2 was found in nearly half of the total patients. Cardiovascular disease (30, 20%) was the most common comorbidity, followed by diabetes (14, 8%), chronic kidney disease (10, 6%). Of 180 patients, fever (138, 77%) and cough (93, 52%) were the most common initial symptoms on admission.

3.2. Laboratory findings

The mean interval between admission and initial laboratory data was 1 day (range, 0–4 days; median, 1 day). The laboratory markers on admission were analyzed and are summarized in Table 1. Compared with the group with noncritical illness, the lymphocyte count was markedly decreased in the critical group. The critical-illness group had higher values in neutrophil, LDH, CRP, procalcitonin, and D-dimer.

3.3. Radiologic findings

The mean interval between the CT on admission and disease's onset was 9 days (range, 2–17 days; median, 9 days). Three confirmed patients had normal initial chest CT. As summarized in Table 1, more than half of the cases had peripheral and central distributions, especially those with critical illness. Although mean interval between the CT on admission and disease's onset was varied, GGO and GGO + consolidation were the 2 most common appearances on the initial CT scan in this study (Figs. 1 and 2). Li et al[14] results showed that of 51 patients with SARS-CoV-2, ground glass opacity (GGO) (18, 35.3%) and consolidation (28, 54.9%) were 2 main signs on the initial CT. Our finding was consistent with above published article. The involvement of multiple lung lobes was common. Five patients had pleural effusion and one patient had lymphadenopathy. Notably, the CT score of critical patients was significantly higher than that of non-critical patients. The CT score measurement determined by the 2 radiologists showed good repeatability with ICC of 0.982 [95% confidence interval (95% CI): 0.975–0.987].

In the univariable analysis, age, underlying disease, lymphopenia, and elevated levels of LDH, CRP, D-dimer, and procalcitonin were related to critical clinical outcomes, as summarized in Table 2. CT findings of GGO + consolidation, peripheral + central distribution, right middle lobe involvement, 5 lobes affected, and CT score were also associated with critical outcomes, as summarized in Table 3. In the multivariable logistic

