Correlation between Chest CT Findings and Clinical Features of 211 COVID-19 Suspected Patients in Wuhan, China

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List of Abbreviations

ARDS: acute respiratory distress syndrome;

AUC: area under curve;

CDC: Center for Disease Control and Prevention;

COVID-19: Coronavirus Disease 2019;

CT: computed tomography;

CIs: confidence intervals;

GGO: ground glass opacities;

ICTV: International Committee on Taxonomy of Viruses;

MPR: multiplanar reconstruction;

ORF1ab: open reading frame 1ab;

PACS: picture archiving and communication systems;

RBC: red blood cell;

ROC: receiver operating characteristic;

RT-PCR: real-time reverse transcription polymerase chain reaction;

SARS-CoV-2: severe acute respiratory syndrome coronavirus 2;

SD: standard deviation; Se: sensitivity;

Sp: specificity.

ABSTRACT

Background: Chest CT has been widely used to assess the pulmonary involvement in COVID-19. We aimed to investigate the correlation between chest CT and clinical features in COVID-19 suspected patients with or without fever.

Methods: We retrospectively enrolled 211 COVID-19 suspected patients who underwent both chest CT and RT-PCR in Wuhan, China. The performance of CT in patients having relevant onset symptoms with fever (n=141) and without fever (n=70) were assessed respectively.

Results: The sensitivity of CT for COVID-19 was 97.3% with AUC of 0.71 (95% CI 0.66-0.76). There were 141 suspected patients with fever and 70 without fever. In fever group, four variables were screened to establish the basic model: age, monocyte, red blood cell, and hypertension. The AUC of basic model was 0.72 (95% CI 0.63-0.81) while CT-aided model was 0.77 (95% CI 0.68-0.85), with significantly difference ($P < 0.05$). In non-fever group, only dry cough was screened out to establish the basic model, AUC was 0.76 (95% CI 0.64-0.88), which made no significantly difference than CT-aided model (P=0.08).

Conclusions: Chest CT has a high sensitivity on COVID-19, and it can improve the diagnostic accuracy for COVID-19 suspected patients with fever in initial screen, while its value for non-fever patients remains questionable.

Key words: COVID-19; Tomography, X-Ray Computed; Reverse Transcriptase Polymerase Chain Reaction; ROC Curve

Introduction

Since December 2019, a cluster of patients with acute respiratory disease with unknown etiology occurred in Wuhan, Hubei Province, China, and the initial cases had a history of exposure to the Huanan seafood market[1-3]. The Chinese Center for Disease Control and Prevention (CDC) isolated a novel coronavirus from the throat swab sample of patients, which was formally named as severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2, previously known as 2019-nCoV[4]) by International Committee on Taxonomy of Viruses (ICTV). The RBD domain of SARS-CoV-2 Spike protein supports strong interaction with human ACE2 molecules[5], indicating the strong infectious capability of the virus to human respiratory epithelial cells[6, 7]. The pneumonia caused by SARS-CoV-2 is named as Coronavirus Disease 2019 (COVID-19), with which most patients demonstrate mild symptoms with good prognosis, while some severe patients rapidly develop to acute respiratory distress syndrome (ARDS), acute respiratory failure, and other serious complications that eventually lead to critical outcomes[1, 3, 8]. The China Health Committee has identified COVID-19 a Class B respiratory infectious disease according to the Law of the People's Republic of China on the Prevention and Control of Infectious Diseases and taken measures to prevent and control the disease at Class A level.

According to World Health Organization interim guidance[4], the respiratory tract specimen has been empirically used to diagnose COVID-19 through real-time reverse transcription polymerase chain reaction (RT-PCR) assay as gold standard[9]. However, the efficiency of RT-PCR has been reduced due to varying factors in practical applications, including but not limited to the course of infection, the viral loads in body fluids, the sampling site and method, quality or stability of the RNA isolation kit, the requirement of specific laboratory environments, which is also time-consuming for promptly obtaining the diagnostic results. [10].

For the patients with COVID-19, chest computed tomography (CT) has been widely practiced as a non-invasive tool for lung conditions assessment[11]. Unlike RT-PCR which requires specific laboratory environments, CT scan is more accessible to Chinese hospitals[12] and can provide timely diagnosis and monitoring of lung lesions. Based on typical CT imaging features of COVID-19, a clinical diagnosis criteria was temporarily adopted in the Chinese guidance Diagnosis and Treatment Protocol for COVID-19 (Trial Fifth Edition)[13]. Compared with RT-PCR, Ai et.al[14] reported that the sensitivity of chest CT for COVID-19 was 97% (580/601), and the false positive rate was 75% (308/413, of which 48% were considered as highly suspicious patients). These pilot results suggested the needs of further investigation on CT's potential role as the initial screening method for the COVID-19 suspected patients.

