Investigative Radiology

Chest CT Findings in Patients with Corona Virus Disease 2019 and its Relationship with Clinical Features

--Manuscript Draft--

Manuscript Number:	IR-D-20-00109R1
Full Title:	Chest CT Findings in Patients with Corona Virus Disease 2019 and its Relationship with Clinical Features
Article Type:	Original Article
Keywords:	SARS-CoV-2, COVID-19, Infection, Pneumonia, Chest CT
Corresponding Author:	Chuanming Li, M.D the Second Affiliated Hospital of Chongqing Medical University Chongqing, China CHINA
First Author:	Jiong Wu, MS
First Author Secondary Information:	
Order of Authors:	Jiong Wu, MS
	Xiaojia Wu, MS
	Chuanming Li, MD
	Wenbing Zeng, MS
	Dajing Guo, MD
	Fang Zheng, MS
	Linli Chen, MS
	Huizhe Huang, MD
Manuscript Region of Origin:	CHINA
Abstract:	Objectives: To investigate the chest computed tomography (CT) findings in patients with confirmed corona virus disease 2019 (COVID-19) and to evaluate its relationship with clinical features. Materials and Methods: Study sample consisted of 80 patients diagnosed as COVID-19 from January to February 2020. The chest CT images and clinical data were reviewed and the relationship between them was analyzed. Results: Totally 80 patients diagnosed with COVID-19 were included. With regards to the clinical manifestations, 58/80 (73%) of patients had cough, 61/80 (76%) of patients had high temperature levels. The most frequent CT abnormalities observed were ground glass opacity (GGO) (73/80 cases, 91%), consolidation (50/80 cases, 63%) and interlobular septal thickening (47/80, 59%). Most of the lesions were multiple, with an average of 12±6 lung segments involved. The most common involved lung segments were the dorsal segment of the right lower lobe (69/80, 86%), the posterior basal segment of the right lower lobe (68/80, 85%), the lateral basal segment of the right lower lobe (64/80, 80%), the dorsal segment of the left lower lobe (61/80, 76%) and the posterior basal segment of the left lower lobe (65/80, 81%). The average pulmonary inflammation index (PII) value was (34%±20%) for all the patients. Correlation analysis showed that the PII value was significantly correlated with the values of lymphocyte count, monocyte count, C-reactive protein, procalcitonin, days from illness onset and body temperature ($p<0.05$). Conclusion: The common chest CT findings of COVID-19 are multiple GGO, consolidation and interlobular septal thickening in both lungs, which are mostly distributed under the pleura. There are significant correlations between the degree of pulmonary inflammation and the main clinical symptoms and laboratory results. CT plays an important role in the diagnosis and evaluation of this emerging global health emergency.

Dear Dr. Val M. Runge,

Thank you very much for your letter and advice. We also appreciate the constructive criticisms of the reviewers. This letter explains the changes made to the manuscript ‘ Chest CT Findings in Patients with 2019 Novel Coronavirus Infection and its Relationship with Clinical Features’ (No. IR-D-20-00109) in response to comments by the reviewers. A point-by-point summary of all revisions is at the end of this letter.

We hope that the revision is acceptable, and I look forward to hearing from you soon.

With best wishes,

Yours sincerely,

We would like to express our sincere thanks to the reviewers for the constructive and positive comments.

Replies to Reviewer 1

Q.1 In this submission to Investigative Radiology the authors analyzed typical imaging pattern of pulmonary disease associated with SARS-CoV-2 infection / COVID-19. The authors included 80 patients with proven infection recently examined with chest CT. This is a very hot topic and the manuscript provides valuable data for the radiologic / medical community.
However, there are some points needing revision before a decision. In general, I would recommend a cross check of the manuscript by a native speaker .
Answer: A cross check of the manuscript has been made by a native speaker in the revised version.

Q.2 Title: I suggest using the most recent names/definitions provided by the WHO for the 2019 novel coronavirus, namely "SARS-CoV-2" and the associated disease, namely "COVID-19", here and throughout the manuscript.
Answer: The names/definitions for the novel coronavirus have been revised according to the reviewer's suggestions.

Q.3 Key words: As for the title, also include "SARS-CoV-2" and "COVID-19" in the key words..
Answer: The key words have been revised according to the reviewer's suggestions.

Q.4 Introduction
Page 3, second paragraph: "The common signs of people infected…" consider revision such as "Common clinical symptoms of patients infected with SARS-CoV-2 include fever,…"
"Severe patients usually have…" -> "In severe cases patients present with …"
"There has been rare study about…" -> "Up to the present there is only limited data available regarding the typical chest CT imaging findings in COVID-19…".
Answer: The sentences have been revised according to the reviewer's suggestions (Line 55-56, 59-62, 62-63).

Q.5 Page 4:
Inclusion criteria:
Consider language revision providing a more concise description of the inclusion criteria.
Answer: The language and including criteria have been revised according to the reviewer's suggestions (Line 73-79).

Q.6 Explain what you mean with "high spatial frequency algorithm". Provide information regarding the convolution kernel and window setting used for reconstruction of image data.
Answer: "High spatial frequency algorithm" should be "High spatial resolution algorithm". Information regarding the convolution kernel and window setting used for the reconstruction of image data has been added in the revised version (Line, 99-105).

Q.7 Page 5/6
Pulmonary inflammation index: As this score is crucial for the statistical evaluation give a

more detailed explanation of the score assessment. I suggest giving an example, based on the imaging findings / case included.
Answer: An example of pulmonary inflammation index has been added in Figure 1 in the revised version.

Q.8 Results
Page 6: Characteristics and clinical manifestation
"None of them was children or pregnant women." -> "None of them were…"
Maybe the authors should move this to the exclusion criteria, i.e. "No children or pregnant women were included in this study".
Be more precise regarding the immunosuppression. What was the underlying cause?
Be more precise regarding the heart disease present in one patient.
Answer: This sentence have been revised and moved to the exclusion criteria (Line 80-82). The underlying causes of immunosuppression were immunosuppressive drugs taking. The heart disease was coronary heart disease. We have made it clear in the revised version (Line 138-139).

Q.9 Page 7:
Indicate if the blood gas analysis was done from arterial blood samples.
Chest CT findings
"All 80 patients were examined by chest CT in 7 ±4 days from…" -> "All patients were examined by chest CT 7+/- 4 days after the onset of disease"
" The major CT abnormalities... " -> "The most frequent CT abnormalities observed…"
Answer: All the blood gas analysis was done from arterial blood samples (Line 96). We have made it clear in the revised version. The sentences have been revised according to the reviewer's suggestions (Line 159, 13-15).

Q.10 Page 9:
"The incidence of expectoration, chest pain, muscle ache, abdominal pain or
diarrhea, pharyngeal discomfort, headache or dizziness and dyspnea were not popular."
Revise!
"….were less common" or "..occurred less frequently".
"On the whole, the CT changes of the lung were significantly heavier than the clinical manifestations" -> "In our study population, pulmonary manifestation of COVID-19 as
Revise!
Answer: The sentences have been revised according to the reviewer's suggestions (Line 196-198; 203-205).

Q.11 "In our study population, pulmonary manifestation of COVID-19 as depicted by chest CT was worse than the clinical situation of the patient would suggest"
However, this statement is sort of contradictive to your statement later on, where you write that there is a significant correlation between the pulmonary changes and the symptoms as well as the lab results. In addition, the correlation coefficients do indicate a rather poor correlation in part.
Comment on this and revise the manuscript being more concise.
Also consider my comment regarding the references, Discuss the stage of the disease in context of your imaging time point.
I would even argue in a different way. If you have rather mild symptoms and severe pulmonary changes on CT, this might be indicative for COVID-19. Thus, CT might be a useful tool to quickly identify high risk patients.

Answer: Compared with other types of pneumonia, COVID-19 seemed to cause milder symptoms and severer pulmonary changes on CT. For example, most of the patients had mild symptoms and mild temperature rise, but their lung manifestations were serious. For different COVID-19 patients, the changes of lung function showed significant correlations with their symptoms and laboratory test results. We have revised it to be more concise (Line 204-205). Our imaging time points and disease stages have been discussed in the revision (Line, 229-239).

Q.12 Page 10, second paragraph: Typo "….the the….." and "…the pulmonary interstitium have been involved" -> "has been involved"
Page 11, second paragraph: "…we found the common chest CT findings of 2019-ncov infection are multiple GGO…," -> "…we found that common chest CT findings in COVID-19 include multiple GGO,…., with mostly subpleural distribution"
"…involving only a relative small sample subjects" -> "…involving a small number of patients with proven SARS-CoV-2 infection"
Answer: The sentences have been revised according to the Reviewer's suggestions (Line 246-247, 257-259, 262-264).

Q.13 References
Make sure to include some brand new publications (i.e. published in Radiology) in the reference list dealing with this topic, when submitting your revised manuscript.
In particular, there is one paper published regarding the time course of changes on chest CT. Here, you could discuss how your patients / image data fit into the stage of the disease / the clinical symptoms.
Answer: Several new publications have been added in the revised version (Line 217-218, 229-237). The paper published regarding the time course of changes on chest CT and our data of imaging time points and disease stages have been discussed in the revised version (Line, 229-239).

Q.14
Figures
In general, I would suggest including sagittal or coronal reformations of the cases / or at least one our two. This would give an overview of the craniocaudal gradient of the pulmonary changes.
Figure 1
Avoid cropping the lung at the anterior part of the chest! This is a lung disease and thus the parenchyma should be display in a whole.
Figure legends:
Very sparse! Include some clinical information of the corresponding patients! This would make the cases more attractive.
Answer: The Figures and Figure legends have been revised according to the reviewer's suggestions.

