

Investigative Radiology

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

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Abstract:	<p>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.</p> <p>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.</p> <p>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).</p> <p>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.</p>

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

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

1 Chest CT Findings in Patients with Corona Virus Disease
2 ~~2019~~ 2019 Novel Coronavirus Infection and its Relationship
3 with Clinical Features
4

5 **Abstract**

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

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

14 **Results:** Totally 80 patients diagnosed with COVID-19 ~~as 2019-nCoV infection~~ were
15 included. With regards to the clinical manifestations, 58/80 (73%) of patients had
16 cough, 61/80 (76%) of patients had high temperature levels. The most frequent CT
17 abnormalities observed ~~The major CT abnormalities observed~~ were ground glass
18 opacity (GGO) (73/80 cases, 91%), consolidation (50/80 cases, 63%) and interlobular
19 septal thickening (47/80, 59%). Most of the lesions were multiple, with an average of
20 12 ± 6 lung segments involved. The most common involved lung segments were the
21 dorsal segment of the right lower lobe (69/80, 86%), the posterior basal segment of
22 the right lower lobe (68/80, 85%), the lateral basal segment of the right lower lobe

23 (64/80, 80%), the dorsal segment of the left lower lobe (61/80, 76%) and the posterior
24 basal segment of the left lower lobe (65/80, 81%). The average pulmonary
25 inflammation index (PII) value was (34% ± 20%) for all the patients. Correlation
26 analysis showed that the PII value was significantly correlated with the values of
27 lymphocyte count, monocyte count, C-reactive protein, procalcitonin, days from
28 illness onset and body temperature (p<0.05).

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

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

37

38 Introduction

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

44 ~~and more~~ an increasing number of patients without ~~being exposing~~ exposed to the
45 animal market ~~were found~~ started to grow exponentially, indicating a fact of
46 human-to-human transmission ~~that human to human transmission is taking place~~. At
47 present, ~~this kind of pneumonia~~ has been confirmed as a new type of acute
48 respiratory infectious disease caused by coronavirus infection.^{2,3} However, it is not
49 clear how ~~expeditiously and sustainably~~ easy and sustainable the virus ~~is to~~
50 ~~spread~~ spreads from person to person. On 12 February, 2020, the International
51 Committee on Taxonomy of Viruses (ICTV) announced that the official classification
52 of the new coronavirus was severe acute respiratory syndrome coronavirus 2
53 (SARS-CoV-2). The same day, the World Health Organization (WHO) announced the
54 ~~same day~~ that the official name of the disease caused by the virus is corona virus
55 disease 2019 (COVID-19) ~~On January 12, 2020, the World Health Organization~~
56 ~~(WHO) named it as 2019 Novel Coronavirus (2019-nCoV)~~ or officially named by the
57 World Health Organization as coronavirus disease 2019 (COVID-19), and the
58 ~~pneumonia caused by this pathogen was called new coronavirus pneumonia~~. The
59 ~~Since then, it~~ Corona Virus has been spreading rapidly around the world, infecting no
60 fewer than thirtyseveny thousands people ~~causing more than thirty thousands of~~
61 ~~patients~~, and leading to a certain degree of public panic.⁴⁻⁶ On January 30, 2020, the
62 International Health Regulations Emergency Committee of the WHO declared the
63 outbreak a “public health emergency of international concern” (PHEIC).
64 The epidemic caused by the new coronavirus has become a public health emergency
65 of international concern.