This study analyzed the value of chest CT in COVID-19 suspected patients with or without fever, the most common onset symptom[1, 15, 16], and evaluated the diagnostic accuracy of chest CT in a cohort of 211 patients.

Material and methods

Patients

This is a retrospective study approved by the Institutional Review Board of Union Hospital, Tongji Medical College, Huazhong University of Science and Technology, and the informed consent was waived. Consecutive COVID-19 suspected patients who underwent both chest multi-slice spiral CT and RT-PCR test in our hospital (in Wuhan, Hubei Province, China) between 29-JAN-2020 and 04-FEB-2020 were retrospectively enrolled. Inclusion criteria: (1) patients with respiratory symptoms but no significant improvement in conventional anti-infective treatment; (2) clinically suspected with COVID-19 due to contact history with COVID-19 patients (positive real-time RT-PCR assay) within 14 days before the symptom onset or due to clustering onset; (3) patients pending invasive operation in need of routine inspection to exclude COVID-19. Exclusion criteria: (1) the first RT-PCR tested more than three days before or after the CT scan; (2) incomplete baseline characteristics and laboratory findings. For those patients with negative first-time RT-PCR but suspicious clinical symptoms supporting COVID-19, a second RT-PCR test was conducted within three days after the first one, the result of which taken as the diagnosis gold standard. For patients with only a single RT-

PCR test, the test result was taken as the diagnosis gold standard. In addition to the CT imaging and RT-PCR results, laboratory characteristics as well as signs and symptoms were also retrospectively collected for this study.

Real-Time RT-PCR Assay for Detection of SARS-CoV-2

The nasopharyngeal or oropharyngeal swab samples were collected for RT-PCR test. Total RNA was extracted using the respiratory sample RNA isolation kit (BGI, Wuhan, China). There were two target genes simultaneously amplified and tested during the RT-PCR assay, including open reading frame 1ab (*ORF1ab*) and nucleocapsidprotein (N). Target 1 (*ORF1ab*): forward primer CCCTGTGGGTTTTACACTTAA; reverse primer ACGATTGTGCATCAGCTGA; and the probe 5'-FAM-CCGTCTGCGGTATGTGGAAAGGTTATGG-BHQ1-3'. Target 2 (N): forward primer GGGGAACTTCTCCTGCTAGAAT; reverse primer CAGACATTTTGCTCTCAAGCTG; and the probe 5′-FAM- TTGCTGCTGCTTGACAGATT-TAMRA-3'. SARS-CoV-2 infection was confirmed only when both two genes returned positive results, according to the recommendation by the Chinese National Institute for Viral Disease Control and Prevention[17].

CT Image Acquisition and Analyze

All the suspected patients underwent thin-slice multi-slice spiral CT scan in supine position. The CT examinations were performed with SOMATOM Definition AS+ scanner (Siemens Healthineers, Forchheim, Germany). The scan covered from the level of the upper thoracic inlet to the inferior level of the costophrenic angle. The CT protocol was as follows: tube voltage, 120 kV, the tube current was regulated by an automatic exposure control system (CARE Dose 4D), detector collimation width, 64×0.6 mm and 64×0.6 mm. The images were reconstructed with a thickness of 1mm and an interval of 1mm, the total scanning time ranged from 5 to 6 seconds, then transmitted to the workstation and picture archiving and communication systems (PACS) for multiplanar reconstruction (MPR) postprocessing. The images were reviewed independently by two radiologists (S.L.S and F.H.W with 8 and 4 years of experience in thoracic radiology, respectively) blinded to the RT-PCR results, and the CT-diagnosis of viral pneumonia was made according to the main imaging manifestations proposed in recent reports on COVID-19[18-20]: bilateral multiple ill-defined ground glass opacities (GGO) or mixed consolidation with diffuse distributed peripherally, bilateral pulmonary consolidation can be presented in severe patients. The non-viral pneumonia on chest CT includes all other pulmonary abnormalities and normal lungs, which excluding viral pneumonia. The final diagnosis was reached by consensus if there was a disagreement.

Statistical analysis

Statistical analyses were performed using SAS software (version 9.4; SAS, Cary NC). Continuous variables were displayed as mean ± standard deviation (SD) and categorical variables were reported as counts. Patients were divided into fever and non-fever groups, because fever is the most common and objective onset symptom of COVID-19[1, 2, 15]. Stepwise logistic regression via a significant level of 0.15 was used to select variables to establish the basic models for COVID-19 diagnosis, the variable of CT result (viral pneumonia / non-viral pneumonia) was forced included as a predictor in all regression models for fever and non-fever groups during stepwise selection to build CT-aided models. The receiver operating characteristics (ROC) curves were used to analyze these models, and the area under curve (AUC) was calculated in order to compare the differences between the basic model and CT-aided model. The DeLong test was used to compare the AUCs for all selected models. The sensitivity (S*e*), specificity (S*p*) of these models for the detection of COVID-19 were calculated. The confidence intervals (CIs) of the analysis above were obtained using Clopper-Pearson method. All statistical tests were two-sided probability tests. $P < 0.05$ was considered to be statistically significant.

