CT findings of patients infected with SARS-CoV-2

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Abstract

Objective: we aimed to describe the chest CT findings in sixty-seven patients infected by Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). Method and material: We retrospectively reviewed 67 patients hospitalized in Ruian People's Hospital. All the patients received the positive diagnosis of SARS-CoV-2 infection. The CT and clinical data were collected between January, 23 and February, 10, 2020. The CT images were analyzed by the radiologists.

Conclusion: There are 54 patients with positive CT findings and 13 patients with negative CT findings. The common CT findings in hospitalized patients with SARS-CoV-2 infection were ground glass opacities (42/54), lesions located in the peripheral area (50/54), multiple lesions (46/54), and lesions located in the lower lobes (42/54). There were some less common CT findings: air bronchogram (n=18), pleural thickening or pleural effusion (14/54), consolidation (12/54), lesions in the upper lobes (12/54), interlobular septal thickening (11/54), reversed halo sign (9/54), single lesion (8/54), cavitaties (4/54), bronchial wall thickening (3/54), intrathoracic lymph node enlargement (2/54).

Background

Since Dec 8, 2019, several cases of pneumonia cases of unknown have been reported in Wuhan, China. The disease rapidly spreaded to the whole country and even the world[1-3]. In February 2020, an increased number of patients infected with this severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) was reported around the world. Most clinical studies focused on the clinical and epidemiological features of the patients infected with SARS-CoV-2[4, 5]. The most common onset symptoms were fever, cough, and myalgia or fatigue; less common symptoms were sputum production, headache, haemoptysis, and diarrhea[4]. However, there are few reports about computed tomography (CT) findings about the patients infected with SARS-CoV-2.

Coronaviruses may produce specific features in chest CT images, such as severe acute respiratory syndrome (SARS) and Middle East respiratory syndrome (MERS)[6-9]. The typical CT findings in patients infected by SARS were ground glass opacities[9]. The SARS lesions can progress rapidly to focal, multifocal or diffuse consolidation[9]. The most common CT findings in patients infected with MERS-CoV is subpleural and basilar airspace changes[8]. In our hospital, chest CT scan was widely
used in the diagnosis and follow-up evaluation of patients infected with SARS-CoV-2. The purpose of this study was to describe the chest CT findings of laboratory-confirmed SARS-CoV-2 cases.

**Methods**

**Patients**

The approval for this study was obtained from the ethics committees of Ruian People’s hospital. The informed consent was waived. 67 patients infected by novel coronavirus were collected from Ruian People's Hospital since January 21st, 2019. We collected demographic, clinical, laboratory, treatment and prognostic data for all patients and followed up to February, 15th, 2020. The diagnosis of coronavirus disease 2019 (COVID-19) was established according to China’s National Health Commission criteria. The oral and pharyngeal swabs and deep cough sputum were tested using the 2019 new coronavirus (ORF lab/E/N gene) nucleic acid detection kit (Shanghai BioGerm Medical Biotechnology Co., Ltd).

**Imaging Techniques**

The chest scan was performed using one of the following multi-slice spiral CT scanners: Siemens SOMATOM Perspective CT Scanner (Siemens Medical Solution, Forchheim, Germany), 32-slice configurations; uCT 528 (United Imaging Healthcare, Shanghai, China), 40-slice configurations. Scanning parameters areas follows: 120kV tube voltage; adaptive tube current, 100~350 mA; Slice thickness, 1.5mm for Siemens CT, and 1.0mm for uCT.

**Image Analysis**

CT images were analyzed on a radiology PACS workstation (Greenlander version 6.0, Mindray Healthcare, Shenzhen, China). All the chest CT examinations were reviewed independently by two senior radiologists. A third senior radiologist was consulted when there was a difference of opinion. The CT imaging features were evaluated, including ground glass opacities, consolidation, air bronchogram, reversed halo sign, interlobular septal thickening, and subpleural linear shadow. The transverse distribution of the abnormalities was categorized as peripheral and central. The lesions in the outer third of the lung were defined as peripheral, and the lesions in the inner two thirds of the lung were defined as central. The distribution of lesions in the middle upper lobe and middle lower
lobe were also recorded. In addition, we also observed the presence of tree-in-bud pattern, cavitation, bronchial wall thickening, intrathoracic lymph node enlargement, and pleural effusion.

