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Chest CT imaging features and clinical outcome of coronavirus disease 2019 (COVID-19): A single-center case study in Ningbo, China

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ABSTRACT

Objective: The purpose of this study was to investigate the chest CT imaging features and clinical outcome of coronavirus disease 2019 (COVID-19) in Ningbo, China.

Methods: In this retrospective study, twenty-eight confirmed and seven highly suspected cases of COVID-19 were enrolled in Ningbo first hospital from January 26, 2020 to March 5, 2020. Cases were confirmed by real-time polymerase chain reaction (RT-PCR). The initial and follow-up chest CT imaging features, epidemiological history, and outcome were analyzed.

Results: The average age of the patients was 57.3 ± 15.3 years (range: 27–96 years), including 25 females and 10 males. On CT images, 89.3% (25/28) confirmed and 100% (7/7) suspected patients had ground-glass opacities (GGOs), and GGOs with mixed consolidations were observed in 35.7% (10/28) confirmed and 42.9% (3/7) suspected cases, most of these lesions were distributed under the peripheral of both lungs. 17 confirmed and 4 suspected cases had a history of participating in Ningbo Tian-tong Temple rituals and all had GGOs in their lungs during the initial CT scan. As of March 25, 2020, the lung lesions of our cases were significantly resolved and all patients have been discharged from the hospital.

Conclusion: The most common chest CT features are multiple bilateral and peripheral GGOs with mixed consolidations or not in the lungs of patients with COVID-19. Chest CT plays an important role in the diagnosis and monitoring treatment response of this disease. There was no reported death in our cases.

1. Introduction

Since December 2019, a cluster of patients with respiratory illness of unknown origin has emerged in Wuhan, Hubei province, China [1]. The confirmed cases were caused by a novel coronavirus, severe acute respiratory syndrome coronavirus 2 (SARS-Cov-2), infection, officially named coronavirus disease 2019 (COVID-19). It is a disease of person-to-person transmission [2]. Up to March 4, 2020, China reported a total of 80,270 confirmed cases, 520 suspected cases, 49,856 cured cases, 4,9864 cured cases, 4,9864 cured cases and 2981 deaths [3]. At present, the disease has been spreading rapidly to > 100 countries and 6 continents, leading to a serious global public health issue [4,5].

The diagnosis of COVID-19 pneumonia is dependent on the epidemiological history, clinical manifestations, chest CT findings and viral nucleic acid detection by real time polymerase chain reaction (RT-PCR). At first, the confirmed cases were almost related to Huanan seafood market in Wuhan, China [6]. Later, numerous cases have been reported to have direct or indirect close contact with individuals of COVID-19 infection from Wuhan or other infected areas [7]. Most of the patients with COVID-19 pneumonia have clinical symptoms of fever, cough, shortness of breath and so on [8]. Chest CT plays a critical role in the diagnosis of the disease and the typical imaging findings were multi-focal ground-glass opacifications at the bilateral peripheral margin, mainly involving the lower right lobe [9]. RT-PCR test remains the reference standard method for diagnosis of COVID-19 even though with a lower sensitivity (59%) compared to chest CT imaging (88%)

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However, the epidemiological characteristics, clinical and imaging manifestations, and outcome were not the same in different areas [7,11].

To date, only limited case studies have reported about the chest CT findings of COVID-19 and its temporal changes and relationship with clinical features [10,12]. Therefore, the purpose of this study was to explore the chest CT imaging features and clinical outcome for patients with COVID-19.

2. Materials and methods

2.1. Patients

This study was approved by the Institutional Review Board of Ningbo First Hospital, Ningbo, Zhejiang province, China. Informed consent was waived for the nature of this retrospective study that involved no potential interest and/or risks between the patients and researchers. All of the data was evaluated with de-identified.