Results

Patients

There were 331 patients initially included, of which 211 met our inclusion and exclusion criteria. The final cohort included 119 male and 92 female with a median age of 51 year-old (IQR, 39-63; range, 17-86 years). There were 141 patients with fever as the onset symptom, 93 (66.0%) of them had positive RT-PCR result, while 70 patients without fever, and 18 (25.7%) of them with positive RT-PCR. Clinical characteristics and laboratory results of all the suspected patients are summarized in **Table 1** and **Table 2**. **Figure 1** shows the flow chart of our study. Among 64 patients whose first RT-PCR assay was negative but with CT suggested viral pneumonia, 41 underwent RT-PCR assay retested within 3 days, of which 9 (22.0%) turned positive. Among the remaining 23 patients, 7 patients with other comorbidities were given antiviral treatment in our hospital before RT-PCR retesting within 3 days, 16 patients were transferred to other designated hospital for treatment, and the results were unavailable. Ultimately, there were 111 patients with positive RT-PCR results, including 62 (55.86%) males and 49 (44.14%) females, with a median age of 55 years old (IQR, 44-67; range, 17-86 years). 100 patients were RT-PCR negative, including 57 (57.0%) men and 43 (43.0%) females with a median age of 47.5 years old (IQR, 35-61.5; range, 22-84 years). There was significant difference in the age ($P < .01$) but no significant difference in sex (P=0.89) between the two groups. No significant differences were noted in the comorbidities between RT-PCR positive and RT-PCR negative groups (P=0.35), the 2 most common comorbidities being cardiovascular disease (22 [10.43%]) and hypertension (12 [5.69%]). The two most common symptoms at onset were fever (141 [66.82%]) and dry cough (85 [40.28%]), which showed significant differences between RT-PCR positive and negative groups (all $P < .01$). Patients with positive RT-PCR had significantly higher mean levels of C-reactive protein (21.89 mg/L vs 9.32mg/L, $P < .01$) and lower lymphocyte count (1.05×10^9/L vs 1.21×10^9, $P < .01$), platelet count (180×10^9 vs 196×10^9, P=0.03), white blood cell count (4.76×10^9 vs 5.35×10^9, P=0.03), and eosinophil (0.01×10^9 vs 0.02×10^9, $P < .01$) than patients with negative RT-PCR. Other laboratory findings showed no significant difference between patients with positive and negative RT-PCR results.

Chest CT Results and Features in Suspected COVID-19 Patients

Among all suspected patients, 163 were diagnosed with viral pneumonia by chest CT, 108 (66.3%) of whom were RT-PCR positive, 55 (33.7%) of whom were RT-PCR negative. For those diagnosed with viral pneumonia by CT, the common radiographic manifestations included bilateral multiple ground glass opacities (GGO) with ill-defined margins, GGO with consolidation accompanied with interlobular/septal thickening, or mixed pattern with diffuse distribution **(Figure 2 A-C)**. 48 patients were found with negative CT findings of viral pneumonia, but 3 (6.3%) of them had positive first RT-PCR assay, all of whom were family members of confirmed COVID-19 patients **(**representative images demonstrated in **Figure 2 D).**

Diagnostic Value of Chest CT in COVID-19

Of the 111 RT-PCR positive patients, 108 were diagnosed with viral pneumonia on CT and 3 were excluded by CT. Of the 100 RT-PCR negative patients, 55 were diagnosed with viral pneumonia by CT, and 45 were excluded by CT. The sensitivity of CT for detection of COVID-19 was 97.3% (108/111 patients), and the specificity was 45.0% (45/100 patients). The AUC was 0.71 (95% CI 0.66-0.76). We selected five variables out based on stepwise logistic regression to establish the basic model: age, monocyte, red blood cell (RBC), hypertension, and dry cough. The AUC of each variable was 0.58 (95% CI 0.51-0.64), 0.52 (95% CI 0.45-0.58), 0.54 (95% CI 0.47-0.60), 0.50 (95% CI 0.46-0.55), 0.68 (95% CI 0.62-0.74), respectively. The AUC of basic model was 0.74 (95% CI 0.67-0.80). The AUC of CT-aided (CT+basic) model was 0.81 (95% CI 0.75-0.87), which was significantly higher than the basic model and only CT scan model (both $P < 0.01$). There were 141 in the fever group and 70 patients in the non-fever group. The diagnostic performance of chest CT in fever and non-fever COVID-19 suspected patients is reported in **Table 3**.