**Result**

As shown in table 1, there are 67 patients, 31 males and 36 females, with an age range of 5-72 years (median age, 44 years). Most of the patients infected with SARS-CoV-2 have lesions in the chest CT images (n=54). Common symptoms at onset of illness were fever (n=58), cough (n=52), and sputum production (n=35). Less common symptoms were chest tightness (n=12), Sore throat (n=8), diarrhea (n=5), dizziness (n=3), shortness of breath (n=4), nausea and vomiting (n=2), myalgia or fatigue (n=3), and headache (n=2). For the job type, 59 patients are self-employed, 4 patients are farmers, and 4 patients are company employees. For the type of infection source, 34 patients lived in Wuhan, 3 patients lived in Hubei province, 27 patients had a history of contact with COVID-19 patients, 2 patients had a history of contact with suspected patients, and only one patient had no histories of contact with COVID-19 patients or suspected patients. For the smoking status, two of sixty-seven patients were former smokers, three patients were current smokers, and the remaining sixty-two patients were non-smokers. There are sixteen patients with one or more of the following comorbidities: hypertension (n=11), diabetes (n=7), cancer (n=1), respiratory disease (n=1), cardiovascular disease (n=1), and connective tissue disease (n=1). After the treatment, 44 patients were cured, and the remaining 23 patients were still hospitalized.

Table 1. Demographic and clinical characteristics of 67 patients with SARS-CoV-2
|                          | Number |
|--------------------------|--------|
| Gender (male)            | 31 (46.3%) |
| Positive CT findings     | 56 (83.6%) |
| Age                      | 44 (5~72) |
| Job type                 | 4 (6.0%) farmers, 59 (88.0%) self-employed, 4 (6.0%) company employees |
| Infection source type    | 34 (50.8%) lived in Wuhan, 3 (4.4%) lived in Hubei Province, 27 (40.3%) got contact with patients, 2 (3.0%) got contact with suspected patient, 1 (1.5%) unknown |
| Smoking status           | 62 (92.5%) are non-smokers, 2 (3.0%) are former smokers, 3 (4.5%) are current smokers |
| Severe patients          | 3 (4.5%) |
| Fever                    | 58 (86.6%) |
| Cough                    | 52 (77.6%) |
| Sputum production        | 35 (52.2%) |
| Chest tightness          | 12 (17.9%) |
| Sore throat              | 8 (11.9%) |
| Diarrhoea                | 5 (7.5%) |
| Dizziness                | 3 (4.5%) |
| Shortness of breath      | 4 (6.0%) |
| Nausea and vomiting      | 2 (3.0%) |
| Myalgia or fatigue       | 3 (4.5%) |
| Headache                 | 2 (3.0%) |
| Current status           | 44 (65.7%) cured, 23 (34.3%) hospitalized |

All the patients underwent CT 1–11 days after admission (median, 4 days). There were 54 of 67 patients with lesions, and the remaining 13 patients were normal in chest CT images. As shown in table 2, fifty of the fifty-four patients had lesions in the peripheral regions (Figure 1), and four patients had lesions in the central regions. Twelve patients had abnormalities in the middle upper lobe, and
the remaining forty-two patients had abnormalities in the middle lower lobe. There were 8 patients with single lesion (Figure 2(a)) and 46 patients with multiple lesions (Figure 1). Forty-two of the fifty-four patients had ground-glass opacities (Figure 1-4) and twelve patients had isolated consolidation (Figure 2(a)). Interlobular septal thickening was identified in eleven patients. Reversed halo sign was noted in nine patients. There were eighteen patients with air bronchogram. Three patients had bronchial wall thickening. Tree-in-bud pattern was identified in one patient (Figure 5(a)). Air cavities were present in four patients (Figure 3). Pleural thickening or pleural effusion was noted in fourteen patients. Only two patients had intrathoracic lymph node enlargement (Figure 4 (d)).

Table 2. CT features in sixty-seven patients with SARS-CoV-2

| Feature                                           | Number                              |
|---------------------------------------------------|-------------------------------------|
| Peripheral/central lesions                        | 50 (92.6%) peripheral; 4 (7.4%) central |
| Lesions in middle upper/lower lobes               | 12 (22.2%) upper lobe; 42 (77.8%) lower lobe |
| Single/multiple lesions                           | 8 (14.8%) single; 46 (85.2%) multiple |
| Ground-glass opacities                            | 42 (77.8%)                          |
| Consolidation                                     | 12 (22.2%)                          |
| Interlobular septal thickening                     | 11 (20.4%)                          |
| Reversed halo sign                                | 9 (16.7%)                           |
| Air bronchogram                                   | 18 (33.3%)                          |
| Bronchial wall thickening                         | 3 (5.6%)                            |
| Tree-in-bud pattern                               | 1 (1.9%)                            |
| Air cavity                                        | 4 (7.4%)                            |
| Pleural thickening or pleural effusion            | 14 (25.9%)                          |
| Intrathoracic lymph node enlargement              | 2 (3.7%)                            |

Discussion

This study shows that multiple peripheral lesions on CT are common in patients hospitalized with SARS-CoV-2 infection. Ground-glass opacities were more extensive than consolidation in most patients. The average time interval between the onset of symptoms to the CT examination was 4.6 days. It suggested the CT findings in our study were typical for COVID-19 patients in the early stage. Given patients with a history of exposure and the imaging features mentioned above, SARS-CoV-2 infection should be recommended, and further tests would be necessary. As the exposure history
became complicated and unclear over time, the chest CT scans would play an important role in the diagnose of COVID-19. However, there were still 13 COVID-19 patients with negative chest CT findings. As far as we know, both CT and nucleic acid detection are indispensable in the diagnose.