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

82

83 **Materials and Methods**

84 **Patients**

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

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88 received Ethics Committee approval of our institutions. ~~The, and the~~ committees
89 waived the need for individual consent ~~because of~~ due to the retrospective nature of
90 the study. The inclusion criteria were: 1. epidemiological history -either
91 travel/residence history in Wuhan or exposure history to febrile patients from Wuhan
92 suffering from respiratory symptoms~~with respiratory symptoms from Wuhan~~ within
93 14 days before the onset of illness; 2. laboratory diagnosis - 1) real-time fluorescence
94 polymerase chain reaction revealed positive detection of SARS-CoV-2 in throat swabs
95 or lower respiratory tract; 2) the virus gene sequencing of respiratory or blood
96 samples is highly homologous with the known SARS-CoV-2. All Patients~~the patients~~
97 underwent thin-section CT at least one time. A) Have an epidemiological history; B)
98 Having one of the following etiological evidences: 1) Real time RT-PCR detection of
99 2019-nCoV nucleic acid positive in respiratory or blood samples; 2) The virus gene
100 sequencing of respiratory or blood samples is highly homologous with the known new
101 coronavirus; . C) Patients who underwent CT examinations. The exclusion criteria
102 were another confirmed concomitant pulmonary pneumonia ~~infection~~ or coronavirus
103 infection. Children and pregnant women were also excluded #from this study

104 Clinical and laboratorial data were obtained from a detailed medical records
105 collected respectively in standardized form~~record~~ by two radiologists with 10 and
106 8 years ~~of~~ experience, ~~respectively, using a standardized form.~~ The following clinical
107 data of the patients were assessed: gender, age, cough, expectoration, chest pain,
108 muscle ache, abdominal pain or diarrhea, pharyngeal discomfort, dyspnea, dizziness
109 or headache, blood in sputum, and presence of comorbidities (including systemic

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110 hypertension, diabetes mellitus, tobacco smoke, asthma, heart disease, chronic
111 obstructive pulmonary disease (COPD), immunodeficiency, and others. Information
112 regarding the physical examination at admission was also evaluated, including the
113 heart rate (HR), body temperature, oxygen saturation, and blood pressure (BP).
114 ~~Regarding~~Moreover, the laboratory data obtained at admission, which included the
115 leukocyte, lymphocyte, neutrophil, monocyte, procalcitonin, and C-reactive protein
116 (CRP), were assessed as well. Blood gas ~~analyses~~analysis were performed in 40
117 patients. ~~Their~~ whose PH value, PaCO₂ and PaO₂ were also assessed. All the blood
118 gas analysis was conducted from arterial blood samples.

119

120 **CT scans and Review**

121 The CT examinations were ~~performed~~carried out with an 16-row multidetector CT
122 scanner (Siemens Somatom Sensation; Siemens, Erlangen, Germany) using the
123 following parameters: 120 kVp, 150 mA, 1.5 mm collimation, 1.35:1 pitch, sharp
124 kernel smoothing (B80f), and reconstruction matrix of 512×512, slice thickness of
125 1.0mm, and high spatial resolution algorithm. All the patients were scanned in a
126 supine position during breath-holding at full inspiration. ~~Thin-section CT images were~~
127 ~~reconstructed with 1.0 mm collimation with a high spatial resolution algorithm~~high
128 ~~spatial frequency algorithm~~. All CT images were evaluated using a lung window, with
129 a window level of -500 HU and window width of 1500 HU. Two certified chest
130 radiologists with 10 and 8 years ~~of~~ experience independently reviewed the CT
131 images while they. ~~They~~ were blinded to the names and clinical data of the patients.

132 The CT imaging features were fully assessed and the following findings were
133 highlighted: ground glass opacity (GGO), consolidation, interlobular septal thickening,
134 bronchial wall thickening, subpleural line, lymph node enlargement, pleural effusion
135 and pericardial effusion in accordance with the standard morphologic descriptors
136 based on the Fleischner Society Nomenclature Committee recommendations and
137 similar studies.^{7,8} ~~As a rule, a~~ consensus had to be reached between the 2
138 radiologists about the abnormalities, ~~and discrepancies were reconciled and tackled~~
139 ~~via. Discrepancies were solved by~~ discussion. ~~Specificly,~~ the evaluation of the size
140 and extent of lung involvement was based on the segments of the lung anatomy: 10
141 segments in the right lung and 10 segments in the left lung (2 segments were
142 considered in the apicoposterior segment of the left upper lobe and 2 segments were
143 considered in the inferior front segment of the left lower lobe). According to the
144 evaluation criterion established by Chongqing Radiologist Association of China, the
145 pulmonary inflammation index (PII) was obtained from each patient. $PII =$
146 $(\text{Distribution score} + \text{Size score}) / 40 * 100\%$ (Fig.1). Distribution score: ~~scored score~~
147 according to the lesion distribution, one score for each lung segment, and 20 scores
148 for left and right lung. Lesion size score: ~~scored score~~ according to whether the lesion
149 ~~occupies~~ occupied more than 50% of the lung segment volume, one score for $\geq 50\%$,
150 and zero score for $< 50\%$. Spearman's correlations were performed to evaluate the
151 relationships between the PII value and the clinical symptom and laboratory results of
152 the patients. All Statistical Analysis was ~~performed~~ conducted using Statistical
153 Package for Social Sciences software version 23.0 (SPSS Inc., Chicago, IL, USA). P

