Correlation Between Quantitative Assessment of Chest Computed Tomography (CT) Imaging and Prognosis of COVID-19 Patients

Background: The aim of our work was to evaluate the correlation between the quantitative parameters of the peak lesion to 25% improvement time (PIT\(_{25}\)) and the prognosis of new coronavirus pneumonia (COVID-19) patients by analyzing the changes of chest CT imaging.

Material/Methods: This retrospective analysis included 68 patients with COVID-19 in the Fifth People’s Hospital of Suzhou City. Three radiologists performed a blind evaluation of 4 chest CT images that included the initial scans, the lesion peak, the lesion decreased to 25% of the peak, and the final scan. The score of chest CT lesion, the imaging characteristics of the lesion, the time of the appearance of symptoms related to the CT examination, quantitative assessment of PIT\(_{25}\), and the absorption of the lesion in last CT image were analyzed. Patients were divided into an obvious absorption group and a non-obvious absorption group according to the reduction of the lesion area by greater than 50% or less than 50%.

Results: In the peak time, the most common images of CT were ground-glass opacities (94.1%), consolidation (85.3%) and reticulation (88.2%), multifocal (97.1%), center and subpleural (54.4%), subpleural distribution (45.6%), and pleural thickening (79.4%). The PIT\(_{25}\) with the prognosis \((r=0.53, p=0.00)\) was significantly relevant. PIT\(_{25}\) was 4.3±0.7 days for the obvious absorption group and 6.8±1.4 days for the non-obvious absorption group.

Conclusions: The features of CT image are specific at the peak. The quantitative parameter PIT\(_{25}\) could be used to predict the prognosis of the patients with COVID-19, as COVID-19 patients with a shorter PIT\(_{25}\) have a better prognosis and vice versa.

MeSH Keywords: Coronavirus • Lung Diseases • Tomography Scanners, X-Ray Computed

Abbreviations: CT – computed tomography; COVID-19 – Coronavirus Disease 2019; SARS-CoV-2 – Severe Acute Respiratory Syndrome Coronavirus 2; SARS-CoV – Severe Acute Respiratory Syndrome Coronavirus; MERS-CoV – Middle East Respiratory Syndrome Coronavirus; qRT-PCR – quantitative real-time polymerase chain reaction; GGO – ground-glass opacity; CRP – C-reactive protein
Background

On January 30, 2020, the World Health Organization (WHO) declared Coronavirus Disease 2019 (COVID-19) as a Public Health Emergency of International Concern, which was first reported from Wuhan, China, on December 31, 2019 [1]. There were 98,023 reported cases of COVID-19 globally, and 3380 deaths as of March 6, 2020. COVID-19 is mainly transmitted human-to-human through respiratory droplets and contact [2], and has created a major public health crisis [3]. So far, the disease has caused a global pandemic, spreading in more than 100 countries.

COVID-19 is caused by a new coronavirus called severe respiratory syndrome coronavirus 2 (SARS-CoV-2) [4] which is an enveloped, non-segmented, positive-sense RNA virus belonging to the Coronaviridae family and the order Nidovirales, and widely occurs in humans and other mammals [5,6]. SARS-CoV-2 is a β-coronavirus that was speculated to originate from the Rhinolophus bat [7].

The target cells of the virus are located in the lower respiratory tract, causing damage to the lungs and causing nonspecific symptoms such as fever, cough, and headache. The most important techniques for diagnosis of COVID-19 are nucleic acid detection and computed tomography (CT). Some studies have summarized the imaging characteristics of COVID-19 [8–10]. These studies were mainly qualitative and showed that the imaging manifestations of COVID-19 were bilateral multiple ground-glass opacities with patchy consolidation by the modality, density and distribution of the lesions. Pan et al. used CT to evaluate the severity of lung involvement in the different stages of COVID-19 infection [11], but the actual progression of the lung lesion is still unclear and tools to predict its prognosis are lacking [12]. Although chest CT re-examination can intuitively evaluate the condition and assist clinical diagnosis and treatment, it also plays a huge role in observing the change and outcome of the disease. The use of CT imaging for predicting the final outcome of the disease needs to be clarified. The purpose of this study was to evaluate the correlation between the quantitative parameters of CT images and prognosis of COVID-19 patients by the quantitative assessment of PIT25 (the time from the highest peak lesion decreased to 25% of highest peak lesion) in chest CT imaging. Our results may provide a basis for clinical CT examination specifications.