Replies to Reviewer 2

Q.1 After the authors have submitted this manuscript, the WHO named this disease as Coronavirus disease 2019 (COVID-19).
Answer: All the names have been corrected in the revised version.

Q.2 The mortality of COVID-19 seems to be higher in the Wuhan area. Therefore, the

authors need to describe this study is from the Wuhan area or outside the Wuhan area.
Answer: This study is from outside of the Wuhan area.We have made it clear in the revised version (Line 69-70).

Q.3 Patients: What were the indications of chest CT? What proportion of patients who were RT-PCR positive underwent chest CT?
Answer: All the patients who were RT-PCR positive underwent chest CT (Line, 79).

Q.4 CT scans and review (page 5): Reference 7 needs to be replaced with a more recent Fleischner Society Glossary (Hansell DM, et al. Radiology 2008).
Answer: Reference 7 has been replaced in the revised version.

Q.5 Chest CT findings (page 7): The authors suggested a new sign, spider web sign, in describing CT findings of COVID-19. However, it is not clear about the clinical significance of this sign. Is this a specific sign for COVID-19 or does this have any prognostic value?
Answer: Spider web sign is a specific sign for COVID-19, which has not been reported in other diseases in the literature. At present, it is not clear whether it has clinical value in evaluating the prognosis of patients (Line 227-229).

Q.6 Chest CT findings (page 7): Procalcitonin can be used in identifying serious bacterial infections. However, in this study, the PII value was significantly correlated with procalcitonin. Does this mean some patients had secondary bacterial infections? How many patients had secondary infections?
Answer: In our study, bacteria were found in blood or sputum cultures of 11 patients, most of whom were severe or critical cases. In fact, previous study have found that procalcitonin could be increased in patients with COVID-19 (Wang D, Hu B, Hu C, et al. JAMA. 2020. doi:10.1001/jama).

Q.7 Chest CT findings (page 7): How was body temperature evaluated in the correlation analysis? As a continuous variable or categorical variable as presented in Table 1?
Answer: The body temperature was evaluated as a continuous variable in the correlation analysis. We have made it clear in the revised version (Line 184).

Chest CT Findings in Patients with Corona Virus Disease 2019 and its Relationship with Clinical Features

Jiong Wu, MS ¶[1] *Xiaojia Wu, MS* ¶[2] *Wenbing Zeng, MS*[1] *Dajing Guo, MD*[2] *Zheng Fang, MS*[2] *Linli Chen, MS*[2] *Huizhe Huang, MD*[3] *Chuanming Li, MD**[2]

1. Department of Radiology, Chongqing Three Gorges Central Hospital, Chongqing, China
2. Department of Radiology, the Second Affiliated Hospital of Chongqing Medical University, Chongqing, China
3. Office of Academic Research, The Second Affiliated Hospital of Chongqing Medical University, Chongqing, China

¶ These authors contributed equally to this work.

* Corresponding author: Chuanming Li, MD, Department of Radiology, The Second Affiliated Hospital of Chongqing Medical University, No. 74 Linjiang Rd, Yuzhong District, Chongqing, 400010, China. Email: lichuanming@hospital.cqmu.edu.cn

Conflicts of interest and sources of funding: This work is funded by the Natural Science Foundation of China (31771619).

Running head: Chest CT findings in patients with COVID-19

Chest CT Findings in Patients with Corona Virus Disease 20192019 Novel Coronavirus Infection and its Relationship with Clinical Features

Abstract

Objectives: To investigate the chest computed tomography (CT) findings in patients with confirmed corona virus disease 2019 (COVID-19)novel coronavirus (SARS-CoV-2)2019 novel coronavirus (2019-ncov) infection and to evaluate its relationship with clinical features.

Materials and Methods: Study sample consisted of 80 patients who had been diagnosed as COVID-19 2019-ncov infection from January to February 2020 were included. The chest CT images and clinical data were reviewed and the relationship betweenof them was analyzed.

Results: Totally 80 patients diagnosed with COVID-19 as 2019-ncov infection were included. With regards to the clinical manifestations, 58/80 (73%) of patients had cough, 61/80 (76%) of patients had high temperature levels. The most frequent CT abnormalities observed The major CT abnormalities observed were ground glass opacity (GGO) (73/80 cases, 91%), consolidation (50/80 cases, 63%) and interlobular septal thickening (47/80, 59%). Most of the lesions were multiple, with an average of 12±6 lung segments involved. The most common involved lung segments were the dorsal segment of the right lower lobe (69/80, 86%), the posterior basal segment of the right lower lobe (68/80, 85%), the lateral basal segment of the right lower lobe

(64/80, 80%), the dorsal segment of the left lower lobe (61/80, 76%) and the posterior basal segment of the left lower lobe (65/80, 81%). The average pulmonary inflammation index (PII) value was (34%±20%) for all the patients. Correlation analysis showed that the PII value was significantly correlated with the values of lymphocyte count, monocyte count, C-reactive protein, procalcitonin, days from illness onset and body temperature ($p<0.05$).

Conclusion: The common chest CT findings of COVID-19~~SARS-CoV-2~~~~2019-ncov infection~~ are multiple GGO, consolidation and interlobular septal thickening in both lungs, which are mostly distributed under the pleura. There are significant correlations between the degree of pulmonary inflammation and the main clinical symptoms and laboratory results. CT plays an important role in the diagnosis and evaluation of this emerging global health emergency.

Key words: SARS-CoV-2, COVID-19,~~2019 novel coronavirus,~~ Infection, Pneumonia, Chest CT

Introduction

Since the middle of December 2019, many cases of pneumonia with ~~unknown~~unidentified cause~~s~~ have been found in some hospitals in Wuhan City, Hubei Province, China.[1] At first, it was reported that ~~many~~a number of patients had ~~some connection~~certain contact with a large seafood and animal market, ~~suggesting~~which suggested an animal-to-human~~animal-to-human~~ transmission. Soon afterwards, ~~more~~

~~and more~~an increasing number of patients without being ~~exposing~~exposed to the animal market ~~were found~~started to grow exponetially, indicating a fact of human-to-human transmission~~that human to human transmission is taking place~~. At present, ~~it~~this kind of pneumonia has been confirmed as a new type of acute respiratory infectious disease caused by coronavirus infection.[2,3] However, it is not clear how expeditiously and sustainably~~easy and sustainable~~ the virus ~~is to spread~~spreads from person to person. On 12 February, 2020, the International Committee on Taxonomy of Viruses (ICTV) announced that the official classification of the new coronavirus was severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). The same day, the World Health Organization (WHO) announced ~~the same day~~ that the official name of the disease caused by the virus ~~is~~was corona virus disease 2019 (COVID-19)~~On January 12, 2020, the World Health Organization (WHO) named it as 2019 Novel Coronavirus (2019-ncov or officially named by the World Health Organization as coronavirus disease 2019 (COVID-19)), and the pneumonia caused by this pathogen was called new coronavirus pneumonia~~. The ~~Since then, i~~~~It~~Corona Virus has been spreading rapidly around the world, infecting no fewer than ~~thirty~~seventy thousands people~~causing more than thirty thousands of patients~~, and leading to a certain degree of public panic.[4-6] On January 30, 2020, the International Health Regulations Emergency Committee of the WHO declared the outbreak a "public health emergency of international concernexternal icon" (PHEIC). The epidemic caused by the new coronavirus has become a public health emergency of international concern.

The ~~novel coronavirus (~~SARS-CoV-2~~2019-ncov~~ is a new strain of coronavirus which has never been found in human body before. Common clinical symptoms of patients infected with SARS-CoV-2 include fever ~~The common signs of people infected with it are fever,~~ fatigue and dry cough. ~~A~~Besides, a small number of patients could have nasal congestion, runny nose, sore throat or diarrhea. Furthermore, in some aggravated cases~~In some serious cases~~, infection ~~can lead~~ has led to severe acute respiratory syndrome, renal failure, and even death. In severe cases patients present with ~~Severe patients usually have~~ dyspnea and / or hypoxemia one week after the onset of the disease, and develop rapidly into acute respiratory distress syndrome, septic shock, metabolic acidosis and coagulation dysfunction which are ~~difficult arduous~~hard to correct. Up to the present there is only limited data available regarding the typical chest CT imaging findings in COVID-19~~There has been rare study about the chest CT findings in patients with 2019-ncov infection in the literature~~. In this study, we retrospectively evaluated the chest CT findings in 80 patients with confirmed COVID-19~~SARS-CoV-2~~~~2019-ncov infection~~ and ~~to~~ evaluate ~~its~~their relationship with the clinical features.