154 values less than 0.05 were considered statistically significant.

155

156 **Results :**

157 **Characteristics and clinical manifestations**

158 This study included 80 patients diagnosed as [COVID-19 SARS-CoV-2 2019-nCoV](#)
159 [infection](#), of which 42 were male (52%) and 38 were female (48%). [All the patients](#)
160 aged 15-79 years with an average age of 44 ± 11 years. 26/80 (33%) [of](#) patients were
161 smokers. 61/80 (76%) [of](#) patients had high temperature levels. 15/80 (18%) [of](#) patients
162 had comorbidities, 4/80 (5%) [of](#) patients had hypertension, 4/80 (5%) [of](#) patients had
163 diabetes, 3/80 (4%) [of](#) patients had COPD, 3/80 (3%) [of](#) patients had
164 immunosuppression ([immunosuppressive drugs taking](#)), 1/80 (1%) [of](#) patients had
165 heart disease ([coronary heart disease](#)). No patients had asthma or other chronic lung
166 disease. With regards to the clinical manifestations, 58/80 (73%) [of](#) patients had
167 cough, 11/80 (14%) [of](#) patients had expectoration, 5/80 (6%) [of](#) patients had chest
168 pain, 13/80 (16%) [of](#) patients had muscle ache, 7/80 (9%) [of](#) patients had abdominal
169 pain or diarrhea, 9/80 (11%) [of](#) patients had pharyngeal discomfort, 8/80 (10%) [of](#)
170 patients had dizziness or headache, 7/80 (9%) [of](#) patients had dyspnea and 3/80 [of](#)
171 patients (4%) had blood in sputum. On physical examination [stastics](#), the median
172 oxygen saturation was 97% (IQR: 96%-98%), the average heart rate was $88.24 \pm$
173 11.67 bpm and the respiratory rate was 21.05 ± 3.74 breaths/min. The average
174 systolic BP was 123.46 ± 14.19 mmHg, and the diastolic BP was $80.00 \pm$

175 14.04 mmHg. Regarding the laboratory data, the median leukocyte count was 5.40
176 (IQR: 4.20-6.95) ($\times 10^9/L$), lymphocyte count was 1.15 (IQR: 0.76-1.40) ($\times 10^9/L$),
177 monocyte count was 0.41 (IQR: 0.27-0.53) ($\times 10^9/L$), neutrophil count was 3.74 (IQR:
178 2.67-5.20) ($\times 10^9/L$), respectively. The median C-reactive protein was 12.39 (IQR:
179 2.71-50.60) (mg/L) and the procalcitonin was 0.04 (IQR: 0.03-0.07) (ng/mL). Blood
180 gas analysis were performed in 40 patients. The average PH value was 7.45 ± 0.02 ,
181 $PaCO_2$ (mmHg) was 39.21 ± 7.25 , and PaO_2 (mmHg) was 85.72 ± 22.11 . The clinical
182 manifestations and laboratory findings were shown in Table 1 [and](#) 2.