In fever group, we selected four variables out based on stepwise logistic regression to establish the basic model: age, monocyte, RBC, and hypertension, the AUC of each variable was 0.55 (95% CI 0.47-0.64), 0.58 (95% CI 0.50-0.67), 0.59 (95% CI 0.50-0.67), and 0.56 (95% CI 0.50-0.63), respectively. The AUC of basic model was 0.72 (95% CI 0.63-0.81). The AUC of CT scan alone was 0.58 (95% CI 0.53-0.64). The AUC of CT-aided (CT+basic) model was 0.77 (95% CI 0.68-0.85), which was significantly higher than the basic model and CT diagnosis alone (both $P < 0.05$). In non-fever group, we only selected dry cough out as a variable to establish the basic model, other variables were dropped by the variable selection analysis. The AUC for the basic model was 0.76 (95% CI 0.64-0.88). The AUC of CT scan alone for non-fever patients was 0.77 (95% CI 0.66-0.88). The AUC of CT-aided (CT+basic) model was 0.84 (95% CI 0.72-0.95), which was significantly higher than CT alone ($P < 0.05$) but made no significantly difference when compared to the basic model (P=0.08). The ROC curves were used to analyze these models in COVID-19 suspected patients with or without fever (**Figure 3**).

Discussion

With rapid increase in the number of patients in epidemic areas, chest CT plays an important role for lung conditions assessment as it can provide immediate visualization of pulmonary abnormalities and monitor the development of the lesions in different stages[18, 19, 21]. A few typical patterns have been identified as the CT imaging features of COVID-19[19], which are similar to the findings in other viral pneumonias. The lack of specificity in CT manifestations requires diagnosis to be made on a multi-factor basis including the image demonstrations, the clinical symptoms, and the epidemiological history. In our study, the sensitivity of CT for detection of COVID-19 was 97.3% (108/111 patients), in consistency with the 97% (580/601 patients) reported by Ai et. al[14]. On the other hand, the specificity of diagnosis made with CT alone in our cohort was merely 45% (45/100 patients), with the RT-PCR result taken as the gold standard, suggesting the importance of patient selection for CT screening to reduce population radiation exposure and to have the scanner resources focused on patients that can benefit from CT scans.

In our cohort, the most common onset symptom was fever, which was significantly more common in RT-PCR positive patients than in RT-PCR negative patients ($P < 0.01$). In fever group, although the sensitivity of CT scan was up to 100% (97/97), the specificity was merely 16.67% (8/48) with an AUC of 0.58. One of the likely reasons might be the presence of patients with high clinical suspicion but negative RT-PCR results. Huang et.al.[22] reported a highly suspected case with typical COVID-19 CT findings, whose RT-PCR were negative in the first two tests and turned positive 6 days later. In our study, there were 32 patients tested negative for two consecutive RT-PCR assays within 3 days, for most of whom chest CT showed typical COVID-19 CT manifestation, including diffuse distributive peripheral GGO, or GGO with interlobular or septal thickening, suggesting highly likely viral pneumonia. However, 9 (22%) of the 41 patients retested RT-PCR within 3 days, which turned positive from the initial negative results, yielding a higher false-positive rate of first time RT-PCR than that reported by Xie et al[23]. The false-negative in RT-PCR test could be likely attributed to: 1) the RNA isolation kit is still under rapid development and irrelatively unmatured for the COVID-19 outbreak; 2) samples from the upper respiratory throat swab could be biased by the sampling site[24] and the individual operation skills; 3) the virus load is below the detection sensitivity at the sampling time. The specificity calculated in our study may have underestimated the accuracy of CT diagnosis, and well-controlled follow-up studies with RT-PCR tests at multiple times are needed to find the true specificity for CT diagnosis in suspected patients without fever.

For suspected patients with fever, the AUC of basic model (considering age, monocyte, RBC, and hypertension) was 0.72. When the CT results were included, the AUC was significantly higher than basic model ($P < 0.05$), albeit the relatively small increment (0.77 v.s. 0.72). This observation suggested the importance of patient epidemiological history and laboratory findings at the diagnosis of COVID-19 suspected patients with fever and the added value of CT to enhance the diagnosis confidence. On the other hand, the AUC was 0.76 for the basic model (dry cough, as screened by the logistic regression study), which increased to 0.84 when CT results were taken into account, but there was no significant difference between these two models (P=0.08), suggesting the questionable role of CT for patients without fever. Dry cough was the second most common symptom in COVID-19 suspected patients, which was also significantly more common in RT-PCR positive patients than in RT-PCR negative patients ($P<.01$). In our study, there were 3 patients with negative CT but positive RT-PCR, who showed mild clinical symptoms (dry cough and fatigue) without fever for only 2 days by the time of CT scan, implying that CT may not reflect the occurrence of COVID-19 at earliest stage[25]. Pan et.al[18] also reported 4 of 24 COVID-19 confirmed patients in early stage (0-4 days onset of initial symptom) that showed negative manifestation in chest CT scan.