Materials and Methods

Patients

The present study sample consisted of 80 patients who had been diagnosed as COVID-19~~SARS-CoV-2~~~~2019-ncov~~ ~~infection~~ in our hospitals (outside of the Wuhan area) from January to February 2020~~were included in the present study~~. This study

Formatted

Formatted

received Ethics Committee approval of our institutions~~. The~~, and the committees waived the need for individual consent ~~because of~~due to the retrospective nature of the study. The inclusion criteria were: 1. epidemiological history -either travel/residence history in Wuhan or exposure history to fevered patients from Wuhan suffering from respiratory symptoms~~with respiratory symptoms from Wuhan~~ within 14 days before the onset of illness; 2. laboratory diagnosis - 1) real-time fluorescence polymerase chain reaction revealed positive detection of SARS-CoV-2 in throat swabs or lower respiratory tract; 2) the virus gene sequencing of respiratory or blood samples is highly homologous with the known SARS-CoV-2. All ~~Patients~~the patients underwent thin-section CT at least one time.~~A) Have an epidemiological history; B) Having one of the following etiological evidences: 1) Real-time RT-PCR detection of 2019-ncov nucleic acid positive in respiratory or blood samples; 2) The virus gene sequencing of respiratory or blood samples is highly homologous with the known new coronavirus; . C) Patients who underwent CT examinations.~~ The exclusion criteria were another confirmed concomitant pulmonary pneumonia~~ infection~~ or coronavirus infection. Children and pregnant women were also excluded ~~in~~from this study

Clinical and laboratorial data were obtained from a detailed medical records collected respectively in standardized form~~record~~ by two radiologists with 10 and 8 years~~ of~~ experience~~, respectively, using a standardized form~~. The following clinical data of the patients were assessed: gender, age, cough, expectoration, chest pain, muscle ache, abdominal pain or diarrhea, pharyngeal discomfort, dyspnea, dizziness or headache, blood in sputum, and presence of comorbidities (including systemic

Formatted

hypertension, diabetes mellitus, tobacco smoke, asthma, heart disease, chronic obstructive pulmonary disease (COPD), immunodeficiency, and others. Information regarding the physical examination at admission was also evaluated, including the heart rate (HR), body temperature, oxygen saturation, and blood pressure (BP). ~~Regarding~~Moreover, the laboratory data obtained at admission, which included the leukocyte, lymphocyte, neutrophil, monocyte, procalcitonin, and C-reactive protein (CRP),were assessed as well. Blood gas analyses~~analysis~~ were performed in 40 patients~~. Their~~ whose PH value, $PaCO_2$ and PaO_2 were also assessed. All the blood gas analysis was conducted from arterial blood samples.

CT scans and Review

The CT examinations were ~~performed~~carried out with an 16-row multidetector CT scanner (Siemens Somatom Sensation; Siemens, Erlangen, Germany) using the following parameters: 120 kVp, 150 mA, 1.5 mm collimation, 1.35:1 pitch, sharp kernel ~~smoothing~~ (B80f), ~~and~~ reconstruction matrix of 512×512, slice thickness of 1.0mm, and high spatial resolution algorithm. All the patients were scanned in a supine position during breath-holding at full inspiration. ~~Thin-section CT images were reconstructed with 1.0-mm collimation with a high-spatial-resolution algorithmhigh spatial frequency algorithm.~~ All CT images were evaluated using a lung window, with a window level of -500 HU and window width of 1500 HU. Two certificated chest radiologists with 10 and 8 years ~~of~~ experience independently reviewed the CT images while they ~~. They~~ were blinded to the names and clinical data of the patients.

The CT imaging features were fully assessed and the following findings were highlighted: ground glass opacity (GGO), consolidation, interlobular septal thickening, bronchial wall thickening, subpleural line, lymph node enlargement, pleural effusion and pericardial effusion in accordance with the standard morphologic descriptors based on the Fleischner Society Nomenclature Committee recommendations and similar studies.[7,8] ~~A~~As a rule, a consensus had to be reached between the 2 radiologists about the abnormalities, and discrepancies were reconciled and tackled via~~. Discrepancies were solved by~~ discussion. Specificly, the evaluation of the size and extent of lung involvement was based on the segments of the lung anatomy: 10 segments in the right lung and 10 segments in the left lung (2 segments were considered in the apicoposterior segment of the left upper lobe and 2 segments were considered in the inferior front segment of the left lower lobe). According to the evaluation criterion established by Chongqing Radiologist Association of China, the pulmonary inflammation index (PII) was obtained from each patient. PII = (Distribution score + Size score) / 40 *100% (Fig.1). Distribution score: scored ~~score~~ according to the lesion distribution, one score for each lung segment, and 20 scores for left and right lung. Lesion size score: scored~~score~~ according to whether the lesion ~~occupies~~occupied more than 50% of the lung segment volume, one score for ≥ 50%, and zero score for < 50%. Spearman's correlations were performed to evaluate the relationships between the PII value and the clinical symptom and laboratory results of the patients. All Statistical Analysis was ~~performed~~conducted using Statistical Package for Social Sciences software version 23.0 (SPSS Inc., Chicago, IL, USA). P

values less than 0.05 were considered statistically significant.

Results：

Characteristics and clinical manifestations

This study included 80 patients diagnosed as COVID-19~~SARS-CoV-22019-ncov infection~~, of which 42 were male (52%) and 38 were female (48%). All the patiens aged 15-79 years with an average age of 44±11 years. 26/80 (33%) of patients were smokers. 61/80 (76%) of patients had high temperature levels. 15/80 (18%) of patients had comorbidities, 4/80 (5%) of patients had hypertension, 4/80 (5%) of patients had diabetes, 3/80 (4%) of patients had COPD, 3/80 (3%) of patients had immunosuppression (immunosuppressive drugs taking), 1/80 (1%) of patients had heart disease (coronary heart disease). No patients had asthma or other chronic lung disease. With regards to the clinical manifestations, 58/80 (73%) of patients had cough, 11/80 (14%) of patients had expectoration, 5/80 (6%) of patients had chest pain, 13/80 (16%) of patients had muscle ache, 7/80 (9%) of patients had abdominal pain or diarrhea, 9/80 (11%) of patients had pharyngeal discomfort, 8/80 (10%) of patients had dizziness or headache, 7/80 (9%) of patients had dyspnea and 3/80 of patients (4%) had blood in sputum. On physical examination stastics, the median oxygen saturation was 97% (IQR: 96%-98%), the average heart rate was 88.24± 11.67 bpm and the respiratory rate was 21.05 ±3.74 breaths/min. The average systolic BP was 123.46 ± 14.19 mmHg, and the diastolic BP was 80.00 ±

14.04 mmHg. Regarding the laboratory data, the median leukocyte count was 5.40 (IQR: 4.20-6.95) (× 10^9/L), lymphocyte count was 1.15 (IQR: 0.76-1.40) (× 10^9/L), monocyte count was 0.41 (IQR: 0.27-0.53) (× 10^9/L), neutrophil count was 3.74 (IQR: 2.67-5.20) (× 10^9/L), respectively. The median C-reactive protein was 12.39 (IQR: 2.71-50.60) (mg/L) and the procalcitonin was 0.04 (IQR: 0.03-0.07) (ng/mL). Blood gas analysis were performed in 40 patients. The average PH value was 7.45 ± 0.02, $PaCO_2$ (mmHg) was 39.21 ± 7.25, and PaO_2 (mmHg) was 85.72 ± 22.11. The clinical manifestations and laboratory findings were shown in Table 1 and 2.

Chest CT findings

All patients were examined by chest CT 7±4 days after the onset of disease.~~All 80 patients were examined by chest CT in 7 ±4 days from the onset of the disease.~~ In chest CT images, 76/80 cases (95%) of the patients had abnormalities indicating the pneumonia. The major CT abnormalities observed were GGO (ground glass opacity) (73/80 cases, 91%), consolidation (50/80 cases, 63%) and interlobular septal thickening (47/80, 59%) (Fig. 1). Besides that, 9/80 (11%) of patients had bronchial wall thickening, 16/80 (20%) of patients had subpleural line, 5/80 (6%) of patients had pleural effusion, 3/80 (4%) of patients had lymph node enlargement, 4/80 (5%) of patients had pericardial effusion. The characteristic signs were “crazy paving sign” (23/80, 29%) and “spider web sign” (20/80, 25%) (~~Figure~~ Fig. 2, 3). The “crazy paving pattern” was characterized by the reticular interlobular septa thickening within the patchy GGO, which had been reported in Severe Acute Respiratory Syndrome

(SARS) literatures. [9,10] The “spider web sign” was the first time we found and named it. It showed a triangular or angular GGO under the pleura with the internal interlobular septa thickened like a net. The adjacent pleura was pulled and formed a spiderweb-like shape~~is pulled and looks like a spider's web~~ in the corner. Most of the lesions were multiple, with an average of 12±6 lung segments involved. The lesions showed subpleural distribution in 42/80 cases (53%), diffuse distribution in 7/80 cases (9%), peribronchial distribution in 3/80 cases (4%) and mixed distribution in 24/80 cases (30%). The most common involved lung segments were the dorsal segment of the right lower lobe (69/80, 86%), the posterior basal segment of the right lower lobe (68/80, 85%), the lateral basal segment of the right lower lobe (64/80, 80%), the dorsal segment of the left lower lobe (61/80,76%) and the posterior basal segment of the left lower lobe (65,81%). The average PII value was (34%±20%) for all the patients. Correlation analysis showed that the PII value was significantly correlated with the values of lymphocyte count, monocyte count, C-reactive protein, procalcitonin, days from illness onset and body temperature (continuous variable) ($p<0.05$). The correlation coefficient values were -.260, -.258, .373, .273, .287, .544 respectively. The chest CT findings of the patients were shown in Table 3.

Discussion

COVID-19~~SARS-CoV-2 2019-nCoV infection~~ , which is primarily transmitted by contact between people and droplets, turns out to be a new disease of human beings~~is~~

~~a new disease of human beings, which is transmitted mainly by contact between people and droplets~~. Whether the novel coronavirus can spread in other ways is unclear, although it could be detected in nasopharyngeal swabs, sputum, lower respiratory secretions, blood, feces and other samples. Early identification and early intervention are ~~the key~~vital to reduce the incidence and mortality of severe cases. In this study, most patients were adults and there was no significant difference between the numbers of either male or~~and~~ female. Cough and fever were the most common clinical symptoms. The incidence of expectoration, chest pain, muscle ache, abdominal pain or diarrhea, pharyngeal discomfort, headache or dizziness and dyspnea were less common~~were not popular~~. This is similar to other types of coronavirus infections such as the SARS and Middle East Respiratory Syndrome (MERS).[11-13] This implies that they can presumably be classifed as~~indicating that they may belong to~~ the same kind of infection and the target cells of SARS-CoV-2~~2019-nCoV~~ may also be located in the lower respiratory tract.