A total of 28 confirmed and 7 suspected patients with COVID-19 who underwent chest CT scans in our hospital were enrolled in this study from January 26, 2020 to March 5, 2020. The following items were investigated in all patients: epidemiological history (travel and/or resident in Wuhan or close contact history to fevered persons who were confirmed or suspected with COVID-19 pneumonia within 14 days before the onset of illness), clinical manifestations (any symptoms of fever, cough, shortness of breath, muscle ache, fatigue, diarrhea, vomit, and etc.), chest CT imaging features (such as ground-glass opacity, consolidation, bronchial wall thickening, interlobular septal thickening, and etc.), laboratory examinations (blood routine test, and etc.), chest CT imaging features (such as ground-glass opacity, consolidation, and etc.), laboratory examinations (blood routine test, and etc.) and RT-PCR test for COVID-19 nucleic acid in throat swabs or lower respiratory tract. The confirmed and highly suspected cases with COVID-19 pneumonia were treated in the isolation ward. All patients were excluded from type A (H1N1, H3N2, H7N9) and B influenza viruses infection by laboratory tests.

According to the protocols from the national health commission of the people’s republic of China, the discharged criteria were: afebrile for ≥ 3 days, respiratory symptoms improved significantly, lung lesions on chest radiograph or CT were significantly resolved, and at least two consecutive negative of COVID-19 nucleic acid tests with an interval of 24 h or more [13].

2.2. Imaging acquisition and evaluation

All patients were imaged with 5 mm slice thickness CT on a 16-row multidetector CT scanner (Siemens Somatom Sensation, Siemens, Erlangen, Germany) using the routine chest protocol. The patients were scanned by our technicians in a supine position, arm raised, during breath-holding at full inspiration. All CT images were evaluated using a lung window, with a window level of − 600 HU and window width of 1400 HU. The slice thickness for reconstruction was 1.5 mm.

Two radiologists with > 20 years of experience (XZ. R and YF. T) analyzed all chest CT images independently and comparatively frame by frame and reached a consensus. The following imaging features on viral pneumonia were fully evaluated according to international standard nomenclature which were defined by the Fleischner Society and related literatures [14,15], including ground glass opacity (GGO), consolidation, bronchial wall thickening, interlobular septal thickening, and etc.

2.3. Statistical analysis

The variables were expressed as the mean ± standard deviation. The statistical comparison in different groups was analyzed by Chi-squared test. The results of the difference between the comparative tests were considered statistically significant at a 2-tailed value of p < 0.05. SPSS version 13.0 software (SPSS Inc., Chicago, IL) was used for all statistical analysis.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Patient characteristics.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variables</td>
<td>Value</td>
</tr>
<tr>
<td>Sex</td>
<td>Male 10 (28.6%) Female 25 (71.4%)</td>
</tr>
<tr>
<td>Age</td>
<td>Mean 57.3 Standard deviation 15.3 Range 27–96</td>
</tr>
<tr>
<td>Exposure history</td>
<td>Exposure to infected patients outside Wuhan 5 (14.3%) Attend to Ningbo Tian-tong temple rituals 21 (60.0%) Exposure to infected patients from Wuhan 7 (20.0%) Unknown exposure 2 (5.7%)</td>
</tr>
<tr>
<td>Symptoms</td>
<td>Fever 25 (71.4%) Cough 23 (65.7%) Shortness of breath 1 (2.9%) Muscle ache 1 (2.9%) Fatigue 2 (5.7%) Vomit 2 (5.7%) Diarrhea 5 (14.3%) No obvious symptoms 1 (2.9%)</td>
</tr>
<tr>
<td>Comorbidities</td>
<td>Diabetes 5 (14.3%) Heart disease 4 (11.4%) Hypertension 15 (42.9%) With known primary cancer 3 (8.6%) Immune diseases 2 (5.7%) Chronic obstructive pulmonary disease 0 (0%)</td>
</tr>
</tbody>
</table>

3. Results

3.1. Patient characteristics

The clinical characteristics were summarized in Table 1. A total of 35 cases were enrolled in this study, including 10 males and 25 females, with an average of 57.3 ± 15.3 years (range: 27–96 years). Twenty-eight cases were confirmed to have COVID-19 pneumonia by RT-PCR and 7 suspected cases were negative in at least three times of RT-PCR tests for COVID-19 (each test interval was > 24 h).