Our study had several limitations: (1) the sample size was small for each group (fever and non-fever); (2) lack of CT monitoring of the patients at different disease stages; (3) lack of RT-PCR follow-ups after the initial two to better determine the false-negative of RT-PCR test. (4) this study regarded RT-PCR assay as gold standard for detection of SARS-CoV-2 that lead to COVID-19 diagnosis, however, there was mild possible that some patients who were indeed infected by SARS-CoV-2 could not be tested out by RT-PCR due to the false negative. So the diagnostic performance of chest CT compared with RT-PCR may be not accurate. Further studies on the false-negative of RT-PCR may reveal the possibility of overestimated sensitivity for chest CT and the underestimated specificity.

In conclusion, chest CT has a high sensitivity when compared to the gold standard RT-PCR assay. Through comprehensive evaluation of epidemiological history and clinical characteristics in COVID-19 suspected patients, adding CT scan can improve the diagnostic accuracy for patients with fever in initial screening, while the value of CT may not hold for suspected patients without fever. The use of CT in initial screening of suspected patients needs to consider both its capability in detailing lesion characteristics and its benefits to a highly selected cluster of patients.

Footnotes:

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Tables

Table 1. Baseline Characteristics of Patients Suspected Infected with SARS-CoV-2

	No. (%)			
	Total (N=211)	**RT-PCR positive (N=111)**	**RT-PCR negative (N=100)**	***P* Value**
Age, median (IQR), y	51 (39-63)	55 (44-67)	47.5 (35-61.5)	$<.01$
$\leq$50	101 (47.87)	45 (40.54)	56 (56.0)	0.03
$>$50	110 (52.13)	66 (59.46)	44 (44.0)	
Sex				
Male	119 (56.40)	62 (55.86)	57 (57.0)	0.89
Female	92 (43.60)	49 (44.14)	43 (43.0)	
Comorbidities	58 (27.49)	34 (30.63)	24 (24.0)	0.35
Hypertension	12 (5.69)	5 (4.50)	7 (7.0)	0.56
Cardiovascular disease	22 (10.43)	12 (10.81)	10 (10.0)	1
Diabetes	12 (5.69)	8 (7.21)	4 (4.0)	0.38
Malignancy	7 (3.32)	5 (4.50)	2 (2.0)	0.45
COPD	10 (4.74)	6 (5.41)	4 (4.0)	0.75
Chronic kidney disease	5 (2.37)	2 (1.80)	3 (3.0)	0.67
Chronic liver disease	10 (4.74)	5 (4.50)	5 (5.0)	1

Initial symptom				
Fever	141 (66.82)	93 (83.78)	48 (48.0)	<.01
Onset of fever to hospital admission, median (IQR),d	7 (4-10)	7 (4-10)	7 (3-10)	0.55
Maximum temperature, ℃	38.2 (37.8-38.7) (n=141)	38.2 (37.8-38.7) (n=93)	38.2 (37.65-38.6) (n=48)	0.50
Fatigue	56 (26.54)	37 (33.33)	19 (19.0)	0.02
Dry cough	85 (40.28)	64 (57.66)	21 (21.0)	<.01
Runny nose	4 (1.9)	1 (0.90)	3 (3.0)	0.35
Myalgia	30 (14.22)	21 (18.92)	9 (9.0)	0.05
Dyspnea	39 (18.48)	23 (20.72)	16 (16.0)	0.48
Diarrhea	22 (10.43)	17 (15.32)	5 (5.0)	0.02
Headache	15 (7.11)	11 (9.91)	4 (4.0)	0.11
Vomiting	5 (2.37)	4 (3.60)	1 (1.0)	0.37

Abbreviations: SARS-CoV-2, severe acute respiratory syndrome coronavirus 2; RT-PCR, real-time reverse transcription polymerase chain reaction; IQR, interquartile range; COPD, chronic obstructive pulmonary disease.

[a]Data are presented as median (IQR) or No. (%). *P* value for age, days of fever onset to hospital admission, maximum temperature were calculated using a t test. *P* values for categorical variables were calcuated from χ^2 analyses.

Table 2. Laboratory Findings of Patients Suspected Infected with SARS-CoV-2 on Admission to Hospital