Material and Methods

Patients and clinical data

In Suzhou city, China, there were 87 confirmed cases of COVID-19 included From January 20, 2020 to March 2, 2020, according to the criteria established by the Chinese Center for Disease Control and Prevention by using quantitative real-time polymerase chain reaction (qRT-PCR). This retrospective study was approved by the Fifth People’s Hospital of Suzhou Institutional Ethics Review Board. No informed patient consent was required.

We recorded the time of symptoms onset of the 87 patients. Eight cases were excluded for lack of pneumonia in CT images, 9 cases were excluded because the lesions too mild to be evaluated, and 2 cases were excluded because they were severe without PIT25 showing. Therefore, 19 cases were excluded and 68 patients were included in our study. Figure 1 indicates the specific examination steps and evaluation process.

The clinical data were recorded, including age, sex, and symptoms, including fever (body temperature >37.3°C), cough, fatigue, nasal congestion, headache, pharyngeal discomfort, chills, dyspnea, and occasional diarrhea. We also collected data from...
laboratory test results, such as lymphocyte count, lymphocyte ratio, and CRP (C-reactive protein).

At the end of our study period (Mar 2, 2020), CT examinations were conducted. The CT scans were obtained every 3–4 days from the day the patients were initially hospitalized to the day the patients were finally discharged. Based on the CT images, we defined the initial lesion, the peak of the lesion, the 25% of the peak lesion, and the last CT examinations. The initial CT was defined as the first CT examination in our hospital, and the peak CT of the lesion was defined as the most extensive and severe CT examination. The 25% of the peak lesion was defined as the size of lesion decreased to 25% of the peak lesion in CT imaging. The last CT imaging was defined as the CT imaging obtained 14 days after the patient was discharged from the hospital. A patient who was discharged from the hospital must meet 4 criteria: afebrile, significant improvement of respiratory symptoms, negative result of nucleic acid test, and significant inflammation absorption in lung images. Based on the decrease of the peak lesion and last CT images, cases were divided into 2 groups of prognoses: an obvious inflammation absorption group (≥50) and a non-obvious inflammation absorption group (≤49).

CT scanning

All patients were scanned using the same equipment (GE Bright Speed Elite 16). The scanning parameters were: tube voltage 120 kV, automatic tube current modulation, pitch 1.0, rotation time 0.5 s, slice thickness 5 mm, matrix 512×512, and field of view 350×350 mm. All images were then reconstructed with a slice thickness of 0.625 mm.

Imaging evaluation and analysis

All CT images were carefully reviewed by 3 radiologists who each had more than 10 years of work experience. The reviewers were blinded to the identity, clinical status, and outcome of each patient. The CT images of all patients were recorded at the initial, the time of the peak lesion, and the time of 25% of the peak lesion (PTI25), and the last scan. The CT signs including ground-glass opacity, reticulation, consolidation, distribution (right lung, left lung, 2 lungs, center, subpleural), and other findings (pleural thickening, thoracic lymph gland, pleural effusion). Moreover, an estimation of approximate size of the abnormalities was recorded according to the percentage of lung involvement for each patient. The lesion score was evaluated in each lobe, with 0 for no lesions, 1 for less than 25%, 2 for 25–49%, 3 for 50–75%, and 4 for more than 75%. Qualitative results were summarized according to consensus. The mean percentage of lung involvement assessed by the 3 reviewers was calculated for quantitative assess of the progression.

The onset of clinical symptoms was defined as day 1, and the initial CT examination of each patient was taken, and the subsequent CT examinations were carried out according to the disease development and expert’s evaluation. The peak time and PTI25 were recorded, and the time interval between the time of peak lesion and the time of 25% of the peak lesion was defined as the PTI25.

Statistical analysis

The statistical analyses were carried out using Statistical Product and Service Software (SPSS ver. 26.0, Chicago, IL, USA). Descriptive statistics were used to assess clinical data and some basic information of CT images. Correlations between PTI25 and prognosis were evaluated by using Pearson’s correlation analysis or Pearson’s chi-square test, and the difference was statistically significant at P<0.05.