For chest CT, 76 cases (95%) had abnormalities indicating the pneumonia. On the whole, ~~the CT changes of the lung were significantly heavier than the clinical manifestations.~~in comparison with~~compared with~~ other types of pneumonia, COVID-19 seemed to cause milder symptoms and severer pulmonary changes on CT. Most of the patients had mild symptoms and mild temperature rise, but their lung manifestations were serious. Multiple lesions were found in multiple segments and lobes of both lungs, which was different from the bacterial pneumonia. In other words, multiple ~~Multiple~~ and large lesions of two lungs involved simultaneously~~at the same~~

~~time~~ is not generally spotted~~popular~~ in the typical bacterial pneumonia.[14,15] The most common involved lung segments were the dorsal segment of the right lower lobe, the posterior basal segment of the right lower lobe, the lateral basal segment of the right lower lobe, the dorsal segment of the left lower lobe and the posterior basal segment of the left lower lobe. There were significant correlations among~~between~~ the degree of pulmonary inflammation and the main clinical symptoms and laboratory results. Our results suggested that chest CT could be used to evaluate the severity of the disease and ~~plays~~played an important role in clinical practice. For CT features, GGO was the most common of all the abnormalities, followed by consolidation and interlobular septal thickening. This is consistent with the results of the recently published studies.[16-18] Occasionally~~Sometimes~~ the subpleural line and bronchial wall thickening could be seen~~. Pleural~~ whereas pleura effusion, pericardial effusion or lymph node enlargement were rare to identify~~was rare~~. Some of the GGO was characterized by the reticular interlobular septa thickening, which ~~is~~ was called "crazy paving pattern". It resulted from the alveolar edema and interstitial inflammatory of acute lung injury, which had ~~be~~been reported in SARS.[9,10] In another situation, some of the GGO showed a triangular or angular shape under the pleura with the internal interlobular septa thickened like a net. The adjacent pleura ~~is pulled and looks like a spider's web~~ was pulled and formed a spiderweb-like shape in the corner. Thus we named it "spider web sign". But the pathological basis needs further pathological confirmation. It is a specific sign for COVID-19, which has not been reported in other diseases in the literature. At present, it is not clear whether it has clinical value in evaluating the

prognosis of patients. Recently, Pan et al have analyzed the time course of lung changes in 21 mild patients with confirmed COVID-19. They found that the initial lung manifestation was subpleural GGO which turned to consolidation two weeks after the onset of the disease, and then the lesions were gradually absorbed, leaving a wide range of GGO and subpleural parenchymal bands.[17] In another article, the authors found that after 7 days of treatment for the mild patients, there was a significant reduction in GGO on chest CT. On the 13th day after admission, most of the ground glass disappeared. Our patients constituted a complete group with mild, severe and critical types.[19] All patients completed CT examination within two days after admission, which was 7 ± 4 days from the onset of the disease.

At present, to our knowledge, all patients have not been examined by pathology in the world, so it is impossible to know the exact pathological manifestations of COVID-19. However, according~~According~~ to the morphological changes of the CT features, pathological manifestations could be speculated although there ~~is~~was no direct evidence. The ground glass density lesions could be caused by the exudation of alveoli. The appearance of consolidation ~~indicates~~indicated that the alveoli were~~are~~ completely filled by inflammatory exudation. The thickening of interlobular septum indicated~~indicates~~ that the the pulmonary interstitium has~~have~~ been involved. In the late stage of acute respiratory distress syndrome, diffuse alveolar and interstitium damage may ~~occured~~occur.

The COVID-19~~SARS-CoV-2 2019-ncov infection~~ needs to be differentiated from other diseases, such as SARS and MERS. They all showed multiple ground

glass shadows and solid lesions in both lungs, mainly distributed under the pleura, which were difficult to distinguish.~~16-18~~20-22 However, SARS and MERS had faster disease progress and heavier lung damages~~have faster and heavier disease progress and lung damage~~ than COVID-19~~SARS-CoV-2 2019-ncov~~ infection did. ~~On the other hand~~Likewise, COVID-19~~it~~ should be distinguished~~differentiated~~ from other kinds of viral pneumonia such as influenza virus, parainfluenza virus, adenovirus, respiratory syncytial virus, rhinovirus, human metapneumovirus and mycoplasma pneumonia.

In conclusion, in this study, we found ~~the~~that common chest CT findings ~~of~~in COVID-19~~SARS-CoV-2 2019-ncov infection are~~were include multiple GGO, consolidation and interlobular septal thickening in both lungs, with mostly subpleural distribution~~which are with mostly distributed under the pleura~~. There ~~are~~were significant correlations ~~between~~among the degree of pulmonary inflammation and the main clinical symptoms and laboratory results. CT play~~s~~ed an important role in the diagnosis and evaluation of this emerging global health emergency. Nevertheless, this ~~This~~ study has ~~severa~~three limitations. First of all, this ~~is~~was a retrospective study involving a small number of patients with proven SARS-CoV-2 infection~~COVID-19involving only a relative small sample subjects~~. Secondly, none of the patients had a lung biopsy or autopsy to reflect the histopathological changes. Thirdly, this study ~~is~~was a cross-sectional study and we could not analyze the dynamic CT changes in different stages. In the future work we will investigate the chest CT features of differential stages of COVID-19~~SARS-CoV-2~~2019-ncov ~~infection~~ by using larger, more diverse samples.

Reference

1. WHO. Novel coronavirus - China. Jan 12, 2020. Available at: https://www.who.int/csr/don/12-january-2020-novel-coronavirus-china/en/. ~~Accessed Jan 19, 2020.~~
2. Chaolin H, Yeming W, Xingwang L, et al. *The lancet*, Published Online January 24, 2020. https://doi.org/10.1016/S0140-6736(20)30183-5.
3. Huang C, Wang Y, Li X, et al. Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. *Lancet*, 2020. doi: 10.1016/S0140-6736(20)30183-5.
4. WHO. Novel coronavirus - Japan (ex-China). Jan 17, 2020. Available at: http://www.who.int/csr/don/17-january-2020-novel-coronavirusjapan-ex-china/en/. ~~Accessed Jan 19, 2020.~~
5. WHO. Novel coronavirus - Republic of Korea (ex-China). Jan 21, 2020. Available at: http://www.who.int/csr/don/21-january-2020-novelcoronavirus-republic-of-korea-ex-china/en/ . ~~Accessed Jan 23, 2020.~~
6. CDC. First travel-related case of 2019 novel coronavirus detected in United States. Jan 21, 2020. Available at: https://www.cdc.gov/media/releases/2020/p0121-novel-coronavirus-travel-case.html. ~~Accessed Jan 23, 2020.~~
7. Hansell DM, Bankier AA, MacMahon H, et al. Fleischner Society: glossary of

terms for thoracic imaging. *Radiology.* 2008; 246: 697-722.

~~7. Austin JH, Muller NL, Friedman PJ, et al. Glossary of terms for CT of the lungs: recommendations of the Nomenclature Committee of the Fleischner Society. *Radiology.* 1996; 200: 327-331.~~

8. Karla S, Natally H, et al. Spectrum of clinical and radiographic findings in patients with diagnosis of H1N1 and correlation with clinical severity. *BMC Infect Dis*. 2019; 19: 964.
9. Ketai L, Paul NS, Wong KT. Radiology of Severe Acute Respiratory Syndrome (SARS): the Emerging Pathologic-Radiologic Correlates of an Emerging Disease. *J Thorac Imaging*. 2006; 21(4):276-283.
10. Wong KT, Antonio GE, Hui DS, et al. Thin-Section CT of Severe Acute Respiratory Syndrome: evaluation of 74 Patients Exposed to or with the Disease. *Radiology.* 2003; 228(2): 395-400.
11. Lee N, Hui D, Wu A, et al. A major outbreak of severe acute respiratory syndrome in Hong Kong. *N Engl J Med*. 2003; 348:1986-1994.
12. Assiri A, Al-Tawfiq JA, Al-Rabeeah 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: 752-761.
13. Muller NL, Ooi GC, Khong PL, et al. High-resolution CT findings of severe acute respiratory syndrome at presentation and after admission. *Am J Roentgenol.* 2004; 182:39-44.

14. Gharib AM, Stern E. Radiology of pneumonia. *Medical Clinics of North America*. 2001; 85: 1461-1491.

15. Koo HJ, Lim S, Choe J, et al. Radiographic and CT Features of Viral Pneumonia. *Radiographics*. 2018; 38:719-739.

16. Song FX, Shi NN, Zhang ZY, et al. Emerging Coronavirus 2019-nCoV Pneumonia. *Radiology*. 2020:200274. doi:10.1148/radiol.2020200274.

17. Pan F, Yan TH, Sun P, et al. Time Course of Lung Changes On Chest CT During Recovery From 2019 Novel Coronavirus (COVID-19) Pneumonia. *Radiology*. 2020:200370. doi:10.1148/radiol.2020200370.

18. Jeffrey K. Chest CT Findings in 2019 Novel Coronavirus (2019-nCoV) Infections from Wuhan, China: Key Points for the Radiologist. *Radiology*. 2020:200241. doi:10.1148/radiol.2020200241.

~~15.~~19. Duan YN, Qin J. Pre- and Posttreatment Chest CT Findings: 2019 Novel Coronavirus (2019-nCoV) Pneumonia. *Radiology*. 2020:200323. doi:10.1148/radiol.2020200323.

~~16.~~20. Das KM, Lee EY, Enani MA, et al. CT correlation with out- comes in 15 patients with acute Middle East respiratory syndrome coronavirus. *AJR*. 2015; 204: 736-742.