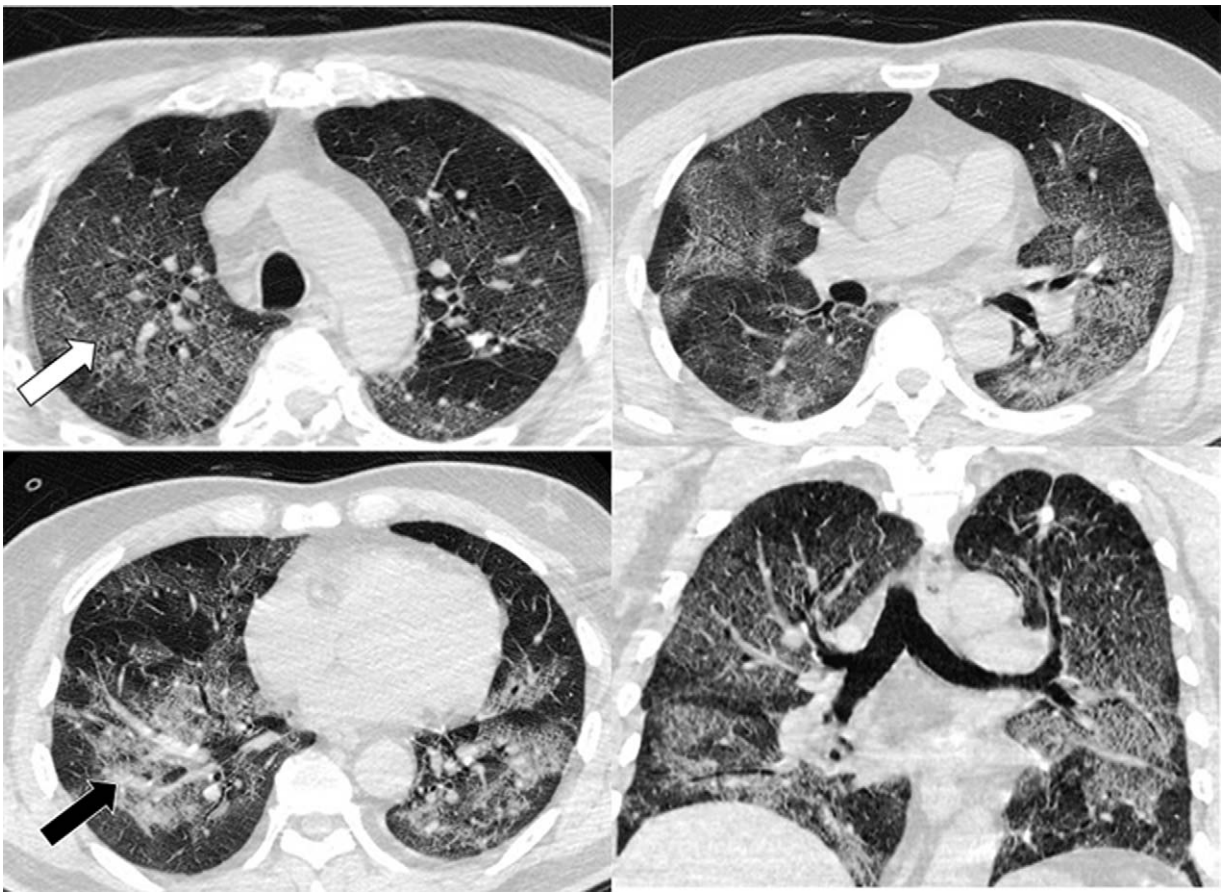

Figure 2. A 43-year-old woman with fever was in critical group. Axial thin-section unenhanced CT images showed diffuse bilateral ground-glass opacities (white arrow) and consolidative opacities (black arrow), peripheral + central distribution, involvement of 5 lobes, and the CT score of 16. The value of CRP and D-dimer was 16.5 mg/L, 6.42 μg/mL, respectively.

regression model, CRP, D-dimer, and CT score on admission were independent risk factors of critical illness in SARS-COV-2 adults. The odds ratio (OR) value of the CRP, D-dimer, and CT score were 1.051 (95% CI:1.024–1.078), 1.911 (95% CI: 1.050–3.478), and 1.29 (95% CI: 1.053–1.529) respectively. The data are presented in Table 4.

To evaluate the predictive ability of the CRP, D-dimer, CT score, and combined model, the ROCs were analyzed (Fig. 3). The combined model bases on these 3 markers demonstrated higher predictive capability (AUC 0.921, 95% CI 0.863–0.960) than that for CRP (AUC 0.789, 95% CI 0.730–0.867), D-dimer (AUC 0.873,95% CI 0.806–0.923), and CT score (AUC 0.807, 95% CI 0.731–0.868), as summarized in Table 5. The optimal predictive threshold of CRP, D-dimer, CT score were > 24.2 mg/L, > 0.66 μg/mL, and > 7, respectively. The predictive performance of the combined model showed significantly

Table 2

Risk factors of clinical and laboratory data associated with critical illness.

Clinical and laboratory data	Univariable OR (95% CI)	*P*	Multivariable OR (95% CI)	*P*
Age, yr	1.053 (1.020–1.088)	.002		
Sex, Female (vs male)	0.928 (0.366–2.351)	.874		
Comorbidity (vs not present) Diabetes	5 (1.510–16.560)	.008		
Cardiovascular disease	8.5 (3.245–22.974)	<.0001		
Chronic kidney disease	52.667 (10.045–276.135)	<.0001		
Lymphocyte count, $\times 10^9$ per L	0.055 (0.013–0.225)	<.0001		
Neutrophil count, $\times 10^9$ per L	1.246 (1.073–1.446)	.004		
LDH, U/L	1.017 (1.010–1.025)	<.0001		
CRP, mg/L	1.052 (1.033–1.072)	<.0001	1.054 (1.019–1.090)	.002
D-dimer, μg/mL	4.381 (1.621–11.845)	.004	18.575 (2.383–144.754)	.005
Procalcitonin, ng/mL 14.755	0.008 (2.019–107.833)			

CI = confidence interval; CRP = C-reactive protein; LDH = Lactate dehydrogenase; OR = odds ratio.

Table 3

Risk factors of radiographic findings associated with critical illness.