183

184 **Chest CT findings**

185 ~~All patients were examined by chest CT 7 ± 4 days after the onset of disease.~~ All 80
186 ~~patients were examined by chest CT in 7 ± 4 days from the onset of the disease.~~ In
187 chest CT images, 76/80 cases (95%) of the patients had abnormalities indicating the
188 pneumonia. The major CT abnormalities observed were GGO ([ground glass opacity](#))
189 (73/80 cases, 91%), consolidation (50/80 cases, 63%) and interlobular septal
190 thickening (47/80, 59%) ([Fig. 1](#)). ~~Besides that,~~ 9/80 (11%) [of](#) patients had bronchial
191 wall thickening, 16/80 (20%) [of](#) patients had subpleural line, 5/80 (6%) [of](#) patients
192 had pleural effusion, 3/80 (4%) [of](#) patients had lymph node enlargement, 4/80 (5%) [of](#)
193 patients had pericardial effusion. The characteristic signs were “crazy paving sign”
194 (23/80, 29%) and “spider web sign” (20/80, 25%) (~~Figure~~ [Fig. 2, 3](#)). The “crazy
195 paving pattern” was characterized by the reticular interlobular septa thickening within
196 the patchy GGO, which had been reported in Severe Acute Respiratory Syndrome

197 (SARS) literatures.^{9,10} The “spider web sign” was the first time we found and named
198 it. It showed a triangular or angular GGO under the pleura with the internal
199 interlobular septa thickened like a net. The adjacent pleura was pulled and formed a
200 spiderweb-like shape~~is pulled and looks like a spider's web~~ in the corner. Most of the
201 lesions were multiple, with an average of 12 ± 6 lung segments involved. The lesions
202 showed subpleural distribution in 42/80 cases (53%), diffuse distribution in 7/80 cases
203 (9%), peribronchial distribution in 3/80 cases (4%) and mixed distribution in 24/80
204 cases (30%). The most common involved lung segments were the dorsal segment of
205 the right lower lobe (69/80, 86%), the posterior basal segment of the right lower lobe
206 (68/80, 85%), the lateral basal segment of the right lower lobe (64/80, 80%), the
207 dorsal segment of the left lower lobe (61/80, 76%) and the posterior basal segment of
208 the left lower lobe (65, 81%). The average PII value was ($34\% \pm 20\%$) for all the
209 patients. Correlation analysis showed that the PII value was significantly correlated
210 with the values of lymphocyte count, monocyte count, C-reactive protein,
211 procalcitonin, days from illness onset and body temperature (continuous variable)
212 ($p < 0.05$). The correlation coefficient values were -.260, -.258, .373, .273, .287, .544
213 respectively. The chest CT findings of the patients were shown in Table 3.

214

215 Discussion

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

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

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

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

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

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

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

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

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

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395 Table 1: Characteristics and clinical manifestations ~~of them~~ 80 patients with
 396 [COVID-19](#) ~~2019-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%)

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

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408 Table 2: Laboratory and physical examination results ~~in~~of the 80 patients with
 409 [COVID-19 SARS-CoV-2](#) ~~2019-nCoV~~ infection.

	Patients (n=80)
White blood cell count, $\times 10^9/L$	5.40 (4.20-6.95)
Increased	10 (10%)
Decreased	7 (9%)
Neutrophil count, $\times 10^9/L$	3.74 (2.67-5.20)
Increased	16 (20%)
Decreased	5 (6%)
Lymphocyte count, $\times 10^9/L$	1.15 (0.76-1.40)
Decreased	34 (43%)
Monocyte count, $\times 10^9/L$	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)

410 Data are n (%), n/N (%), mean (SD) or and median (IQR), where N is the total
411 number of patients with available data. Increasing means exceeding the upper limit of
412 the normal range, and decreasing means being below the lower limit of the normal
413 range. [COVID-19](#)~~2019-nCoV~~= [Corona Virus Disease 2019](#)~~2019-nCoV~~ ~~novel coronavirus~~.
414 SaO₂ = Arterial oxygen saturation. PH = Potential of hydrogen. PaCO₂ = Arterial
415 partial pressure of carbon dioxide. PaO₂ = Arterial oxygen tension. *Data available for
416 40 patients.

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429 Table 3: Chest CT findings ~~in~~ of the 80 patients with430 [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%)

431 Data are n (%), n/N (%) or mean (SD), where N is the total number of patients with

432 available data. [COVID-19= Corona Virus Disease 2019](#). GGO = ground glass opacity.