On admission, most cases had symptoms of fever (25/35, 71.4%) and cough (23/35, 65.7%), and other symptoms were included in Table 1. The comorbidities include hypertension (15/35, 42.9%), diabetes (5/35, 14.3%), heart disease (4/35, 11.4%), with known primary cancer (3/35, 8.6%) and immune disease (2/35, 5.7%). No patients had chronic obstructive pulmonary disease. Laboratory examination (Table 2) showed the majority of the patients had a decreased and normal level of white blood cell count (33/35, 94.3%) and lymphocyte

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Laboratory examination results of the 35 patients.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variables</td>
<td>All cases</td>
</tr>
<tr>
<td>White blood cell count (×10^9/L)</td>
<td></td>
</tr>
<tr>
<td>&lt; 3.5</td>
<td>26 (74.3%)</td>
</tr>
<tr>
<td>&gt; 3.5</td>
<td>7 (20%)</td>
</tr>
<tr>
<td>Lymphocyte count (×10^9/L)</td>
<td></td>
</tr>
<tr>
<td>&lt; 1.1</td>
<td>13 (37.1%)</td>
</tr>
<tr>
<td>&gt; 1.1</td>
<td>22 (62.9%)</td>
</tr>
<tr>
<td>C reactive protein (mg/L)</td>
<td></td>
</tr>
<tr>
<td>&lt; 4</td>
<td>24 (68.6%)</td>
</tr>
</tbody>
</table>

Reference range: white blood cell count: (3.5–9.5) × 10^9/L; lymphocyte count: (1.1–3.2) × 10^9/L; C reactive protein: (0–4) mg/L.
Initial chest CT imaging features of 28 confirmed cases and 7 suspected cases with COVID-19 in Ningbo, China.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Confirmed cases (n = 28)</th>
<th>Suspected cases (n = 7)</th>
<th>Related to Ningbo Tian-tong Temple (n = 21)</th>
<th>Not related to Ningbo Tian-tong Temple (n = 14)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground-glass opacity</td>
<td>25 (89.3%)</td>
<td>7 (100%)</td>
<td>21 (100%)</td>
<td>11 (78.6%)</td>
</tr>
<tr>
<td>Consolidation</td>
<td>10 (35.7%)</td>
<td>3 (42.9%)</td>
<td>7 (33.3%)</td>
<td>6 (42.9%)</td>
</tr>
<tr>
<td>Interlobular septal thickening</td>
<td>9 (32.1%)</td>
<td>2 (28.6%)</td>
<td>8 (38.1%)</td>
<td>3 (21.4%)</td>
</tr>
<tr>
<td>Crazy paving pattern</td>
<td>10 (35.7%)</td>
<td>4 (57.1%)</td>
<td>11 (52.4%)</td>
<td>3 (21.4%)</td>
</tr>
<tr>
<td>Subpleural line</td>
<td>8 (28.6%)</td>
<td>1 (14.3%)</td>
<td>5 (23.8%)</td>
<td>4 (28.6%)</td>
</tr>
<tr>
<td>Bronchial wall thickening</td>
<td>13 (46.4%)</td>
<td>3 (42.9%)</td>
<td>11 (52.4%)</td>
<td>5 (35.7%)</td>
</tr>
<tr>
<td>Lung lobes involved</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The left upper lobe</td>
<td>19 (67.9%)</td>
<td>3 (42.9%)</td>
<td>14 (66.7%)</td>
<td>8 (57.1%)</td>
</tr>
<tr>
<td>The left lower lobe</td>
<td>16 (57.1%)</td>
<td>3 (42.9%)</td>
<td>10 (47.6%)</td>
<td>9 (63.3%)</td>
</tr>
<tr>
<td>The right upper lobe</td>
<td>13 (46.4%)</td>
<td>2 (28.6%)</td>
<td>10 (47.6%)</td>
<td>5 (35.7%)</td>
</tr>
<tr>
<td>The right middle lobe</td>
<td>11 (39.3%)</td>
<td>2 (28.6%)</td>
<td>10 (47.6%)</td>
<td>3 (21.4%)</td>
</tr>
<tr>
<td>The right lower lobe</td>
<td>23 (82.1%)</td>
<td>3 (42.9%)</td>
<td>15 (71.4%)</td>
<td>11 (78.6%)</td>
</tr>
<tr>
<td>Subpleural distribution</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subpleural distribution</td>
<td>19 (67.9%)</td>
<td>5 (71.4%)</td>
<td>13 (61.9%)</td>
<td>11 (78.6%)</td>
</tr>
<tr>
<td>Peripheral distribution</td>
<td>22 (78.6%)</td>
<td>7 (100%)</td>
<td>17 (81.0%)</td>
<td>12 (85.7%)</td>
</tr>
<tr>
<td>Peri-bronchial distribution</td>
<td>2 (7.1%)</td>
<td>1 (14.3%)</td>
<td>3 (14.3%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Diffuse distribution</td>
<td>2 (7.1%)</td>
<td>0 (0%)</td>
<td>2 (9.5%)</td>
<td>0 (0%)</td>
</tr>
</tbody>
</table>

