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RESEARCH PAPER

CT Imaging Features and Clinical Characteristics of 2019 Novel Coronavirus Pneumonia (COVID-19) During Rehabilitation

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Abstract

This study aims to explore the clinical characteristics of the patients with novel coronavirus pneumonia (COVID-19) during rehabilitation. One hundred and twelve confirmed patients were enrolled, while 72 were females (64.3%) and 40 were males (35.7%). The age of the patients was 51.63 ± 4.07 years old. Those patients were divided into mild group, moderate group and severe group based on lesion volume and proportion of total lesion on CT images. The age, gender, past medical history, finger pulse oxygen (SPO2), heart rate (HR) and body temperature and other clinical characteristics of patients were collected. Lesion volume was measured by CT. Compared with mild group, age, lesion volume and total lesion proportion in moderate group were significantly higher. Age, lesion volume and total lesion proportion in severe group were also higher than those in moderate group. Age and past medical history were the risk factors for the lesion volume of COVID-19. Older the patient has larger CT lesion range ($R = 0.232$, $P = 0.045$). Without past medical history or combination of post-medical history, the COVID-19 patients had smaller CT lesion ranges, and the history of previous cardiovascular disease and pulmonary disease was important risk factors for the larger CT lesion ranges. The patients who were older or combined with chronic diseases, especially cardiovascular diseases, respiratory disease and diabetes, tended to have the larger lesions. Age and past medical history of patients with COVID-19 period are significantly related to the lesion volume and total lesion proportion on CT images.

Keywords 2019 novel coronavirus pneumonia · Rehabilitation period · CT image · Lesion · Risk factor

Abbreviations

COVID-19	2019 Novel coronavirus pneumonia
SPO2	Finger pulse oxygen
HR	Heart rate
WHO	World Health Organization
SD	Standard deviation
ANOVA	Analysis of variance

1 Introduction

Since December 2019, multiple cases of pneumonia with unknown causes were found in Wuhan City, Hubei province, China. On January 12, 2020, the pathogenic pathogen was named novel coronavirus (2019-nCoV) by the world health organization (WHO) (Han et al. 2020). Subsequently, 2019-nCoV spread rapidly in China and other countries. Moreover, the sharp increase in the number of cases has caused widespread panic among the people.

2019-nCoV belongs to the β genus coronavirus, and its genome is more than 85% homologous to the highly contagious bat SARS-like coronavirus (bat sl-CoVZC45) (Xie

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and Chen 2020). The mode of transmission is respiratory droplets (cough, sneeze) and contact, and the population is generally susceptible (Chu et al. 2020; Wang et al. 2020). Fever, dry cough, fatigue, chest tightness and other symptoms may occur after infection (Ye et al. 2020). Most of patients have good prognosis, and some of them have mild symptoms without obvious fever. In severe cases, patients may develop respiratory distress syndrome, even accompanied by sepsis, and eventually die due to multiple organ failure, which seriously threatens the life and health of patients (Li et al. 2020a). According to the diagnosis and treatment of coronavirus disease-19 (7th trial edition), after the patient is discharged from the hospital, it is recommended to continue the isolation management and health monitoring for 14 days (Rasmussen et al. 2020; Lin and Li 2020). The discharged patient is arranged to stay at isolation point or rehabilitation station.

Early studies on radiological follow-up of COVID-19 pneumonia showed residual abnormalities at follow-up CT scan, with a high prevalence, especially in the short- and medium-term (Besutti et al. 2022). The clinical significance of these abnormal findings is unclear, and the degree of persistency of residual pulmonary abnormalities will remain uncertain. In order to explore the correlation between imaging features and other clinical characteristics, the clinical characteristics of the patients infected with 2019-nCoV who were in rehabilitation period were collected and analyzed retrospectively in the present study.

2 Materials and Methods

2.1 Patients

A total of 112 confirmed patients with COVID-19 who recovered from makeshift hospital of Jianghan University between February 2020 and March 2020 were enrolled in this retrospective study. The methods of this retrospective study were adopted with reference to the diagnosis and treatment of coronavirus disease-19 (7th trial edition) (Rasmussen et al. 2020; Lin and Li 2020). Those patients were transferred from square cabin hospital, and their nucleic acid test turned negative. The courses of disease were basically the same, and the treatment period in square cabin hospital was 2 weeks. Inclusion criteria: patients who had a clear epidemiological exposure history and clinical symptoms and/or pulmonary imaging features of COVID-19 according to the diagnosis and treatment of coronavirus disease-19 (7th trial edition) (Rasmussen et al. 2020; Lin and Li 2020). Exclusion criteria: (1) patients who had serious organic diseases including heart, liver and lung (e.g., acute onset of cardiogenic diseases, pulmonary tuberculosis, pulmonary bullae, emphysema, lung tumor, mediastinal tumor, etc.); (2) patients with mental illness; (3) patients with diseases of the immune system; and (4) patients with diseases of the blood system, malignant tumors and other diseases that affect the results. This study was approved by the Ethics Committee of Wuhan First Hospital. All patients gave informed written consent to participate in the study.