Radiographic findings	Univariable OR (95% CI)	*P*	Multivariable OR (95% CI)	*P*
Peripheral + central (vs Peripheral)	5.78 (1.21–25.70)	.027		
Ground glass with Consolidation (vs Ground glass)	2.54 (1.06–6.09)	.037		
5 lobes affected (vs not)	10.1 (1.4–86.70)	.023		
Right middle lobe (vs not)	7.744 (1.739–34.434)	.007		
CT score	22.63 (4.84–105.83)	<.0001	1.488 (1.283–1.726)	<.0001

CI = confidence interval; OR = odds ratio.

improved over the CRP marker ($P = .046$, Table 5). The value of AUC, sensitivity, and specificity in the combined model were 0.921, 82.35%, and 89.43%, respectively. The value of the positive and negative predictive value for the combined model were 49.34% and 97.59%, respectively.

4. Discussion

In this study, the baseline CT and clinical data were retrieved to investigate the predictive risk factors for adverse outcomes in adult patients with SARS-COV-2. Results indicated that CRP, D-dimer, and CT score on admission were associated with ICU admission, ARDS, and death. The combined clinical and radiological model achieved a better performance in predicting disease progression, compared with clinical biomarkers or CT score alone.

The emergence of SARS-CoV-2 infection was first reported at a seafood wholesale market, Wuhan, Hubei province, China, in December 2019.[1] Later on, it had rapidly spread across Wuhan and many other cities in Hubei province including Jingmen, which had caused a major issue of workload at the local hospitals and Clinics. In order to reduce high workload of local clinicians, solve temporary shortage of health resources, and enable local patients with SARS-CoV-2 to receive timely treatment, some experienced clinicians at Sir Run Run Shaw Hospital went to First People's Hospital of Jingmen to provide help. Finally, after negotiation, we obtained SARS-COV-2 raw data from First People's Hospital of Jingmen from January 18, 2020, to February 16, 2020. Fortunately, the pandemic has been now under effective control in China. As of November 30, 86,542 confirmed SARS-COV-2 cases have been reported with 4634 deaths in China. And there were currently 277 SARS-COV-2 patients under treatment, according to the National Health Commission official website.[15] The characteristics of SARS-COV-2 on CT were bilateral, subpleural GGO, and consolidation, which were similar to the CT features of SARS and the Middle East respiratory syndrome (MERS).[12,16,17] The CT score as an independent risk factor could predict the SARS-COV-2 disease course in this study. We found that a wide range of pneumonia and multiple affected lobes were more common in critical illness than in noncritical illness, which usually corresponded to a higher CT score. CT score was calculated based on the infection lobe volume/entire lobe volume by visual quantitative evaluation, no consideration of attenuation of lesions such as GGO, and consolidations. These patients with higher CT score may demonstrate disease progression, as manifested by increasing extent. Although interval time between the CT on admission and disease's onset is varied, patients with higher CT score on admission predicted its most likely poorer prognosis of SARS-COV-2.

The D-dimer and CRP were independent risk factors associated with critical illness in our study, which was in line with previous reports.[18,19] The level of D-dimer is elevated as a consequence of the activation of coagulation and fibrin deposition. Studies have shown that inflammation leads to the downregulation of physiological anticoagulation mechanisms. In addition, vascular endothelial damage, as a consequence of excessive stimulation of inflammatory factors, stimulates monocytes to express tissue factors, leading to the activation of the systemic coagulation system.[20,21] During the course of the current studied time span, there is no effective treatment or vaccine, just antivirals, antibiotics, or steroids. And anticoagulation was not part of the treatment regimens that patients received. CRP as an indicator of inflammation is one of the most

Table 4

Multivariable logistic regression model in patients with SARS-COV-2.

Variable	OR	95% CI	*P*
CRP	1.051	1.024–1.078	.000
D-dimer	1.911	1.050–3.478	.034
CT score	1.269	1.053–1.529	.012

CI = confidence interval, CRP = C-reactive protein, OR = odds ratio.