~~17.~~21. Ajlan AM, Ahyad RA, Jamjoom LG,et al. Middle East Respiratory Syndrome Coronavirus (MERS-CoV) Infection: Chest CT Findings. *AJR*. 2014; 203: 782-787.

~~18.~~22. Hui DS, Memish ZA, Zumla A. Severe acute respiratory syndrome vs. the

Middle East respiratory syndrome. *Curr Opin Pulm Med*. 2014; 20: 233-421.

Table 1: Characteristics and clinical manifestations of thein 80 patients with COVID-192019-ncov infection.

	Patients (n=80)
Characteristics	
Age, years	44 (11)
Sex	
Female	38 (48%)
Male	42 (52%)
Smokers	26 (33%)
Days from illness onset	7 (4)
Comorbidity	15 (18%)
Hypertension	4 (5%)
Diabetes	4 (5%)
COPD	3 (4%)
Immunosuppression	3 (3%)
Heart disease	1 (1%)
Asthma	0 (0%)
Signs and symptoms	
Fever	61 (76%)
Highest temperature, °C	37.80 (37.30-38.20)
<37.30	19 (24%)
37.30–38.00	38 (47%)

38.10–39.00	20 (25%)
>39.00	3 (4%)
Cough	58 (73%)
Expectoration	11 (14%)
Chest pain	5 (6%)
Muscle ache	13 (16%)
Dyspnoea	7 (9%)
Abdominal pain and diarrhea	7 (9%)
Pharyngeal discomfort	9 (11%)
Dizziness and headache	8 (10%)
Blood in sputum	3 (4%)

Data are n (%), n/N (%), mean (SD), where N is the total number of patients with available data. COVID-19~~2019-nCoV~~ = Corona Virus Disease 2019 ~~2019-novel coronavirus~~. COPD = Chronic obstructive pulmonary disease.

Table 2: Laboratory and physical examination results ~~in~~of the 80 patients with COVID-19~~SARS-CoV-2 2019-ncov infection~~.

	Patients (n=80)
White blood cell count, × 10^9 /L	5.40 (4.20-6.95)
Increased	10 (10%)
Decreased	7 (9%)
Neutrophil count, × 10^9 /L	3.74 (2.67-5.20)
Increased	16 (20%)
Decreased	5 (6%)
Lymphocyte count, × 10^9 /L	1.15 (0.76-1.40)
Decreased	34 (43%)
Monocyte count, × 10^9 /L	0.41 (0.27-0.53)
Increased	8 (10%)
Decreased	1 (1%)
C-reactive protein (mg/L)	12.39 (2.71-50.61)
Increased	37 (46%)
Procalcitonin (ng/mL)	0.04 (0.03-0.07)
Increased	32 (40%)
Heart rate (bpm)	88.24 (11.67)
Respiratory rate (breaths/min)	21.05 (3.74)
Systolic pressure (mm Hg)	123.46 (14.19)
Diastolic pressure (mm Hg)	80.00 (14.04)

SaO_2, % room air	97% (96%-98%)
PH value*	7.45 (0.02)
$PaCO_2$ (mmHg) *	39.21 (7.25)
PaO_2 (mmHg) *	85.73 (22.11)

Data are n (%), n/N (%), mean (SD) or and median (IQR), where N is the total number of patients with available data. Increasing means exceeding the upper limit of the normal range, and decreasing means being below the lower limit of the normal range. COVID-19~~2019 nCoV~~= Corona Virus Disease 2019~~2019 novel coronavirus~~. SaO_2 = Arterial oxygen saturation. PH = Potential of hydrogen. $PaCO_2$ = Arterial partial pressure of carbon dioxide. PaO_2 = Arterial oxygen tension. *Data available for 40 patients.

Table 3: Chest CT findings ~~in~~of the 80 patients with COVID-19~~SARS-CoV-2 2019-ncov infection~~.

	Patients (n=80)
CT features	
GGO	73 (91%)
Consolidation	50 (63%)
Interlobular septal thickening	47 (59%)
Crazy paving pattern	23 (29%)
Spider web sign	20 (25%)
Subpleural line	16 (20%)
Bronchial wall thickening	9 (11%)
Lymph node enlargement	3 (4%)
Pericardial effusion	4 (5%)
Pleural effusion	5 (6%)
Lung segment involved	
Average lung segments involved	12 (6)
Dorsal segment of the right lower lobe	69 (86%)
Lateral basal segment of the right lower lobe	64 (80%)
Posterior basal segment of the right lower lobe	68 (85%)
Dorsal segment of the left lower lobe	61 (76%)
Posterior basal segment of the left lower lobe	65 (81%)

PII value	34% (20%)
Distribution	76 (95%)
Subpleural distribution	42 (53%)
Diffuse distribution	7 (9%)
Peribronchial distribution	3 (4%)
Mixed distribution	24 (30%)

Data are n (%), n/N (%) or mean (SD), where N is the total number of patients with available data. COVID-19= Corona Virus Disease 2019. GGO = ground glass opacity. PII = pulmonary inflammation index.

FIGURE 1. A-C, Chest CT of a 38 years old male. The clinical manifestations were fever (38 ℃), cough, expectoration, muscle pain and dyspnea. C-reactive protein and procalcitonin increased. Ground glass opacity (GGO) (white triangle), consolidation (white thick arrow) and interlobular septal thickening (white thin arrow) distributed under the pleura were seen. Nine lung segments including the lateral basal segment, posterior basal segment, posterior basal segment, anterior basal segment of the both lower lobe, and the dorsal segment of the left inferior lobe were involved. In three segments the lesions occupied more than 50% of the total volume. PII= (9+3)/40 *100%=30%.

448

449 **FIGURE 2.** A-C, Chest CT of a 60 years old male. The clinical manifestations were

450 fever (37.8 °C), cough, expectoration and dyspnea. Neutrophil count, lymphocyte

451 count and C-reactive protein increased. “crazy paving sign” (white thin arrow) were

452 seen.

453

FIGURE 3. A-C, Chest CT of a 44 years old male. The clinical manifestations were fever (38.5 °C), cough, dizziness and headache. C-reactive protein increased. "spider web sign" (white thin arrow) were seen.~~**Figure 1 a-b.** Chest CT of a 38-year-old man with 2019-ncov infection. Ground glass opacity (GGO) (white triangle), consolidation (white thick arrow) and interlobular septal thickening (white thin arrow) distributed under the pleura are seen.~~

~~**Figure 2 a-b.** Chest CT of a 60-year-old man with 2019-ncov infection. "crazy paving sign" (white thin arrow) are seen.~~

~~**Figure 3 a-b.** Chest CT of a 44-year-old man with 2019-ncov infection "spider web sign" (white thin arrow) are seen.~~

Figure 1

Click here to access/download;Figure;FIGURE1.jpg

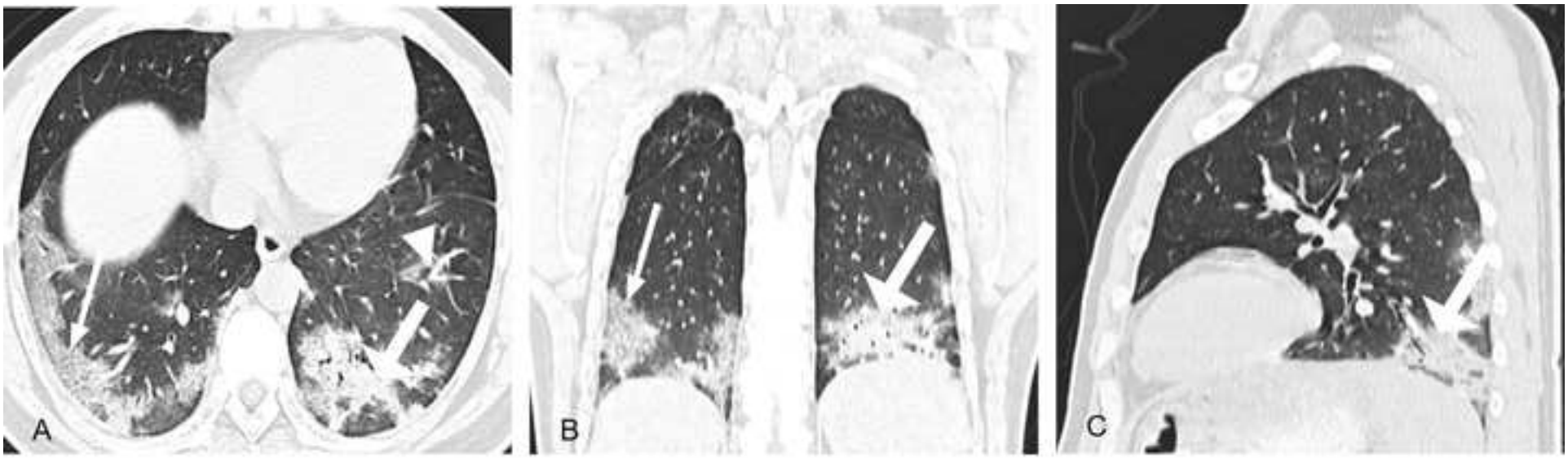
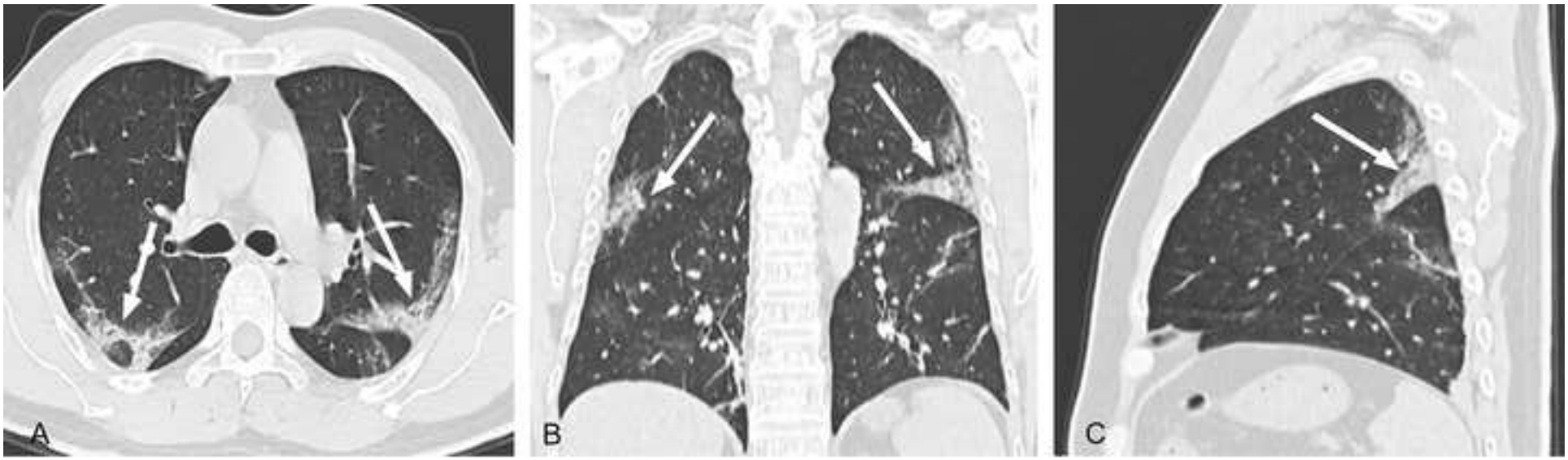