2.2 Grouping

Those patients were divided into mild group ($n = 62$), moderate group ($n = 35$) and severe group ($n = 15$) based on lesion volume and total lesion proportion on CT images. Mild type: the clinical symptoms were mild; no pneumonia was found in imaging. (The proportion of total lesions on CT image was less than 1%.) Moderate type: there are fever, respiratory tract and other symptoms; pneumonia can be seen in imaging. (The proportion of total lesions on CT image is more than or equal to 1% and less than 10%.) Severe type: Adults meet any of the following criteria: (a) shortness of breath, RP $\geq$ 30 times/min; (b) low oxygen saturation under resting state $\leq$ 93%; (c) PaO2/FiO2 $\leq$ 300 mmHg (1 mmHg = 0.133 kPa); (d) pulmonary imaging showed that the lesions progressed more than 50% in 24–48 h. (The proportion of total lesions on CT image is more than or equal to 1% and less than 10%.)

2.3 Measurement

The CT equipment was obtained from Lianying uCT520 (Shanghai Lianying Medical Technology Co., Ltd., Shanghai, China), the software cloud platform was provided by Beijing Shenrui Technology Co., Ltd. (Beijing, China), and AI intelligence was used to calculate the lesion volume (CT, cm^3) and the total lesion proportion (CT, %). Pulse oximeter was provided by CONTEC (Qinhuangdao, Hebei, China). When SPO2 was measured, the patient sat down in a resting state. Heart rate (HR) was measured by Kapatch hand-held ECG card (Hangzhou Proton Technology Co., Ltd., Hangzhou, China), when the patient sat down in a resting state. The axillary temperature was measured by ordinary mercury thermometer for 5 min.

2.4 Clinical characteristic collection

The age, gender, past medical history, finger pulse oxygen (SPO2), heart rate (HR) and body temperature and other clinical characteristics of patients were collected.

2.5 Statistical analysis

SPSS22.0 (International Business Machines, corp., Armonk, NY, USA) was used for statistical analysis. The

measurement data were expressed as means ± standard deviation (SD). Data satisfying normal distribution were assessed by one-way analysis of variance (ANOVA), while non-normal distribution data were assessed by non-parametric test. After univariate analysis, variables with statistical significance were selected and included in logistic regression analysis to investigate the independent sensitivity index of the lesion range in patients with COVID-19 in rehabilitation period. $P < 0.05$ was considered statistically significant.

3 Results

3.1 Clinical characteristics of convalescent patients with COVID-19

Among the 112 convalescent patients with COVID-19, 72 were females (64.3%), and 40 were males (35.7%). There was no significant difference of gender among the three groups ($P > 0.05$). Those patients aged 20–76 years old, with a median age of 51.63 ± 4.07 years old. Patients in moderate group were notably older than those in mild group, and patients in severe group were also markedly older than those in moderate group (46.61 ± 1.72 vs. 57.40 ± 1.37 vs. 58.87 ± 2.99; $P < 0.05$, respectively). Furthermore, there were 33 patients (29.5%) with post-medical history, mainly including respiratory diseases (asthma/bronchitis, etc.), cardiovascular diseases (hypertension/angina pectoris/supraventricular tachycardia, etc.), diabetes and others (insomnia/anxiety disorders, etc.). However, there were no significant differences in SPO2, HR and axillary temperature among the three groups ($P > 0.05$). Clinical characteristics of convalescent patients with COVID-19 are shown in Table 1.

3.2 CT images

Based on the current clinical practice, those patients with COVID-19 were divided into mild group, moderate group and severe group. The CT lesion proportion and CT infection volume among the three groups were compared. As shown in Table 1, there were significant differences among the three groups ($P < 0.05$). The lesion volume and total lesion proportion in moderate group were significantly higher than those in mild group, and the lesion volume and total lesion proportion in severe group were significantly higher than those in moderate group ($P < 0.05$). Typical CT images are shown in Fig. 1.