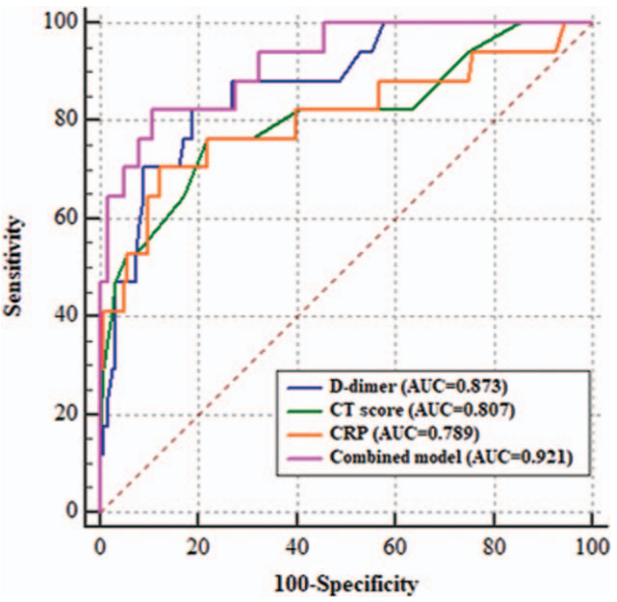

Figure 3. These were ROC curves of the CRP, D-dimer, CT score, and combined model for prediction of severe degree in patients with SARS-COV-2.

Table 5

Effectiveness of the CRP, D-dimer, CT score, and combined model in prediction of critical outcomes in patients with COVID-19.

Variable	AUC	Cutoff	95% CI	Sensitivity (%)	Specificity (%)	*P*	*P
CRP	0.789	>24.2	0.730–0.867 75.00	88.16	<.0001	.046	
D-dimer	0.873	>0.66	0.806–0.923 82.35	81.75	<.0001	.231	
CT score	0.807	>7	0.731–0.868 80.00	80.62	<.0001	.062	
Combined model	0.921		0.863–0.960 82.35	89.43	<.0001		

AUC = Area under the curve, CI = confidence interval, CRP = C-reactive protein. **P* vs Combined model.

important and sensitive markers in acute phase reaction in humans. CRP was a significant biomarker for poor prognosis in MERS.[22] Elevated levels of inflammation indicators may be related to cytokine storms induced by virus invasion.[23]

The combination of radiological and clinical data has been less investigated. Li et al[22] also investigated the predictive value of both clinical and CT features; however, they performed the univariate analysis. Another study has reported that older age and more consolidation lesions in upper lungs on admission were related to adverse outcomes.[24] But they did not analyze the value of other clinical characteristics beyond age, such as CRP and D-dimer. These clinical biomarkers were also important risk factors of critical SARS-COV-2, reported by other studies and the present study. Yuan et al[25] found that the median CT score of the mortality group was higher than that of the survival group, without analysis of clinical factors. As shown above, the risk factors were diversified in the present study. The consistency test results of CT visual quantitative analysis showed good repeatability with ICC 0.982. CT score was an easy method to quantify pulmonary inflammation on CT images based on extension of lesions. As a risk factor of radiographic findings associated with critical illness, CT score may play an important role in monitoring disease progression and evaluating therapeutic efficacy. Independent risk factors associated with poor outcomes remain unclear and need to be further verified with large amounts of data. Our results demonstrated there could be a relationship between the radiological, laboratory factor and critical pneumonia. If these risk factors were detected, before a composite endpoint occurrence of death, ARDS, or ICU admission, the management of patients will be optimized.

This study comprehensively analyzed potential clinical and radiological factors in terms of critical outcomes, investigated the predicting performance of a combined model. The combined model achieved better performance with the highest AUC compared with three risk factors (CRP, D-dimer, and CT score) alone. The predictive performance of the combined model showed significant improvement over CRP. Although there was no statistical difference between the combined model and CT score only, the *P* value was .062 indicating its potential trends. The combined mode showed a favorable predictive ability for SARS-COV-2 disease severity.

Our study had several limitations. First, this study had a small sample size, and the number of noncritical illness and critical illness was significantly different at the single center. Second, some laboratory data might be incomplete in the electronic database. Third, the treatment for SARS-COV-2 was not considered as a factor for disease prognosis in this study. However, treatments were limited to supportive therapy instead of specific treatment at that time. Fourth, in addition to the lesion extension in each lobe, the attenuation of the lesions such as GGO and consolidations, pleural effusion, and the nature of the lesion including cavities were not weighted into CT score, which may have associations with poor prognosis. In the future, we will include more comprehensive information from multiple centers to verify our results, and generate an improved version of the CT score to better predict disease prognosis.

5. Conclusion

CRP, D-dimer, and CT score on admission were independent risk factors of critical illness in adults with SARS-COV-2. The combined clinical and radiological model achieved better predictive performance than clinical or radiological factors alone.

Author contributions

Conceptualization: Ting Yue, Wenli Zhou, Jie He, Hongjie Hu.
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Formal analysis: Ting Yue.
Funding acquisition: Hongjie Hu.
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