Results

Patient demographics and clinical findings

For the 68 cases confirmed with COVID-19 in our study, their ages ranged from 22 to 70 years old (mean: 47.8 years old; standard deviation: 13.2 years old), with 39 males (57.4%) and 29 females (42.6%). Fever (73.5%) and cough (76.5%) were the main onset symptoms of the patients. The other symptoms were pharyngeal discomfort (22.1%), fatigue (17.6%), chill (2.9%), headache (2.9%), muscle ache (22.1%), rhinobyon and runny nose (5.9%), chest tightness (7.4%), short of breath (4.4%), dyspnea (1.5%), diarrhea (4.4%), and nausea and vomiting (7.4%). In the peak time, the clinical symptoms changed as fever accounting for 29.4% and cough for 14.7%, and the other symptoms gradually reduced or disappeared later. The first time of laboratory examinations results in our hospital indicate that 27 cases of lymphocyte reduced (39.7%), 23 cases of lymphocyte ratio reduced (33.8%), and 38 cases of CRP rose (55.9%) when first symptoms onset. The laboratory examinations results obtained at the peak CT scan time in our hospital indicate that 23 cases of lymphocyte reduced (33.8%), and 19 cases of lymphocyte ratio reduced (27.9%), and 36 cases of CRP rose (52.9%) in the peak time (Table 1).

Chest CT images in peak and 25% improvement

The most common features of CT images of COVID-19 in peak time were ground-glass opacities (94.1%), consolidation (85.3%), reticulation (88.2%), multifocal (97.1%), center and subpleural (54.4%), subpleural distribution (45.6%), and pleural thickening (79.4%). There were ground-glass opacities (97.1%), consolidation (80.9%), reticulation (89.7%), multifocal (97.1%), center and subpleural (47.1%), subpleural distribution (51.5%),
and pleural thickening (80.9%) in 25% improvement (Table 2). Thoracic lymph gland was rare, and only 1 patient was seen (1.5%) in lung findings at the peak time. The mean scores of the initial CT images, the images in peak time, and those with 25% improvement were 4.8, 5.9, and 4.7, respectively. The mean score of the scan in peak time was the highest. Furthermore, the mean score of each lobe was also calculated as shown in Table 3 and Figures 2, 3.
Table 3. Imaging score of pulmonary lesions by disease course.

| Disease course                | Scores* by lobe |                  |                  |
|-------------------------------|-----------------|------------------|------------------|
|                               | Right upper lobe| Right middle lobe| Right lower lobe |
| Initial (n=68)                | 0.9             | 0.7              | 1.3              |
| Peak (n=68)                   | 1.0             | 0.7              | 1.7              |
| 25% Improvement (n=68)        | 0.9             | 0.6              | 1.3              |
| Total                         | 4.8             | 5.9              | 4.7              |

* Data are mean.
Figure 2. (A–I) A 39-year-old man with COVID-19. A–C = day 7, D–F = day 10, G–I = day 33, PIT = 3 days. (A–C) In the peak CT, chest images obtained on day 7 from symptoms onset. Chest axial image A, coronal reconstruction image B, and sagittal construction C show mixed lesions of GGO and reticulation in bilateral lower lobes, which are distributed in subpleural area (white arrow). (D–F) In the 25% improvement CT, chest images obtained on day 10 from symptoms onset. Chest axial image A, coronal reconstruction image B, and sagittal construction C show the lesions absorbed in the lower lobe, mainly in the left lung (short black arrow), and some of them transformed into consolidations (long black arrow). (G–I) In the last CT, chest images obtained on day 33 from symptoms onset. Chest images show the lesions in bilateral lung absorbed well.
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CLINICAL RESEARCH

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A

B

C

D

E

F
Correlation between CT images and clinical and prognostic classification

The relationship of PIT$_{25}$ and the prognosis of patients were analyzed. The results showed they are significantly relevant ($r=0.53$, $p=0.00$). The PIT$_{25}$ of 68 cases was 4.9±1.3 days. The PIT$_{25}$ in the obvious improvement (≥50%) group with 56 patients was 4.3±0.7 days, and the PIT$_{25}$ of the non-obvious improvement group (≤49%) with 12 patients was 6.8±1.4 days, which showed a significant difference between the 2 groups (Table 4).

Table 4. Radiographic disease progression by disease pattern.

| Pattern                | No. of patients | Mean age (yr) | Disease parameters (days) | PIT$_{25}$ |
|------------------------|-----------------|---------------|---------------------------|-----------|
| A: Obvious improvement | 56              | 47.4±14.1     | 10.8±4.9 (n=56)           | 4.3±0.7 (n=56) |
| B: Unobvious improvement | 12              | 49.8±8.0      | 13.2±4.8 (n=12)           | 6.8±1.4 (n=12) |

PIT$_{25}$ – the peak to 25% improvement time.