Counts by lung distribution area (Table 3), and these features were similar to the confirmed cases (Fig. 2). Of the 21 cases related to Ningbo Tian-tong Temple rituals, 17 were confirmed to have COVID-19 pneumonia and the remaining 4 were suspected, all of them had GGOs in the lungs during the initial CT scans, which were similar to the confirmed cases from other areas (Fig. 3).

In our 35 cases, there were no signs of pericardial effusion, pleural effusion and enlarged lymph nodes on initial CT scans. Three old patients exhibited a progress on the second CT scan, but the lesions were resolved significantly during follow-up CT scans (Fig. 4).

3.2. Chest CT imaging features and temporal changes

A total of 110 chest CT scans were performed in 35 patients, 2–5 times per patient, with an average interval of 5.6 ± 2.8 days (range: 1–20 days). The initial chest CT scans were performed at 6.1 ± 3.7 days (range: 1–16 days) after the onset illness. The chest CT imaging features of 28 confirmed cases, 7 suspected cases, and cases related to Ningbo Tian-tong Temple or not were shown in Table 3.

Of the 28 confirmed cases, the most common CT features were bilateral and peripheral GGOs, which were observed in 25 cases (Fig. 1), followed by GGOs with mixed consolidations (10/28). One patient just had micronodular foci at the subpleural basal segment of the lower lobe of the right lung. Two patients were negative on initial CT scans. Of the 7 suspected cases, peripheral GGOs were observed in all of them (Table 3), and these features were similar to the confirmed cases (Fig. 2). Of the 21 cases related to Ningbo Tian-tong Temple rituals, 17 were confirmed to have COVID-19 pneumonia and the remaining 4 were suspected, all of them had GGOs in the lungs during the initial CT scans, which were similar to the confirmed cases from other areas (Fig. 3).

In our 35 cases, there were no signs of pericardial effusion, pleural effusion and enlarged lymph nodes on initial CT scans. Three old patients exhibited a progress on the second CT scan, but the lesions were resolved significantly during follow-up CT scans (Fig. 4).

4. Discussion

By March 4, 2020, a total of > 80,000 confirmed cases with SARS-CoV-2 infection were reported in China [3]. The clinical characteristics and epidemiological history of COVID-19 have been illustrated by many studies [6–8,16]. However, the disease of COVID-19 caused varying degrees of illness and the clinical characteristics were different in different regions [7,16]. Xu et al. [7]. reported that as of early February 2020, the symptoms of patients with COVID-19 in Zhejiang province were relatively mild compared to patients in Wuhan. However, only limited studies have been reported the chest CT findings of COVID-19 pneumonia and its relationship to clinical features [12,17]. Therefore, in the present study, we investigated the CT imaging features and clinical outcome in a series of patients with COVID-19 in Ningbo,
Our results showed that the most common CT features are multiple bilateral and peripheral GGOs mixed with mixed consolidations or not in the lungs of patients with COVID-19. Chest CT plays an important role in the diagnosis and monitoring treatment response of this disease. In our sample of 35 patients, there was no reported death. Whether there is a gender difference in SARS-Cov-2 infected patients still needs systematic evaluation. Studies vary by region. Xu et al. [7] reported that most of the COVID-19 patients were male in Zhejiang province. However, no significant difference of sex ratio was revealed in SARS-Cov-2 infection in Beijing [18]. In our results, the female to male ratio is 2.5. As investigating the epidemiological history, we found that almost two thirds of the patients were related to the assembly of Ningbo Tian-tong Temple. This would be explained by the cluster characteristics of COVID-19 pneumonia as specific populations are

Fig. 2. Case 1 is a 67-year-old woman and case 2 is a 65-year-old woman, both of them had a history of attending Ningbo Tian-tong Temple assembly. The initial chest CT scan was performed on day 8 for case 1 and on day 7 for case 2 after onset illness. Similar chest CT findings were observed that a patchy ground glass opacification was seen in the subpleural area of the right lower lobe of the lung. During follow-up CT scan on day 15, which showed the lesions on both cases were obviously resolved and the size was decreased.