433 PII = pulmonary inflammation index.

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438 **FIGURE 1. A-C.** Chest CT of a 38 years old male. The clinical manifestations were
439 fever (38 °C), cough, expectoration, muscle pain and dyspnea. C-reactive protein and
440 procalcitonin increased. Ground glass opacity (GGO) (white triangle), consolidation
441 (white thick arrow) and interlobular septal thickening (white thin arrow) distributed
442 under the pleura were seen. Nine lung segments including the lateral basal segment,
443 posterior basal segment, posterior basal segment, anterior basal segment of the both
444 lower lobe, and the dorsal segment of the left inferior lobe were involved. In three
445 segments the lesions occupied more than 50% of the total volume. $PII = (9+3)/40$
446 $*100\% = 30\%$.

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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.

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455 **FIGURE 3.** A-C. Chest CT of a 44 years old male. The clinical manifestations were

456 fever (38.5 °C), cough, dizziness and headache. C-reactive protein increased. “spider

457 web sign” (white thin arrow) were seen. **Figure 1 a-b.** Chest CT of a 38 year old man

458 with 2019-neov infection. Ground glass opacity (GGO) (white triangle), consolidation

459 (white thick arrow) and interlobular septal thickening (white thin arrow) distributed

460 under the pleura are seen.

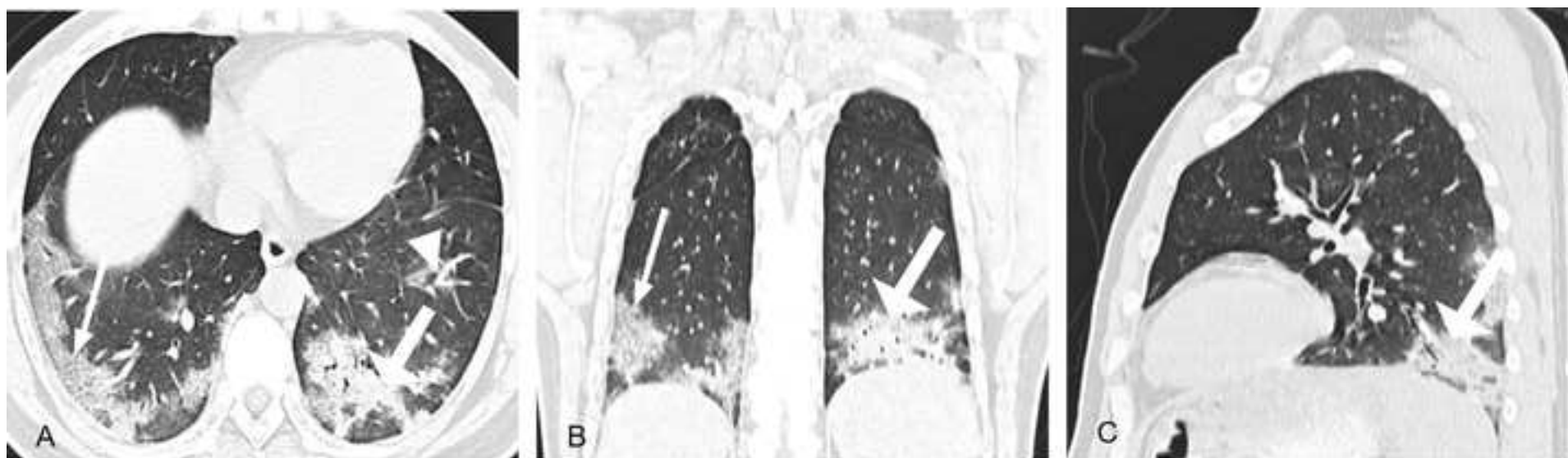
461 **Figure 2 a-b.** Chest CT of a 60 year old man with 2019-neov infection. “crazy paving

462 sign” (white thin arrow) are seen.