	Normal Range	Median (IQR) Total (N=211)	RT-PCR positive (N=111)	RT-PCR negative (N=100)	*P* Value
SpO_2, %	96%-100%	99 (97-100)	99 (96-100)	98 (97-99)	0.14
C-reactive protein, mg/L	<8.00	15.19 (4.63-50.24)	21.89 (9.94-57.72)	9.32 (0.67-25.605)	<.01
Lymphocyte count, $\times10^9$/L	1.1-3.2	1.115 (0.82-1.49)	1.05 (0.8-1.34)	1.21 (0.89-1.64)	<.01
Platelet count, $\times10^9$/L	125-350	185 (147-235)	180 (144-216)	196 (155.5-256)	0.03
White blood cell count, $\times10^9$/L	3.5-9.5	5.05 (4.04-6.24)	4.76 (3.73-6.11)	5.35 (4.285-6.345)	0.03
RBC, $\times10^{12}$/L	4.3-5.8	4.635 (4.23-5.06)	4.65 (4.28-5.08)	4.62 (4.21-5.035)	0.31
Hemoglobin, g/L	130-175	138 (124-149)	138 (124-153)	138 (124.5-146)	0.63
Eosinophil, $\times10^9$/L	0.02-0.52	0.01 (0-0.04)	0.01 (0-0.02)	0.02 (0-0.07)	<.01
Basophil, $\times10^9$/L	<0.06	0.01 (0-0.01)	0 (0-0.01)	0.01 (0-0.01)	0.21
Monocyte, $\times10^9$/L	0.1-0.6	0.36 (0.28-0.47)	0.36 (0.27-0.44)	0.36 (0.29-0.505)	0.26
Neutrophil, $\times10^9$/L	1.8-6.3	3.51 (2.52-4.3)	3.32 (2.39-4.26)	3.62 (2.645-4.345)	0.20

Abbreviations: SARS-CoV-2, severe acute respiratory syndrome coronavirus 2; IQR, interquartile range; RT-PCR, real-time reverse transcription polymerase chain reaction; SpO_2, Saturation of Peripheral Oxygen; RBC, red blood cell.

[a]Data are presented as median (IQR). *P* value was calculated using a *t* test.

Table 3. Diagnostic Performance of Basic Model Compared with CT-aided model in COVID-19 Suspected Patients

Model	**Sensitivity (%)**	**Specificity (%)**	**AUC (95% CI)**	***P* value**
Overall				
Basic model			0.74 (0.67, 0.80)	<.01
Age	59.46	56.00	0.58 (0.51, 0.64)	<.01
Monocyte	45.95	51.00	0.52 (0.45, 0.58)	<.01
RBC	54.05	53.00	0.54 (0.47, 0.60)	<.01
Hypertension	10.81	90.00	0.50 (0.46, 0.55)	<.01
Dry cough	57.66	79.00	0.68 (0.62, 0.74)	<.01
CT model	97.30	45.00	0.71 (0.66, 0.76)	<.01
CT-aided model			0.81 (0.75, 0.87)	
Fever				
Basic model			0.72 (0.63, 0.81)	0.04
Age	64.52	45.83	0.55 (0.47, 0.64)	<.01
Monocyte	46.24	37.50	0.58 (0.50, 0.67)	<.01
RBC	54.84	62.50	0.59 (0.50, 0.67)	<.01
Hypertension	8.60	79.17	0.56 (0.50, 0.63)	<.01
CT model	100.00	16.67	0.58 (0.53, 0.64)	<.01
CT-aided model			0.77 (0.68, 0.85)	
Non-fever				

Basic model				0.08
Dry cough	55.56	96.15	0.76 (0.64, 0.88)	0.08
CT model	83.33	71.15	0.77 (0.66, 0.88)	0.02
CT-aided model			0.84 (0.72, 0.95)	

Abbreviations: COVID-19, Coronavirus Disease 2019; RBC, red blood cell; AUC, area under curve; CI, confidence interval.

[a]The stepwise logistic regression via a significant level of 0.15 was used to select variables to establish the basic models for COVID-19 diagnosis, the variable of CT result (viral pneumonia / non-viral pneumonia) was forced included as a predictor in all regression models for fever and non-fever groups during stepwise selection to build CT-aided models.

[b]The DeLong test was used to compare the AUCs for all selected models.

Figure legends

Figure 1: Flowchart for patient inclusion. COVID-19, Coronavirus Disease 2019; CT, computed tomography; RT-PCR, real-time reverse transcription polymerase chain reaction.

Figure 2: Chest CT images of COVID-19 confirmed patients

(A) - (C) 56-year-old male presenting with fever. Axial CT image (A, B) demonstrates bilateral, diffuse distribution ground-glass opacities in a lobular configuration with interlobular septal thickening; coronal reformatted CT image (C) shows bilateral, lower lung predominance GGO with consolidations.

(D) 49-year-old female, a family member of the RT-PCR positive patient, presenting with dry cough for 2 days, and her RT-PCR proved positive. The chest CT shows no obvious abnormality in bilateral lungs.

Figure 3: The receiver operating characteristics (ROC) curve on COVID-19 suspected patients

(A) The ROC curve on all the 211 COVID-19 suspected patients;

(B) The ROC curve on COVID-19 suspected patients with fever;