Discussion

COVID-19 is recognized as a global health hazard. Its clinical symptoms are atypical, and are similar to the common cold, such as fever and cough. We observed 68 patients and found...
that the incidence of fever and cough at the peak time is lower than that at symptoms onset. This finding illustrates the inconsistency between clinical symptoms and pulmonary lesion of CT images. In the early course of the disease, fever is caused by the response to viral infections, and cough is induced by part of the bronchial airway damage. At the peak time, cough is mainly attributed to deep or peripheral lung lesions, but pathological damage in this period has not been repaired or eliminated. Symptomatic medication can also relieve symptoms during hospitalization.

In our study, we noted that the scores in peak time were related to the laboratory test results, such as lymphocyte count, lymphocyte ratio, and CRP. This was in agreement with previously published results [5]. At the peak time, the lesions of the lung became so serious that they might cause the body’s immune response and this response to the virus might induce the pathophysiological changes, and could reduce lymphocyte action. All patients were transferred to our hospital for isolation and treatment after they were confirmed or suspected to have COVID-19.

A study has shown that CT images play an important role in early screening and diagnosis of COVID-19 [13]. In our study, we focused on CT images of the initial, the peak, and the 25% improvement of pulmonary involvements, and their lesion scores were 4.8, 5.9, and 4.7 on average, respectively. CT images at the peak time showed that the abnormal attenuations were highly involved bilateral multiple lung lobes and distributed in the subpleural and center areas of the lungs. The main signs were ground-glass opacities, consolidation, and reticulation, and these overlapped with each other. The above typical signs of CT images were similar to previous studies [14], but not exactly the same. First, the incidence of consolidation was higher than in previous studies. Second, the lesion in the center was more common in our study compared to other studies [15]. The reasons for these different may that we chose different parameters to judge the prognosis of COVID-19. We note that PIT25 may be used to predict the prognosis of COVID-19. In our study, there were 56 cases in which the lung lesions had good improvement the in obvious absorption group. In this group, the lesions of 3 cases completely recovered or disappeared, while other cases obviously improved. The lesion improved quickly, which was consistent with previous reports of COVID-19 [10], but which is inconsistent with other viral infections. The changes of 25% improvement of the lesions were mainly manifested in the reduction of the lesion area, the reduction of ground-glass opacity, and the increase of consolidation and reticulation. However, no case completely recovered within 3 days at the peak time. It was worthwhile to mention a special case, a woman at 30 weeks pregnancy, who developed hypoxemia and underwent immediate surgery because both the mother and baby were in danger. A series of CT scans were performed, the total score of bilateral lungs was 10 points, and the left lower lobe given 4 points from the peak CT images. PIT25 was 4 days when the score dropped to 6. After emergency surgery, the patient had good recovery. In our study, the 12 patients who had lung lesions absorbed in an unapparent way were assigned to the non-obvious improvement group. In these cases, the extent of the lesion did not change significantly compared with the obvious improvement group. However, the density of the lesions may change, mainly manifested as ground-glass opacities or reticulation, which was a typical symptom for fibrosis that needs a longer time to recover or has caused irreversible damage. Among the cases excluded in this study, 9 cases had too few lesions to determine the peak time, and 2 severe cases did not show PIT25. Therefore, combined with clinical practice, PIT25 could be used to predict the prognosis and is beneficial to reduce the frequency and delay the interval between CT scans.

Our study has several limitations. Firstly, the premise of this study is the cases of Suzhou China under the condition of standardized protective control management and diagnosis management from the beginning. So, it may only represent our region instead of the whole country or the world. Secondly, the follow-up period of these 68 cases is not sufficient, and further research is needed.
Conclusions

In summary, this study describes a classification of prognosis in COVID-19 patients according to the extent of lesions diagnosed by CT images in Suzhou, China. From our study, we have proposed a new quantitative indicator, PIT\textsubscript{25}, to assess the prognosis of the disease which is the time from the highest peak lesion decreased to 25% of highest peak lesion. The results showed that PIT\textsubscript{25} has a good correlation with prognosis, and could be used to predict the outcome of patients, evaluate treatment effects, and reduce the frequency of CT examinations.

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