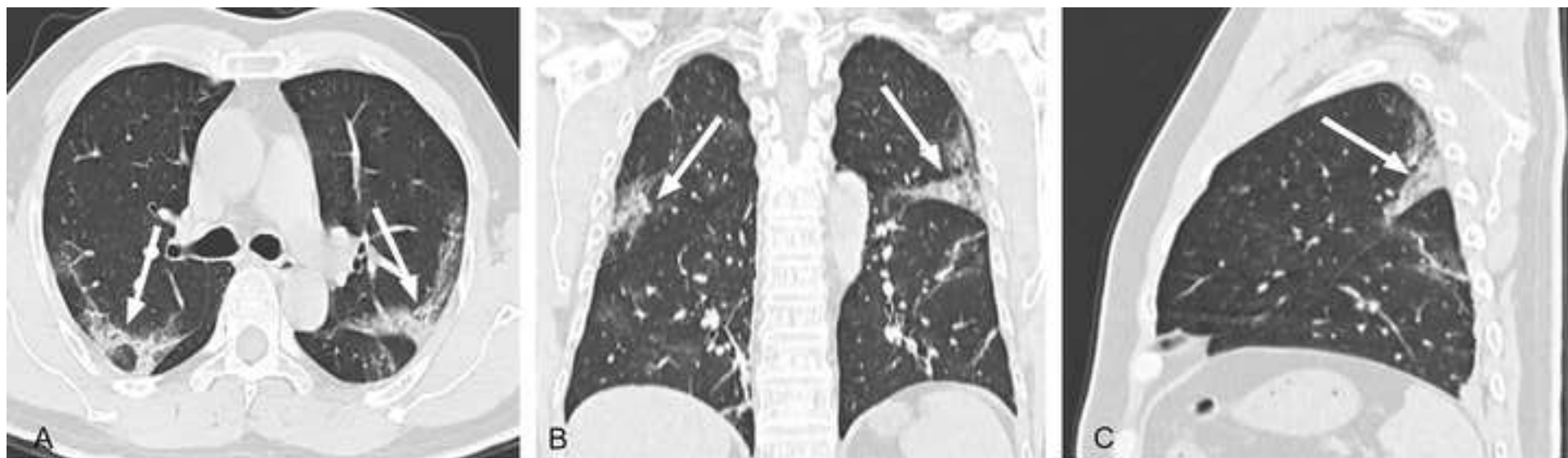
463 **Figure 3 a-b.** Chest CT of a 44 year old man with 2019-neov infection “spider web

464 sign” (white thin arrow) are seen.

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

3

4 **Abstract**

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

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

11 **Results:** Totally 80 patients diagnosed with COVID-19 were included. With regards
12 to the clinical manifestations, 58/80 (73%) of patients had cough, 61/80 (76%) of
13 patients had high temperature levels. The most frequent CT abnormalities observed
14 were ground glass opacity (GGO) (73/80 cases, 91%), consolidation (50/80 cases,
15 63%) and interlobular septal thickening (47/80, 59%). Most of the lesions were
16 multiple, with an average of 12 ± 6 lung segments involved. The most common
17 involved lung segments were the dorsal segment of the right lower lobe (69/80, 86%),
18 the posterior basal segment of the right lower lobe (68/80, 85%), the lateral basal
19 segment of the right lower lobe (64/80, 80%), the dorsal segment of the left lower
20 lobe (61/80, 76%) and the posterior basal segment of the left lower lobe (65/80, 81%).
21 The average pulmonary inflammation index (PII) value was ($34\% \pm 20\%$) for all the
22 patients. Correlation analysis showed that the PII value was significantly correlated

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

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

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

32

33 **Introduction**

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

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

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

66

67 **Materials and Methods**

68 **Patients**

69 The present study sample consisted of 80 patients who had been diagnosed as
70 COVID-19 in our hospitals (outside of the Wuhan area) from January to February
71 2020. This study received Ethics Committee approval of our institutions, and the
72 committees waived the need for individual consent due to the retrospective nature of
73 the study. The inclusion criteria were: 1. epidemiological history -either
74 travel/residence history in Wuhan or exposure history to fevered patients from Wuhan
75 suffering from respiratory symptoms within 14 days before the onset of illness; 2.
76 laboratory diagnosis - 1) real-time fluorescence polymerase chain reaction revealed
77 positive detection of SARS-CoV-2 in throat swabs or lower respiratory tract; 2) the
78 virus gene sequencing of respiratory or blood samples is highly homologous with the
79 known SARS-CoV-2. All the patients underwent thin-section CT at least one time.
80 The exclusion criteria were another confirmed concomitant pulmonary pneumonia or
81 coronavirus infection. Children and pregnant women were also excluded from this
82 study