Figure 2

Click here to access/download;Figure;FIGURE2.jpg

Figure 3

Click here to access/download;Figure;FIGURE3.jpg



Chest CT Findings in Patients with Corona Virus Disease 2019 and its Relationship with Clinical Features

Abstract

Objectives: To investigate the chest computed tomography (CT) findings in patients with confirmed corona virus disease 2019 (COVID-19) and to evaluate its relationship with clinical features.

Materials and Methods: Study sample consisted of 80 patients diagnosed as COVID-19 from January to February 2020. The chest CT images and clinical data were reviewed and the relationship between them was analyzed.

Results: Totally 80 patients diagnosed with COVID-19 were included. With regards to the clinical manifestations, 58/80 (73%) of patients had cough, 61/80 (76%) of patients had high temperature levels. The most frequent CT abnormalities observed were ground glass opacity (GGO) (73/80 cases, 91%), consolidation (50/80 cases, 63%) and interlobular septal thickening (47/80, 59%). Most of the lesions were multiple, with an average of 12±6 lung segments involved. The most common involved lung segments were the dorsal segment of the right lower lobe (69/80, 86%), the posterior basal segment of the right lower lobe (68/80, 85%), the lateral basal segment of the right lower lobe (64/80, 80%), the dorsal segment of the left lower lobe (61/80, 76%) and the posterior basal segment of the left lower lobe (65/80, 81%). The average pulmonary inflammation index (PII) value was (34%±20%) for all the patients. Correlation analysis showed that the PII value was significantly correlated

with the values of lymphocyte count, monocyte count, C-reactive protein, procalcitonin, days from illness onset and body temperature ($p<0.05$).

Conclusion: The common chest CT findings of COVID-19 are multiple GGO, consolidation and interlobular septal thickening in both lungs, which are mostly distributed under the pleura. There are significant correlations between the degree of pulmonary inflammation and the main clinical symptoms and laboratory results. CT plays an important role in the diagnosis and evaluation of this emerging global health emergency.

Key words: SARS-CoV-2, COVID-19, Infection, Pneumonia, Chest CT

Introduction

Since the middle of December 2019, many cases of pneumonia with unidentified causes have been found in some hospitals in Wuhan City, Hubei Province, China.[1] At first, it was reported that a number of patients had certain contact with a large seafood and animal market, which suggested an animal-to-human transmission. Soon afterwards, an increasing number of patients without being exposed to the animal market started to grow exponetially, indicating a fact of human-to-human transmission. At present, this kind of pneumonia has been confirmed as a new type of acute respiratory infectious disease caused by coronavirus infection.[2,3] However, it is not clear how expeditiously and sustainably the virus spreads from person to person. On 12 February, 2020, the International Committee on Taxonomy of Viruses (ICTV)

announced that the official classification of the new coronavirus was severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). The same day, the World Health Organization (WHO) announced that the official name of the disease caused by the virus was corona virus disease 2019 (COVID-19). The Corona Virus has been spreading rapidly around the world, infecting no fewer than seventy thousands people, and leading to a certain degree of public panic.[4-6] On January 30, 2020, the International Health Regulations Emergency Committee of the WHO declared the outbreak a “public health emergency of international concernexternal icon” (PHEIC). The epidemic caused by the new coronavirus has become a public health emergency of international concern.

The SARS-CoV-2 is a new strain of coronavirus which has never been found in human body before. Common clinical symptoms of patients infected with SARS-CoV-2 include fever fatigue and dry cough. Besides, a small number of patients could have nasal congestion, runny nose, sore throat or diarrhea. Furthermore, in some aggravated cases, infection has led to severe acute respiratory syndrome, renal failure, and even death. In severe cases patients present with dyspnea and / or hypoxemia one week after the onset of the disease, and develop rapidly into acute respiratory distress syndrome, septic shock, metabolic acidosis and coagulation dysfunction which are hard to correct. Up to the present there is only limited data available regarding the typical chest CT imaging findings in COVID-19. In this study, we retrospectively evaluated the chest CT findings in 80 patients with confirmed COVID-19 and evaluate their relationship with the clinical features.

Materials and Methods

Patients

The present study sample consisted of 80 patients who had been diagnosed as COVID-19 in our hospitals (outside of the Wuhan area) from January to February 2020. This study received Ethics Committee approval of our institutions, and the committees waived the need for individual consent due to the retrospective nature of the study. The inclusion criteria were: 1. epidemiological history -either travel/residence history in Wuhan or exposure history to fevered patients from Wuhan suffering from respiratory symptoms within 14 days before the onset of illness; 2. laboratory diagnosis - 1) real-time fluorescence polymerase chain reaction revealed positive detection of SARS-CoV-2 in throat swabs or lower respiratory tract; 2) the virus gene sequencing of respiratory or blood samples is highly homologous with the known SARS-CoV-2. All the patients underwent thin-section CT at least one time. The exclusion criteria were another confirmed concomitant pulmonary pneumonia or coronavirus infection. Children and pregnant women were also excluded from this study

Clinical and laboratorial data were obtained from a detailed medical records collected respectively in standardized form by two radiologists with 10 and 8 years experience. The following clinical data of the patients were assessed: gender, age, cough, expectoration, chest pain, muscle ache, abdominal pain or diarrhea, pharyngeal discomfort, dyspnea, dizziness or headache, blood in sputum, and presence of

comorbidities (including systemic hypertension, diabetes mellitus, tobacco smoke, asthma, heart disease, chronic obstructive pulmonary disease (COPD), immunodeficiency, and others. Information regarding the physical examination at admission was also evaluated, including the heart rate (HR), body temperature, oxygen saturation, and blood pressure (BP). Moreover, the laboratory data obtained at admission, which included the leukocyte, lymphocyte, neutrophil, monocyte, procalcitonin, and C-reactive protein (CRP),were assessed as well. Blood gas analyses were performed in 40 patients whose PH value, $PaCO_2$ and PaO_2 were also assessed. All the blood gas analysis was conducted from arterial blood samples.

CT scans and Review

The CT examinations were carried out with an 16-row multidetector CT scanner (Siemens Somatom Sensation; Siemens, Erlangen, Germany) using the following parameters: 120 kVp, 150 mA, 1.5 mm collimation, 1.35:1 pitch, sharp kernel (B80f), reconstruction matrix of 512×512, slice thickness of 1.0mm, and high spatial resolution algorithm. All the patients were scanned in a supine position during breath-holding at full inspiration. All CT images were evaluated using a lung window, with a window level of -500 HU and window width of 1500 HU. Two certificated chest radiologists with 10 and 8 years experience independently reviewed the CT images while they were blinded to the names and clinical data of the patients. The CT imaging features were fully assessed and the following findings were highlighted: ground glass opacity (GGO), consolidation, interlobular septal thickening, bronchial

wall thickening, subpleural line, lymph node enlargement, pleural effusion and pericardial effusion in accordance with the standard morphologic descriptors based on the Fleischner Society Nomenclature Committee recommendations and similar studies.[7,8] As a rule, a consensus had to be reached between the 2 radiologists about the abnormalities, and discrepancies were reconciled and tackled via discussion. Specificly, the evaluation of the size and extent of lung involvement was based on the segments of the lung anatomy: 10 segments in the right lung and 10 segments in the left lung (2 segments were considered in the apicoposterior segment of the left upper lobe and 2 segments were considered in the inferior front segment of the left lower lobe). According to the evaluation criterion established by Chongqing Radiologist Association of China, the pulmonary inflammation index (PII) was obtained from each patient. PII = (Distribution score + Size score) / 40 *100% (Fig.1). Distribution score: scored according to the lesion distribution, one score for each lung segment, and 20 scores for left and right lung. Lesion size score: scored according to whether the lesion occupied more than 50% of the lung segment volume, one score for ≥ 50%, and zero score for < 50%. Spearman's correlations were performed to evaluate the relationships between the PII value and the clinical symptom and laboratory results of the patients. All Statistical Analysis was conducted using Statistical Package for Social Sciences software version 23.0 (SPSS Inc., Chicago, IL, USA). P values less than 0.05 were considered statistically significant.