In our study, four patients had small cavities in the chest CT (Fig. 3), and their clinical symptoms were relatively acute. The short-term progress of chest CT imaging was relatively obvious (Fig. 3). Our study reported that tree-bud pattern was identified in one case before the treatment and fully recovered after the treatment. Thus, tree-bud pattern was not considered to be a typical CT feature caused by SARS-CoV-2 due to the short duration of the COVID-19 presence. Distinguished from previous reports of viral pneumonia, cavitation, bronchial wall thickening, and pleural effusion were found in the patients infected with SARS-CoV-2 (Table 2). In fifty-four positive CT finding cases, there are 5 cases with single lesion and the maximum of major axis length is 23 mm. To our knowledge, a single lesion located in the middle of the lung with the major axis length over 30 mm is possibly not a COVID-19 lesion.

After the treatment, thirty-nine of sixty-seven patients infected with SARS-CoV-2 were cured and discharged. Repeated nucleic acid tests were performed to show SARS-CoV-2 clearance before hospital discharge. The chest CT scans before hospital discharge were also partially or fully recovered compared to the first ones after hospitalization. The partial recovery in lung lesions could be caused by the clinical lag of lung imaging. We also noticed that there were 13 cases with the progress of CT findings during the treatment, and ten of the 13 cases recovered in CT features after 10-day treatment.

There are two limitations in our study. First, our patient cohort was small. The number of severe patients was small. Recently, a large number of patients were confirmed to have SARS-CoV-2 infection. Future studies should involve a large patient population over a long follow-up period. Second, we did not perform a sequential CT study due to the urgency of sharing our CT findings of this new disease. In the next step, we will further evaluate the change of CT features during the treatment and develop a predictive outcome model based on CT imaging.

Conclusion
In summary, the CT features of patient with SARS-CoV-2 were predominantly subpleural multiple ground glass opacities in two lungs, some with consolidations. There are also less common CT features, such as air bronchogram and reversed halo sign. It is rare to observe some features, such as bronchial wall thickening, tree-in-bud pattern, and pleural effusion. The CT features can play an important role in the early diagnosis and follow-up of COVID-19 patients.

**Abbreviations**

SARS-CoV-2
Severe acute respiratory syndrome coronavirus 2
CT
Computed tomography
COVID-19
Coronavirus disease 2019
SARS
Severe acute respiratory syndrome
MERS
Middle East respiratory syndrome
PACS
Picture archiving and communication system

**Declarations**

**Ethics approval and consent to participate**

The informed consent was waived by the Institutional Review Board (IRB) of Ruian People’s Hospital.

**Consent for publication**

None

**Availability of data and materials**

Data is available and can be accessed online in the supplementary material.

**Competing interests**

None

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Authors' contributions

X. W. and C. L. wrote the manuscript; L. H. and C. Y. did the statistical analysis; J. D., Q. J., and G. S. collected the data; W. P. and Q. S. revised the manuscript and support our study. All authors have read and approved the manuscript.

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Figures

Figure 1

A male patient infected with SARS-CoV-2 who presented severe difficulty in breathing. Transverse CT performed on 6 days after onset of symptoms shows peripheral ground glass opacities (red arrow) under the pleura of the middle and lower lobes in both lungs.
Figure 2
A male patient infected with SARS-CoV-2. (a) The first CT was performed 3 days after onset of symptoms. Chest CT image shows single consolidation in the right middle lobe and air bronchogram (red arrows). (b) The second CT was performed 13 days after the treatment. Chest CT image shows tree-in-bud pattern (white arrows).

Figure 3
A male patient infected with SARS-CoV-2. (a) The first CT was performed 3 days after onset of symptoms. Chest CT image shows ground glass opacities in the lower lobe and cavities (red arrows). (b) The second CT was performed 3 days after the treatment. Chest CT image shows ground glass opacities occupying the left lower lobe (blue arrow).
A female patient infected with SARS-CoV-2. The first CT (a) and (c) was performed 4 days after onset of symptoms. The second CT (b) and (d) was performed 10 days after the treatment. Chest CT image shows ground glass opacity enlargement (red arrows) and intrathoracic lymph node enlargement (blue arrows) after 10-day treatment.
A male patient infected with SARS-CoV-2. (a) The first CT was performed 3 days after onset of symptoms. Chest CT image shows tree-in-bud pattern (red arrow). (b) The second CT was performed 2 weeks after the treatment. Chest CT image shows the tree-in-bud pattern was fully absorbed after the treatment.

Supplementary Files
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Supplementary.xls