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

88 comorbidities (including systemic hypertension, diabetes mellitus, tobacco smoke,
89 asthma, heart disease, chronic obstructive pulmonary disease (COPD),
90 immunodeficiency, and others. Information regarding the physical examination at
91 admission was also evaluated, including the heart rate (HR), body temperature,
92 oxygen saturation, and blood pressure (BP). Moreover, the laboratory data obtained at
93 admission, which included the leukocyte, lymphocyte, neutrophil, monocyte,
94 procalcitonin, and C-reactive protein (CRP), were assessed as well. Blood gas analyses
95 were performed in 40 patients whose PH value, PaCO₂ and PaO₂ were also assessed.
96 All the blood gas analysis was conducted from arterial blood samples.

97

98 **CT scans and Review**

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

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

130

131 **Results :**

132 **Characteristics and clinical manifestations**

133 This study included 80 patients diagnosed as COVID-19, of which 42 were male
134 (52%) and 38 were female (48%). All the patients aged 15-79 years with an average
135 age of 44 ± 11 years. 26/80 (33%) of patients were smokers. 61/80 (76%) of patients
136 had high temperature levels. 15/80 (18%) of patients had comorbidities, 4/80 (5%) of
137 patients had hypertension, 4/80 (5%) of patients had diabetes, 3/80 (4%) of patients
138 had COPD, 3/80 (3%) of patients had immunosuppression (immunosuppressive drugs
139 taking), 1/80 (1%) of patients had heart disease (coronary heart disease). No patients
140 had asthma or other chronic lung disease. With regards to the clinical manifestations,
141 58/80 (73%) of patients had cough, 11/80 (14%) of patients had expectoration, 5/80
142 (6%) of patients had chest pain, 13/80 (16%) of patients had muscle ache, 7/80 (9%)
143 of patients had abdominal pain or diarrhea, 9/80 (11%) of patients had pharyngeal
144 discomfort, 8/80 (10%) of patients had dizziness or headache, 7/80 (9%) of patients
145 had dyspnea and 3/80 of patients (4%) had blood in sputum. On physical examination
146 stastics, the median oxygen saturation was 97% (IQR: 96%-98%), the average heart
147 rate was 88.24 ± 11.67 bpm and the respiratory rate was 21.05 ± 3.74 breaths/min.
148 The average systolic BP was 123.46 ± 14.19 mmHg, and the diastolic BP was $80.00 \pm$
149 14.04 mmHg. Regarding the laboratory data, the median leukocyte count was 5.40
150 (IQR: 4.20-6.95) ($\times 10^9/L$), lymphocyte count was 1.15 (IQR: 0.76-1.40) ($\times 10^9/L$),
151 monocyte count was 0.41 (IQR: 0.27-0.53) ($\times 10^9/L$), neutrophil count was 3.74 (IQR:
152 2.67-5.20) ($\times 10^9/L$), respectively. The median C-reactive protein was 12.39 (IQR:
153 2.71-50.60) (mg/L) and the procalcitonin was 0.04 (IQR: 0.03-0.07) (ng/mL). Blood