3.3 Analysis of influencing factors

Multiple logistic regression analysis was performed in COVID-19 patients to analyze the risk factors affecting the occurrence of COVID-19. Age, gender and post-medical history were independent variables, and the severity of COVID-19 CT lesion was dependent variables. In the statistical analysis, the past medical history of chronic diseases was divided into five categories in the following order: respiratory disease, cardiovascular disease, diabetes, others and no special past history. The results showed that the older the patient was, the larger the CT lesion range of COVID-19 convalescent patients was ($R = 0.232$, $P = 0.045$). Without past medical history or combination of post-medical history, the COVID-19 patients had smaller CT lesion ranges, and the history of previous cardiovascular disease and pulmonary disease was an important risk factor for the larger CT lesion ranges (Table 2). The past medical history of patients in the three groups is shown in Table 3. There were 52, 25 and 8 patients having past medical history in mild, moderate and severe groups, respectively.

4 Discussion

Before releasing from isolation, the patients infected with COVID-19 should be performed with CT examination. The first choice is a volumetric CT scan with a thickness of 5 mm, in which all above 16 layers of CT can be achieved. The reconstruction should be a thin layer of 1.0–1.5 mm. Based on thin-slice CT reconstruction, observation in cross section, sagittal plane and coronal plane is conducive to assess lesion changes and find subtle changes that DR is difficult to observe (Li et al. 2020c). There is a lack of systematic radiological findings and case–control data.

Table 1 Clinical characteristics of convalescent patients with COVID-19

Items	Mild group	Moderate group	Severe group	*F*	*P*
Age (years old)	46.61 ± 1.72	57.40 ± 1.37	58.87 ± 2.99	12.53	< 0.05
Total lesion proportion (CT, %)	0.18 ± 0.03	3.32 ± 0.34	25.87 ± 3.66	148.35	< 0.05
lesion volume (CT, cm^3)	9.40 ± 1.40	131.16 ± 13.15	845.35 ± 158.52	84.18	< 0.05
SPO_2 (mmHg)	98.06 ± 0.12	97.91 ± 0.16	97.93 ± 0.23	0.33	> 0.05
HR (times/min)	94.02 ± 1.21	94.37 ± 2.38	91.13 ± 1.73	0.51	> 0.05
T (°C)	36.40 ± 0.04	36.33 ± 0.06	36.43 ± 0.08	0.72	> 0.05

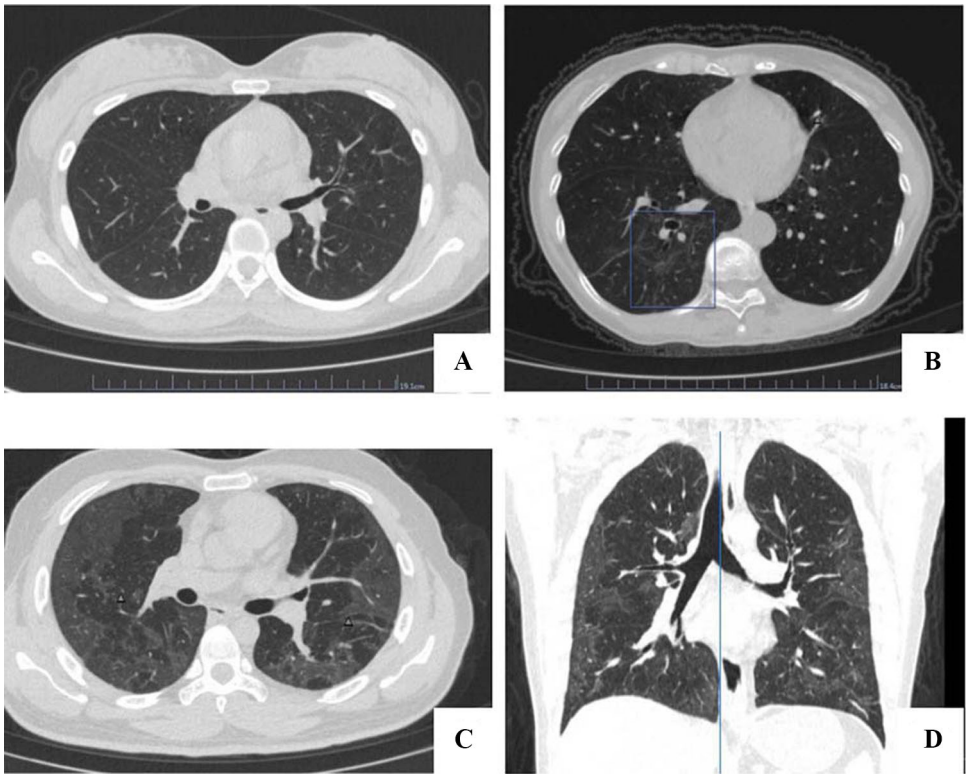

Fig. 1 Typical CT images of patients with COVID-19. **A** This was a female patient with 36 years old in mild group. CT image showed no obvious abnormal high and low-density shadow in both lungs. **B** This was a female patient with 41 years old in moderate group. The lamellar ground glass shadow was observed in the dorsal segment, inner basal segment, anterior basal segment, outer basal segment and posterior basal segment of the lower lobe of the right lung. The maximum layer area was about 30.49 cm^2, and the volume was about 96.73 cm^3. **C**, **D** This was a male patient with 37 years old in severe group. The flaky ground glass density shadow was observed in the dorsal segment, anterior inner basal segment, outer basal segment and posterior basal segment of the left lower lobe, with the maximum layer area of about 122.33 cm^2 and volume of about 1277.52 cm^3