(C) The ROC curve on COVID-19 suspected patients without fever

Figure 1

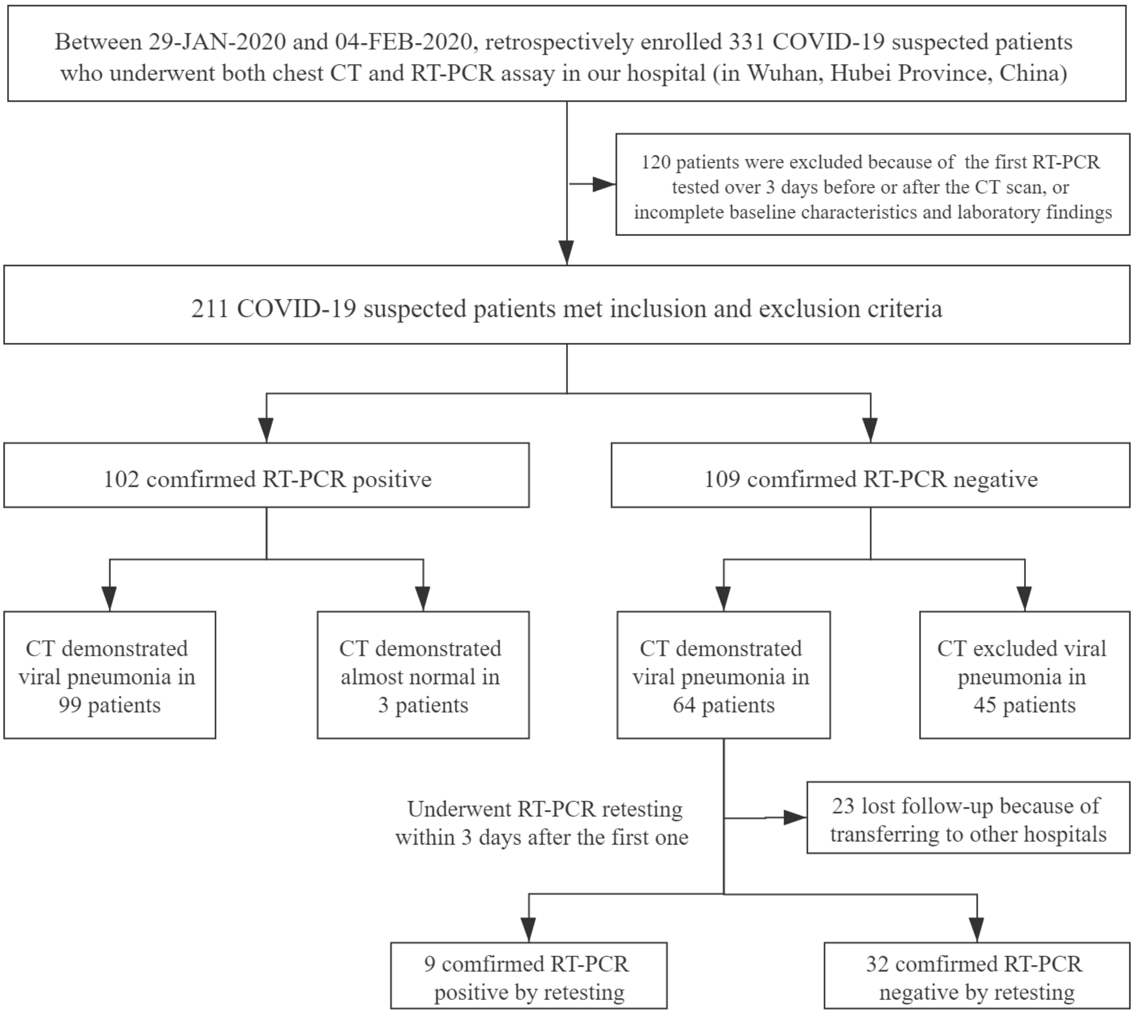

Between 29-JAN-2020 and 04-FEB-2020, retrospectively enrolled 331 COVID-19 suspected patients who underwent both chest CT and RT-PCR assay in our hospital (in Wuhan, Hubei Province, China)
120 patients were excluded because of the first RT-PCR tested over 3 days before or after the CT scan, or incomplete baseline characteristics and laboratory findings
211 COVID-19 suspected patients met inclusion and exclusion criteria
102 comfirmed RT-PCR positive
109 comfirmed RT-PCR negative
CT demonstrated viral pneumonia in 99 patients
CT demonstrated almost normal in 3 patients
CT demonstrated viral pneumonia in 64 patients
CT excluded viral pneumonia in 45 patients
Underwent RT-PCR retesting within 3 days after the first one
23 lost follow-up because of transferring to other hospitals
9 comfirmed RT-PCR positive by retesting
32 comfirmed RT-PCR negative by retesting