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

157

158 **Chest CT findings**

159 All patients were examined by chest CT 7 ± 4 days after the onset of disease. In chest
160 CT images, 76/80 cases (95%) of the patients had abnormalities indicating the
161 pneumonia. The major CT abnormalities observed were GGO (ground glass opacity)
162 (73/80 cases, 91%), consolidation (50/80 cases, 63%) and interlobular septal
163 thickening (47/80, 59%) (Fig. 1). Besides that, 9/80 (11%) of patients had bronchial
164 wall thickening, 16/80 (20%) of patients had subpleural line, 5/80 (6%) of patients
165 had pleural effusion, 3/80 (4%) of patients had lymph node enlargement, 4/80 (5%) of
166 patients had pericardial effusion. The characteristic signs were “crazy paving sign”
167 (23/80, 29%) and “spider web sign” (20/80, 25%) (Fig. 2, 3). The “crazy paving
168 pattern” was characterized by the reticular interlobular septa thickening within the
169 patchy GGO, which had been reported in Severe Acute Respiratory Syndrome (SARS)
170 literatures.^{9,10} The “spider web sign” was the first time we found and named it. It
171 showed a triangular or angular GGO under the pleura with the internal interlobular
172 septa thickened like a net. The adjacent pleura was pulled and formed a
173 spiderweb-like shape in the corner. Most of the lesions were multiple, with an average
174 of 12 ± 6 lung segments involved. The lesions showed subpleural distribution in 42/80
175 cases (53%), diffuse distribution in 7/80 cases (9%), peribronchial distribution in 3/80

176 cases (4%) and mixed distribution in 24/80 cases (30%). The most common involved
177 lung segments were the dorsal segment of the right lower lobe (69/80, 86%), the
178 posterior basal segment of the right lower lobe (68/80, 85%), the lateral basal segment
179 of the right lower lobe (64/80, 80%), the dorsal segment of the left lower lobe
180 (61/80,76%) and the posterior basal segment of the left lower lobe (65,81%). The
181 average PII value was (34% ±20%) for all the patients. Correlation analysis showed
182 that the PII value was significantly correlated with the values of lymphocyte count,
183 monocyte count, C-reactive protein, procalcitonin, days from illness onset and body
184 temperature (continuous variable) (p<0.05). The correlation coefficient values were
185 -.260, -.258, .373, .273, .287, .544 respectively. The chest CT findings of the patients
186 were shown in Table 3.

187

188 **Discussion**

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

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

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

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

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

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

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

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

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

269

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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%)

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

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

	Patients (n=80)
White blood cell count, $\times 10^9/L$	5.40 (4.20-6.95)
Increased	10 (10%)
Decreased	7 (9%)
Neutrophil count, $\times 10^9/L$	3.74 (2.67-5.20)
Increased	16 (20%)
Decreased	5 (6%)
Lymphocyte count, $\times 10^9/L$	1.15 (0.76-1.40)
Decreased	34 (43%)
Monocyte count, $\times 10^9/L$	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)

367 Data are n (%), n/N (%), mean (SD) or and median (IQR), where N is the total
368 number of patients with available data. Increasing means exceeding the upper limit of
369 the normal range, and decreasing means being below the lower limit of the normal
370 range. COVID-19= Corona Virus Disease 2019. SaO₂ = Arterial oxygen saturation.
371 PH = Potential of hydrogen. PaCO₂ = Arterial partial pressure of carbon dioxide. PaO₂
372 = Arterial oxygen tension. *Data available for 40 patients.

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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%)

386 Data are n (%), n/N (%) or mean (SD), where N is the total number of patients with

387 available data. COVID-19= Corona Virus Disease 2019. GGO = ground glass opacity.

388 PII = pulmonary inflammation index.

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392 **FIGURE 1.** A-C, Chest CT of a 38 years old male. The clinical manifestations were
393 fever (38 °C), cough, expectoration, muscle pain and dyspnea. C-reactive protein and
394 procalcitonin increased. Ground glass opacity (GGO) (white triangle), consolidation
395 (white thick arrow) and interlobular septal thickening (white thin arrow) distributed
396 under the pleura were seen. Nine lung segments including the lateral basal segment,
397 posterior basal segment, posterior basal segment, anterior basal segment of the both
398 lower lobe, and the dorsal segment of the left inferior lobe were involved. In three
399 segments the lesions occupied more than 50% of the total volume. PII= (9+3)/40
400 *100%=30%.

401

402 **FIGURE 2.** A-C, Chest CT of a 60 years old male. The clinical manifestations were
403 fever (37.8 °C), cough, expectoration and dyspnea. Neutrophil count, lymphocyte
404 count and C-reactive protein increased. “crazy paving sign” (white thin arrow) were
405 seen.
406

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