Table 2 The multivariate logistic regression analysis

Items	*B*	SE	*t*	*P*
Age	0.02	0.01	4.31	< 0.05
Sex	− 0.176	0.13	− 1.37	> 0.05
Past medical history	− 0.106	0.05	− 2.02	< 0.05

Table 3 Past medical history in the three groups

Groups	Past medical history		Sum up
	Yes	No	
Mild group	52	10	62
Moderate group	25	10	35
Severe group	8	7	15
Sum up	85	27	112

In this study, the CT manifestations of patients with COVID-19 were classified as mild, moderate and severe groups according to the range of lesions in CT image. In the recovered population, most of the mild patients had no abnormal findings on CT image. CT findings in moderate group showed multiple patchy ground glass shadows in one or both lungs. This result presented as fine mesh shadows or "pavement stone signs" (Dai et al. 2020). It can also appear as a very thin ground glass shadow, with localized ground glass shadows around small blood vessels. CT findings in severe group showed patchy ground glass shadows in large areas of both lungs, and "white lung" existed when most of both lungs were involved. Those results were similar with previous study (Li et al. 2020b).

The ratio of patients remained asymptomatic and patients with mild symptoms was found higher in females as compared to males, suggesting that males are more susceptible to develop symptoms. Furthermore, the combination of Traditional Chinese Medicine with Aribidol hydrochloride can be used as effective therapeutic option against COVID-19, specifically in the case of patients with mild symptoms (Khan et al. 2020). The majority of patients

with COVID-19 showed stable and improved condition after isolation treatment, which was manifested as narrowing of the scope of lesions, gradually reducing the density and the number of lesions, and fully absorbing the ground glass shadow (Asensio et al. 2020). In some patients, the lesion can evolve into fibrotic cord shadow in a short period of time (Wei et al. 2020). Whether this fibrosis manifestation is a characteristic of lesion reversal remains to be further explored. In a small number of older patients or patients with basic diseases, the disease progressed in the course of disease, the range of lung lesions was enlarged, the structure was distorted and became dense, and "white lung" appeared in severe cases.

In a previous longitudinal study of CT images of SARS patients, consolidation shadow can be classified as ground glass shadow or disappear, while ground glass shadow can continue to exist and even progress to interlobular septal thickening, fibrosis, bronchial distortion and dilatation (Zhong et al. 2020). Therefore, large sample size and multi-center researches are needed to explore its evolution and law from the perspective of radiology. In the similar course of disease, the age and past medical history of COVID-19 convalescent patients were significantly correlated with the lesion volume and the total lesion proportion of lesions in CT images. Special attention should be paid to older patients or patients with past medical history, and the outcome of those types of patients' condition should be paid attention to at any time.

Although there were significant differences in the ranges of pulmonary CT inflammation among the three groups, the clinical indicators were good in the actual clinical observation and management. It may be that the patients are in the recovery period, and the body immunity is in a better state. In addition to the influence of pulmonary inflammation on rehabilitation, patients in this state also consider the risk of symptoms caused by systemic diseases.

In conclusion, in the actual clinical work, even if the patients' CT images show a large range of inflammation without absorbed, if the patient is young and has no history of systemic diseases, the risk of emergent emergency is greatly reduced. There is a risk of first aid for the elderly with a past medical history of systemic diseases and a large area of severe infection. The patients with mild and moderate infection on CT images also showed better rehabilitation.

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Authors' contributions ZL designed the study and wrote the protocol, YW performed research, ZH contributed important reagents, HS and RZ managed the literature searches and analyses, JZ undertook the statistical analysis, and WX wrote the first draft of the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials The datasets used or analyzed during the current study are available from the corresponding author upon reasonable request.

Declarations

Conflict of interest The authors declare that they have no conflict of interest.

Ethics approval This study was approved by the Ethics Committee of Wuhan No.1 Hospital, China.

Consent for publication Informed consent was obtained from all individual participants included in the study.

Informed consent All patients gave informed written consent to participate in the study.

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