Results：

Characteristics and clinical manifestations

This study included 80 patients diagnosed as COVID-19, of which 42 were male (52%) and 38 were female (48%). All the patiens aged 15-79 years with an average age of 44±11 years. 26/80 (33%) of patients were smokers. 61/80 (76%) of patients had high temperature levels. 15/80 (18%) of patients had comorbidities, 4/80 (5%) of patients had hypertension, 4/80 (5%) of patients had diabetes, 3/80 (4%) of patients had COPD, 3/80 (3%) of patients had immunosuppression (immunosuppressive drugs taking), 1/80 (1%) of patients had heart disease (coronary heart disease). No patients had asthma or other chronic lung disease. With regards to the clinical manifestations, 58/80 (73%) of patients had cough, 11/80 (14%) of patients had expectoration, 5/80 (6%) of patients had chest pain, 13/80 (16%) of patients had muscle ache, 7/80 (9%) of patients had abdominal pain or diarrhea, 9/80 (11%) of patients had pharyngeal discomfort, 8/80 (10%) of patients had dizziness or headache, 7/80 (9%) of patients had dyspnea and 3/80 of patients (4%) had blood in sputum. On physical examination stastics, the median oxygen saturation was 97% (IQR: 96%-98%), the average heart rate was 88.24±11.67 bpm and the respiratory rate was 21.05 ±3.74 breaths/min. The average systolic BP was 123.46±14.19 mmHg, and the diastolic BP was 80.00± 14.04 mmHg. Regarding the laboratory data, the median leukocyte count was 5.40 (IQR: 4.20-6.95) (× 10^9/L), lymphocyte count was 1.15 (IQR: 0.76-1.40) (× 10^9/L), monocyte count was 0.41 (IQR: 0.27-0.53) (× 10^9/L), neutrophil count was 3.74 (IQR: 2.67-5.20) (× 10^9/L), respectively. The median C-reactive protein was 12.39 (IQR: 2.71-50.60) (mg/L) and the procalcitonin was 0.04 (IQR: 0.03-0.07) (ng/mL). Blood

gas analysis were performed in 40 patients. The average PH value was 7.45 ± 0.02, $PaCO_2$ (mmHg) was 39.21 ± 7.25, and PaO_2 (mmHg) was 85.72 ± 22.11. The clinical manifestations and laboratory findings were shown in Table 1 and 2.

Chest CT findings

All patients were examined by chest CT 7±4 days after the onset of disease. In chest CT images, 76/80 cases (95%) of the patients had abnormalities indicating the pneumonia. The major CT abnormalities observed were GGO (ground glass opacity) (73/80 cases, 91%), consolidation (50/80 cases, 63%) and interlobular septal thickening (47/80, 59%) (Fig. 1). Besides that, 9/80 (11%) of patients had bronchial wall thickening, 16/80 (20%) of patients had subpleural line, 5/80 (6%) of patients had pleural effusion, 3/80 (4%) of patients had lymph node enlargement, 4/80 (5%) of patients had pericardial effusion. The characteristic signs were "crazy paving sign" (23/80, 29%) and "spider web sign" (20/80, 25%) (Fig. 2, 3). The "crazy paving pattern" was characterized by the reticular interlobular septa thickening within the patchy GGO, which had been reported in Severe Acute Respiratory Syndrome (SARS) literatures. [9,10] The "spider web sign" was the first time we found and named it. It showed a triangular or angular GGO under the pleura with the internal interlobular septa thickened like a net. The adjacent pleura was pulled and formed a spiderweb-like shape in the corner. Most of the lesions were multiple, with an average of 12±6 lung segments involved. The lesions showed subpleural distribution in 42/80 cases (53%), diffuse distribution in 7/80 cases (9%), peribronchial distribution in 3/80

cases (4%) and mixed distribution in 24/80 cases (30%). The most common involved lung segments were the dorsal segment of the right lower lobe (69/80, 86%), the posterior basal segment of the right lower lobe (68/80, 85%), the lateral basal segment of the right lower lobe (64/80, 80%), the dorsal segment of the left lower lobe (61/80,76%) and the posterior basal segment of the left lower lobe (65,81%). The average PII value was (34%±20%) for all the patients. Correlation analysis showed that the PII value was significantly correlated with the values of lymphocyte count, monocyte count, C-reactive protein, procalcitonin, days from illness onset and body temperature (continuous variable) ($p<0.05$). The correlation coefficient values were -.260, -.258, .373, .273, .287, .544 respectively. The chest CT findings of the patients were shown in Table 3.

Discussion

COVID-19, which is primarily transmitted by contact between people and droplets, turns out to be a new disease of human beings. Whether the novel coronavirus can spread in other ways is unclear, although it could be detected in nasopharyngeal swabs, sputum, lower respiratory secretions, blood, feces and other samples. Early identification and early intervention are vital to reduce the incidence and mortality of severe cases. In this study, most patients were adults and there was no significant difference between the numbers of either male or female. Cough and fever were the most common clinical symptoms. The incidence of expectoration, chest pain, muscle

ache, abdominal pain or diarrhea, pharyngeal discomfort, headache or dizziness and dyspnea were less common. This is similar to other types of coronavirus infections such as the SARS and Middle East Respiratory Syndrome (MERS).[11-13] This implies that they can presumably be classifed as the same kind of infection and the target cells of SARS-CoV-2 may also be located in the lower respiratory tract.

For chest CT, 76 cases (95%) had abnormalities indicating the pneumonia. On the whole, in comparison with other types of pneumonia, COVID-19 seemed to cause milder symptoms and severer pulmonary changes on CT. Most of the patients had mild symptoms and mild temperature rise, but their lung manifestations were serious. Multiple lesions were found in multiple segments and lobes of both lungs, which was different from the bacterial pneumonia. In other words, multiple and large lesions of two lungs involved simultaneously is not generally spotted in the typical bacterial pneumonia.[14,15] The most common involved lung segments were the dorsal segment of the right lower lobe, the posterior basal segment of the right lower lobe, the lateral basal segment of the right lower lobe, the dorsal segment of the left lower lobe and the posterior basal segment of the left lower lobe. There were significant correlations among the degree of pulmonary inflammation and the main clinical symptoms and laboratory results. Our results suggested that chest CT could be used to evaluate the severity of the disease and played an important role in clinical practice. For CT features, GGO was the most common of all the abnormalities, followed by consolidation and interlobular septal thickening. This is consistent with the results of the recently published studies.[16-18] Occasionally the subpleural line and bronchial wall

thickening could be seen whereas pleura effusion, pericardial effusion or lymph node enlargement were rare to identify. Some of the GGO was characterized by the reticular interlobular septa thickening, which was called "crazy paving pattern". It resulted from the alveolar edema and interstitial inflammatory of acute lung injury, which had been reported in SARS.[9,10] In another situation, some of the GGO showed a triangular or angular shape under the pleura with the internal interlobular septa thickened like a net. The adjacent pleura was pulled and formed a spiderweb-like shape in the corner. Thus we named it "spider web sign". But the pathological basis needs further pathological confirmation. It is a specific sign for COVID-19, which has not been reported in other diseases in the literature. At present, it is not clear whether it has clinical value in evaluating the prognosis of patients. Recently, Pan et al have analyzed the time course of lung changes in 21 mild patients with confirmed COVID-19. They found that the initial lung manifestation was subpleural GGO which turned to consolidation two weeks after the onset of the disease, and then the lesions were gradually absorbed, leaving a wide range of GGO and subpleural parenchymal bands.[17] In another article, the authors found that after 7 days of treatment for the mild patients, there was a significant reduction in GGO on chest CT. On the 13th day after admission, most of the ground glass disappeared. Our patients constituted a complete group with mild, severe and critical types.[19] All patients completed CT examination within two days after admission, which was 7 ± 4 days from the onset of the disease.

At present, to our knowledge, all patients have not been examined by pathology

in the world, so it is impossible to know the exact pathological manifestations of COVID-19. However, according to the morphological changes of the CT features, pathological manifestations could be speculated although there was no direct evidence. The ground glass density lesions could be caused by the exudation of alveoli. The appearance of consolidation indicated that the alveoli were completely filled by inflammatory exudation. The thickening of interlobular septum indicated that the the pulmonary interstitium has been involved. In the late stage of acute respiratory distress syndrome, diffuse alveolar and interstitium damage may occur.

The COVID-19 needs to be differentiated from other diseases, such as SARS and MERS. They all showed multiple ground glass shadows and solid lesions in both lungs, mainly distributed under the pleura, which were difficult to distinguish.[20-22] However, SARS and MERS had faster disease progress and heavier lung damages than COVID-19 infection did. Likewise, COVID-19 should be distinguished from other kinds of viral pneumonia such as influenza virus, parainfluenza virus, adenovirus, respiratory syncytial virus, rhinovirus, human metapneumovirus and mycoplasma pneumonia.

In conclusion, in this study, we found that common chest CT findings in COVID-19 include multiple GGO, consolidation and interlobular septal thickening in both lungs, with mostly subpleural distribution. There were significant correlations among the degree of pulmonary inflammation and the main clinical symptoms and laboratory results. CT played an important role in the diagnosis and evaluation of this emerging global health emergency. Nevertheless, this study has three limitations. First

of all, this was a retrospective study involving a small number of patients with proven SARS-CoV-2 infection. Secondly, none of the patients had a lung biopsy or autopsy to reflect the histopathological changes. Thirdly, this study was a cross-sectional study and we could not analyze the dynamic CT changes in different stages. In the future work we will investigate the chest CT features of differential stages of COVID-19 by using larger, more diverse samples.