Fig. 3. Cases 3 and 4 are both 57-year-old females. Case 3 had a history of exposure to an infected patient outside Ningbo Tian-tong Temple, and the initial CT scan was performed on day 1. Case 4 had a history of attending Ningbo Tian-tong Temple assembly, and the initial CT scan was performed on day 4. Multi-focal GGOs and consolidations were observed on both initial CT scans. During follow-up CT scans on day 7 and 14 for case 3 and day 10 and 20 for case 4, which showed that both lung lesions were significantly resolved.
distributed in certain areas. Moreover, we compared the chest CT imaging features between the infected patients that related to Ningbo Tian-tong Temple and those from other areas. Our results showed that the imaging features were similar to each other and both had bilateral and peripheral GGOs in the lungs. Although some of the patients were older, even 96 years old, the lung lesions were resolved with varying degrees after treatment. In our study, only three patients (8.6%, 3/35) exhibited a progress on the second CT scan which was different from the cases reported by Pan et al. in Wuhan (85.7%, 54/63) [19]. This might due to no severe comorbidities were happened in our samples. No “white lung” was seen and nobody died during the course of our study.

The sensitivity and efficacy of chest CT and RT-PCR in the diagnosis of COVID-19 were compared by several studies [10,20,21]. Fang et al. [20] reported a series of 51 patients and compared the sensitivity of chest CT and RT-PCR in the detection of COVID-19 infection, and the former was much higher than the latter (98% vs. 71%). A large sample of case studies compared the efficacy of CT and RT-PCR in diagnosing COVID-19, which also revealed that chest CT scan had a higher sensitivity than RT-PCR [10]. Xie et al. [21] suggested that repeated swab tests should be recommended for highly clinical suspected cases with negative RT-PCR. However, Chinese and US radiologists show both a high variability in sensitivity (72% to 94%) and in specificity (24% to 100%) for the diagnosis of COVID-19 infection using chest CT [22]. In our results, 3 of the 28 confirmed cases showed no significant abnormalities on the initial CT scan, possibly because these patients were in the very early stage of COVID-19 pneumonia. Typical CT features of bilateral and peripheral GGOs were observed in the 7 suspected cases (negative RT-PCR). Besides, these 7 cases had clinical symptoms of fever or cough, and a history of close contact with confirmed cases. Influenza A and B infection were excluded from these patients. No evidence showed bacterial superimposed infections. Moreover, the clinical symptoms of fever and cough were relieved and the lung lesions were resolved significantly after the same treatment regimen with the confirmed cases. Therefore, chest CT plays an important role in the diagnosis of COVID-19 but not the golden criteria, a comprehensive diagnosis is very important when patients with negative RT-PCR.

To our knowledge, this is the first case study to evaluate the chest CT imaging features and clinical outcome of COVID-19 in Ningbo, China. We have all the information about the patients from admission to discharge, including the epidemiological history, clinical features, laboratory analysis and temporal changes of chest CT images. Therefore, to some extent, it can reflect the characteristics of patients with COVID-19 in Ningbo. However, there are some limitations in our study. First of all, the number of the patients enrolled in this study was relatively small owing to a single-center case review. Second, the time from onset illness to the initial chest CT scan was inconsistent, and the time interval of each follow-up CT scans was different, so the temporal changes of CT imaging features to different patients could not be accurately evaluated.

In conclusion, our results showed that the most common CT features are multiple bilateral and peripheral GGOs with mixed consolidations or not in the lungs for patients with COVID-19. Chest CT plays an important role in the early diagnosis and evaluating treatment response of this disease. The diagnosis of COVID-19 should integrate the epidemiology history, clinical symptoms, laboratory test and CT features when RT-PCR test was negative. There was no reported death in this series of cases. Due to small sample size, multicenter research with a large sample size is warranted.

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Declaration of competing interest
There are no conflicts of interest.

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