Figure 2

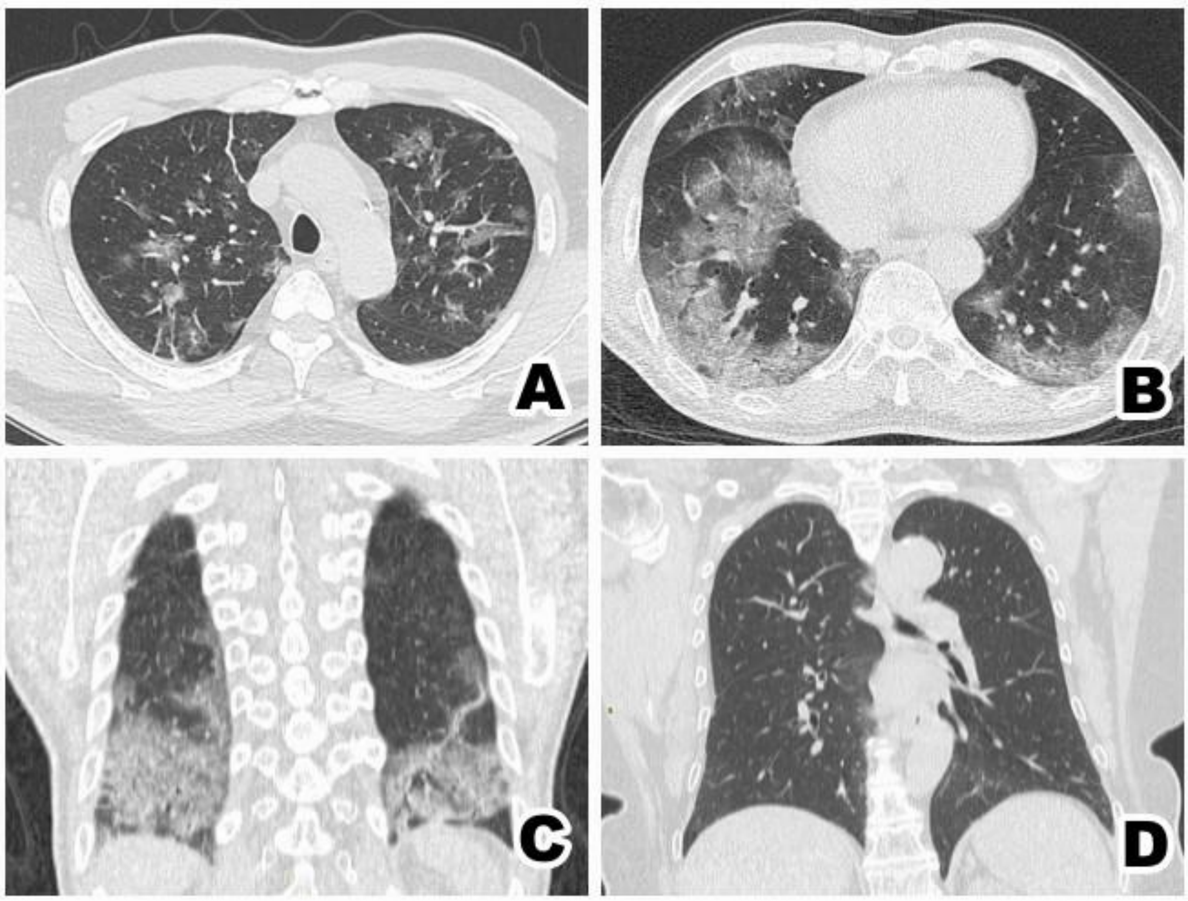
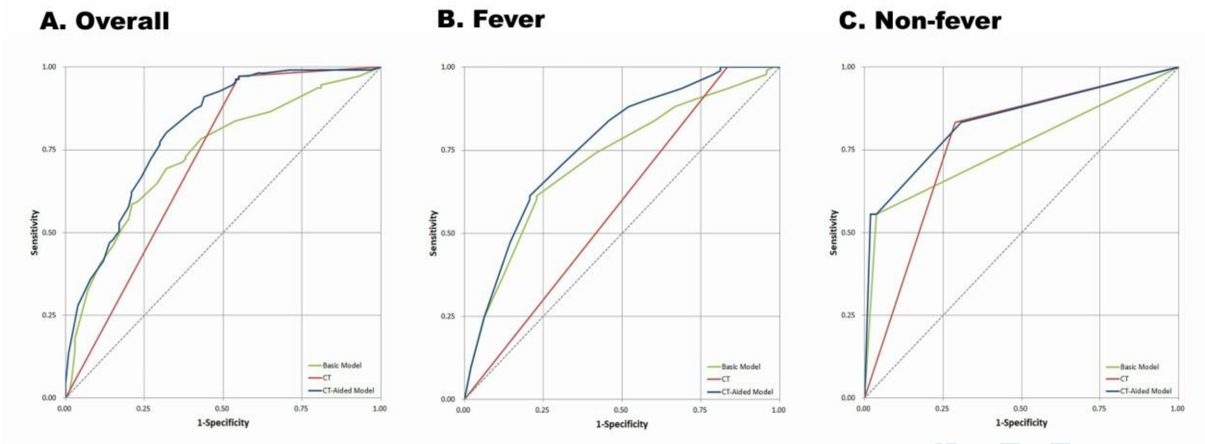


Figure 3


A. Overall
B. Fever
C. Non-fever
Sensitivity
1-Specificity
Basic Model
CT
CT-Aided Model