Reference

1. WHO. Novel coronavirus - China. Jan 12, 2020. Available at: https://www.who.int/csr/don/12-january-2020-novel-coronavirus-china/en/.
2. Chaolin H, Yeming W, Xingwang L, et al. *The lancet*, Published Online January 24, 2020. https://doi.org/10.1016/S0140-6736(20)30183-5.
3. Huang C, Wang Y, Li X, et al. Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. *Lancet*, 2020. doi: 10.1016/S0140-6736(20)30183-5.
4. WHO. Novel coronavirus - Japan (ex-China). Jan 17, 2020. Available at: http://www.who.int/csr/don/17-january-2020-novel-coronavirusjapan-ex-china/en/.
5. WHO. Novel coronavirus - Republic of Korea (ex-China). Jan 21, 2020. Available at: http://www.who.int/csr/don/21-january-2020-novelcoronavirus-republic-of-korea-ex-china/en/ .

6. CDC. First travel-related case of 2019 novel coronavirus detected in United States. Jan 21, 2020. Available at: https://www.cdc.gov/media/releases/2020/p0121-novel-coronavirus-travel-case.html.

7. Hansell DM, Bankier AA, MacMahon H, et al. Fleischner Society: glossary of terms for thoracic imaging. *Radiology.* 2008; 246: 697-722.

8. Karla S, Natally H, et al. Spectrum of clinical and radiographic findings in patients with diagnosis of H1N1 and correlation with clinical severity. *BMC Infect Dis*. 2019; 19: 964.

9. Ketai L, Paul NS, Wong KT. Radiology of Severe Acute Respiratory Syndrome (SARS): the Emerging Pathologic-Radiologic Correlates of an Emerging Disease. *J Thorac Imaging*. 2006; 21(4):276-283.

10. Wong KT, Antonio GE, Hui DS, et al. Thin-Section CT of Severe Acute Respiratory Syndrome: evaluation of 74 Patients Exposed to or with the Disease. *Radiology.* 2003; 228(2): 395-400.

11. Lee N, Hui D, Wu A, et al. A major outbreak of severe acute respiratory syndrome in Hong Kong. *N Engl J Med*. 2003; 348:1986-1994.

12. Assiri A, Al-Tawfiq JA, Al-Rabeeah 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: 752-761.

13. Muller NL, Ooi GC, Khong PL, et al. High-resolution CT findings of severe

307 acute respiratory syndrome at presentation and after admission. *Am J*
308 *Roentgenol.* 2004; 182:39-44.
309 14. Gharib AM, Stern E. Radiology of pneumonia. *Medical Clinics of North*
310 *America*. 2001; 85: 1461-1491.
311 15. Koo HJ, Lim S, Choe J, et al. Radiographic and CT Features of Viral Pneumonia.
312 *Radiographics.* 2018; 38:719-739.
313 16. Song FX, Shi NN, Zhang ZY, et al. Emerging Coronavirus 2019-nCoV
314 Pneumonia. *Radiology*. 2020:200274. doi:10.1148/radiol.2020200274.
315 17. Pan F, Yan TH, Sun P, et al. Time Course of Lung Changes On Chest CT During
316 Recovery From 2019 Novel Coronavirus (COVID-19) Pneumonia. *Radiology*.
317 2020:200370. doi:10.1148/radiol.2020200370.
318 18. Jeffrey K. Chest CT Findings in 2019 Novel Coronavirus (2019-nCoV) Infections
319 from Wuhan, China: Key Points for the Radiologist. *Radiology*. 2020:200241.
320 doi:10.1148/radiol.2020200241.
321 19. Duan YN, Qin J. Pre- and Posttreatment Chest CT Findings: 2019 Novel
322 Coronavirus (2019-nCoV) Pneumonia. *Radiology*. 2020:200323.
323 doi:10.1148/radiol.2020200323.
324 20. Das KM, Lee EY, Enani MA, et al.
325 CT correlation with out- comes in 15 patients with acute Middle
326 East respiratory syndrome coronavirus. *AJR.* 2015; 204: 736-742.
327 21. Ajlan AM, Ahyad RA, Jamjoom LG,et al. Middle East Respiratory Syndrome
328 Coronavirus (MERS-CoV) Infection: Chest CT Findings. *AJR.* 2014; 203:

782-787.

22. Hui DS, Memish ZA, Zumla A. Severe acute respiratory syndrome vs. the Middle East respiratory syndrome. *Curr Opin Pulm Med.* 2014; 20: 233-421.

352 Table 1: Characteristics and clinical manifestations of the 80 patients with COVID-19.

	Patients (n=80)
Characteristics	
Age, years	44 (11)
Sex	
Female	38 (48%)
Male	42 (52%)
Smokers	26 (33%)
Days from illness onset	7 (4)
Comorbidity	15 (18%)
Hypertension	4 (5%)
Diabetes	4 (5%)
COPD	3 (4%)
Immunosuppression	3 (3%)
Heart disease	1 (1%)
Asthma	0 (0%)
Signs and symptoms	
Fever	61 (76%)
Highest temperature, °C	37.80 (37.30-38.20)
<37.30	19 (24%)
37.30–38.00	38 (47%)
38.10–39.00	20 (25%)

>39.00	3 (4%)
Cough	58 (73%)
Expectoration	11 (14%)
Chest pain	5 (6%)
Muscle ache	13 (16%)
Dyspnoea	7 (9%)
Abdominal pain and diarrhea	7 (9%)
Pharyngeal discomfort	9 (11%)
Dizziness and headache	8 (10%)
Blood in sputum	3 (4%)

Data are n (%), n/N (%), mean (SD), where N is the total number of patients with available data. COVID-19 = Corona Virus Disease 2019 . COPD = Chronic obstructive pulmonary disease.

365 Table 2: Laboratory and physical examination results of the 80 patients with
366 COVID-19.

	Patients (n=80)
White blood cell count, × 10^9 /L	5.40 (4.20-6.95)
Increased	10 (10%)
Decreased	7 (9%)
Neutrophil count, × 10^9 /L	3.74 (2.67-5.20)
Increased	16 (20%)
Decreased	5 (6%)
Lymphocyte count, × 10^9 /L	1.15 (0.76-1.40)
Decreased	34 (43%)
Monocyte count, × 10^9 /L	0.41 (0.27-0.53)
Increased	8 (10%)
Decreased	1 (1%)
C-reactive protein (mg/L)	12.39 (2.71-50.61)
Increased	37 (46%)
Procalcitonin (ng/mL)	0.04 (0.03-0.07)
Increased	32 (40%)
Heart rate (bpm)	88.24 (11.67)
Respiratory rate (breaths/min)	21.05 (3.74)
Systolic pressure (mm Hg)	123.46 (14.19)
Diastolic pressure (mm Hg)	80.00 (14.04)

SaO_2, % room air	97% (96%-98%)
PH value*	7.45 (0.02)
$PaCO_2$ (mmHg) *	39.21 (7.25)
PaO_2 (mmHg) *	85.73 (22.11)

Data are n (%), n/N (%), mean (SD) or and median (IQR), where N is the total number of patients with available data. Increasing means exceeding the upper limit of the normal range, and decreasing means being below the lower limit of the normal range. COVID-19= Corona Virus Disease 2019. SaO_2 = Arterial oxygen saturation. PH = Potential of hydrogen. $PaCO_2$ = Arterial partial pressure of carbon dioxide. PaO_2 = Arterial oxygen tension. *Data available for 40 patients.

385 Table 3: Chest CT findings of the 80 patients with COVID-19.

	Patients (n=80)
CT features	
GGO	73 (91%)
Consolidation	50 (63%)
Interlobular septal thickening	47 (59%)
Crazy paving pattern	23 (29%)
Spider web sign	20 (25%)
Subpleural line	16 (20%)
Bronchial wall thickening	9 (11%)
Lymph node enlargement	3 (4%)
Pericardial effusion	4 (5%)
Pleural effusion	5 (6%)
Lung segment involved	
Average lung segments involved	12 (6)
Dorsal segment of the right lower lobe	69 (86%)
Lateral basal segment of the right lower lobe	64 (80%)
Posterior basal segment of the right lower lobe	68 (85%)
Dorsal segment of the left lower lobe	61 (76%)
Posterior basal segment of the left lower lobe	65 (81%)
PII value	34% (20%)
Distribution	76 (95%)

Subpleural distribution	42 (53%)
Diffuse distribution	7 (9%)
Peribronchial distribution	3 (4%)
Mixed distribution	24 (30%)

Data are n (%), n/N (%) or mean (SD), where N is the total number of patients with available data. COVID-19= Corona Virus Disease 2019. GGO = ground glass opacity. PII = pulmonary inflammation index.

FIGURE 1. A-C, Chest CT of a 38 years old male. The clinical manifestations were fever (38 ℃), cough, expectoration, muscle pain and dyspnea. C-reactive protein and procalcitonin increased. Ground glass opacity (GGO) (white triangle), consolidation (white thick arrow) and interlobular septal thickening (white thin arrow) distributed under the pleura were seen. Nine lung segments including the lateral basal segment, posterior basal segment, posterior basal segment, anterior basal segment of the both lower lobe, and the dorsal segment of the left inferior lobe were involved. In three segments the lesions occupied more than 50% of the total volume. PII= (9+3)/40 *100%=30%.

FIGURE 2. A-C, Chest CT of a 60 years old male. The clinical manifestations were fever (37.8 ℃), cough, expectoration and dyspnea. Neutrophil count, lymphocyte count and C-reactive protein increased. “crazy paving sign” (white thin arrow) were seen.

FIGURE 3. A-C, Chest CT of a 44 years old male. The clinical manifestations were fever (38.5 °C), cough, dizziness and headache. C-reactive protein increased. “spider web sign” (white thin arrow) were seen.